INDUSTRIAL PRODUCTS

SERVICE MANUAL
FOR
2400 RANGE DIESEL ENGINES

2401E 4 cyl. 2,36 litre (144 cu in)

2402E 6 cyl. 3,54 litre (216 cu in)

CONTENTS

Ford policy is one of continuous improvement and whilst every effort is made to ensure that this publication is up to date and correct in all respects, the right to change specifications and equipment at any time without notice is reserved. Accordingly this publication is not to be regarded as a description of any individual engine.

SECTION 1

ENGINE

CONTENTS

GENERAL DESCRIPTION

The 2400 Range 4 and 6 cylinder in-line high speed diesel engines operate on the four stroke cycle, with indirect injection. The piston bores are inclined at 22½° to the left of vertical and the pistons run directly in the block bores. Aluminium alloy solid skirt pistons incorporating a shallow swirl chamber in the crown are used. Each piston has three rings above the piston pin.

The camshaft and injection pump are driven by the crankshaft via a toothed belt; a tensioner is fitted between the injection pump drive gear and the crankshaft pulley to maintain tension. When the tensioner belt is removed, the camshaft and crankshaft can turn independently and therefore extreme caution should be taken to avoid piston/valve contact.

Five main bearings support the crankshaft on the four cylinder engine and seven main bearings support the crankshaft on the six cylinder engine. The crankshaft rear oil seal is lipped. The camshaft is mounted high on the left hand side of the cylinder block, enabling the use of short and robust push rods. Camshaft thrust is taken by a thrust plate bolted to the cylinder block front face; four steel backed camshaft bearings are fitted to the four cylinder and six for the six cylinder engines. The bob tailed cylinder block is extended below the crankshaft axis, giving greater block rigidity.

The cast iron cylinder head is fitted with replaceable steel valve guides and valve seats. The upper part of the combustion chamber is hemispherical in shape and is machined in the cylinder head. The lower part is formed by machined plugs which incorporate a throat connecting the combustion chamber to the cylinder bore. The valves are mounted vertically in the cylinder head. The head diameter of the inlet valve is larger than that of the exhaust. Both valves are of a two piece design. Double valve springs are used on the exhaust valve. The oil pump is located in the front of the cylinder block and is driven by a gear on the crankshaft.

The oil pans are reversible and can therefore be used as front or rear well pans without changing the pick-up pipes. This applies to both four and six cylinder engines.

The four cylinder engine can be fitted with either a Simms Minimec or a Bosch fuel injection pump. The Simms Minimec injection pump only is fitted to six cylinder engines.

There is provision for power take off from the crankshaft pulley.

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

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

2,4 LITRE DIESEL ENGINE

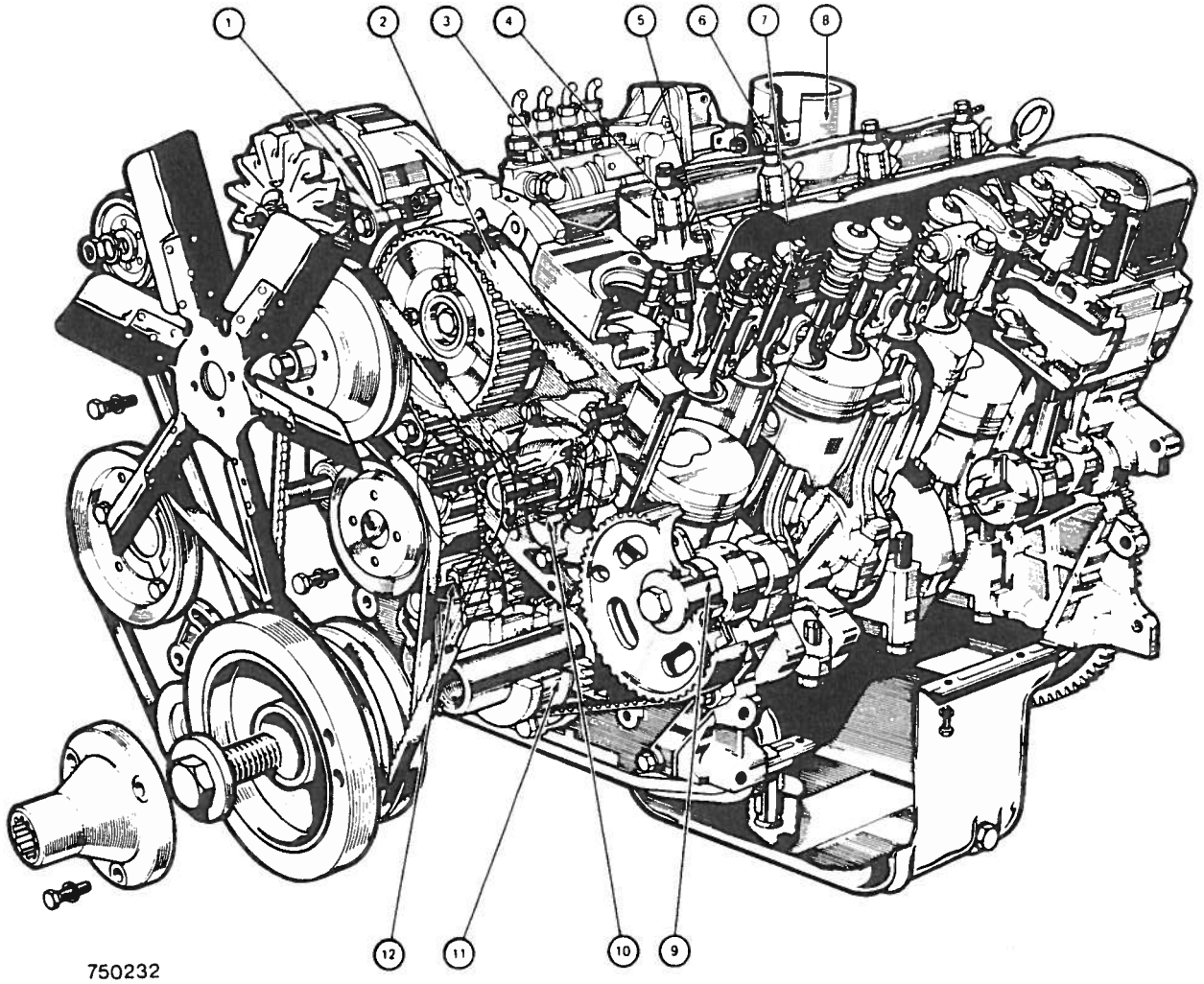


Fig. 1. Sectional View of 2401E 4 cyl Engine

1. Alternator
2. Timing belt
3. Injection pump
4. Injector
5. Exhaust valve
6. Thermostart 'Glow-Plug'
7. Inlet valve
8. Inlet manifold
9. Camshaft
10. Water pump
11. Belt drive gear
12. Oil pump

INLET AND EXHAUST MANIFOLDS

The inlet and exhaust manifolds are separate and are retained on the right and left hand sides of the cylinder head respectively by bolts and washers. The inlet manifold is an aluminium casting providing an unrestricted passage to the inlet ports.

The exhaust manifold is of cast iron with separate ports for each cylinder and incorporates a flange for attaching the exhaust pipe.

ROCKER COVER

The Rocker cover is a steel pressing retained by screws around a flanged end.

CYLINDER HEAD

The cast iron cylinder head incorporates replaceable valve guides and valve seat inserts, and is retained by M12 diameter by 105 mm long bolts. A composition type cylinder head gasket is used.

Later type cylinder heads on 4 cylinder engines only, have one glow plug fitted in each pre-combustion chamber.

VALVES AND SPRINGS

The valves are mounted vertically in the cylinder head, the inlet valve diameter being larger than the exhaust. Their respective diameters are 44,40 mm and 36,40 mm.

Double valve springs are fitted to the exhaust valves only.

ROCKER SHAFT ASSEMBLY

The rocker arms are fitted with self locking screws for tappet adjustment and are located on the rocker shaft between supports, each pair of rockers being spaced by a compression spring. The rocker shaft supports are retained on the cylinder head by bolts fitted with spring washers. The extreme ends of the rocker shaft are sealed with expansion plugs.

CYLINDER BLOCK

The bob tailed cylinder block is cast integral with the upper half of the crankcase from cast iron. The pistons run directly in the block bores which are inclined at 22½° to the left of vertical.

Internally, the crankcase incorporates five main bearings (4 cyl) and seven main bearings (6 cyl). The main bearing caps are retained by self locking bolts M14 diameter by 91,50 mm long.

The parent bores for the camshaft bearings are situated high on the left hand side of the cylinder block. The camshaft runs in four

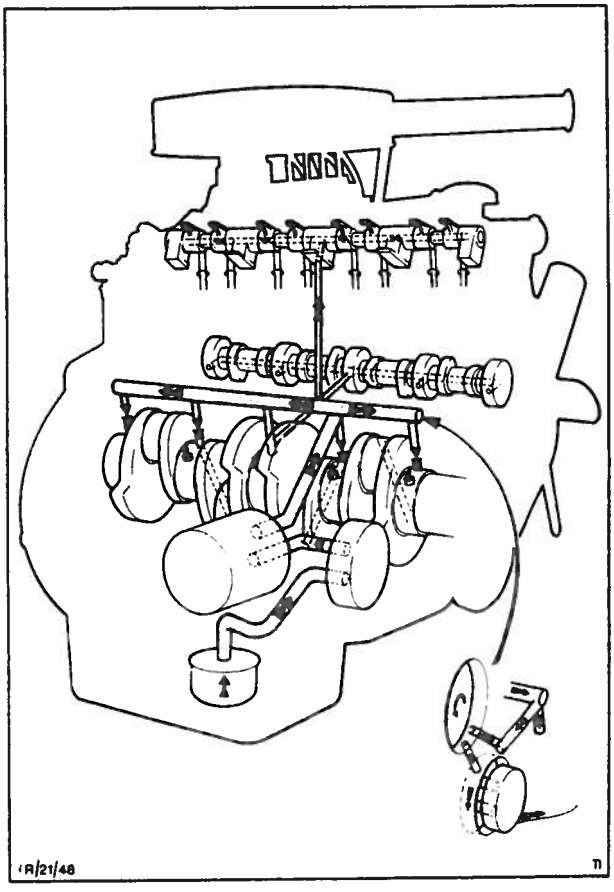


Fig. 2 Lubrication System

bearings (4 cylinder) and six bearings (6 cylinder). Standard or 0,50 mm oversize outside diameter bearings are available in service.

Tappet bores and push rod bores are drilled in the cylinder block along the left hand side. Oil channels carry the oil from the main gallery to each of the crankshaft main bearings and small drillings in the top of each main bearing support direct jets of oil to the underside of each piston. A drilling from the crankshaft centre bearing carries oil to the camshaft centre bearings and via the cylinder head to the rocker shaft assembly. A drilling through the centre of the camshaft carries oil to the other camshaft bearings. Oil-ways in the front housing carry oil to and from the injection pump and the exhauster/compressor (Fig. 2).

ENGINE VENTILATION SYSTEM

Engine ventilation has been achieved by creating a flow of air through the crankcase by venting the crankcase to the suction of the inlet manifold and allowing air to enter the engine through the oil filler cap (see Fig. 3). The air drawn in passes into the rocker cover and then through the oil drain holes to the crankcase. The mixture of air and crankcase fumes then passes through the oil separator mounted on the right-hand side of the block to the inlet manifold via a rubber pipe. This air is then drawn into the engine cylinders together with the air drawn through the air cleaner.

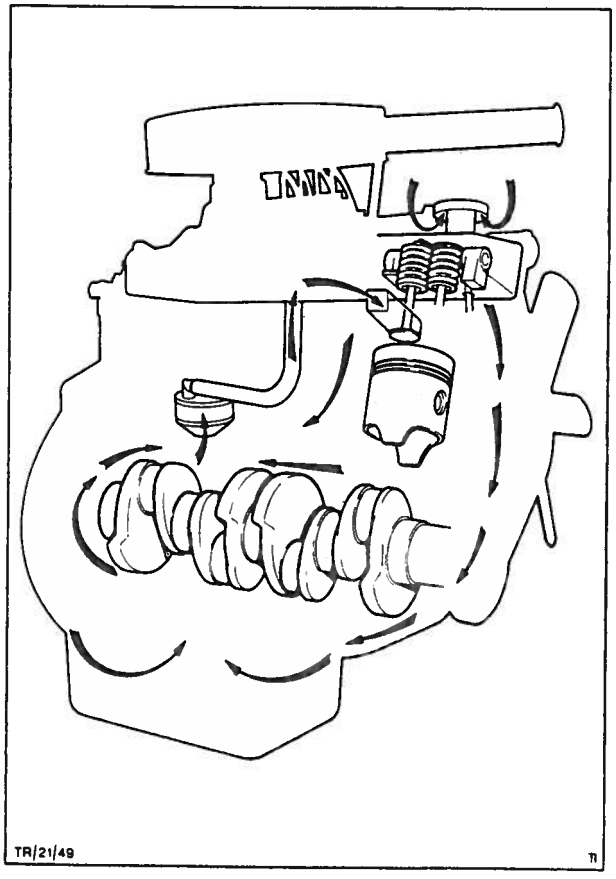


Fig. 3 Ventilation System

CAMSHAFT AND GEARS

The cast camshaft is retained by a thrust plate bolted to the cylinder block front face. A plate is also bolted on the rear face of the engine block. The drive gear is retained by a centre bolt. A spacer and seal are fitted between the camshaft and gear.

PUSH RODS AND TAPPETS

The push rods are forged steel with a ball at the lower end and a cup at the upper. The ball end locates in a cup in the tappet which is of the mushroom type and made of chilled cast iron. The tappet adjusting screw locates in the push rod cup end.

CRANKSHAFT AND BEARINGS

The nodular cast iron crankshaft runs in five main bearings (4 cyl) and seven main bearings (6 cyl) fitted with steel backed aluminium/tin or copper/lead liners. These main bearing liners are in two halves, the upper and lower halves incorporating oil feed holes and an oil groove with the exception of the rear bearing liners which have the oil hole only. Bearing liners

available are standard or 0,25 mm, 0,50 mm and 0,75 mm undersize and 0,40 mm oversize outside diameter.

Crankshaft thrust and endfloat are controlled by thrust washers located in recesses on either side of the centre main bearing. These thrust washers are steel faced with aluminium tin on the bearing surface and are in two halves, the lower incorporating a tang which locates in a slot in the bearing cap to prevent the washers rotating (Fig. 17). In addition to standard size washers, the following oversizes are available – 0,06 mm (0,0025 in), 0,12 mm (0,005 in), 0,18 mm (0,007 in, 0,25 mm (0,01 in), 0,40 mm (0,15 in) and 0,50 mm (0,020 in).

The crankshaft main bearing journals and crankpins may be ground 0,25 (0,010 in), 0,50 mm (0,020 in) or 0,75 mm (0,030 in) undersize. When grinding crankshafts the fillet radii must be maintained at 3,0 to 3,50 mm (0,119 to 0,130 in) and also must be smooth and free from visual chatter marks. The crankpin length must not exceed 28,484 mm (1,272 in). The main journal lengths can be increased to 34,554 mm (1,360 in). The centre main journal length can be increased by up to 0,50 mm (0,020 in) provided that an equal amount is machined from each face and corresponding oversize thrust washers are fitted. Main bearing journal and crankpin ovality should not exceed 0,00641 mm (0,0025 in) and taper 0,0127 mm (0,005 in). Thrust face taper should not exceed 0,051 mm (0,002 in) and the runout total indicater reading 0,0127 mm (0,0005 in). After grinding, crankpins and journals should be polished with a fine lapping paper to produce a good surface finish. Grinding and polishing should both be against the direction of crankshaft rotation.

The front and rear crankshaft seals have a single spring loaded lip, which is fitted with the lip toward the crankshaft.

TIMING HOUSING AND COVER

The cast aluminium timing gear cover is botled to the cylinder block front face and is located by a spacer sleeve around the crankshaft journal. Ten bolts secure the housing to the cylinder block.

The injection pump is mounted on the right hand side of the cylinder block and, together with the camshaft, is driven via a reinforced glass fibre toothed belt by a toothed gear fitted to the crankshaft. A belt tensioner is located between the injection pump driving gear and the crankshaft gear, thus ensuring the belt tension is correctly maintained. A moulded asbestos cover, reinforced with poly-propylene encases the drive belt and is retained to the cylinder block front face by five screws.

CONNECTING RODS

The connecting rods are H section steel forgings with detachable big end caps. The caps are retained by two 7/16 in – 20 UNF x 3 in rolled thread bolts and self locking nuts.

Steel backed aluminium/tin or copper/lead bearings are used for the big ends. They are available as standard and 0,25 mm (0,010 in), 0,50 mm (0,020 in), 0,75 mm (0,030 in) and 1,00 mm (0,040 in) undersize. The crankpin diameter is 59,98 to 60,00 mm (2,3617 to 2,3622 in). A steel backed bronze bush is fitted to the small end. This bush is lubricated by oil splashes and mist which enter through a drilling in the connecting rod end.

PISTON, PISTON PINS AND RINGS

The pistons are made of aluminium alloy and are of the solid slipper type with the swirl cavity and valve recesses machined in the crown. When assembling the piston to the connecting rod ensure that the 'FRONT' markings on the piston and connecting rod are aligned. (Fig. 4).

Three ring grooves are machined in the piston above the piston pin bore, two for compression rings and one for an oil control ring. Radial holes drilled in this lower groove into the inside of the piston provide a return for oil scraped from the cylinder wall.

The pistons are weighed during manufacture and if necessary the weight is adjusted by removing surplus metal from the inside of the bottom skirt. On assembling the piston pin and connecting rods, the assemblies are weighed. The maximum variation in weight between all the piston and connecting rod assemblies fitted to an engine is 18 gram.

NOTE: When replacing pistons ensure that the letter 'H' or 'L' stamped on the piston crown corresponds with the others (i.e. all 'H' or 'L') H = Heavy, L = Light.

The tubular steel piston pins are fully floating and are retained in position by 'Seeger' circlips installed in grooves at each end of the piston bore. The piston pin bores are graded during manufacture and are marked with paint spots corresponding to the grades (see specification). The piston pins are selected to give the correct fit in the piston pin bore and small end bush

in the connecting rod. The upper compression ring is barrel faced and the intermediate ring is plain faced;

Pistons are available 0,65 mm (0,025 in) and 1,00 mm (0,004 in) oversize.

FLYWHEEL AND RING GEAR

The cast iron dynamically balanced flywheel is attached to the crankshaft by eight 10 mm bolts. An accurately machined recess in the front face ensures that the flywheel is located concentrically on the crankshaft flange.

Depending on the application, the engine may be fitted witha heavy duty undrilled flywheel or a flywheel suitable to take a standard manual clutch, PTO, or torque convertor.

The flywheel ring gear is shrunk onto the flywheel. The ring gear may be removed by cutting between two adjacent teeth with a hacksaw and splitting the gear with a chisel. Under no circumstances should pressure be applied in an attempt to dismantle the ring gear for repositioning on the flywheel.

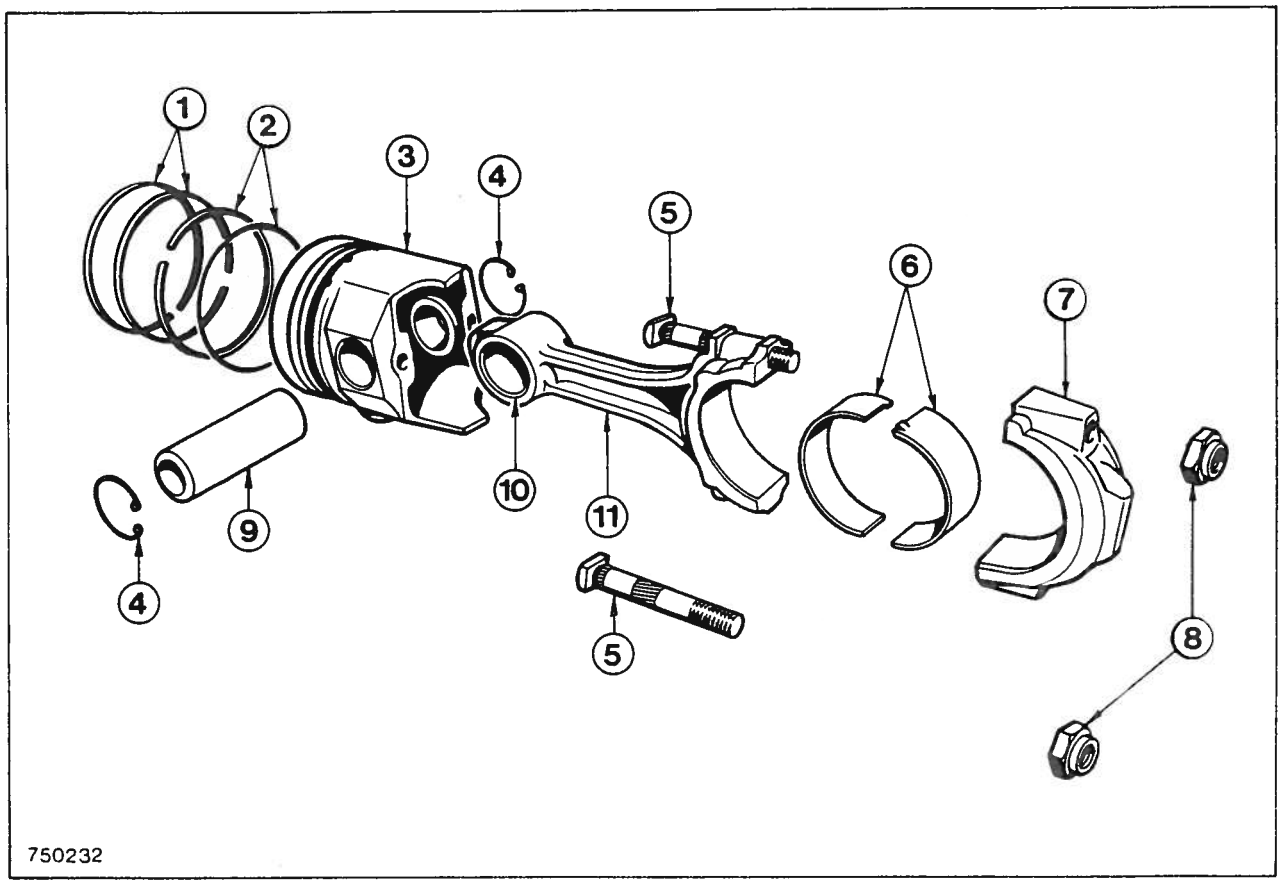


Fig. 4 Piston and connecting rod assembly

1. Compression Rings
2. Oil Control Ring
3. Piston
4. Circlip
5. Connecting Rod Bolt
6. Bearing Liners
7. Bearing Cap
8. Connecting Rod Bolt Nut
9. Piston Pin
10. Small End Bush
11. Connecting Rod

When fitting a new ring gear it must be heated evenly to a temperature not exceeding 315°C, or the wear resistant properties of the ring gear will be destroyed. If the ring gear is heated by a naked flame, place the ring gear on a bed of fire bricks, then play the flame in a circular motion onto the bricks about 38,0 mm (1,5 in) from the inside of the gear until it reaches the required temperature. The correct temperature can be detected by using a special type of temperature sensitive crayon, or alternatively by polishing a section of the ring gear and heating until it turns a light yellow tint. Fit the ring gear with the chamfered edge toward the engine, allow to cool naturally in air – DO NOT QUENCH.

The clutch spigot bearing is located in a bore machined in the centre of the flywheel.

NOTE: One of the flywheel bolts is offset which ensures that the flywheel can only be fitted in one position.

CRANKSHAFT PULLEY

The crankshaft pulley is retained by six bolts to the drive gear which is retained to the crankshaft by a special shouldered bolt. This bolt must be tightened to a torque of 312 to 339 Nm (230 to 250 lbf ft or 31,8 to 34,6 kgf m).

OIL PAN

The pressed steel oil pan is bolted to the base of the cylinder block and is reversible. For each model the same oil pan can therefore be used as a front or rear well unit without changing the oil pick-up pipes.

A shallow type, made of LMG aluminium alloy, with facilities for mounting an engine oil cooler is available for marine use.

The oil pan is retained to the cylinder block by four 8 x 12 mm socket caps with sixteen 8 x 12 mm (4 cyl) and twenty-two 8 x 12 mm (6 cyl) hexagon headed bolts. The bolts fitted to later engines have a 'locking patch' on the threads and are self sealing. The gaskets are in four pieces dove-tailed together. When fitting the oil pan apply EM-4G-47 jointing compound to the gasket joints and to both end sections of the gasket where they abut the two covers.

DISMANTLING

1. Steam clean the engine and mount it on the engine stand using the special mounting bracket 21-015 – see Fig. 5.
2. Drain the engine oil, remove the dipstick and the oil filter. Replace the sump plug.
3. Remove air cleaner assembly.
4. Disconnect crankcase vent pipe from the inlet manifold.
5. Remove the fuel pipes and the fuel filter(s) complete with mounting bracket. Replace bolt securing dipstick tube to cylinder block.
6. Remove high pressure pipes using wrench, Tool No. 21-041 and fit dust caps to injector and pump connections.
7. On 4 cylinder engines fitted with glow plug cylinder heads, disconnect the glow plug loom connection at the front of the inlet manifold – see Fig. 6.

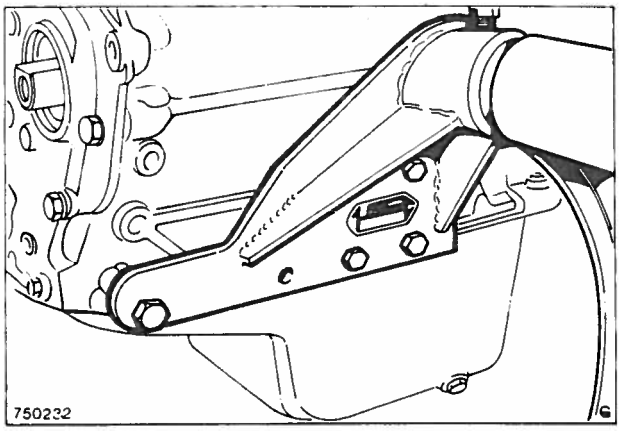


Fig. 5 Engine mounting bracket

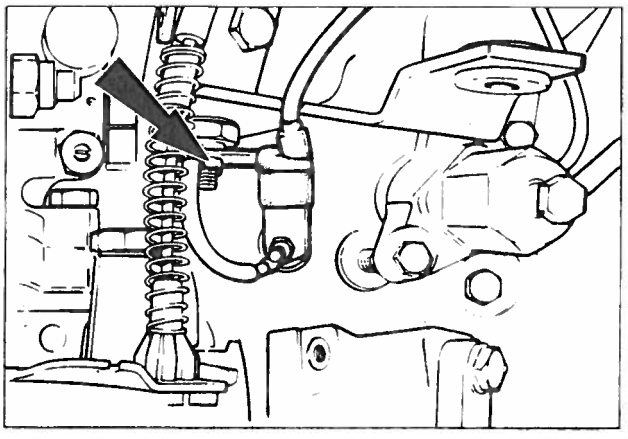


Fig. 6 Glow plug loom connection

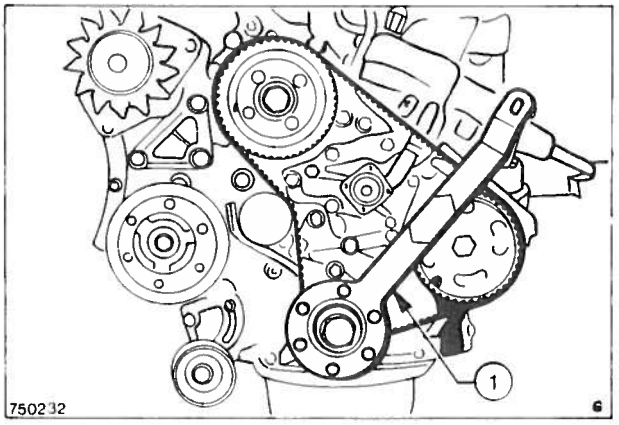


Fig. 7 Locking the crankshaft
1. Crankshaft locking bar Tool No. 21-018

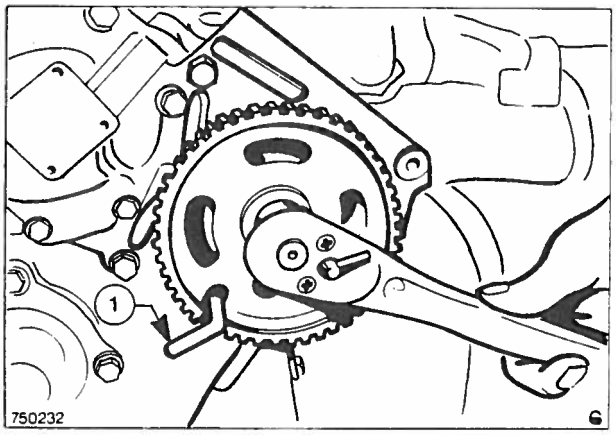


Fig. 8 Locking the camshaft gear
1. Timing gear alignment pin Tool No. 21-016

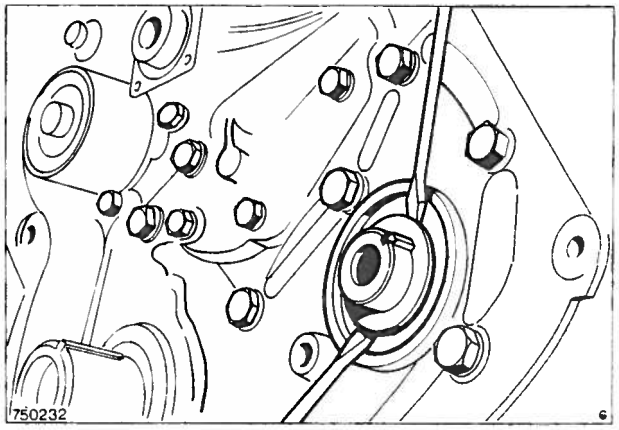


Fig. 9 Prising off the camshaft spacer

8. Remove the alternator and mounting bracket. Remove the starter motor.

9. Where fitted, remove the exhauster pump/compressor drive belt and jockey pulley.

10. Remove the fan belt(s), fan, water pump pulley and crankshaft pulley.

11. Remove the timing belt cover, lock the crankshaft using Tool No. 21-018 and remove the crankshaft centre bolt. (Fig. 7).

12. Remove the timing belt tensioner, timing belt and crankshaft hub, leaving the locking bar attached. Lock the camshaft gear, using timing gear alignment pin Tool No. 21-016 (Fig. 8) and remove the camshaft centre bolt and gear.

13. Using two suitable levers in the spacer grooves Fig. 9 prise off the spacer. Do not attempt to turn the crankshaft with the timing belt removed and the cylinder head in position.

4. Remove the exhauster pump/compressor pulley and centre nut. Use a suitable puller to remove the hub, Fig. 10.

15. Disconnect the by-pass pipe and remove the water pump. Remove the oil pump cover, oil pump, exhauser pump/compressor and mounting bracket.

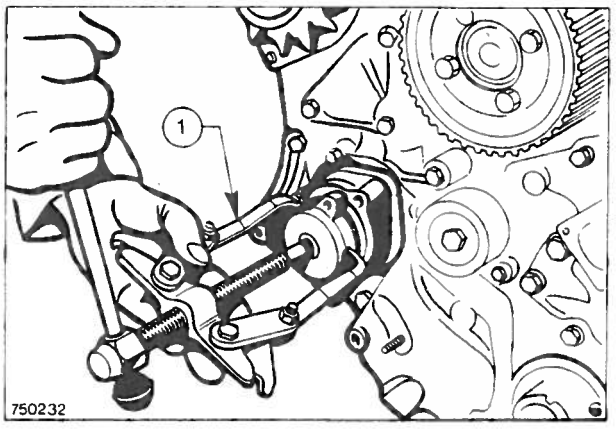


Fig. 10 Removing the exhauster pump/compressor hub
1. Hub puller

16. Remove the injection pump drive gear and remove the pump Fig. 11. Remove the front housing complete with water inlet connection.

17. Remove the bolts securing inlet manifold to engine and remove the manifold.

NOTE: On 4 cylinder engines with glow plug cylinder heads, lift manifold clear of engine, disconnect glow plug internal loom connection and remove the manifold – see Fig. 12.

Disconnect and remove the loom from the three glow plugs. Using a socket spanner, remove the four glow plugs from cylinder head – see Fig. 13.

18. Remove the exhaust manifold.

19. Remove the rocker cover and gasket.

20. Remove the rocker shaft and push rods, noting the order in which they were removed. The extreme ends of the rocker shaft are sealed with expansion plugs; these do not retain the end supports. It is therefor advisable to attach a piece of cord between them when removing the rocker shaft assembly, to prevent accidental disassembly.

21. Remove the cylinder head and discard the gasket.

22. Where applicable, remove the caps from the end of the valve stems.

Using a valve spring compressor, depress the springs, remove the valve stem collets, valves, valve springs, spring caps and oil seals.

23. Remove the clutch assembly (where fitted) and the flywheel.

24. Invert the engine and remove the oil pan and the oil pick up pipe.

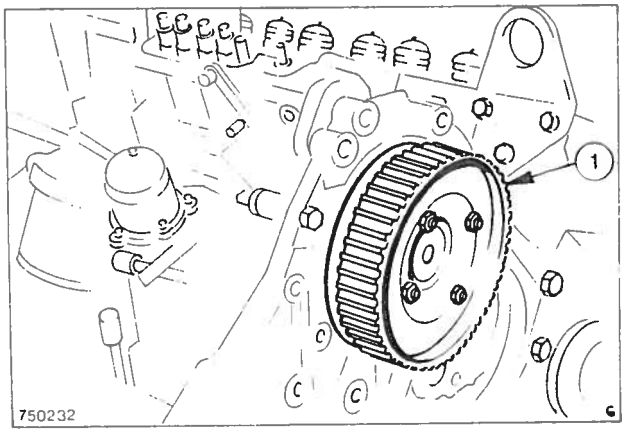


Fig. 11 Removing the injection pump
1. Injection pump gear

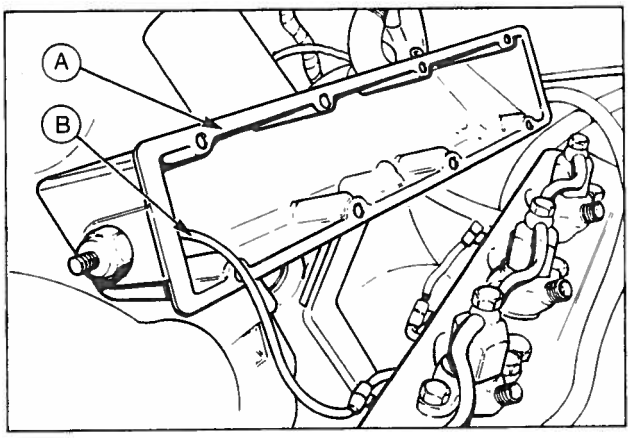


Fig. 12 Removal of inlet manifold
A – Inlet manifold
B – Glow plug loom connection

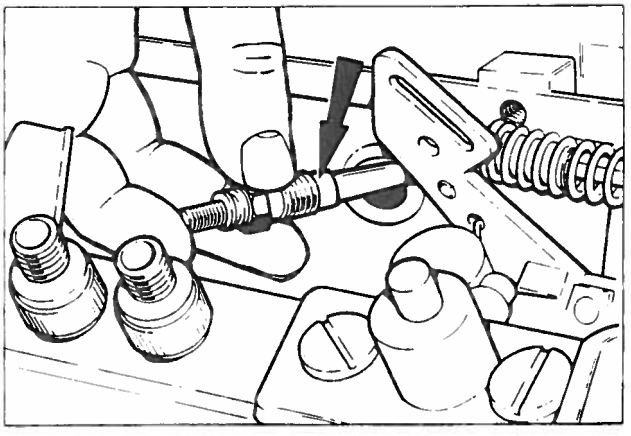


Fig. 13 Glow plug removal

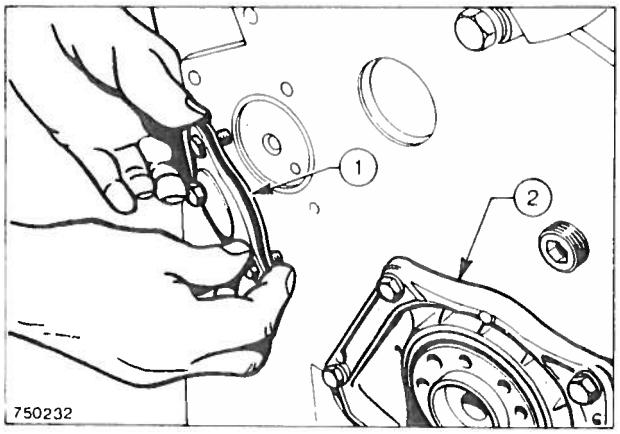


Fig. 14 Removing the camshaft rear cover plate
1. Camshaft rear cover plate
2. Crankshaft rear oil seal cover

25. Remove the crankshaft rear oil seal cover and the camshaft rear cover plate Fig. 14.
26. Remove the camshaft front retainer plate, remove the camshaft and the cam followers.
27. Remove the connecting rod cap nuts and remove the pistons and connecting rod assemblies from the top of the block.

    To remove the piston pins, remove the circlips and warm the piston. Support the piston and push out the piston pin.
28. Remove the crankshaft main bearing caps and liners ensuring that they are kept in their correct sequence. Lift out the crankshaft, taking care not to damage the crankshaft journals.
29. Remove the oil pressure relief valve components. The crankcase ventilation oil separator should not be removed unless cracked or otherwise damaged, in which case it should be renewed.
30. Remove the block from the stand and steam clean. Flush out the oil and water ways and dry them using compressed air.

COMPONENT INSPECTION AND RENEWAL

All components should be thoroughly cleaned, and particular attention paid to joint faces and bearing surfaces. Any local high spots or burrs on the joint faces should be removed by stoning lightly. Ensure that any piece of gasket material or dirt which enters a blind, tapped hole during cleaning, is removed. Otherwise the bolt may bottom on the resulting plug before the bolt head pressurises the mating part.

Clean the carbon from the tops of the cylinder bores.

Inspect all moving parts and bearing surfaces for wear. Check the dimensions of worn parts against the 'General Specification' given at the end of this section and select new parts where necessary.

If the camshaft bearings are found to be in need of replacement proceed as follows, using Remover/Replacer Tool No. 21-022. Assuming the bearings to be numbered from the front of the engine, remove bearings 6, 5, 4, 3 and 2. Working from the rear of the engine remove bearing number 1. Figs. 15 and 16.

Inspect the bores in the cylinder block for damage or wear. If necessary the block may be line bored and bearings with oversize outside diameters fitted (see specifications).

Fit the new bearings in reverse order, using Tool No. 21-022. Ensure that the tang on the front bearing aligns with the slot in the bore. Bend the locating tag in the slot.

Visually examine the cylinder bores for glazing, scuffing, or metallic deposits. If these are evident, determine the cause and rectify.

Measure the diamenter of the cylinder bores in line with, and at 90° to the crankshaft axis, at the following three places:

a. Immediately below the top compression ring upper reversal point.
b. At 90 mm (3,54 in) below the top face of the cylinder block.
c. At 165 mm (6,50 in) below the top face of the cylinder block.

Calculating the mean value of the six measurements thus taken will give the mean diameter of the bore. Carry out operations 'a, b, c' to all bores. Note that these measurements will also determine bore ovality and/or taper. If more than 0,075 mm (0,003 in) ovality in a bore is recorded, then it should be rebored.

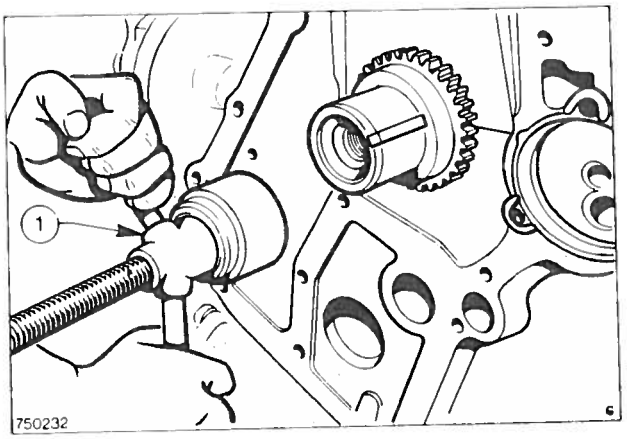


Fig. 15 Removing/replacing the camshaft bearings working from the front of the engine.
1. Bearing remover/replacer, Tool No. 21-022

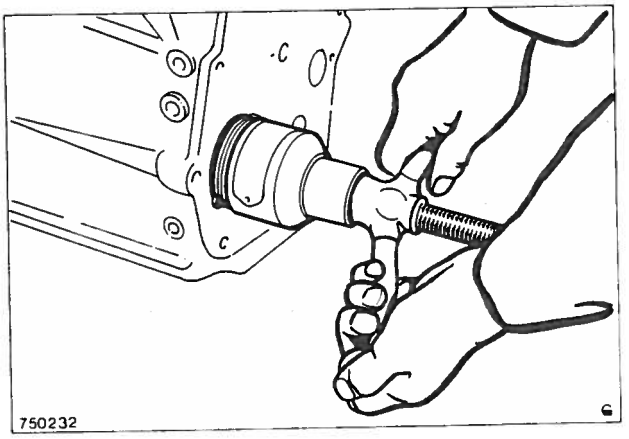


Fig. 16 Removing/replacing the front camshaft bearing from the rear of the engine.

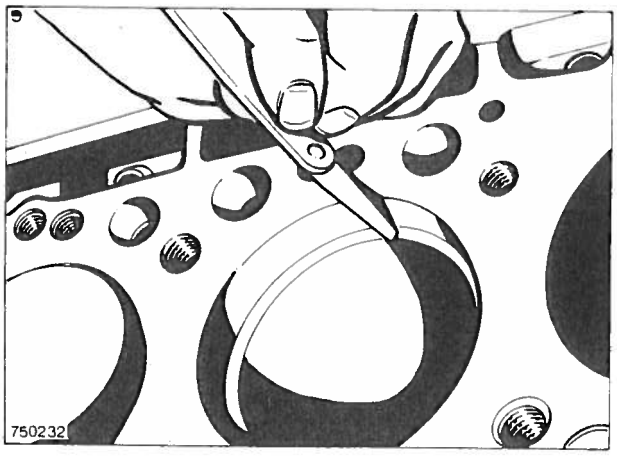


Fig. 17 Checking the piston ring gaps

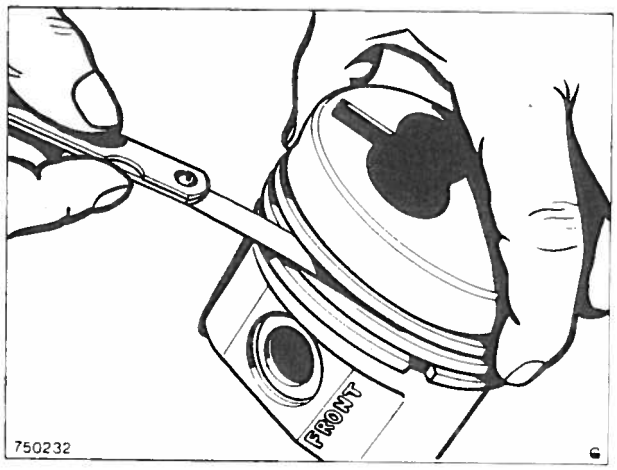


Fig. 18 Measuring the vertical clearance of the piston ring.

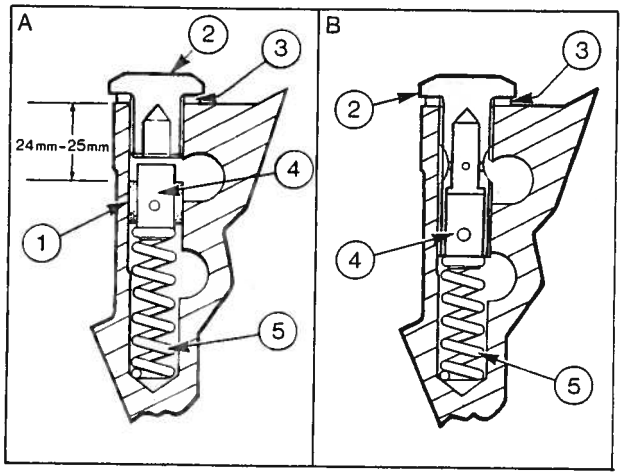


Fig. 19 Oil pressure relief valve (shown partly open)

A. Old type
B. New type
1. Sleeve
2. Cap
3. Sealing washer
4. Valve
5. Spring

Measure the piston diameter at 90° to the piston pin axis, and at 90 mm (3,54 in) from its top face. The effective piston clearance can now be calculated by subtracting the mean piston diameter from the mean bore diameter. If the resultant clearance is more than that given in Specifications, then a piston of the next grade should be selected.

NOTE: When renewing pistons, ensure that the letter 'H' or 'L' stamped on the piston crown corresponds with the other pistons (i.e. all 'H' or 'L'). 'H' = Heavy, 'L' = Light.

Check the piston ring gaps by positioning each ring in the *lower unworn portion* of the bore, and measuring the gap with a feeler gauge. Compare the gap with the Specifications. Note that Fig. 17 shows a piston ring in the *incorrect position.*

Measure the vertical clearance between each piston ring. Fig. 18 and its groove and compare with the specifications. Renew piston and rings as necessary.

Examine the piston markings to check the connecting rods for straightness. A heavy marking on the piston skirt above the pin at one side, together with a correspondingly heavy marking below the pin on the other side indicates a bent connecting rod which should either be straightened or a replacement fitted. Inspect the small end bush for damage and compare the internal diameter with that specified. New small end bushes can be fitted in service, providing suitable equipment is available to machine accurately the bore to the correct size. This bore is 32,000 to 32,050 mm diameter and must be parallel with the big end bore to within 0,013 mm per 25,00 mm and in the same plane to within 0,038 mm per 25,00 mm. Assemble the bush to the connecting rod so that the oil hole is in alignment with the hole in the connecting rod. With the big end bearing liner in place, check that the connecting rod to crankshaft end float is within specification.

On engines built after January 1978, the oil pressure relief valve sleeve and valve retaining cap are combined; check the internal bore of the sleeve for wear and, if necessary, renew the combined plug and sleeve – see Fig. 19.

NOTE: A modified sleeve/plug with a longer thread was introduced in 1979. This overcame the situation occasionally encountered, where an engine (especially when fitted with an external oil cooler), failed to achieve normal oil pressure build-up. All engines being serviced should be fitted with the later type of sleeve, Pt. No. 785F-6A616-AAC in place of the earlier type Pt. No. 785F-6A616-AAB; the Pt. No. is stamped on the head of the plug.

Earlier engines have a sleeve which is pressed into the cylinder block and reamered 'in situ'; check for wear using a small mirror and a lead lamp. Any wear will be visible at the top of the sleeve. A ready machined sleeve is now available as a service replacement for the earlier type of sleeve and should be fitted as follows:

a. Extract the worn sleeve using special tool No. 21-533/1 TBE.

b. Carefully clean up the outside diameter surface using emery cloth to remove ridges created during sleeve removal. Measure the outside diameter of the sleeve with a micrometer at various points and compare the mean value with those given in the following table; from this data determine the correct replacement sleeve.

Measured Outside Diameter of the Removed Sleeve	Pt. No. of Replacement Sleeve	Outside Diameter of Replacement Sleeve
17,556 to 17,596 mm (0.6912 to 0,6928 in)	715F-6K803-ACA	17,500 to 17,530 mm (0.6890 to 0,6902 in)
17,806 to 17,846 mm (0,7010 to 0,7026 in)	715F-6K803-ADA	17,750 to 17,780 mm (0,6988 to 0,7000 in)

NOTE: Allowance should be made for removal damage.

c. Fit the new sleeve onto the special insertion tool, No. 21-533/2 TBE using a small piece of tape to prevent the sleeve falling off.

d. Unsing a small round file remove any burrs from the threaded portion of the block bore. Check that new sleeve passes easily through the thread.

e. Remove the excess oil from the bore and using 'Loctite primer N' (Ford specification ESEM-4G-1001A) and a clean wiper remove all traces of oil and other debris inside the bore; particular attention should be paid to the lower walls and thread through which the sleeve will pass as oil will contaminate the 'Loctite' retaining compound.

f. Clean the outside surface of the sleeve with 'Loctite' primer and a wiper.

g. Spray both the sleeve and the lower walls of the bore with 'Loctite primer N'. Leave for 2-3 minutes to dry.

h. Apply 'Loctite 601' (Ford specification SDM-4G-9106-A) on both the outer surface of the sleeve and the portion of the block bore in which the sleeve will rest. A small artist's paint brush is a suitable applicator for the block bore. DO NOT PUT 'LOCTITE 601' BETWEEN THE INSERTION TOOL AND SLEEVE.

Locate the sleeve at the correct depth inside the block bore using the special insertion tool.

A light hammer may be necessary to 'drift in' the tool. Ensure that the tool fully abuts the top of the block bore. If 'drifted in', the insertion tool may be withdrawn immediately.

Should the tool simply push in, twist the tool once it has reached its limit to spread the 'Loctite', and remove the tool gently after 10 minutes to avoid disturbing the joint.

Using a small rule check that the sleeve is correctly positioned at between 24 and 25 mm (0,940 and 0,980 in) from the top of the bore. Refit if incorrect.

Leave the engine for 24 hours before assembling the rest of the valve components and refitting the end plug.

Using a piece of bent wire, check that the Loctite has retained the sleeve securely, since inadequate cleaning will contaminate the Loctite.

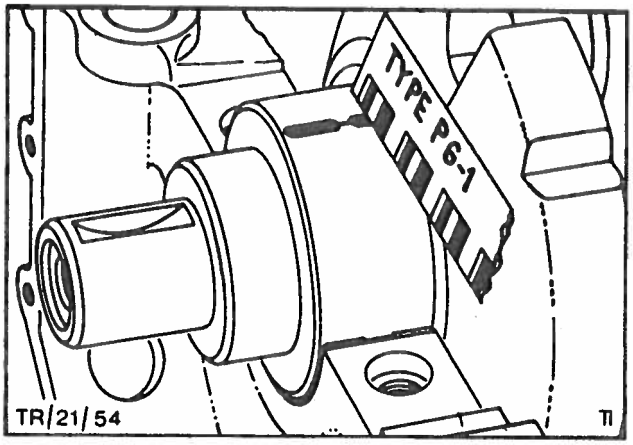


Fig. 20 Checking the main bearing clearance with the use of 'Plastigauge'

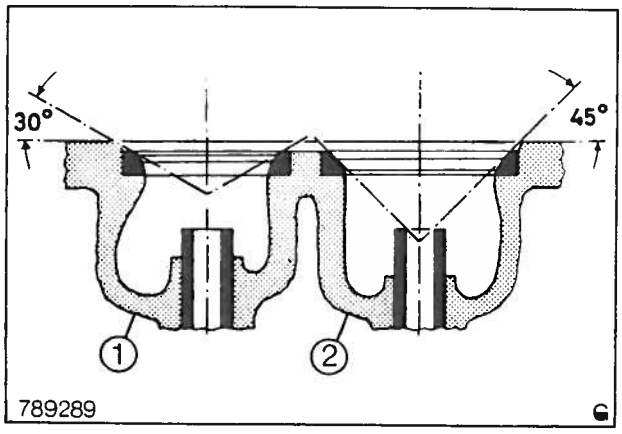


Fig. 21 Valve seat re-cutting
1. Exhaust 2. Inlet

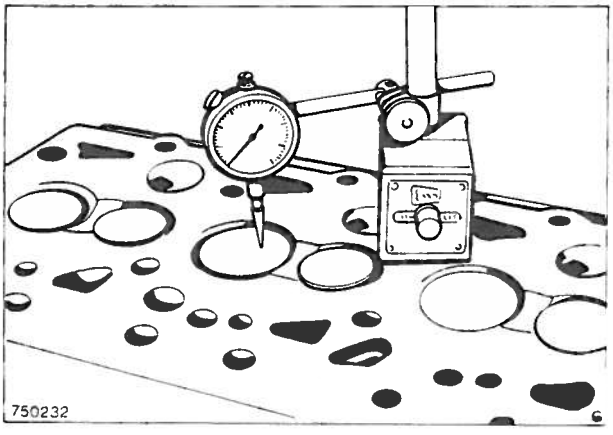


Fig. 22 Measuring the valve depth

Check the condition of the camshaft. Pitting of up to 50% of an area 6,0 mm (0,24 in) on either side of the cam lobe nose is acceptable, and is not detrimental to performance. With the aid of a vernier gauge, measure the cam lobe 'nose-to-heel' dimension, and if this is not less than:

44,60 mm (1,835 in) for exhaust lobes
44,70 mm (1,878 in) for inlet lobes

then the camshaft is within Specifications.

Measure the crankshaft bearing journals for excessive wear, scoring or other damage. Check the main bearing clearances by using 'Plastigauge' – see Fig. 20. If the crankshaft journals are not to specification, then they must be re-ground. Fit new bearings as necessary.

Inspect the valves and valve seats for pitting or damage. If the damage is slight, both the valve seat and valve seating face can be lightly cut, Fig. 21. If the damage is beyond repair or cutting the valves and seat increases the valve depth to more than the specified maximum, Fig. 22, new parts must be fitted.

Examine the area around the valve seats and combusion chamber inserts for evidence of cracking. Superficial 'hair line' cracks less than 4 mm (0,156 in) in length and in the positions shown in Fig. 23, are acceptable and the cylinder head can be used again.

Cracks between the valve seat inserts and combustion chamber insert as illustrated in Fig. 23 are NOT acceptable and the cylinder head must be renewed.

If a cylinder head is cracked badly enough to warrant replacement, then the cooling system should be examined to ascertain the causes of the cracking.

Carefully check the following items and rectify as required:

a. Water Leaks
b. Low Fan Belt Tension
c. Faulty Header Tank Pressure Cap
d. Faulty Thermostat Operation
e. Radiator Blockages

Damaged or worn valve guides can be driven out using Tool No. 21-021. The same tool is used to drive in a new guide from the cylinder head top until the legs of the tool attachment just touch the cylinder head. The guide is then set to the correct protrusion, Fig. 24. A new service replacement valve guide can be identified by a groove on its outer diameter.

Later engines fitted with valve stem caps have shorter valve guides. These can be installed using Tool No. 21-021 but the correct protrusion must be achieved by measurement as the guide is being driven in – refer to Specifications.

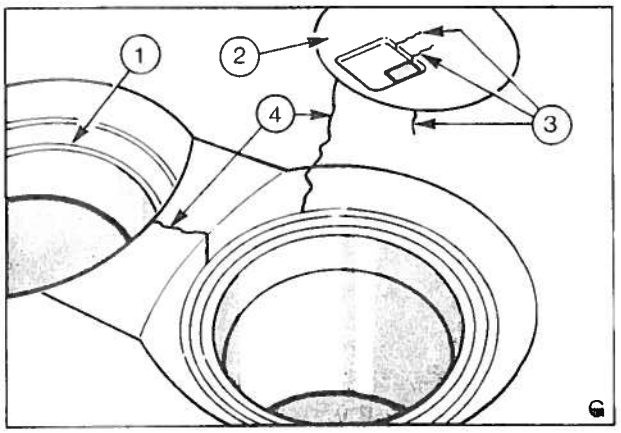


Fig. 23 Cylinder head cracking
1. Valve seat insert
2. Combustion chamber insert
3. Acceptable hair-line cracks – less than 4 mm in length
4. Unacceptable hair-line cracks

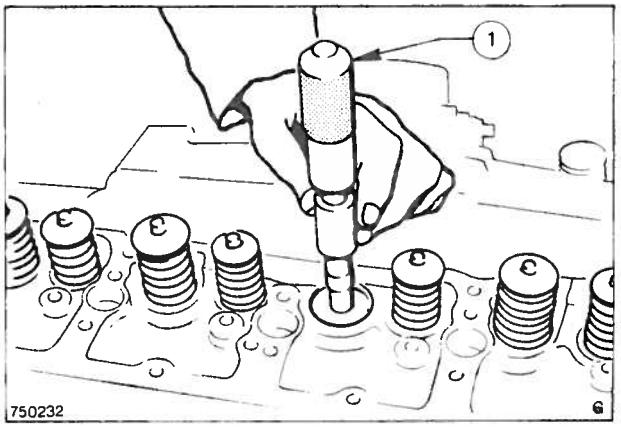


Fig. 24 Setting the valve guide protrusion
1. Valve guide remover & installer, Tool No. 21-021

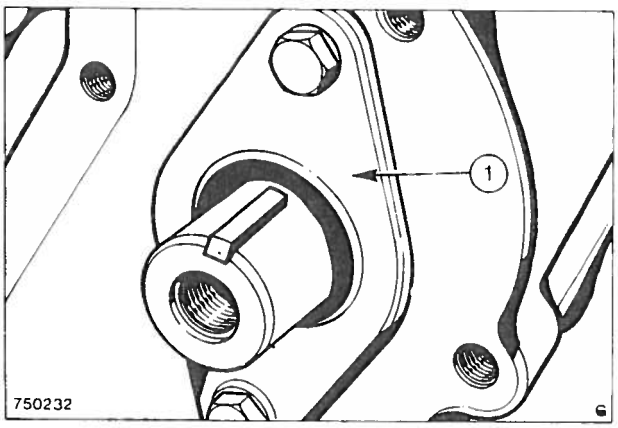


Fig. 25 Refitting camshaft thrust plate
1. Camshaft thrust plate

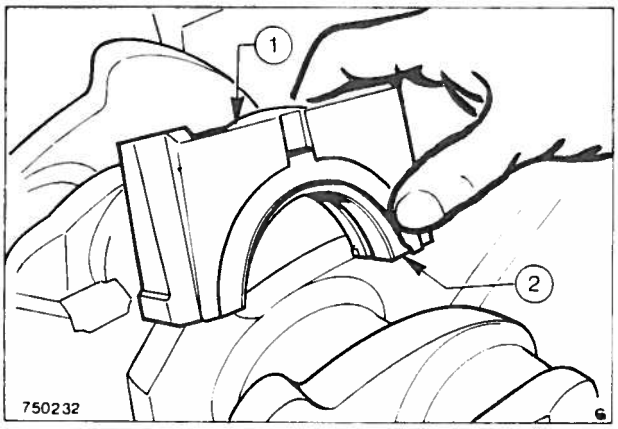


Fig. 26 Replacing the main bearing cap
1. Main bearing cap
2. Thrust washer

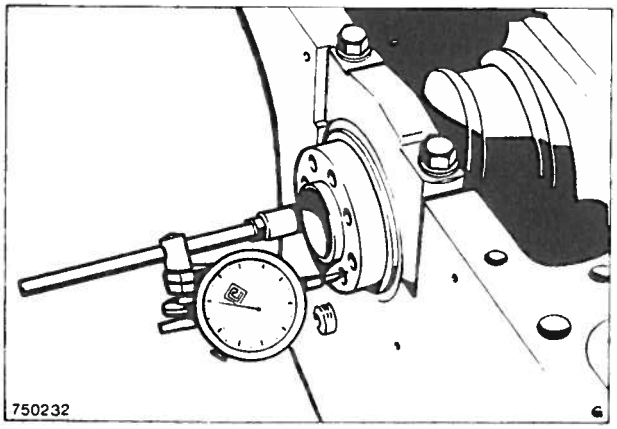


Fig. 27 Checking crankshaft end float

ASSEMBLY

1. Mount the engine on the engine stand, using mounting bracket 21-015 (Fig. 5). Where the crankcase ventilation oil separator has been removed, apply an even coat of sealer ESEE-M4G-1005A to the stem of the separator and press the assembly fully home into the cylinder block.

2. After ensuring that the sealing washer is clean and undamaged, lightly smear the oil pressure relief valve with clean engine oil and assemble the valve components to the block – see Fig. 19. Tighten the plug to the specified torque (see Specifications).

3. Turn the engine oil pan face upwards on the stand. Lightly oil the cam followers with clean engine oil and assemble them to the cylinder block.

4. Check that the oil gallery sealing balls are correctly located at each end of the camshaft. Lightly oil the cam lobes and bearing journals with clean engine oil, then refit the camshaft, ensuring that the bearings are not damaged in the process.

5. Check the camshaft thrust plate for signs of wear, or scoring. The opportunity should be taken here to fit the latest type of thrust plate, which has two 6,0 mm (0,24 in) holes drilled on a 56,0 mm (2,21 in) pitch circle diameter (PCD), if this is not already fitted, tightening the bolts to their specified torque – see Fig. 25.

6. Refit the camshaft rear cover plate, complete with a new gasket – see Fig. 14.

7. Lightly oil the main bearing liners with clean engine oil and position them in the cylinder block. The bearings with an oil hole only should be fitted at the rear. Fit the crankshaft, thrust washers and main bearing caps ensuring that the arrow heads on the caps face the front of the engine – see Fig. 26. Tighten the main bearing cap bolts in two stages as specified (see Specifications).

8. Using a dial indicator, check that the crankshaft end-float is within specifications – see Fig. 27. If not, fit new or oversized thrust washers.

9. Assemble each piston to its connecting rod, ensuring that the 'FRONT' markings on both the piston and the connecting rod are aligned. Warm the piston and press in the piston pin. Refit the circlips.

   Fit the rings to each piston. Both the top and intermediate rings must be fitted with the surface marked 'TOP' uppermost. The oil control ring can be fitted either way up.

NOTE: The upper surface of the top compression rings is angled to approximately 7° – see Fig. 28. Space the piston ring gaps at 120° intervals.

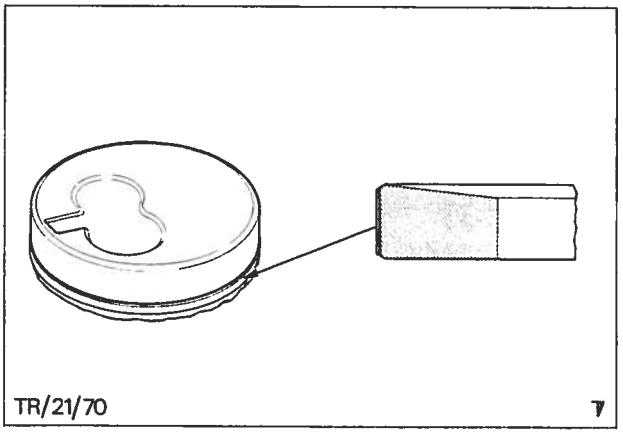


Fig. 28 The top compression ring

10. Lightly coat the bore, rings, small-end and big end bearing with clean engine oil.

11. Using a piston ring clamp as shown in Fig. 29, insert each piston assembly into the cylinder bore with the 'FRONT' markings to the front of the cylinder, taking care not to damage the bores. If possible, cover the exposed thread on the cap bolt with tubing (nylon) during this operation. Fit the big-end bearing liners and the caps and tighten the new self locking nuts to the specified torque (see Specifications).

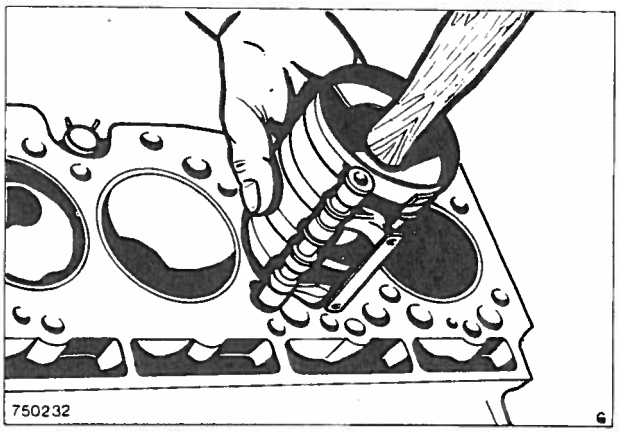


Fig. 29 Fitting the pistons to the bores

12. Fit a new oil seal to the rear crankshaft cover. Apply a thin coat of grease to specification ESEW-M1C-1004-A to the crankshaft oil seal journal. Fit a new gasket and position the cover to the back using the centraliser, Tool No. 21-011A, Fig. 30, to centralise the oil seal around the crankshaft. The seal should be parallel to the joint face and positioned such that it runs on an unused part of the shaft to the engine side of the previous locations. Ensure that the lower face of the retainer is parallel to the cylinder block face and fit the lower two bolts to align the gasket. Fit the remaining two bolts to align the gasket. Fit the remaining two bolts and tighten all four bolts to the specified torque (see Specifications).

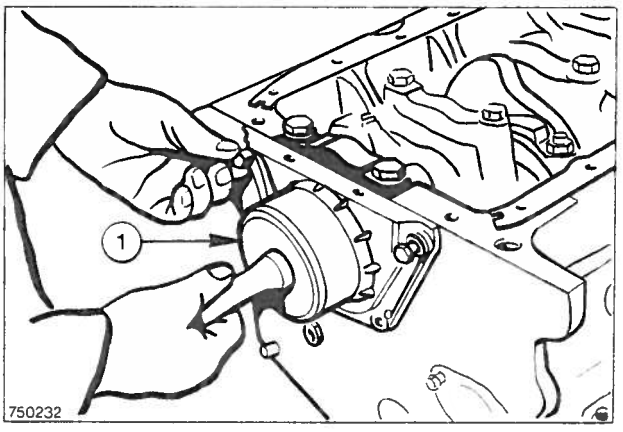


Fig. 30 Centralising the crankshaft rear oil seal cover
1. Centraliser, Tool No. 21-011A

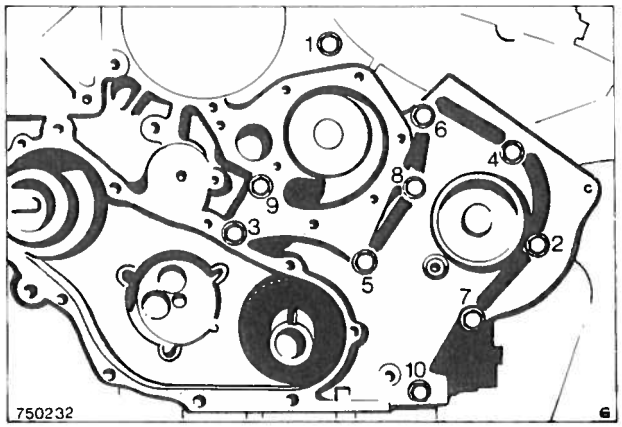


Fig. 31 Bolt tightening sequence for front housing.

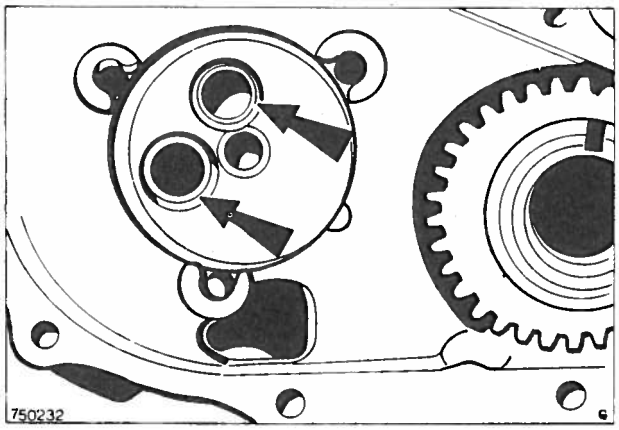


Fig. 32 Location of the oil pump seals

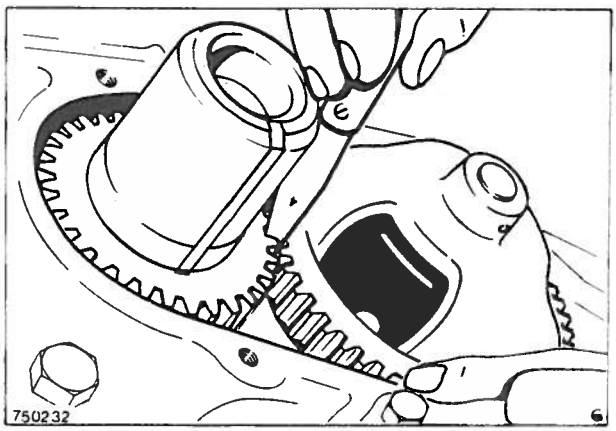


Fig. 33 Checking the backlash of the oil pump drive gears

13. Ensure that the front housing oilways are clear and fit a new camshaft seal using Tool no. 21-017, ensuring that the seal is positioned such that it runs on an unused part of the camshaft collar (replace collar if required). Fit a new gasket and position the cover to the block using Tool No. 21-017 to centralise the cover around the camshaft and ensure that the bottom of the cover is parallel to the block face. Fit the ten bolts and tighten to the specified torque (see Specifications) in the sequence shown in Fig. 31.

14. Before attempting to install the oil pump, check for clearances and wear as detailed in the section 'Lubrication System and Cooling System'.

15. Fit new seals to the oil pump galleries – see Fig. 32. Ensure that all components are thoroughly clean, paying particular attention to joint faces and bearing surfaces. Fill the engine oil pump with the correct grade of oil before installing – refer to Specifications in 'Lubrication' section.

16. Align the notch in the pump retaining plate with the cross headed bolt, position the pump in the block ensuring that the oilways are aligned and the gears are fully meshed. Fit the three bolts and tighten evenly to the specified torque. Where 'jacking' screws are incorporated in the pump assembly (refer to Fig. 3 in 'Lubrication System and Cooling System'), ensure that the screw facing pads are below the pump body mounting face before fitting the pump otherwise distortion to mounting face will occur. On completion of pump fitting, tighten the 'jacking' screws evenly until seated. Do not overtighten; the maximum torque is 13,6 to 14,9 Nm (10 to 11 lbf ft or 1,4 to 1,5 kgf m).

17. Turn the engine on the stand so that the front is uppermost. Check the backlash between the oil pump and crankshaft gears – see Fig. 33. The backlash should not exceed the specified limits. Refit the oil pump cover using a new gasket.

18. Apply an even coat of sealer EM-4G-47 to the front face of the camshaft spacer and then carefully fit the spacer to the camshaft ensuring that the sealing lip of the seal is not damaged during this operation.

19. When applying sealer EM-4G-47 to the rear face of the camshaft gear centre boss, sealer should also be applied *around the locating key and slot.* Refit the gear to the camshaft. Apply an even coat of sealer EM-4G-47 to the underside of the gear retaining bolt head and loosely fit the bolt. Lock the gear with the timing peg, Fig. 8, and torque to the specified figure. Remove the peg.

20. Check the camshaft end float by mounting a dial gauge stand, Fig. 34, in an existing bolt hole. With the gauge (set to zero) touching the centre bolt, gently prise the camshaft gear upwards with a suitable lever until the end float is taken up. The reading on the gauge should be within the maximum permitted figure – see specifications; renew parts as necessary.

21. Turn the engine normal way up. Fit the water pump, injection pump and, where applicable, the exhauster pump/compressor.

22. Fit a new seal to the front cover and position the cover to the block using Tool No. 21-025 to centralise the oil seal around the crankshaft (Fig. 35). Ensure that the seal runs on an unworn part of the spacer, or alternatively replace the spacer. Install the dowel bolt into the uppermost bolt hole, and finger tighten. Fit the remaining bolts and tighten to the specified torque (see Specifications).

23. Apply an even coat of grease to specification EM-1C-B to the inside and outside diameters of the crankshaft spacer (Fig. 36). Fit the spacer. Apply an even coat of sealer EM-4G-47 to the rear face of the timing belt drive gear (three sheave crankshaft pulley) or to the rear face of the pulley hub and timing belt drive gear (two sheave crankshaft pulley) and fit it to the engine. In the case of engines with two sheave crankshaft pulleys apply a coating of EM-4G-47 to the rear of the crankshaft centre bolt. Fit the bolt and tighten to the specified torque (see Specifications).

    When renewing the belt retainer/crankshaft timing collar, ensure that the latest type (Part No. 715F-6K527-ACB) with a 'silver finish' is fitted. If however, the latest type of belt retainer/timing collar is being fitted, the timing gear cover (Pt. No. 715F-6059-AAF) MUST ALSO be renewed, otherwise engine timing will be affected.

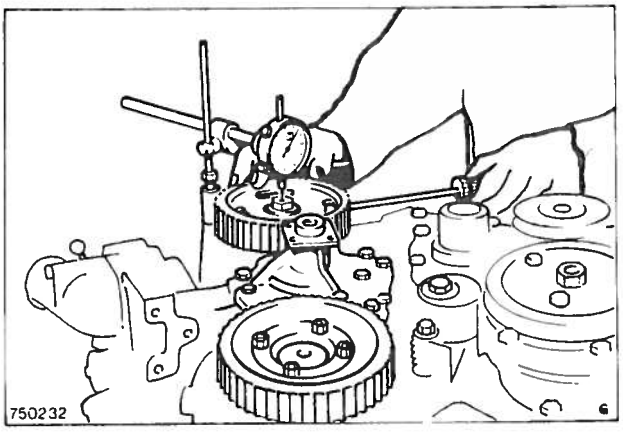


Fig. 34 Checking the camshaft end float

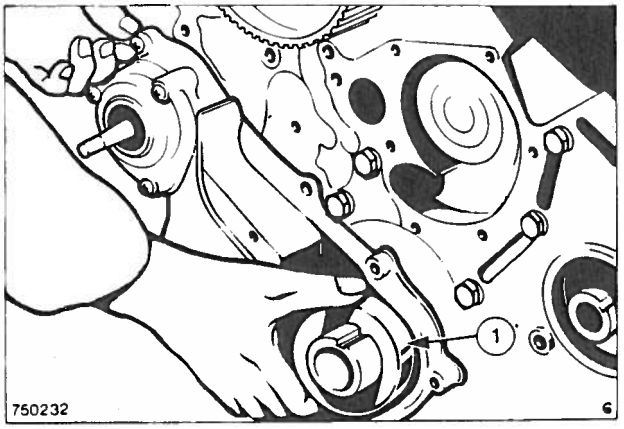


Fig. 35 Centralising the front cover oil seal
1. Tool No. 21-025

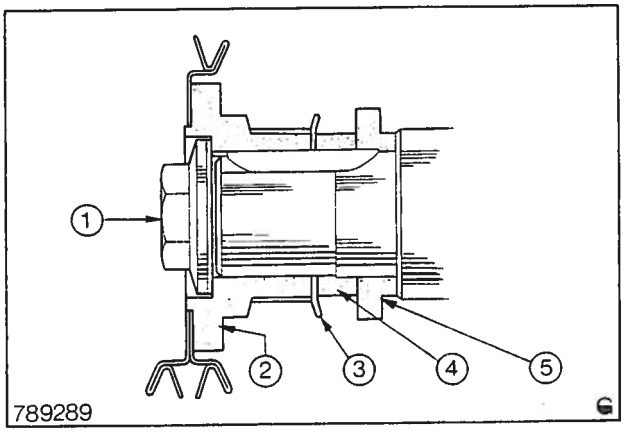


Fig. 36 Section through crankshaft front end
1. Crankshaft pulley
2. Drive gear/hub
3. Belt retainer
4. Spacer
5. Gear

Front timing gear covers supplied in Service are not stamped with a timing mark and therefore it will be necessary to stamp a timing mark as follows:

Set number one piston at T.D.C.
Stamp the timing gear cover adjacent to the notch on the belt retainer/crankshaft timing collar.

24. The drive belt tensioner can now be fitted. Lightly oil (SAE 50) the pivot/mounting bolt and the rear face of the tensioner assembly. Fit the spring to the tensioner, ensuring that the spring retaining leg is located in the tension arm slot (Fig. 37). Fit the complete tensioner assembly to the front housing ensuring that the spring hook is located in the housing recess, then screw the pivot/mounting bolt into the housing but do not tighten. Fit the idler locking bolt and nut but do not tighten.

Press the tensioner assembly to the extreme left hand position (against the spring tension) and temporarily lock in position by tightening the pivot/mounting bolt and idler locking bolt.

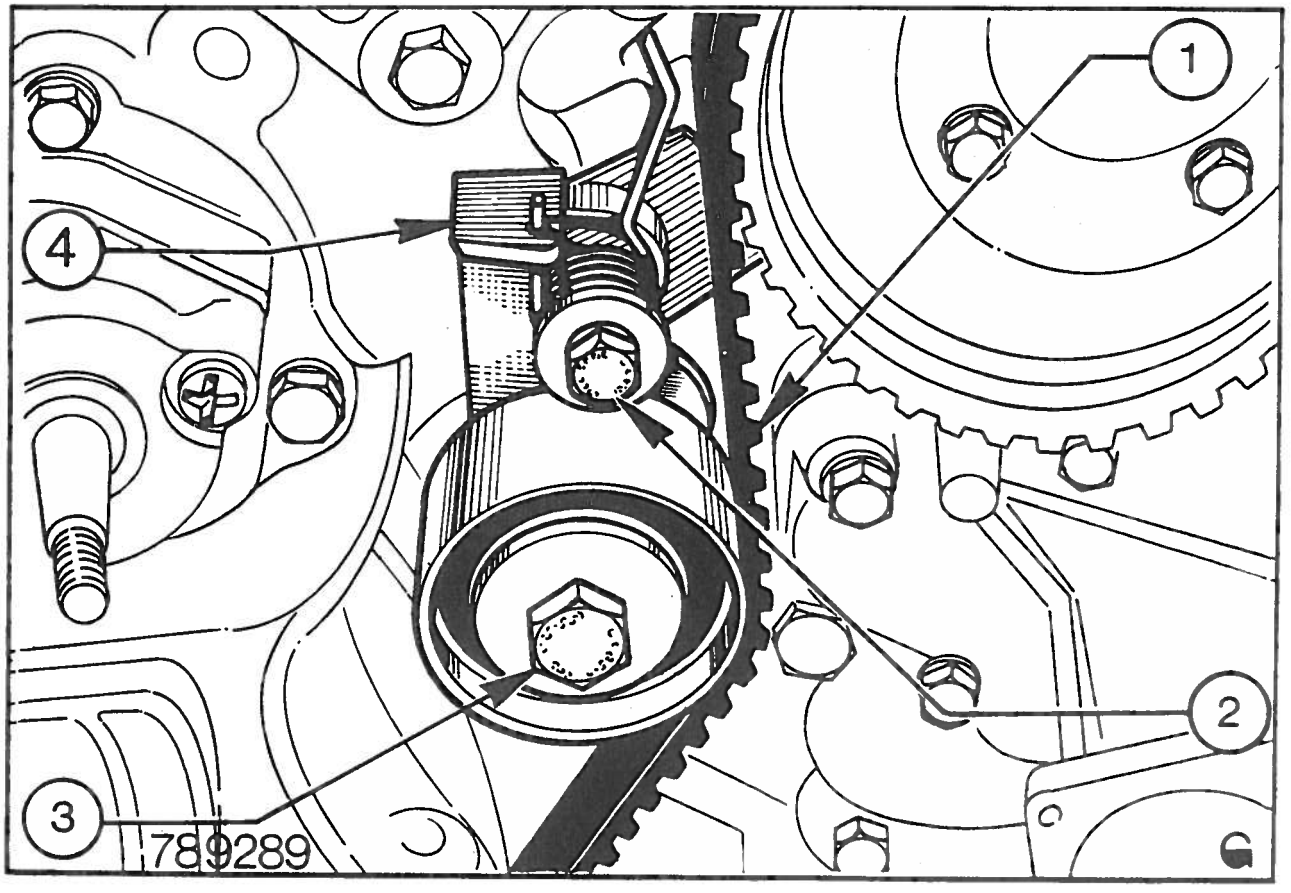


Fig. 37 The drive belt tensioner

1. Drive belt
2. Tensioner pivot/mounting bolt
3. Idler locking bolt
4. Timing belt tensioner

25. Align the crankshaft timing marks (Fig. 38) and fit the camshaft gear timing peg – Tool Number 21-016.

26. Re-fit the injection pump gear and finger tighten the retaining bolts. Turn the injection pump gear until the pump pointer coincides with the 12° B T D C line (Fig. 39).

    On 4 cylinder engines with cylinder head glow plugs, fit the injection pump timing gear so that the studs are at the left hand end of the slots – see Fig. 40. Lightly tighten the gear securing nuts, then turn injection pump gear until timing peg can be inserted as shown in Fig. 41.

    A suitable peg can be easily manufactured to the dimensions given.

27. Visually examine the timing belt and check for:–
    a. Fraying of the belt edges and severing of the cords.
    b. Cracking, splitting or excessive wear of the material in the teeth area.
    c. Heavy scoring or bearing marks on the back of the belt.

    If there is any doubt on the serviceability of the belt it should be changed.

When renewing the timing belt, ensure that the correct Ford type is fitted.

NOTE: From January 1978, modified crankshaft, camshaft and fuel injection pump timing gears will be fitted to all engines, together with a new type of timing belt. This later type of belt can be fitted to earlier type timing gears. The later type of timing gears other than marine can be identified by their expoxy resin coating. Later type timing gears for marine applications are nickel plated.

28. Feed the timing belt over the crankshaft, camshaft and injection pump gears, ensuring that it passes to the right of the idler pulley (Fig. 37).

    If necessary move the injection pump drive gear on the pump hub using the slotted holes in the gear to allow the belt to mesh correctly.

    Check that all the timing marks are still correctly aligned and tighten the pump gear nuts.

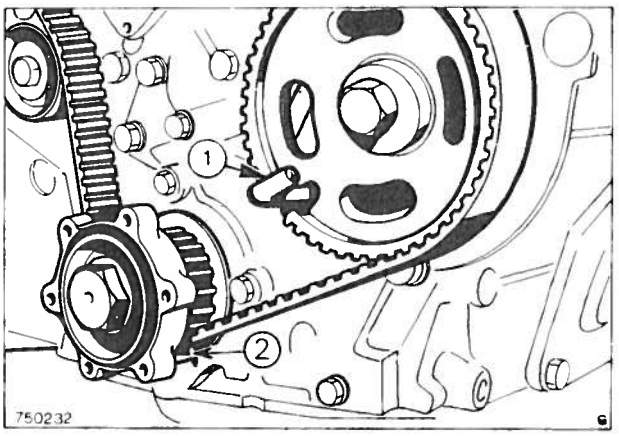


Fig. 38 Fitting the camshaft gear timing peg
1. Tool No. 21-016
2. Crankshaft timing marks

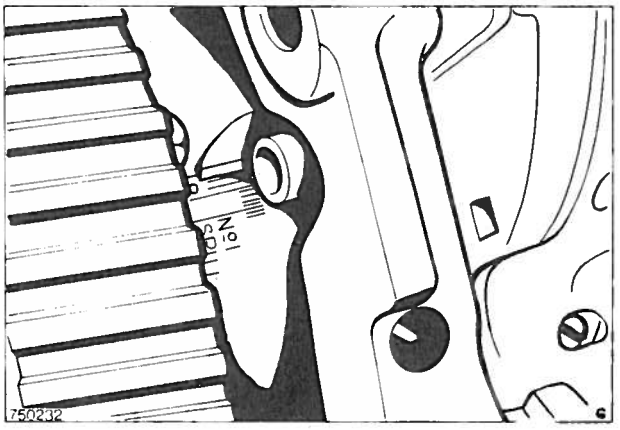


Fig. 39 Timing the injection pump

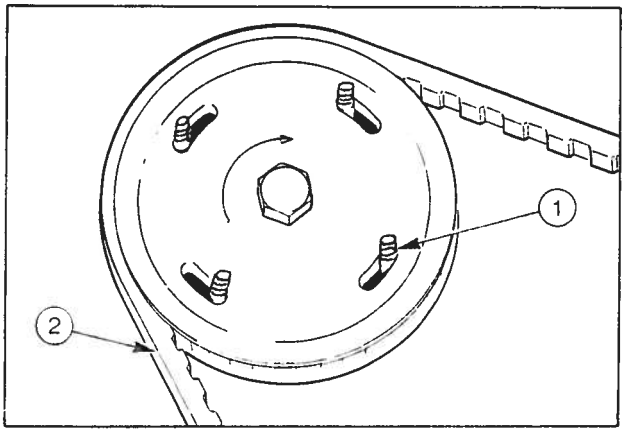


Fig. 40 Injection pump timing gear
1. Auto-advance stud
2. Timing belt

NOTE: Turn in direction of arrow to advance the timing.

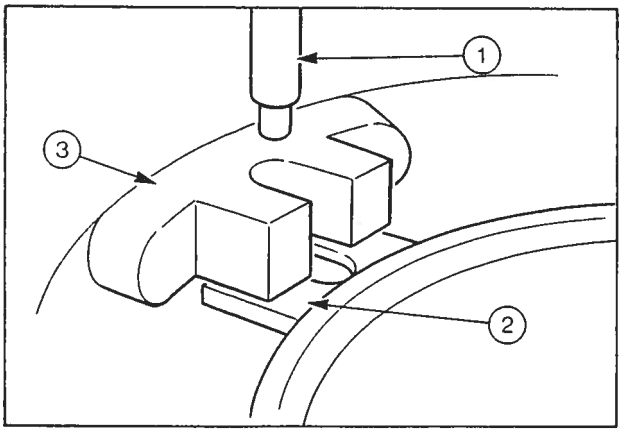


Fig. 41
1. Timing peg.
   Diameter 7,978 to 8,00 mm
2. Fixed to auto-advance unit
3. Fixed to pump

NOTE: Turn in direction of arrow to advance the timing.

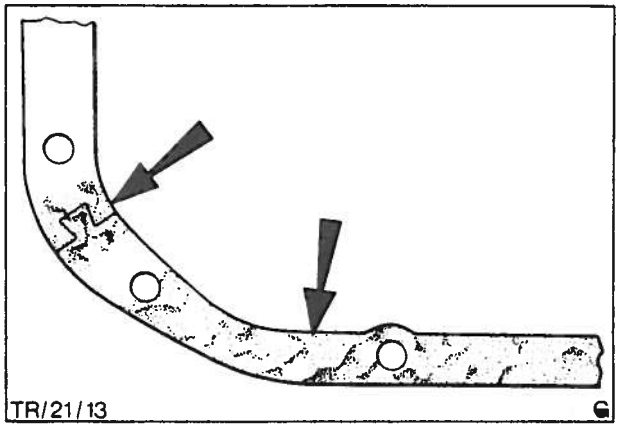


Fig. 42 Sump gasket

29 Loosen the belt tensioning pulley locking bolt and pivot mounting bolt until the tensioner is able to rotate freely and take up the designed static tension.

Remove the camshaft gear locating pin (and, where fitted, the injection pump timing peg) and rotate the crankshaft two revolutions, re-setting it to the TDC mark. Activate the tensioner by depressing the timing belt vigorously between the camshaft and fuel injection pump gears. Tighten the pivot/mounting bolts to a torque of 19,7 Nm (14,5 lbf ft or 2 kgf m). Tighten the idler locking bolt to a torque of 39,3 Nm (29 lbf ft or 4 kgf m).

On 4 cylinder engines with cylinder head glow plugs, turn the crankshaft back to 11° BTDC. This position can be established exactly by measuring the rise of No. 1 piston with a clock gauge mounted on the top face of the cylinder block. When the piston is 0,99 ± 0,05 mm (0,039 ± 0,002 in) below its highest point, the crankshaft is at 11° BTDC.

Slacken the injection pump timing gear nuts and turn the pump hub, while keeping the gear stationary, until the pump timing peg can be inserted – see Fig. 41. Tighten pump gear nuts and check that camshaft is still at 11° BTDC. Remove pump timing peg.

30. Replace the timing belt cover. On engines for use with a twin sheave crankshaft pulley the pulleys may now be assembled onto the hub. On engines for use with three sheave crankshaft pulleys the rear faces of the pulley and the crankshaft bolt should be coated with EM-4G-47. The pulley and bolt should now be fitted to the crankshaft and the bolt tightened to the specified torque.

31. With the engine inverted fit the oil pick-up pipe, complete with new flange gasket. On later engines, fit a new 'O' ring to the recess in the engine block – no flange gasket is used. Position the four sections of the sump gasket on the block, Fig. 42, ensuring that the dovetail joints are correctly located. To assist in positioning the gasket, small patches of sealer may be applied along the block jointing faces.

Apply an even coat of sealer EM-4G-47 over the dovetailed areas and to the surface of the gasket along the full length of the front and rear abutments.

Locate the sump and refit the retaining bolts and spring washers ensuring that the four socket cap bolts are positioned in the bolt holes at the front and rear of the pan. Torque the bolts to the specified torque. The sequence of bolt tightening is not important.

The oil pan retaining bolts fitted to current production engines are self-sealing; they can be identified by the 'locking patch' on the threads.

Any engine which has persistently leaked oil from the oil pan should have the latest type of bolts fitted. In addition, the spring washers should be replaced by flat washers Pt. No. E830111-S82 (Finis Code 1477027) and the gasket should be coated with sealer Pt. No. A77SX-19554-BA (Finis Code 5003459). Tighten bolts to the specified torque value; DO NOT overtighten.
Self-sealing bolts can be re-used up to a maximum of four times; if in doubt regarding serviceability, fit new bolts.

32. Clean the crankshaft rear flange and position the flywheel on the crankshaft.

NOTE: One of the flywheel bolt holes is offset, so that the flywheel can only be fitted in one position. Fit the flywheel bolts and tighten them in a diagonal sequence to the specified torque (see Specifications). Using a dial indicator check the flywheel clutch face run-out at a radius of 120 mm (5,0 in). This should not exceed the specified figure. If the run-out is outside the specified limits, the flywheel must be removed and the mating surfaces re-cleaned.

Heavy Flywheels

In addition to the flywheel retaining bolts a dowel is used on heavy flywheels for added security. If a new heavy flywheel is fitted, the following procedure must be followed:–

a. Tighten the retaining bolts to the specified torque.
b. Enlarge the dowel hole, using a 9,5 mm drill.
c. Enlarge the dowel hole, using a 10,5 mm drill.
d. Ream the dowel hole, using an 11,0 mm reamer.
e. Remove all traces of swarf from the dowel hole before fitting the dowel.

In cases where a new crankshaft has been fitted with the original heavy flywheel, the drilling and reaming procedure will be necessary to enlarge the dowel hole in the crankshaft flange.

Where applicable fit the clutch assembly.

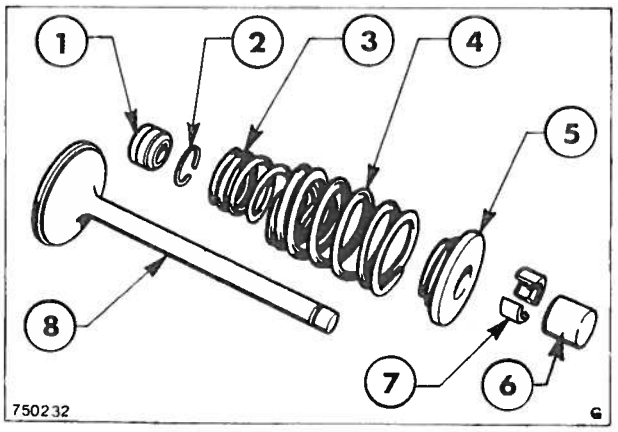


Fig. 43 Exhaust valve and springs

1. Oil Seal
2. Circlip
3. Inner Spring
4. Outer Spring
5. Retainer
6. Cap
7. Collets
8. Valve

33. Refit the valves, fit a new oil seal over the valve guides ensuring that the circlip is positioned correctly and refit the valve springs and valve spring retainers. When refitting valve springs, note that later built engines are fitted with inlet valve springs Part No. 755F-6513-AAA which have a reduced working stress. Note that when replacing springs on all engines, the previously fitted, and the later type springs can be inter-mixed. Using the valve spring compressor, depress the spring and refit the valve spring collets.

NOTE: Double springs are fitted to the exhaust valve only, Fig. 43.

From January 1978, valve stem caps have been fitted to production engines to reduce rocker arm wear. To accomodate the caps, new valves, spring retainers and valve guides have been introduced. These components are not interchangeable with the earlier parts which are still available.

34. Clean the joint faces of the cylinder head and the cylinder block. Fit a new cylinder head gasket to the block, with the stamped 'part number' uppermost.

    Position the cylinder head and locate on the two dowels. Tighten the cylinder head bolts to the specified torque as shown in Figs. 44 and 45. Connect the water pipe by-pass hose, Fig. 46.

35. After checking the pushrods for straightness they can be refitted together with the rocker shaft assembly.

    Engines built prior to January 1978 which exhibit symptoms of noisy valve gear or which cause difficulties in setting valve clearances, should have the existing rocker arms with black phosphate coated pads replaced by the later type arms, Pt. No. 715F-6529-ABA (Finis Code 1587038).

    The new type arms, which have chromium plated pads, can be fitted to engines with earlier or later type valve assemblies. Valve clearances remain the same.

36. Adjust the valve clearnances (Fig. 47) in the sequence shown using a ring spanner or socket. See Specifications for the clearance.

ADJUSTMENT SEQUENCE

4 Cylinder

Valve Fully Open	Valves to Adjust
1 EX	4 IN and 7 EX
2 IN	5 EX and 8 IN
4 IN	1 EX and 6 IN
5 EX	2 IN and 3EX

6 Cylinder

Valve Fully Open	Valves to Adjust
1 EX	10 IN and 11 EX
2 IN	7 EX and 12 IN
3 EX	8 IN and 9 EX
7 EX	2 IN and 5 EX
8 IN	3 EX and 6 IN
11 EX	1 EX and 4 IN

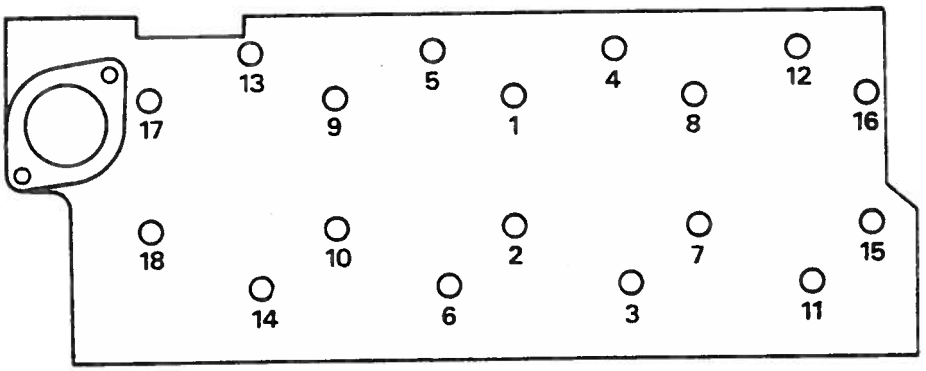


Fig. 44 Bolt tightening sequence – 4 cyl.

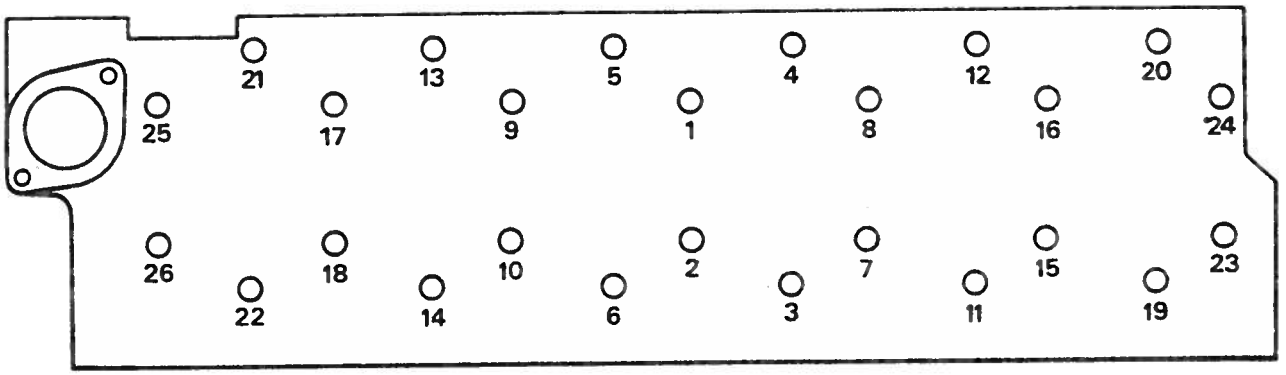


Fig. 45 Bolt tightending sequence – 6 cyl.

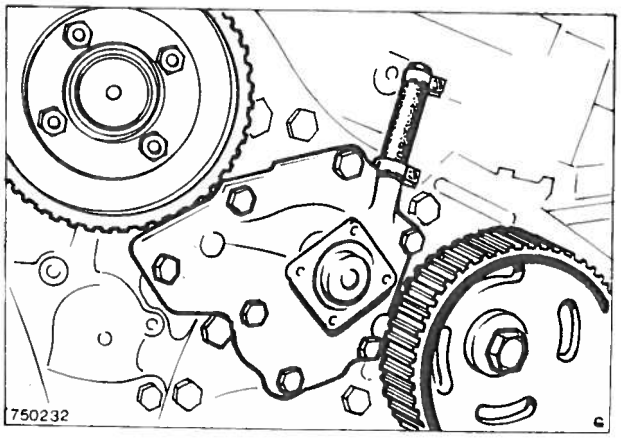


Fig. 46 The water pump and by-pass hose

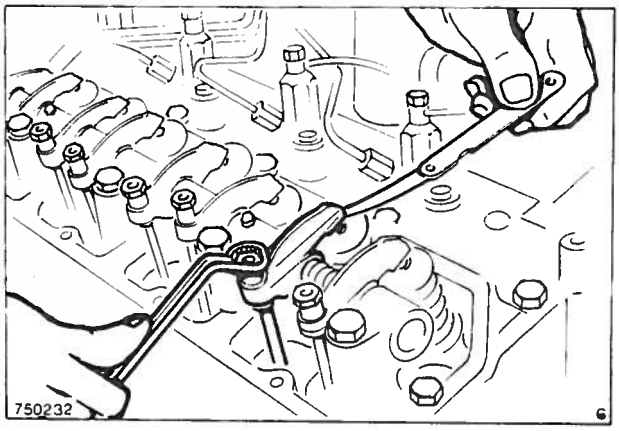


Fig. 47 Adjusting the valve clearances

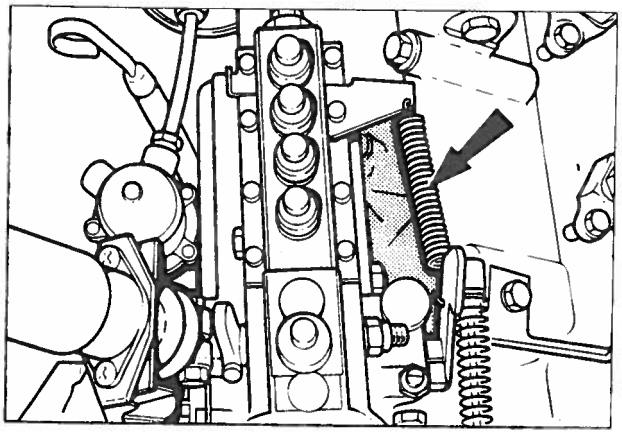


Fig. 48 Throttle lever return spring

37. Refit the rocker cover with a new gasket.

38. Replace the exhaust manifold.

39. On 4 cylinder engines fitted with glow plug cylinder heads, screw the four glow plugs into the cylinder head. If new glow plugs are being fitted, install the latest type with the reduced sheath length. All four plugs must be renewed at the same time.

NOTE: The normal service life of the plugs is 1 000 hours or 50 000 km (30 000 miles), after which they should be renewed; if, however, the pump timing is maladjusted by as little as 3° or 4°, the increased peak temperature reached in the cylinder will seriously reduce the effective service life of the glow plugs.
Connect the loom to the three glow plugs located inside the inlet manifold. New lock nuts must be used.

40. Remove the injection pump throttle lever return spring – see Fig. 48.

41. Clean the inlet manifold gasket mating surfaces and place a new gasket in position. On glow plug head engines, connect the glow plug loom to the inlet manifold – see Fig. 49. New lock nuts must be used to secure the glow plug loom.

    Secure the inlet manifold to the cylinder head.

42. Replace the injection pump throttle lever spring – see Fig. 48.

43. On 4 cylinder engines fitted with glow plug cylinder heads, connect the glow plug loom at the front of the inlet manifold – see Fig. 50.

44. Fit injectors and connecting leak-off pipes.

45. Connect the high pressure fuel pipes to the injectors and injection pump using wrench, Tool. No. 21-041.

46. Refit the fuel filter(s) complete with bracket. Replace fuel pipes and bleed air from system.

47. Replace the water pump pulley and fan.

48. Fit the starter motor.

49. Fit the alternator mounting bracket and replace the alternator.

50. Fit and adjust the fan belt(s).

51. Where applicable, replace the exhauster pump/compressor drive belt pulley, jockey pulley and drive belt. Adjust jockey pulley to give the correct drive belt tension.

52. Reconnect crankcase vent pipe to inlet manifold.

53. On 4 cylinder glow plug head engines, use a mirror to look down the manifold air intake and check that the loom does not pass over the air cleaner securing bolt hole – see Fig. 51. Relocate wire if required.

54. Refit air cleaner assembly.

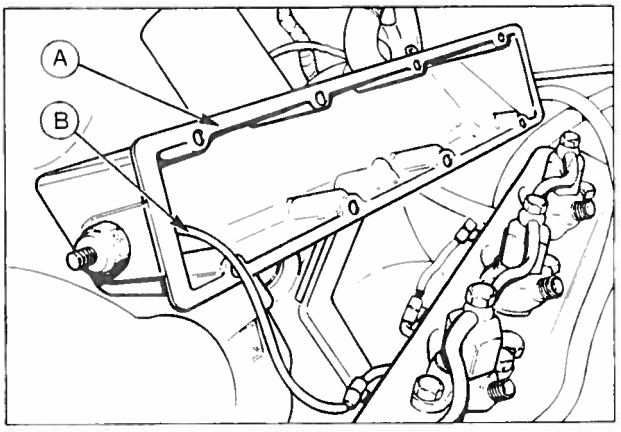


Fig. 49 Replacing inlet manifold
A – Inlet manifold
B – Glow plug loom connection

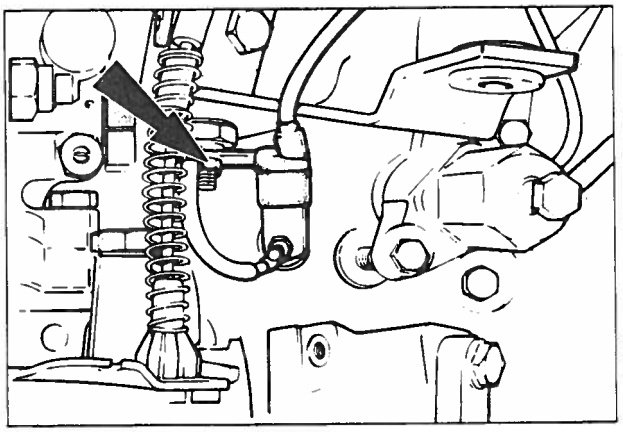


Fig. 50 Glow plug loom connection

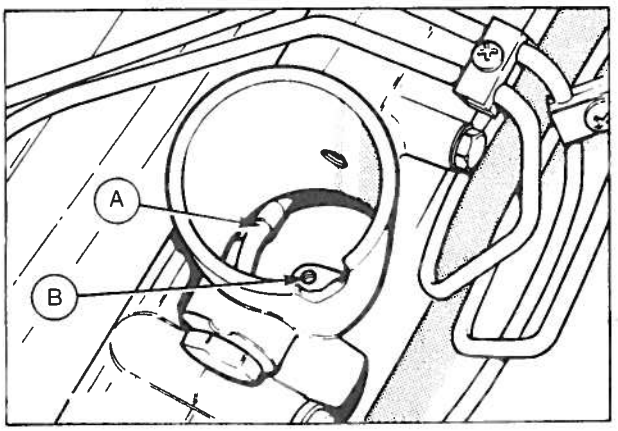


Fig. 51 Inlet manifold air intake
A – Glow plug internal loom
B – Air cleaner bolt hole

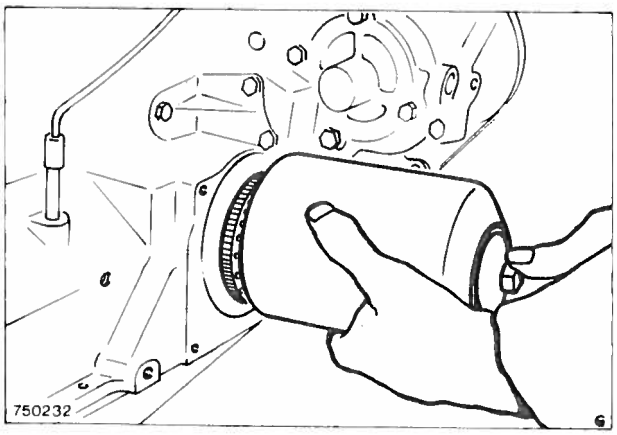


Fig. 52 Fitting the oil filter assembly

55. Using a suitable hand syringe, pump a minimum of 1,14 litre (2 pint) of the correct specification engine oil, into the main oil gallery, through the oil filter centre oilway. Fit the oil filter assembly, Fig. 52, using a new element. Replace the dipstick. Fill the engine to the specified level with the correct engine oil.

56. Remove the engine from the stand and detach the special mounting bracket 21-015.

SPECIFICATIONS

ENGINE	4 CYLINDER	6 CYLINDER
Model Number	2401E	2402E
Type	Diesel engine with overhead valves and indirect injection	
Bore	93,67 mm (3,68 in)	93,67 mm (3,68 in)
Stroke	85,58 mm (3,36 in)	85,58 mm (3,36 in)
Capacity	2359 cc (144 cu in)	3540 cc (216 cu in)
Compression Ratio	21,5:1	21,5:1
Compression Pressure	2756 kN/m² (400 lbf/in² or 28,1 kgf/cm²)	2756 kN/m² (400 lbf/in² or 28,1 kgf/cm²)
Variation between cylinders	827 kN/m² (120 lbf/in² or 8,4 kgf/cm²)	827 kN/m² (120 lbf/in² 8,4 kgf/cm²)
Max Output (kW)		
Overload BS 649	43,6 at 3600 rpm	64,9 at 3600 rpm
Continuous BS 649	39,5 at 3600 rpm	58,9 at 3600 rpm
Continuous B DIN 6270	39,0 at 3600 rpm	59,9 at 3600 rpm
Continuous A DIN 6270	35,7 at 3600 rpm	53,7 at 3600 rpm
Max torque (Nm)		
Overload BS 649	121 at 2250 rpm	180 at 2250 rpm
Continuous BS 649	110 at 2250 rpm	164 at 2250 rpm
Continuous B DIN 6270	116 at 2250 rpm	176 at 2250 rpm
Continuous A DIN 6270	107 at 2250 rpm	158 at 2250 rpm
Firing Order	1.2.4.3.	1.5.3.6.2.4.

CAMSHAFT

Material	Special Ford Cast iron alloy
Drive	Toothed belt
Maximum Cam Lift	
– Inlet	6,5 mm (0,256 in)
– Exhaust	7,0 mm (0,275 in)
Bearing type	Steel backed bushes, front copper/lead, remainder tin based babbitt/copper/lead
Number of bearings	4 6
Oversize bearings available	0,50 mm (0,20 in) O/S O.D. Std. I.D.
Journal diameter	55,957 to 55,944 mm (2,2030 to 2,2025 in)
Bearing clearance	0,050 to 0,139 mm (0,002 to 0,0055 in)
Camshaft end float	0,05 to 0,20 mm (0,002 to 0,008 in)

CONNECTING RODS AND BIG END BEARINGS

Connecting rod type	Right angled split, H section shank
Length – centre to centre	154 mm (6,065 in) Nominal ± 0,025 mm (0,001 in)
Small end bore – (with bush)	29,010 to 29,022 mm (1,1421 to 1,1426 in)
Small end bush	Steel backed bronze
Big end bore	63,506 to 63,520 mm (2,500 to 2,504 in)
Big end bearings	Steel backed aluminium/tin or copper/lead
Underzise of liner	0,25 mm (0,010 in), 0,50 mm (0,020 in) 0,75 mm (0,030 in), 1,0 mm (0,040 in)
Liner Width	25,87 to 26,13 mm (1,009 to 1,029 in)
Liner thickness (Std.)	1,726 to 1,735 mm (0,0680 to 0,0685 in)
Clearance on crankpin	0,036 to 0,088 mm (0,0014 to 0,0035 in)
End float on crankpin	0,127 to 0,279 mm (0,005 to 0,011 in)
Clearance between small end bush and piston pin	0,0125 to 0,030 mm (0,0005 to 0,0013 in)

CRANKSHAFT AND MAIN BEARINGS

Material	Nodular cast iron
Main journal (diameter)	
– rear	76,98 to 77,00 mm (3,0267 to 3,0275 in)
– remainder	69,98 to 70,00 mm (2,7550 to 2,7560 in)
Main journal (length)	
– front	27,95 to 28,45 mm (1,100 to 1,120 in)
– intermediate	34,04 to 34,30 mm (1,3402 to 1,3505 in)
– centre	35,55 to 35,60 mm (1,3396 to 1,4026 in)
– rear	30,10 to 30,85 mm (1,185 to 1,215 in)
Main journal fillet radii	3,754 to 4,250 mm (0,148 to 0,167) and 2,50 to 3,50 mm (0,098 to 0,138 in)
Crankpin journal fillet radii	3,00 to 3,50 mm (0,119 to 0,138 in)
Main bearing material	Steel backed aluminium/tin or copper/lead
Main bearing liner thickness	
– Std.	1,970 to 1,979 mm (0,0676 to 0,0679 in) – Red 1,980 to 1,989 mm (0,0679 to 0,0683 in) – Blue
– undersizes	0,25 mm (0,010 in), 0,50 mm (0,020 in) 0,75 mm (0,030 in)
– oversizes	0,40 mm (0,015 in)
Main bearing clearance	0,052 to 0,090 mm (0,0020 to 0,0034 in)
Length of Main bearing liners	
– front and intermediate	22,87 to 23,13 mm (0,900 to 0,911 in)
– centre	26,86 to 27,10 mm (1,057 to 1,067 in)
– rear	21,87 to 22,13 mm (0,861 to 0,871 in)
Thrust washer thickness	
– Std	2,311 to 2,362 mm (0,091 to 0,093 in)
– oversizes	0,06 mm (0,0025 in), 0,12 mm (0,005 in) 0,18 mm (0,007 in), 0,25 mm (0,010 in) 0,40 mm (0,015 in), 0,50 mm (0,020 in)
Camshaft end float	0,05 to 0,25 mm (0,002 to 0,010 in)
Wear limit	0,33 mm (0,013 in)
Crankpin journal diameter	59,98 to 60,00 mm (2,3617 to 2,3622 in)
Crankpin journal length	32,28 to 23,38 mm (1,2709 to 1,2748 in)
Crankpin journal clearance	0,036 to 0,088 mm (0,0015 to 0,0035 in)
Crankpin bearing liner thickness	
– Std	1,726 to 1,735 mm (0,0680 to 0,0685 in)
– Undersizes	0,25 mm (0,010 in), 0,50 mm (0,020 in) 0,75 mm (0,030 in), 1,0 mm (0,04 in)
Crankpin bearing length	25,87 to 26,13 mm (1,019 to 1,029 in)
Number of teeth on crankshaft gear	32

CYLINDER BLOCK

Type	Monobloc casting, integral with top half of crankcase
Material	Ford cast iron alloy
Water jackets	Full length
Standard cylinder bore (diameter)	Graded
Grade (measured 90 mm (3,50 in) from top face)	
– 1	93,648 to 93,660 mm (3,6869 to 3,6874 in)
– 2	93,660 to 93,672 mm (3,6874 5o 3,6879 in)
– 3	93,672 to 93,684 mm (3,6879 to 3,6884 in)
– 4	93,684 to 93,696 mm (3,6884 to 3,6889 in)
Bore for main bearing liners	
– Rear (Std)	80,02 to 81,00 mm (3,1505 to 3,189 in)
– Except rear (Std)	74,00 to 74,02 mm (2,9135 to 2,9145 in)
Bore for camshaft bearing bush	61,00 to 61,046 mm (2,4016 to 2,4035 in)

CYLINDER HEAD	
Type	Cast iron with vertical valves, cross flow, with indirect injection pre-combustion chambers
Length of valve guide	
– early types	61,50 mm (2,42 in)
– later type	58,0 mm (2,283 in)
Valve guide – internal diameter before installation in cylinder head	
– early service type (std. & O.S.)	8,988 to 9,008 mm (0,3538 to 0,3546 in)
– later type (std. production only)	7,840 to 7,960 mm (0,3086 to 0,3133 in)
Valve guide external diameter	
– std. (early & later types)	14,725 to 14,738 mm (0,5795 to 0,580 in)
– oversize (early service type only)	15,225 to 15,238 mm (0,5994 to 0,5999 in)
Valve guide protrusion	
– inlet and exhaust (early type)	19,5 mm (0,768 in)
– inlet and exhaust (later type)	0,8 to 1,3 mm (0,031 to 0,051 in)
Valve seat insert recess diameter (Std)	
– inlet	45,71 to 45,75 mm (1,7995 to 1,8102 in)
– exhaust	37,96 to 38,00 (1,4945 to 1,4960 in)
Valve seat insert recess depth (Std)	
– inlet	9,42 to 9,73 mm (0,371 to 0,383 in)
– exhaust	9,42 to 9,73 mm (0,371 to 0,383 in)
Oversize inserts available	
– inlet	0,25 mm (0,010 in) O/S O.D.
– exhaust	0,25 mm (0,010 in) O/S O.D.
Valve seat angle	
– inlet	45° to 45° 30′
– exhaust	30° to 30° 30′
Valve head depth in cylinder head	
– inlet	0,81 to 1,33 mm (0,032 to 0,053 in)
– exhaust	0,55 to 1,07 mm (0,022 to 0,042 in)
FLYWHEEL	
Clutch face run out (T.I.R.)	0,16 mm (0,006 in) at 120 mm (5 in) radius
Number of teeth on ring gear	112
Flywheel retention	Eight 10 mm dia. bolts
Flywheel ring gear retention	Shrink fit 0,30 to 0,53 mm (0,012 to 0,021 in) interference
PISTONS	
Type	Slipper piston with swirl cavity in crown
Material	Aluminium alloy – tin plated
Number of rings	Two compression, one oil control
Width of ring grooves	
– upper compression	2,416 to 2,451 mm (0,0951 to 0,0965 in)
– lower compression	2,416 to 2,451 mm (0,0951 to 0,0965 in)
– oil control	4,776 to 4,800 mm (0,188 to 0,189 in)
Piston pin bore diameter	
Grade	
– 1	93,508 to 93,520 mm (3,6814 to 3,6819 in)
– 2	93,520 to 93,532 mm (3,6819 to 3,6824 in)
– 3	93,532 to 93,544 mm (3,6824 to 3,6829 in)
– 4	93,544 to 93,556 mm (3,6829 to 3,6834 in)
Oversize pistons available	
Clearance between block face and piston crown at TDC	0,114 to 0,213 mm (0,0045 to 0,0084 in)
PISTON PIN	
Type	Fully floating
Outside diameter	28,9900 to 28,9975 mm (1,1413 to 1,1416 in)
Length	74,25 to 74,50 mm (3,923 to 2,933 in)
Clearance in piston at 22°C (70°F)	0,0000 to 0,0050 mm (0,0000 to 0,0002 in)

PISTON RINGS

Upper compression ring	Cast iron, chrome plated, barrel faced, half keystone
Lower compression ring	Cast iron, chrome plated, plain faced, internal chamfer
Oil control ring	Cast iron, chrome plated, comformable, helical expander
Piston Ring Gap	
– top compression	0,25 to 0,50 mm (0,010 to 0,020 in)
– lower compression	0,25 to 0,50 mm (0,010 to 0,020 in)
– oil control	0,25 to 0,58 mm (0,010 to 0,023 in)
Width of piston ring	
– top compression	2,362 to 2,375 mm (0,0930 to 0,0935 in)
– lower compression	2,362 to 2,375 mm (0,0930 to 0,0935 in)
– oil control	4,724 to 4,737 mm (0,1860 to 0,1865 in)
Ring to groove clearance	
– Compression rings	0,041 to 0,089 mm (0,0016 to 0,0035 in)
– Oil control	0,039 to 0,076 mm (0,0015 to 0,0030 in)

PUSH RODS AND TAPPETS

Length of push rods	154,4 to 155,4 mm (6,08 to 6,12 in)
Diameter of push rods	7,72 to 8,03 mm (0,304 to 0,316 in)
Diameter of tappet stem	15,973 to 15,984 mm (0,6288 to 0,6293 in)
Overall length of tappet	62,00 mm (2,442 in)

ROCKER SHAFT AND ROCKERS

Rocker shaft diameter	18,87 to 18,90 mm (0,7430 to 0,7442 in)
Number of rocker shaft springs	4 6
Compressed length and load of spring	26,92 mm at 1,8 to 2,3 kg (1,06 in at 4 to 5 lb)
Clearance between rocker arm and shaft	0,02 to 0,08 mm (0,0008 to 0,0003 in)

VALVES

Valve head diameter	
– inlet	44,10 to 44,40 mm (1,736 to 1,748 in)
– exhaust	36,10 to 36,40 mm (1,421 to 1,433 in)
Angle of valve head	
– inlet	44° 30′ to 45°
– exhaust	29° 30′ to 30°
Stem to guide clearance	
– inlet	0,016 to 0,072 mm (0,0006 to 0,0028 in)
– exhaust	0,034 to 0,090 mm (0,0013 to 0,0035 in)
Valve stem diameter	
– inlet	8,941 to 8,966 mm (0,3520 to 0,3530 in)
– exhaust	8,923 to 8,948 mm (0,3513 to 0,3523 in)

VALVE SPRINGS

Number of coils on valve spring	
– exhaust outer	6,5 total, 4,5 active
– exhaust inner	7,5 total, 5,5 active
– inlet (early type)	5,9 total, 3,9 active
– inlet (later type)	6,2 total, 3,8 active
Free length of valve springs	
– exhaust outer	51,4 mm (2,024 in)
– exhaust inner	47,1 mm (1,854 in)
– inlet (early type)	44,83 mm (1,765 in)
– inlet (later type)	44,45 mm (1,750 in)
Length under load	
– exhaust outer	33,3 mm (1,311 in) at 62 kg (137 lb) ± 2,3 kg (5,1 lb)
– exhaust inner	29,3 mm (1,154 in at 36,5 kg (80 lb) ± 1,4 kg (3,1 lb)
– inlet (early type)	39,9 mm (1,570 in) at 33,0 kg (73 lb) ± 1,65 kg (3,6 lb)
– inlet (later type)	39,9 mm (1,570 in) at 33,0 kg (73 lb) ± 1,65 kg (3,6 lb)

VALVE TIMING AND CLEARANCES

Nominal valve timing at 0,534 mm (0,021 in) clearance	
Inlet opens	10° BTDC
Inlet closes	30° ABDC
Exhaust opens	54° BBDC
Exhaust closes	10° ATDC
Valve lift – inlet	9,75 mm (0,384 in)
– exhaust	10,50 mm (0,413 in)
Valve clearance (hot), inlet and exhaust	0,33 to 0,38 mm (0,013 to 0,015 in)

FAN BELT ADJUSTMENT

The correct tension of the fan belt is such that when the belt is alternatively pushed and pulled midway between the alternator and crankshaft pulley, the total belt movements must not exceed 12 mm (0,5 in).

TIGHTENING TORQUES

	Nm	lbf ft	kgf m
Main bearing cap bolts – 1st stage	118 to 127,4	87 to 94	12 to 13
– 2nd stage	127 to 136	94 to 100	13 to 13,8
Connecting rod nuts – 1st stage	47,5 to 61	35 to 45	4,8 to 6,2
– 2nd stage	61 to 74,6	45 to 55	6,2 to 7,6
Cylinder head bolts	136 to 149	100 to 110	13,8 to 15,2
Flywheel to crankshaft flange bolts	58,3 to 63,7	43 to 47	6 to 6,5
Camshaft centre bolt	103 to 118	76 to 87	10,5 to 12
Oil pan drain plug	20,3 to 27,1	15 to 20	2,1 to 2,8
Rocker shaft pedestal bolts – M10	65 to 69,2	48 to 51	6,6 to 7,1
– M8	16,3 to 20,3	12 to 15	1,7 to 2,1
Front housing to cylinder block – bolts 1 to 9 (Fig. 24)	27,1 to 27,5	20 to 23	2,8 to 3,2
– bolt 10 (Fig. 24)	20,3 to 24,4	15 to 18	2,1 to 2,5
Oil pump cover to front housing	13,6 to 16,3	10 to 12	1,4 to 1,7
Oil pan to cylinder block – plain bolts with spring washers	13,6 to 20,3	10 to 15	1,4 to 2,1
– self-seal bolts with flat washers	9,5 to 13,5	7 to 10	1,0 to 1,4
Inlet manifold bolts	10,8 to 13,6	8 to 10	1,1 to 1,4
Exhaust manifold bolts	40,7 to 50,2	30 to 37	4,2 to 5,1
Crankshaft centre bolt	312 to 339	230 to 250	31,8 to 34,6
Rear oil seal retainer to block	16,3 to 20,3	12 to 15	1,7 to 2,1
Oil pump to cylinder block	16,3 to 20,3	12 to 15	1,7 to 2,1
Injection pump to front housing	20,3 to 27,1	15 to 20	2,1 to 2,8
Water pump to front housing	13,6 to 20,3	10 to 15	1,4 to 2,1
Camshaft blanking plate to cylinder block	16,3 to 20,3	12 to 15	1,7 to 2,1
Camshaft thrust plate to cylinder block	24,4 to 29,8	18 to 22	2,5 to 3,0
Maximum torque to turn crankshaft in block (without pistons)	3,1	2,20	3,0
Vacuum pump to front housing (nuts and bolts)	31,2 to 39,3	23 to 29	3,2 to 4,0
Blanking plate to front housing	24,4 to 29,8	18 to 22	2,5 to 3,0
Oil filter to cylinder block	20,3 to 24,4	15 to 18	2,1 to 2,5
Oil filter/cooler adaptor to cylinder block	40,7 to 44,8	30 to 33	4,2 to 4,6
Oil pump pick-up pipe to cylinder block	9,5 to 14,9	7 to 11	1,0 to 1,5
Oil pressure relief valve plug to block	54,2 to 58,3	40 to 43	5,5 to 5,9
Timing belt cover to front housing	4,9 to 8,8	3,6 to 6,5	0,5 to 0,9
Alternator mounting bracket	9,5 to 14,9	7 to 11	1,0 to 1,5
Alternator to alternator mounting bracket	9,5 to 14,9	7 to 11	1,0 to 1,5

SECTION 2

LUBRICATION AND COOLING SYSTEMS

CONTENTS

LUBRICATION SYSTEM

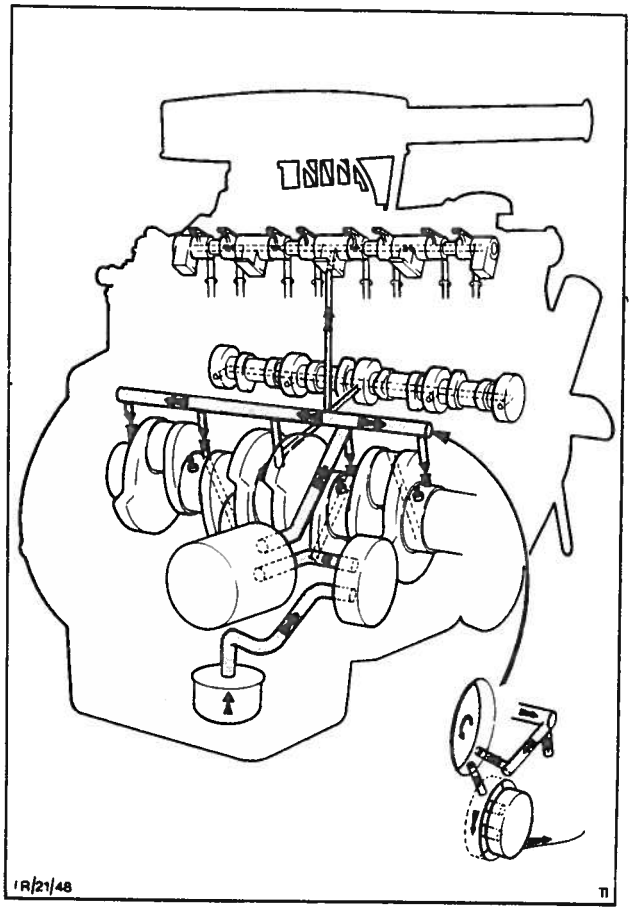


Fig. 1 The lubrication system

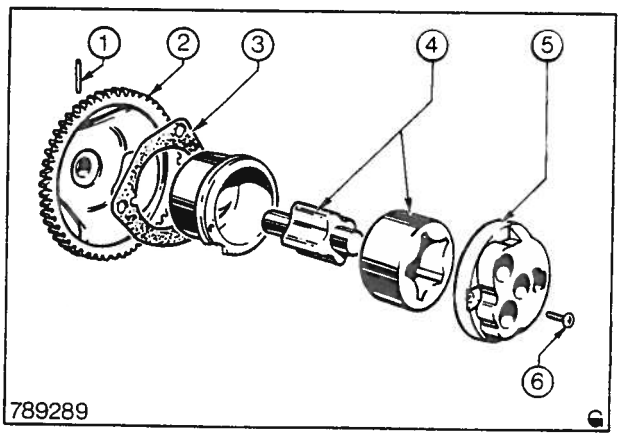


Fig. 2 4 cylinder Oil Pump

1. Pin
2. Gear
3. Plate
4. Rotor Assembly
5. Cover
6. Screw

DESCRIPTION

The engine lubrication system is of the forced feed type, the oil being circulated by a pump which is located in the front of the cylinder block, behind an alloy cover and is driven by a gear on the crankshaft.

Oil from the engine oil pan is drawn into the oil pump through a gauze screen and inlet pipe.

Oil flows direct from the pump to the filter via the relief valve (by-pass type) which bleeds off the surplus to maintain the correct pressure.

Later engines are fitted with an oil filter (Part No. 755F-6714-AAA) incorporating a 'ball-type' by-pass valve, which gives a positive seating at all pressures, thus eliminating seepage at low pressures, caused by flutter of the flap-type valve previously used.

From the main oil gallery, drillings carry the oil direct to each of the crankshaft main bearings. Drillings in the crankshaft carry oil to the big-end bearings, and small drillings in the top of each main bearing supprot direct jets of oil to the underside of each piston for cooling and cylinder bore lubrication.

A drilling from the crankshaft main bearing carries oil to the camshaft centre bearing and via the cylinder head to the rocker shaft assembly.

A drilling through the centre of the camshaft carries oil to the rest of the camshaft bearings. Three oilways in the front housing carry oil to and from the injection pump and the exhauster/ compressor, which are pressure lubricated, Fig. 1.

Note that the oil pan used on Marine engines is of the cast-alloy type, whereas all other engines in the range are fitted with a pressed steel oil pan.

Care should be taken when refitting the oil pick-up (oil inlet) pipe, particularly on Marine engines, as the action of fitting the oil pan could fracture the paper flange gasket used on earlier engines.

BI-ROTOR TYPE PUMP

Operation

The bi-rotor type pump consists of two sets of rotors, driven on the same shaft. Oil from the sump is drawn into the pump through a gauze screen and inlet pipe. The inner rotor is pressed onto a shaft. On pumps fitted to four cylinder engines, it is positively retained to the gear housing by a pin (Fig. 2). On six cylinder engines,

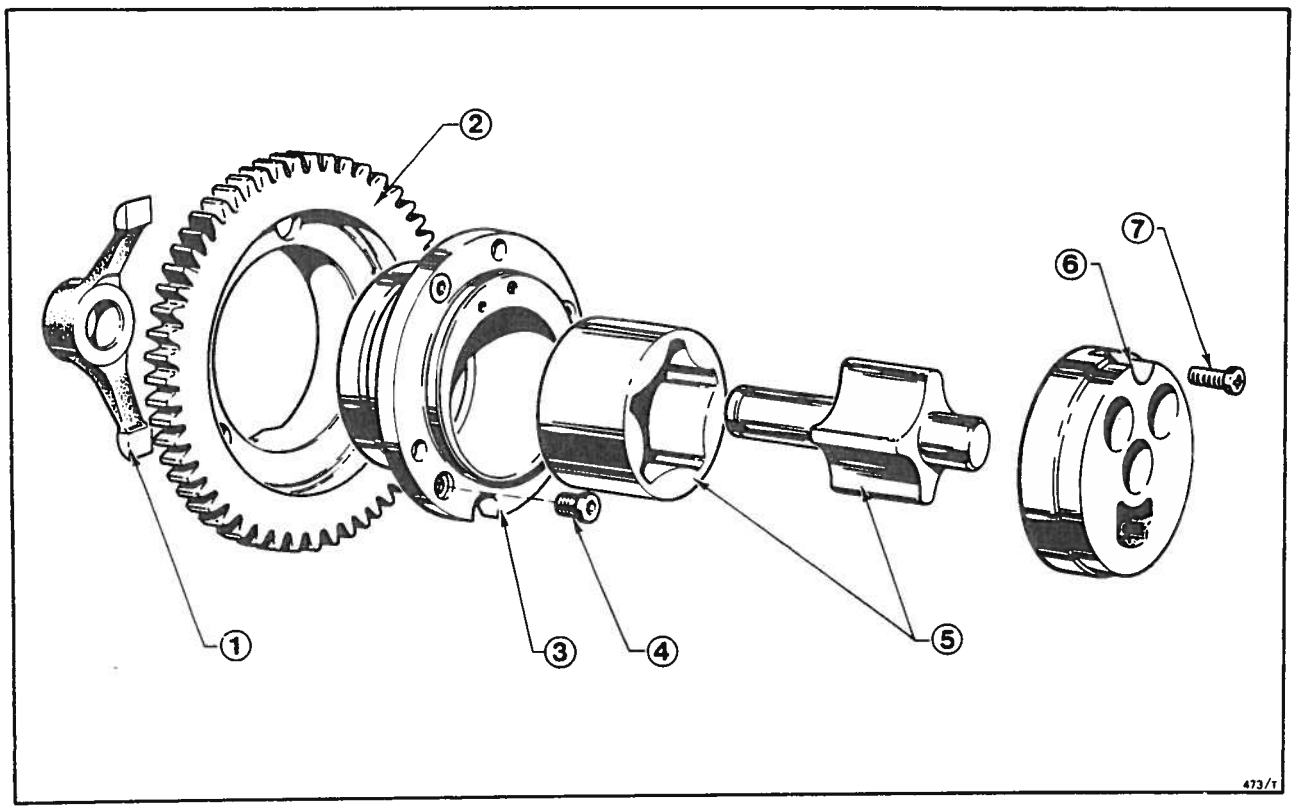


Fig. 3 6 Cylinder Oil Pump

1. Drive dog
2. Drive gear
3. Housing
4. Jacking screw
5. Rotors
6. Cover
7. Screw

the inner rotor is retained by a drive dog (Fig. 3).

The inner rotor has four lobes which mesh internally with the five segments in the outer rotor, Figs. 2 & 3. Rotation of the inner rotor thus causes the outer rotor to revolve also, but at $\frac{4}{5}$ of the speed, in the ratio of the number of lobes to segments.

The inlet port is connected to the oil pan, and the outlet port is connected vai the full flow filter to the oil galleries in the engine. Oil is drawn, via the inlet port, into the space formed between the inner and outer rotors as they revolve and is then carried round between the lobes to the outlet port. Here the space between the rotors starts to decrease and the oil is forced through the outlet port and filter into the engine oil galleries.

The action of the pump is a continuous repetition of this process.

To Dismantle

1. Drain the cooling system and engine oil.
2. Remove the fan belt, exhauster/compressor drive belt, (where fitted) and the fan, water pump and the crankshaft pulleys. Remove the exhauster pump drive pulley and hub.

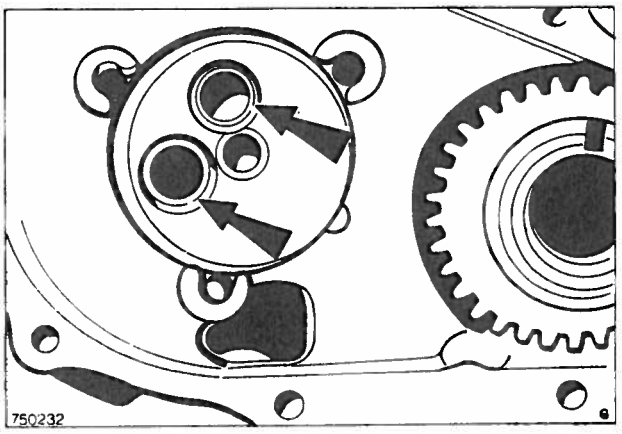


Fig. 4 Location of Oil Pump Gallery Seals

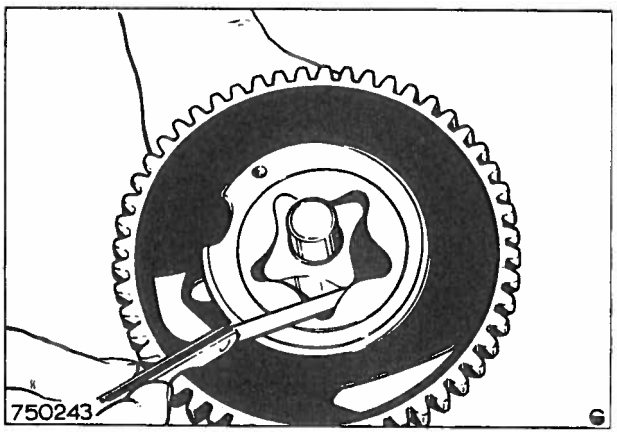


Fig. 5 Checking the clearance between the inner and outer rotors

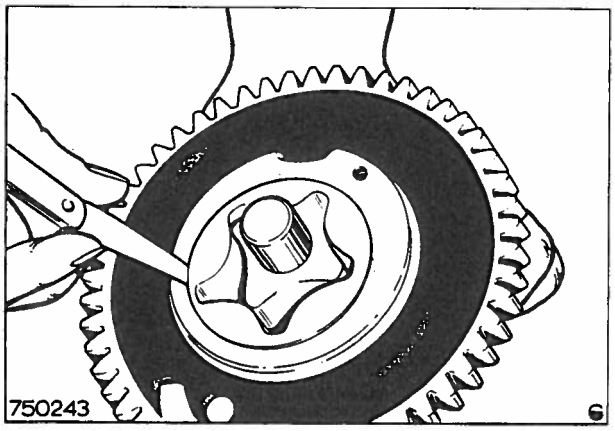


Fig. 6 Checking the clearance between the outer rotor and housing.

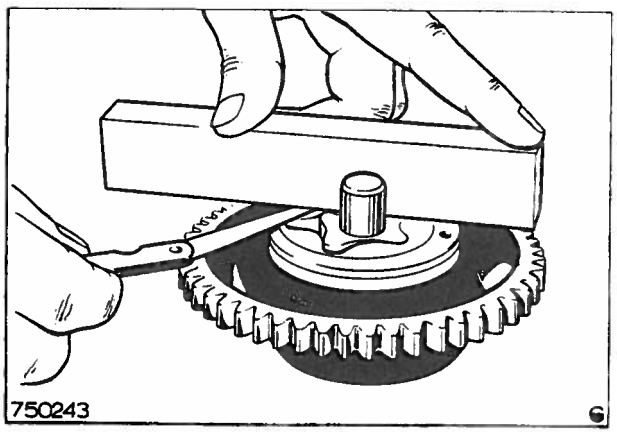


Fig. 7 Checking rotor end-float.

3. Turn the engine so that No. 1 piston is at TDC on the compression stroke and the crankshaft and camshaft timing marks are aligned.
4. Remove the timing belt cover. Slacken the timing belt tensioner bolts and release the spring.
5. Secure the crankshaft with the crankshaft locking bar and remove the crankshaft centre bolt. Remove the timing belt drive hub and the timing belt.
6. Remove the oil pump cover and gasket. Remove the spacer from the crankshaft.
7. Remove the three bolts retaining the oil pump assembly and withdraw the pump and gear from its housing. Remove the two rubber seals from the oil galleries, Fig. 4.

To Overhaul – 4 Cylinder Oil Pump

1. Unscrew the cross-headed bolt securing the end cover to the pump body, refer to Fig. 2 and remove the cover.
2. Check the clearance between the lobes of the outer and inner rotor, Fig. 5. If the clearance is excessive (see Specifications) a new rotor assembly must be fitted. Inner and outer rotors are services only as an assembly.
3. Check the clearance between the outer rotor and housing, Fig. 6. If the clearance is excessive (see Specifications) a new rotor assembly and/or a new pump assembly must be fitted.
4. Place a straight edge across the face of the pump body Fig. 7 and check the clearance between the face of the rotor and the straight edge (see Specifications). If the clearance is excessive, the face of the pump body must be relapped. Examine the end cover for wear or damage and renew if required.
5. If it is necessary to remove the inner rotor or drive gear, mask the inlet and outlet connections in the oil pump cover to prevent the ingress of foreign material. Remove the peened end of the drive gear retaining pin, then with a suitable punch remove the retaining pin.
6. Support the oil pump on the rear face of the drive gear, Fig. 8. The mounting plate and the pump should clear the drive gear supports.
7. Using a suitable press, press the rotor shaft and pump through the gear.

To Reassemble – 4 Cylinder Oil Pump

8. Support the base of the rotor shaft, Fig. 9, to prevent movement of the shaft within the rotor.
9. Position the gear so that the pre-drilled hole in the gear is in line as far as possible with the existing shaft hole.
10. Press the gear onto the shaft, Fig. 9, to a dimension of between 25,44 and 25,84 mm (1,00 to 1,02 in) from the rear face of the gear to the face of the cover, Fig. 10.
11. Drill a new hole through the gear and shaft at approximately 90° to the existing drillings.
12. Fit a new securing pin and peen both ends.
13. Remove the tape from the inlet and outlet connections.
14. Introduce oil into the pump inlet and rotate the drive gear. This will lubricate the rotors and ensure the pump primes when the engine is restarted.
15. With the pump lubricated check the pump for free movement. The torque to initiate movement should not exceed 0,56 Nm (5 lbf in or 60 gf m) and to rotate a minimum of 5 revolutions the torque should not exceed 0,45 Nm (4 lbf in or 46 gf m).

To Install

1. Ensure that all components are thoroughly clean, paying particular attention to the joint faces and bearing surfaces.
2. Fit two new rubber ring seals into the recesses in the oil pump housing galleries. Align the notch in the pump retaining plate with the cross headed bolt. Position the pump in the block ensuring that the oilways are aligned and the gears are fully meshed. Fit the three bolts and tighten evenly to the specified torque.
3. Using feeler blades, check the backlash between the crankshaft and oil pump gears. Fig. 11. Turn the crankshaft clockwise through 180°. Check the gear backlash again in this position. If the backlash exceeds the specified limits, either one or both gears must be replaced.

NOTE: As there is a slight clearance between the key and the keyway, the crankshaft gear should be held still or else false readings may be obtained.

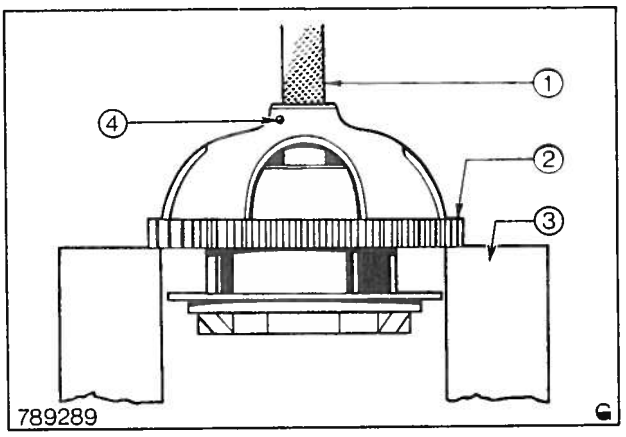


Fig. 8 Removing the Pump Drive Gear.
1. Press Adaptor
2. Drive Gear
3. Drive Gear Support
4. Retaining Pin Hole

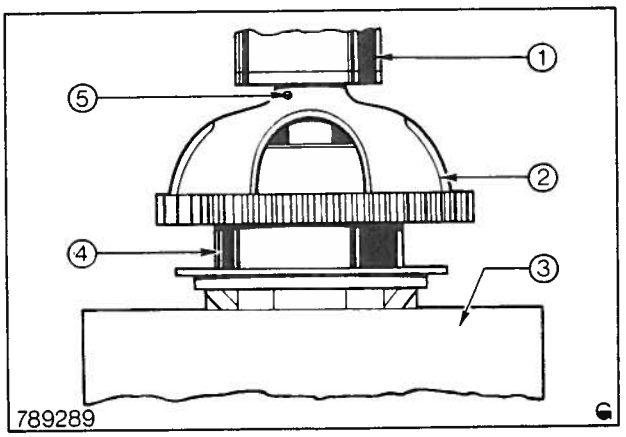


Fig. 9 Pressing the Drive Gear into position
1. Press Adaptor
2. Drive Gear
3. Base Support
4. Oil Pump
5. Retaining Pin Hole

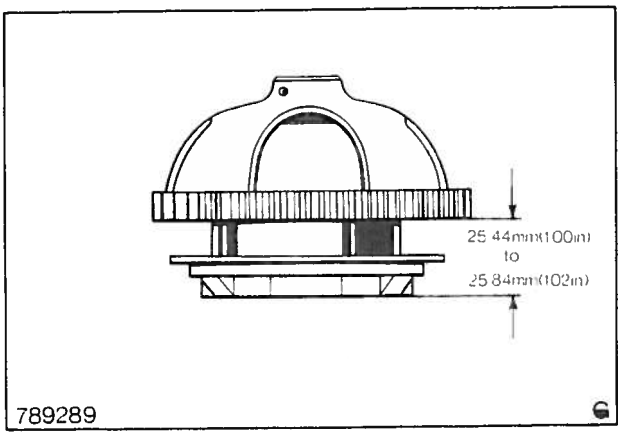


Fig. 10 Positioning the Oil Pump Drive Gear

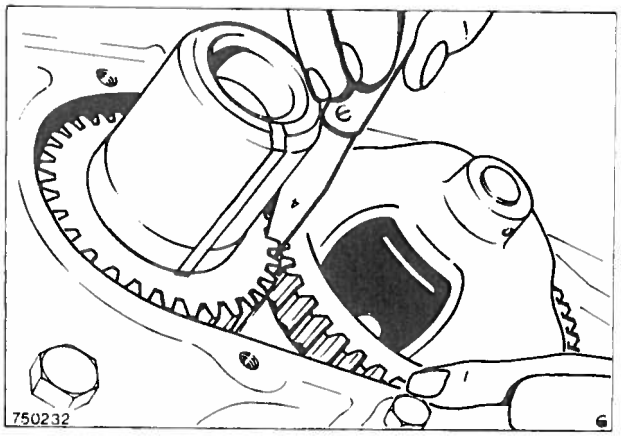


Fig. 11 Checking the Oil Pump Gear Backlash

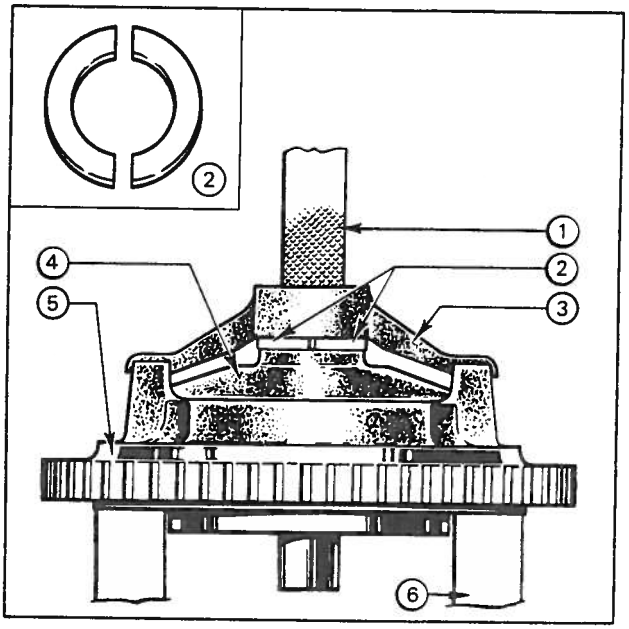


Fig. 12 Pressing out the shaft and rotor assembly

1. Press Adaptor
2. Packing Pieces
3. Drive Dog
4. Pump Body
5. Pump Gear
6. Drive Gear Support

4. Position a new oil pump cover gasket on the back plate. Using the oil seal replacer tool, fit the cover.
5. With reference to Section 1 fit the crankshaft spacer, timing belt drive gear and hub/pulley and crankshaft centre bolt. Check that the timing marks are aligned, fit and tension the timing belt, timing belt cover, crankshaft pulley, water pump pulley, and exhauster/compressor pulley.

To Overhaul – 6 Cylinder Oil Pump

1. Unscrew the cross-headed bolt securing the end cover to the pump body, Fig. 3.
2. Check the rotor clearances are detailed for the 4 cylinder pump.
3. If after inspection it is considered necessary to remove the inner rotor or drive gear proceed as follows:
   (a) Invert the oil pump and remove the outer rotor.
   (b) Support the pump body on a suitable press, as shown in Fig. 12, making sure that the jacking screws are clear of the support facing.
   (c) Add packing pieces (e.g. a suitable washer cut in half across its diameter) between the drive dog and pump body to prevent excessive strain on the drive dog arms when activating the press.
   (d) Press out the centre shaft and rotor assembly.

To Reassemble – 6 Cylinder Oil Pump

4. Fit the pump body and rotor shaft assembly to the gear housing, support the rotor shaft and press on the drive dog to achieve the dimensions as shown in Fig. 13.
5. Fit the end cover and secure with the cross-headed screw.
6. Apply oil to the pump and rotate several times.
7. With the pump lubricated, check the pump for free movement. The torque to initiate movement should not exceed 0,56 Nm (5 lbf in or 60 gf m) : to rotate a minimum of 5 revolutions the torque should not exceed 0,45 Nm (4 lbf in or 46 gf m).

To Install

1. Ensure that all components are thoroughly clean.

2. Fit two new rubber ring seals into the recesses in the oil pump galleries.
3. Fit the oil pump spacer, ensuring that the slot is located in the pump flange. Position the pump in the block, ensuring that the gears are meshed. Fit the three screws and tighten evenly to the specified torque.
4. Torque the three 'jacking' screws to 13,6 to 14,9 Nm (10 to 11 lbf ft or 1,4 to 1,5 kgf m).
5. Check the backlash between the crankshaft and oil pump gear as described previously.

OIL FILTER

The full flow type oil filter is fitted to the right hand side of the cylinder block. It is either bolted directly to the block (Fig. 14), or mounted using an adaptor, Fig. 15.

Oil from the pump enters the filter at a pressure regulated by the relief valve and passes through the element, from the outside to the inside, before entering the engine lubrication galleries.

The oil filter element should be renewed and the filter body thoroughly cleaned after every 100 hours when the engine oil is changed, or more frequently if the lubricant has become excessively fouled. To remove the filter, unscrew the securing bolt and withdraw the filter and element.

Remove the sealing ring from the groove in the cylinder or filter body mounting flange. Lubricate the sealing ring and filter mounting face with clean engine oil, then locate the new ring (supplied with the replacement element) in the groove at four diametrically opposite points.

Do not fit the ring at one point and then work it around the groove, as the rubber may stretch causing a surplus which may result in an oil leak.

Thoroughly clean the filter body, insert a new element and refit the filter assembly. Tighten its securing bolt to a torque of 20,3 to 24,4 Nm (15 to 18 lbf ft or 2,1 to 2,5 kgf m).

The gauze filter in the oil filter cap (where fitted) should be cleaned every 100 hours or whenever the engine oil is changed. To clean the filter it is only necessary to wash the cap in petrol which removes any accumulated dirt. Oil the gauze with clean engine oil, shaking off any surplus.

ENGINE VENTILATION

Engine Ventilation is achieved by venting the crankcase to the suction of the inlet manifold and allowing air to enter the engine through the

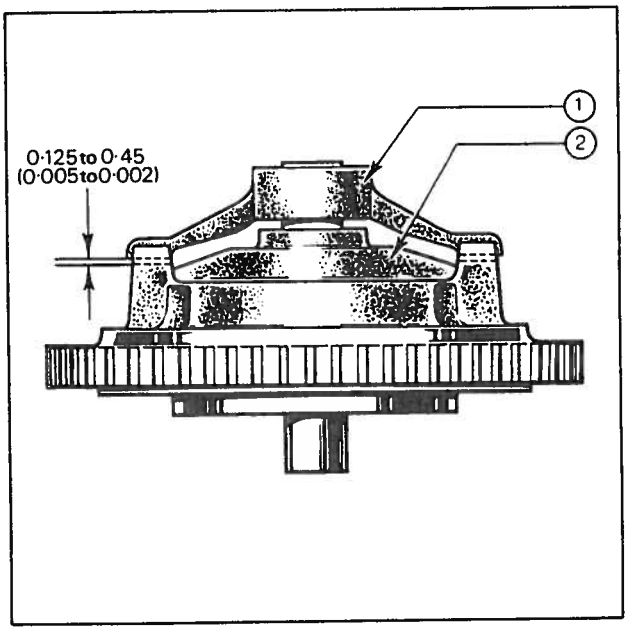


Fig. 13 Position of the Drive Dog
1. Drive Dog
2. Pump Body

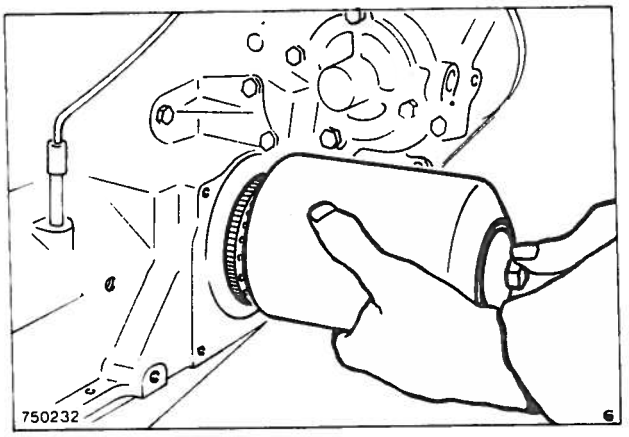


Fig. 14 The full-flow Oil Filter

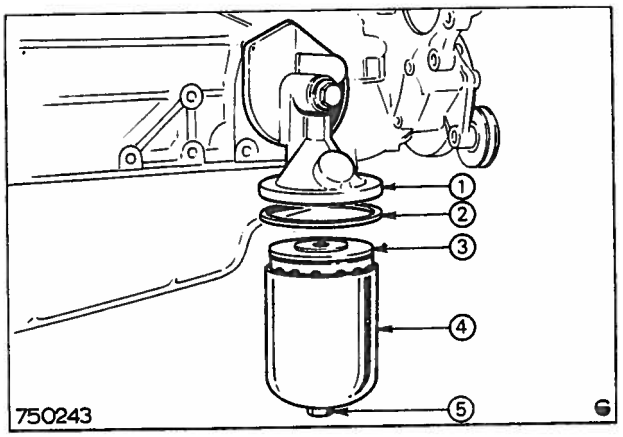


Fig. 15 The oil filter and 90° adaptor
1. Filter Adaptor Housing
2. Seal
3. Filter
4. Shell
5. Bolt

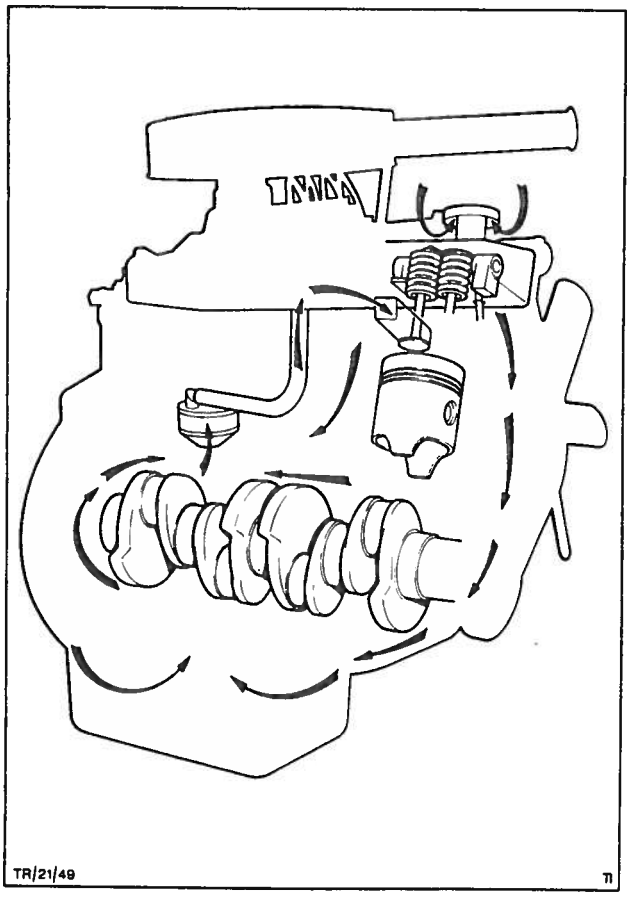


Fig. 16 Engine ventilation system

oil filler cap. The air drawn in passes through the oil filler cap into the rocker cover and then through the oil drain holes in the crankcase. The mixture of air and crankcase fumes then passes through the oil separator mounted on the right hand side of the block to the inlet manifold via a rubber pipe. This air is then drawn into the engine cylinders together with the air drawn through the air cleaner, Fig. 16.

COOLING SYSTEM

WATER PUMP

The water pump is mounted on the front face of the housing plate and is driven by a fan belt from the crankshaft pulley. The pump is of the centrifugal type. The pump shaft and bearing are serviced as an assembly and should not be dismantled, Fig. 17.

To Remove

1. Slacken off the alternator mounting bolts and adjusting bolt. Tilt the alternator towards the engine and remove the belt. Remove the water pump pulley and the timing belt cover.
2. Drain the coolant from the engine and disconnect the by-pass hose from the pump.
3. Unscrew the water pump retaining bolts and remove the pump.

To Dismantle

1. Press the shaft and bearing assembly from the pump body ensuring that even pressure is applied to the outer casing.
2. Press the impeller off the shaft, Fig. 18.

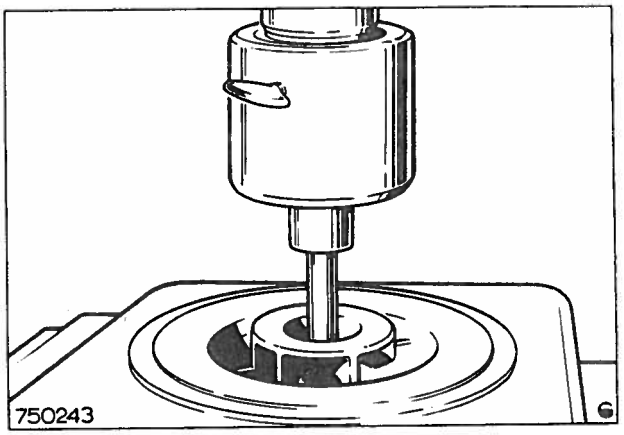


Fig. 18 Pressing the impeller off the shaft

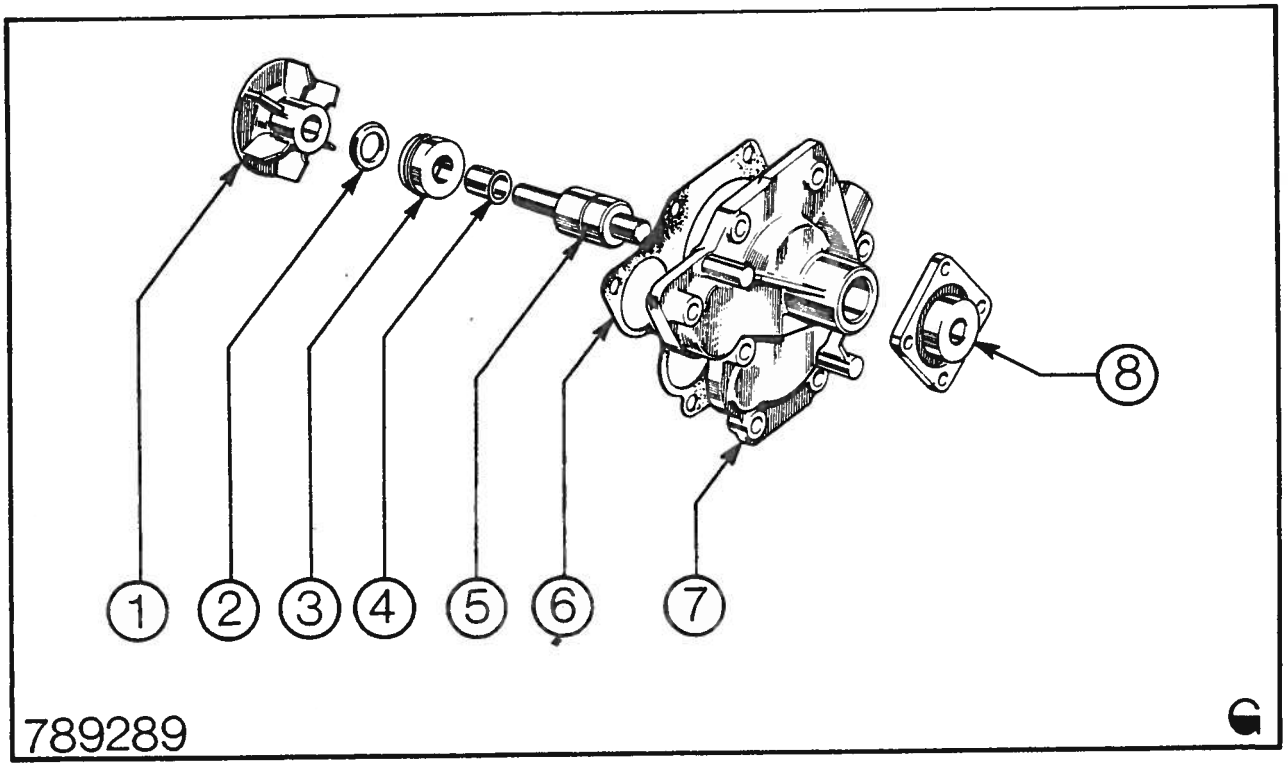


Fig. 17 The water pump assembly

1. Impeller
2. Washer
3. Seal
4. Shaft Slinger
5. Bearing and Shaft Assembly
6. Gasket
7. Water Pump Housing
8. Fan Mounting Flange

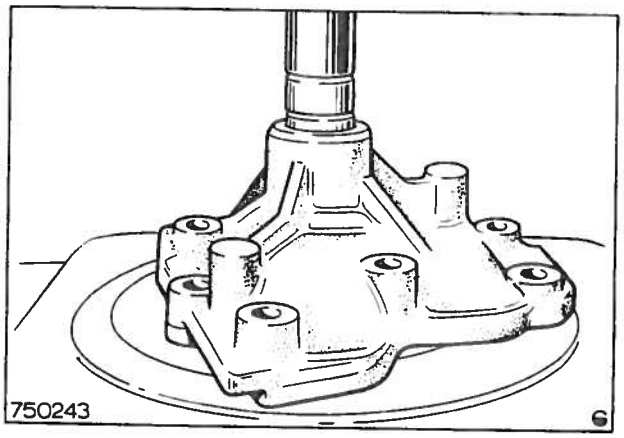


Fig. 19 Pressing the shaft and bearing assembly into the housing

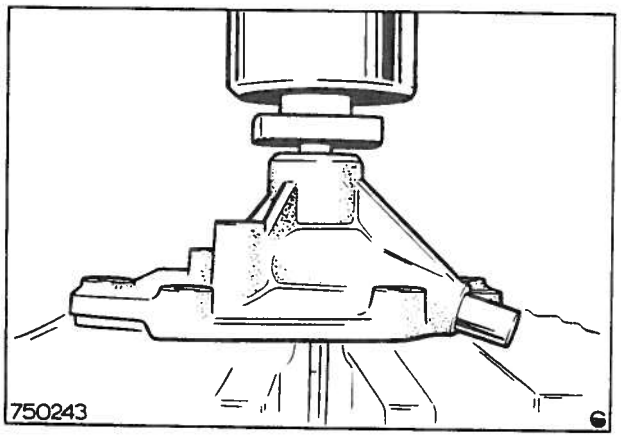


Fig. 20 Pressing the pulley hub onto the shaft

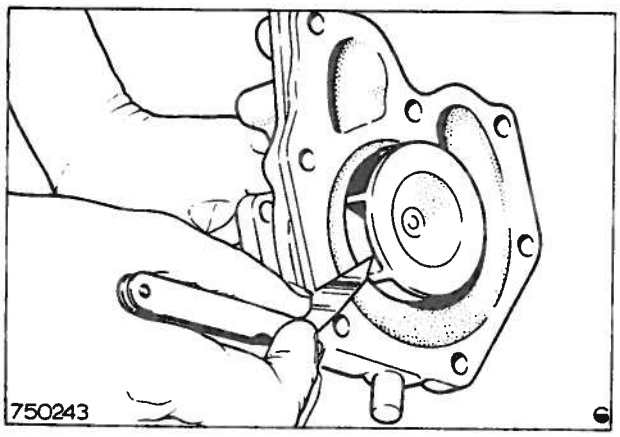


Fig. 21 Measuring the impeller to body clearance

3. Remove the seal assembly and the ceramic-faced washer, and if necessary, remove slinger bush from the shaft. On later type pumps with improved sealing capacity, the ceramic-faced washer and slinger bush are NOT fitted. The pumps (Part No. 745F-8501-AAA for 4-cy STD; 735F-8501-ABA for 4-cyl HD; 745F-8501-BAA for 6-cyl STD; 745F-8501-BBA for 6-cyl HD), are all available as Service replacements.
4. Clean and inspect all parts.

To Reassemble

1. Fit a new slinger bush if necessary (flanged end first) to the rear of the shaft.

   Press the bush onto the shaft with the aid of a suitable adaptor such that the small end is approximately 13 mm (0,5 in) from the end of the shaft.
2. Using a tube of the correct diameter to locate on the outer race, press the bearing into the pump body until the end is flush, with the body. On later pumps, the end of the bearing should be 0,5 mm (0,020 in) below the pump body.
   In the case of heavy duty pumps, the end of the bearing should be 87 ± 0,25 mm (3,427 ± 0,010 in) from the rear face of the pump body.
3. Supporting the rear end of the shaft, press on the pulley mounting flange until the relevant dimension is obtained:

   Standard Pumps

   78,10 ± 0,75 mm (3,071 ± 0,030 in) from flange boss to rear face of pump body.

   Heavy Duty Pumps

   99,37 ± 0,37 mm (3,912 ± 0,015 in) from pulley mounting face of flange to rear face of pump body.
4. Press the seal fully into the housing. Press on the flange ensuring that the flange inner face is flush with the housing face, spring facing uppermost and that the 'plastic' is clean and undamaged. Remove the pvc retainer (where fitted), and discard.
5. Where applicable, fit the ceramic counter faced washer on to the shaft with the rubber backing towards the impeller face. Ensure that the working face is clean.
6. Press the impeller onto the shaft until a clearance of 0,76 mm (0,030 in) is obtained (Fig. 21) between the impeller blades and the housing. The front of the shaft should be suitably supported.

On new type pumps, press the impeller on to the shaft until a dimension of 14,16 ± 0,25 mm (0,557 ± 0,01 in) for all pumps, is achieved between the outer face of the impeller and the mounting face of the housing, this giving the correct working clearance between the impeller blades and the housing.

THERMOSTAT

Wax type thermostats are located beneath the water outlet on the cylinder head – a single thermostat on 4 cylinder engines and twin thermostats for 6 cylinder units.

When the coolant is cold, the thermostat/s is/are in the closed position preventing the circulation of water through the radiator. Water can however circulate through the engine via the by-pass hose. When the engine coolant reaches normal operating temperature the thermostat/s begin/s to open and the radiator is then brought into circuit. In this way, by the constant opening and closing of the thermostat/s, the temperature of the engine can be maintained at the optimum level.

To Remove the Thermostat

1. Drain the cooling system, slacken the top hose clip from the thermostat housing and remove the top hose. Remove the housing bolts, the housing and the thermostat/s.

Testing the Thermostat/s

If it is suspected that a thermostat is not operating correctly, it may be tested in the following manner.

Suspend the thermostat in a suitable container. Add water and heat gradually, checking the temperature frequently with an accurate thermometer. Neither the thermostat nor the thermometer must touch the container.

Four different types of thermostat are in current use, stamped either 71° or 82°. They are fitted to the following engines:

Stamped Number	Starts to Open	Type of Engine
71°	69 to 72,5°C	4 cyl industrial
82°	79,5 to 83,5°C	4 cyl marine
82°	80,5 to 84°C	6 cyl industrial
82°	81 to 84°C	6 cyl marine

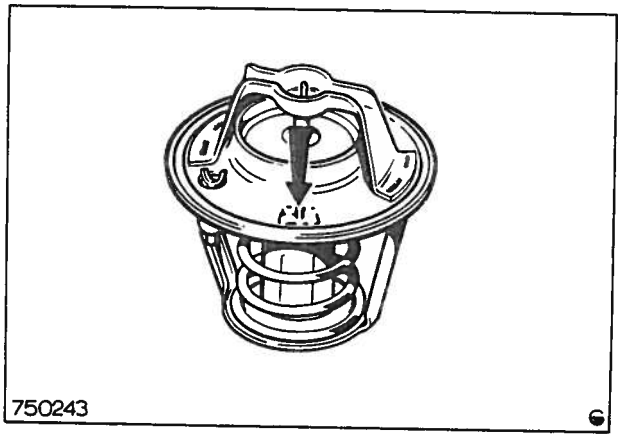


Fig. 22 Location of stamping showing thermostat 'crack-open temperature

If the thermostat does not function properly do not attempt any adjustments but replace it with a new unit.

To Replace

1. Ensure that the jointing faces of the cylinder head thermostat adaptor and thermostat housing are clean and free from pieces of old gasket and sealer, etc. Fit the thermostat/s into the locating groove/s in the cylinder head aperture/thermostat adaptor.
2. Fit the gasket, the thermostat housing and the top hose.
3. Refill the cooling system and check for leaks.

FAN

The fan should be checked periodically to ensure that the blades are true and not distorted.

NOTE: Do not attempt to turn the engine by means of the fan, as this will distort the blades.

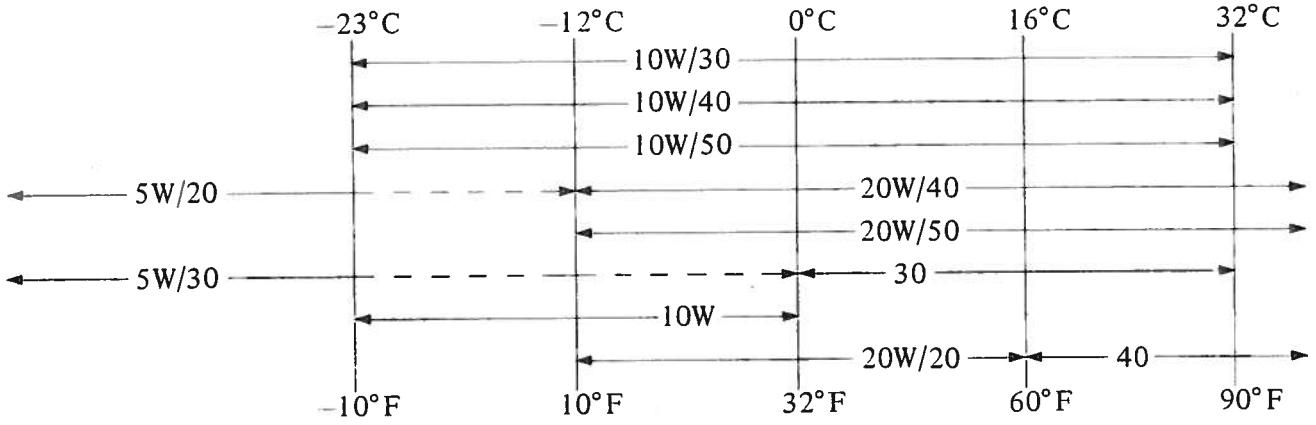
FAN BELT

A V-type belt is used to drive the alternator and water pump from the crankshaft pulley. Combinations of drive belts using one or more sheaves of the crankshaft and water pump pulleys are available for high level mounted fan operations. Correct fan adjustment is important, otherwise the belt/s may be damaged or undue strain placed upon the alternator and water pump bearings.

Fan belt adjustment is obtained by moving the alternator on its mounting.

SPECIFICATIONS

	2401E	2402E
LUBRICATION SYSTEM		
Oil Pan Capacity (including Filter but excluding oil cooler)	6,5 litre (11,5 pint)	11,0 litre (19,5 pint)
Oil Filter	External Full-Flow Type with Replaceable Elements	
Oil Filter Capacity	1 litre (1,8 pints)	1,25 litres (2 pints)
Oil Temperature	116°C (240°F)	
Oil Drain Point	Plug at Base of Oil Pan	
Grade of Lubricant	The oil used must meet Ford specification SPM-2C-9104A and must be of the following viscosity:–	



Lubrication	Pressure Fed by Bi-Rotor Type Pump
Pressure Feed Bearings	Main, Camshaft and Connecting Rod Big-ends
Metered Feed	OHV gear, fuel injection pump
Oil Pump	
Type	Centrifugal
Drive Gear Backlash	0,051 to 0,330 mm (0,002 to 0,013 in)
Capacity	56 litre/min (12,3 gal/min) at 2,460 rpm
Pump Body Bore Diameter	57,2262 to 57,3024 mm (2,253 to 2,256 in)
Drive Shaft Diameter	15,8242 to 15,8369 mm (0,623 to 0,6235 in)
Rotor End Float	0,018 to 0,099 mm (0,0007 to 0,0039 in)
Rotor Tip Clearance	0,152 mm (0,006 in) maximum
Outer Rotor Body Clearance	0,18 to 0,30 mm (0,007 to 0,012 in)
Oil Pressure (Min.)	1,04 bar (15 lbf/in² or 1,05 kgf/cm²)
COOLING SYSTEM	
Type	Thermo Syphon system, thermostatically controlled, Impeller Assisted
Engine Coolant Capacity	6 litre (10 pint) 8,5 litre (15 pint)
Operating Temperature	85°C (185°F)
Fan Belt Tension	12,7 mm (0,5 in) free movement
Thermostat	
Location	Cylinder Head

Stamped Number	Starts to Open	Fully Open	Fitted To
71°	69 to 72,5°C	86°C	4 cyl Industrial
82°	79,5 to 83,5°C	93,5 to 96°C	4 cyl Marine
82°	80,5 to 84°C	98°C	6 cyl Industrial
82°	81 to 84°C	98°C	6 cyl Marine

SECTION 3
FUEL SYSTEM

CONTENTS

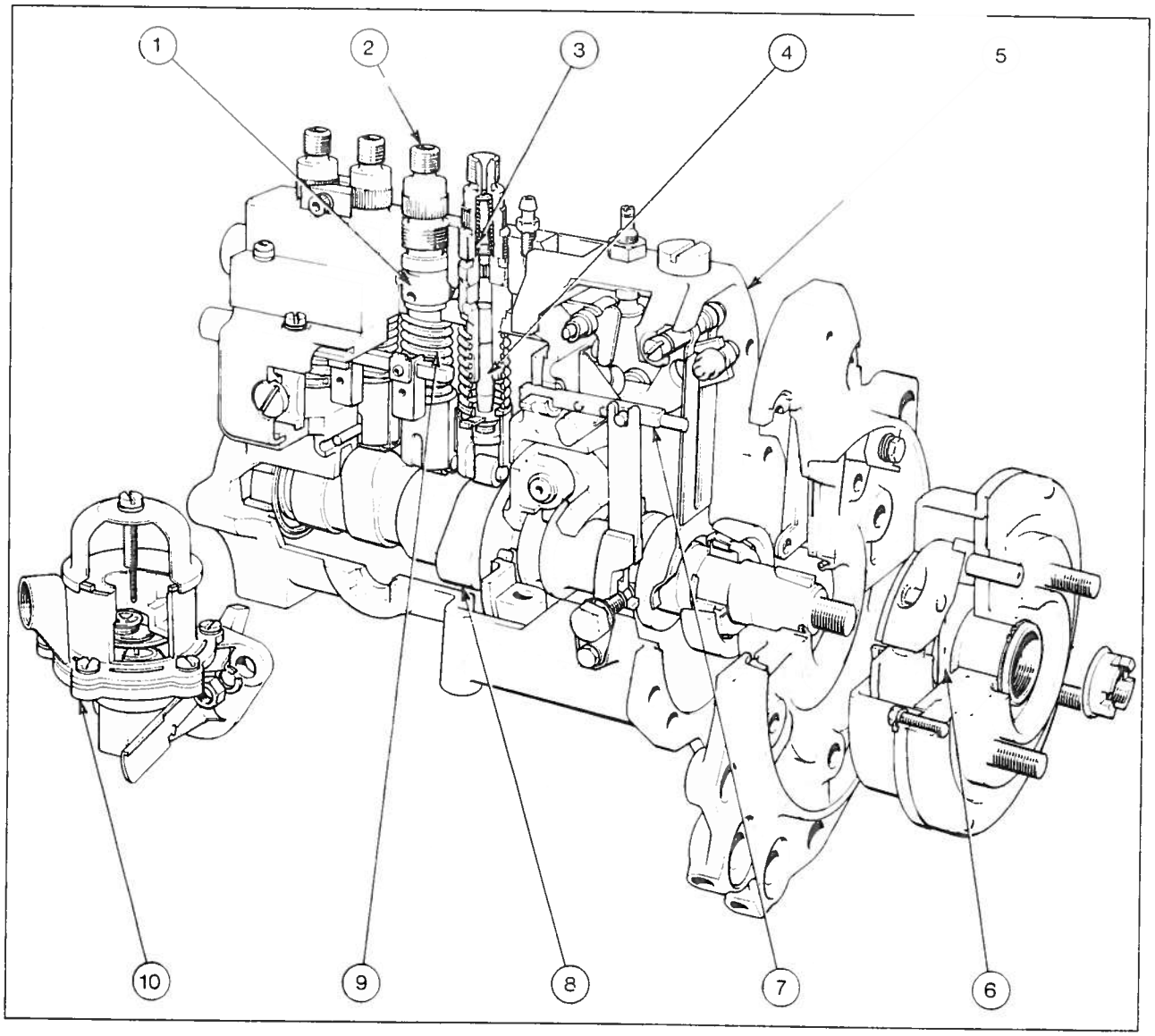


Fig. 1 CAV 'MICROMEC' FUEL INJECTION PUMP

1 Pump Body
2 Pump Element
3 Plunger Return Spring
4 Fork
5 Tappet Body
6 Plunger
7 Cambox and Governor Housing
8 Camshaft
9 Phasing Spacer
10 Governor Weight Assy.
11 Delivery Valve Holder
12 Volume Reducer
13 Delivery Valve Plunger
14 Delivery Valve Carrier
15 Control Rod
16 Rocking Lever
17 Automatic Advance Unit Flyweights
18 Automatic Advance Unit Sleeve
19 Automatic Advance Unit Cover
20 Automatic Advance Unit Housing

INTRODUCTION

The fuel system of the 2400 range engines consists of a fuel tank, lift pump, filter, injection pump and injectors.

The fuel lift pump is mounted on the injection pump body and is operated by an eccentric on the camshaft. Both the CAV and Bosch lift pumps incorporate a hand priming lever to enable the fuel system to be bled.

From the fuel lift pump the fuel passes through a replaceable element type, single or twin bowl, filter to the injection pump. Fuel at high pressure is then passed in turn to each of the injectors mounted in the cylinder head. The injectors are lubricated by fuel oil leaking back past the needle valve stems. This fuel is then returned to the fuel tank by a 'leak off' pipe.

The fuel injection pump may be one of three types, the CAV/Simms 'Micromec', the CAV/ Simms High Speed 'Minimec' or the Bosch 'M type' injection pump.

The CAV/Simms injection pumps are used on the 4 and 6 cylinder engines: the Bosch injection pump is used on the 4 cylinder engine only.

CAV/SIMMS INJECTION PUMPS

The 'Micromec' fuel injection pump is similar to the 'Minimec': both are of the in-line single acting plunger type with a separate element.

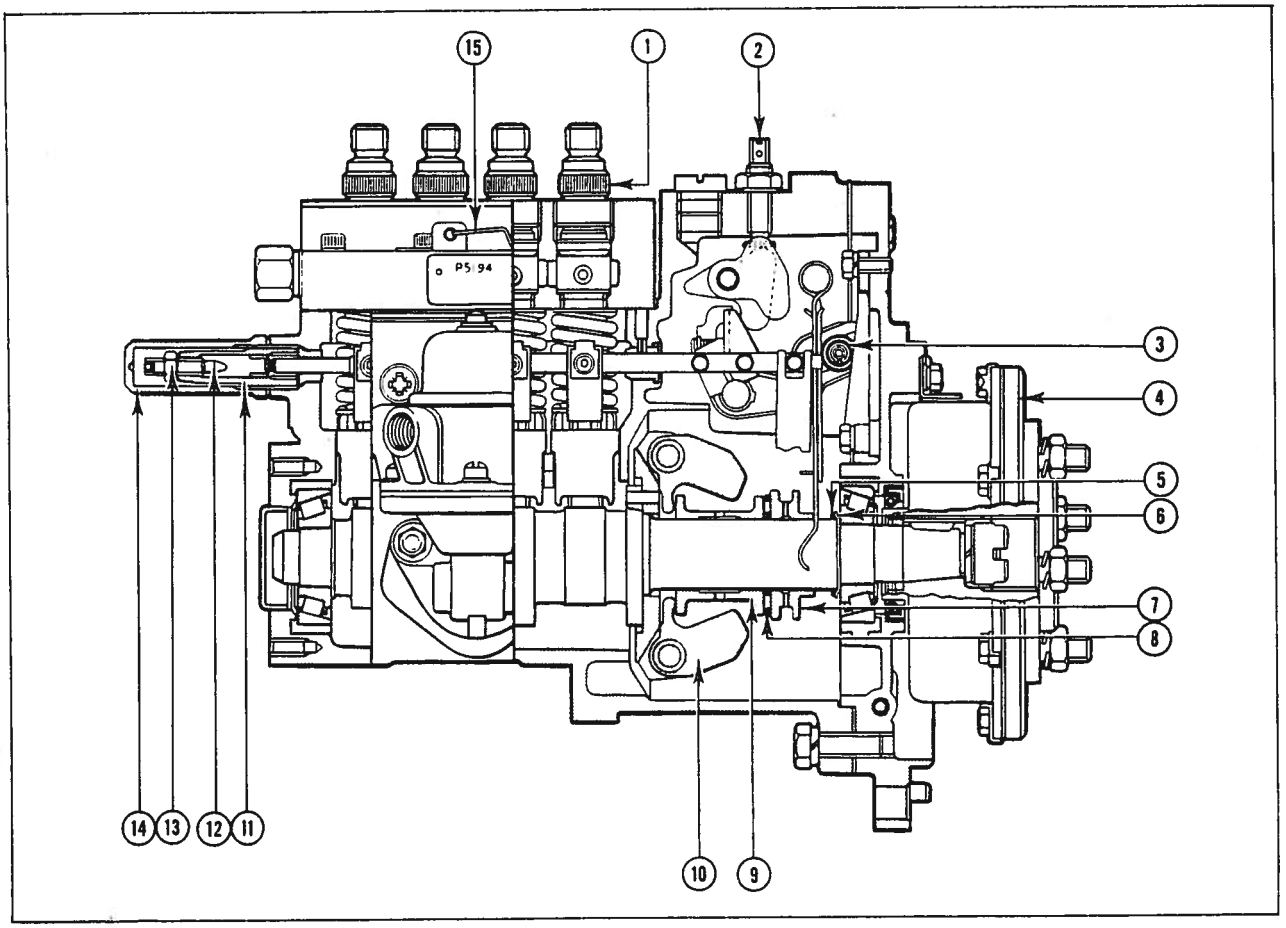


Fig. 2 CAV 'MINIMEC' FUEL INJECTION PUMP

1 Valve Holder
2 Maximum Fuel Stop Screw
3 Ramp Roller Assy.
4 Auto Advance Unit Assy.
5 Spacing Ring
6 Stop Disc
7 Thrust Pad
8 Needle Thrust Bearing
9 Sleeve Assy.
10 Governor Weight Assy.
11 Control Rod Bush Retainer
12 Adjusting Screw
13 Locking Nut
14 Cover
15 Stop Control Lever Return Spring

for each engine cylinder.

The fuel lift pump is of the lever operated, diaphragm type and is driven by a cam on the injection pump camshaft.

The governor springs for the 'Minimec' consist of a primary, secondary, interleaf and rack buffer spring, whereas the 'Micromec' pump has a primary and secondary spring only .

The 'Minimec' pump also has tappet locating 'Tee' pieces fitted between each pair of tappet bores in the pump housing.

BOSCH INJECTION PUMPS

This injection pump is of the single-acting plunger type with a separate pumping element for each engine cylinder. Each pumping element consists of a plunger and a barrel. The plunger being very accurately fitted to the barrel with a clearance of about 0,03 mm (0,0001 in). This is to provide perfect sealing under very high pressure without special sealing rings and because of this the plungers and barrels must be replaced as complete assemblies only.

The pump plunger is actuated in the delivery stroke by a cam and in the filling stroke by the plunger return spring.

THE CAV/SIMMS INJECTION PUMPS

DESCRIPTION

The CAV 'Micromec' and 'Minimec' injection pumps (see Figs. 1 and 2) are self-contained units with a camshaft and governor assembly operating separate pumping elements for each cylinder of the engine.

The pump body and governor housing are cast integral.

The camshaft runs in two bearings, one in the rear face of the cambox housing and the other in the front cover of the governor housing.

Located on the front of the injection pump is the governor.

The pump body is attached to the top of the cambox housing and holds the fuel gallery for the pumping elements, fuel entering the body through a connection at the rear.

OPERATION

Fuel Delivery

As the plunger stroke is not variable, the quantity of fuel injected is achieved by a helical control edge at the top of the plunger and a port in the barrel. A longitudinal groove is machined in the plunger which connects the control edge and the upper barrel space, Fig. 3.

Depending on how rotation of the plunger is controlled, the longitudinal groove provides a connection between the upper barrel space, the control edge and the control port.

Rotating the plunger controls the position of the helical control edge, which determines the cut-off time for the fuel.

When the plunger is at Bottom Dead Centre, the barrel chamber fills up with fuel through an inlet port. When the plunger moves upwards, the upper edge of the plunger closes the inlet port. The plunger then forces the fuel in the barrel through a delivery valve to the injector. Fuel flow ceases as soon as the helical control edge uncovers the control port. When the port is uncovered by the control edge, the pressure on the fuel in the barrel is released. This fuel then flows through the longitudinal groove and the port, back into the pressure chamber of the injection pump.

Above each pump element is the delivery valve, which has a valve seat and a two-section valve shaft. The lower section has four vertical grooves, while the upper section forms a small plunger which is lapped to fit in the bore of the valve guides.

The delivery valve is held on its seat by a metering plunger situated in the upper section of the delivery valve holder.

The delivery valve, spring and guide are held in position by the delivery valve holder, which also serves to support the pump element barrel. The delivery valve holder is serrated on the outside to facilitate removal and is sealed by a large nylon washer.

The special design of the delivery valve ensures that pressure in the delivery valve is relieved to obtain a quick closing action of the injector plunger to prevent a continued supply of fuel into the combustion chamber. As soon as the control edge of the plunger has uncovered the control port, the pressure in the pump barrel drops. The higher pressure in the pipe, assisted by the valve spring, holds the delivery valve on its seat. This action isolates the delivery pipe from the pump barrel until, at the next pressure stroke the flow of fuel starts again.

During the flow period, the delivery valve is lifted off its seat so that the fuel can enter the delivery pipe via the longitudinal grooves.

Above the annular groove is a further short cylindrical shaft (small plunger) which fits accurately in the valve support.

At the end of the flow phase the small plunger

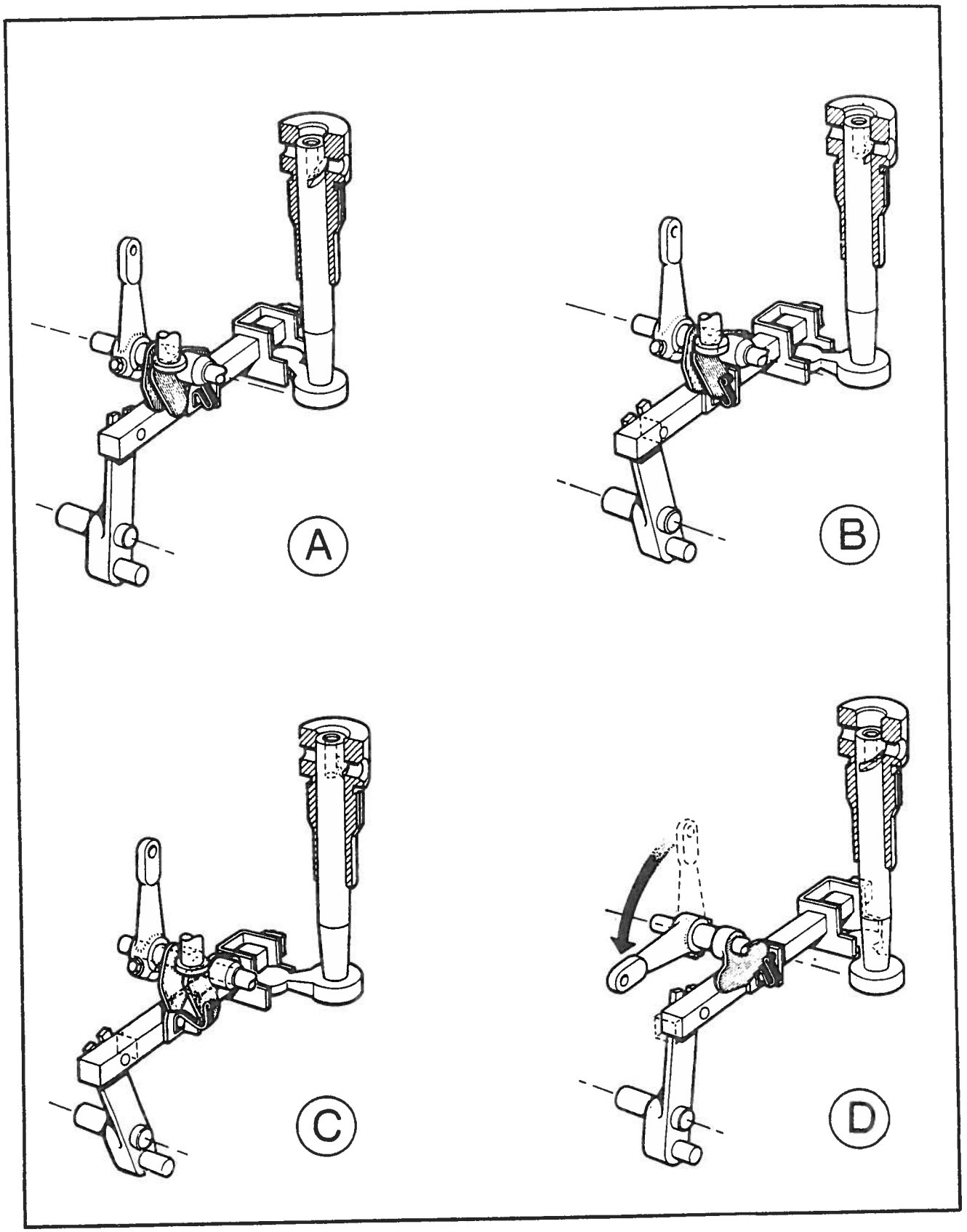


Fig. 3 PUMP ELEMENT

A	Idling	C	Excess Fuel
B	Full Load	D	No Flow

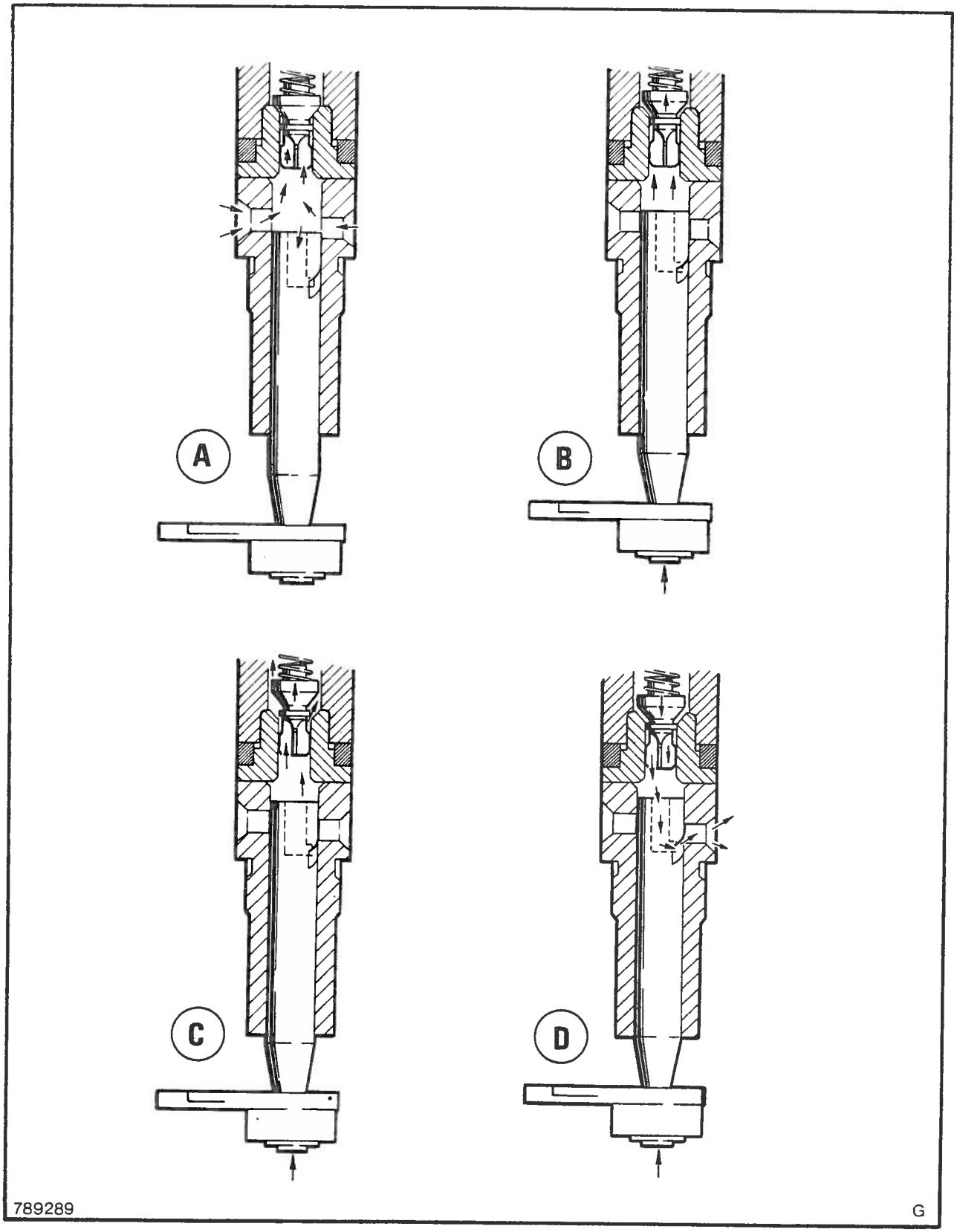


Fig. 4 DELIVERY VALVE

A	Delivery Valve Closed	C	Delivery Valve Open
B	Pressure Rise	D	Pressure Release

enters the valve support and shuts off the delivery pipe from the barrel chamber.

The valve head then returns to its seat. This causes the space available to the fuel in the delivery pipe to be increased by the volume of the small plunger. The pressure of the fuel in the delivery pipe drops quickly and the injector plunger closes.

The plungers are rotated in their barrels by means of arms attached to the base of each plunger, which in turn engage in forks on the control rod. Moving the control rod forward will increase the effective stroke, whilst moving it rearwards will decrease the stroke until the no delivery position is reached. The control rod is connected to the governor by a rocking lever, so that a movement of the governor alters the volume of fuel delivered and thus controls the engine speed, Fig. 4.

Governor – CAV GX Type

The GX governor of the Ford diesel is required to ensure smooth idling and to limit the maximum speed of the engine. Also, as the load on engine increases (independent of the position of the speed control lever), the governor has the function of regulating the quantity of fuel in such a way that the smoke region is not reached. When the load is reduced, it is responsible for reducing the fuel flow.

When the actuating lever is in the idling position, see Fig. 5, the dumb-bell shaped roller is at the top and the force of the governor spring is small. Under these conditions, the weights move outwards and the control rod is pushed forward by the rocking lever, actuated by the hub in the camshaft, so that the quantity of fuel injected is reduced until steady idling results.

If the speed of the engine drops, the centrifugal force on the governor weights is reduced and is finally overcome by the force of the governor spring. This causes the rocking lever to move the control rod backwards, which increases the amount of fuel injected and so causes the engine speed to rise. With an increase in the engine speed, the centrifugal force on the governor weights again exceeds the force of the spring and the quantity of fuel injected is again reduced by the rocking lever and the control rod. Fluctuations in the engine speed are therefore damped out by the governor. An adjustable governor damper, or a device which prevents engine stalling, is mounted on the cover of the governor casing.

If the actuating lever is brought to the full load position, see Fig. 5, the roller moves downwards and the force of the governor spring is increased. The force of the spring is then sufficient to overcome the centrifugal force on the governor weights and to move the weight carrier and hub along the camshaft. This movement is transmitted through the rocking lever to the control rod, which is pulled backwards, so that the amount of fuel injected and the engine speed are increased. The position of maximum fuel supply is reached when the stop on the control rod comes into contact with the bellcrank.

Turning of the bellcrank is prevented by the stop for maximum fuel supply, which is screwed into the top of the governor casing.

If the engine speed should increase further after the control rod has reached this position, the force of the spring is exceeded by the centrifugal force on the governor weights causing the weight carrier and hub to move along the camshaft. The rocking lever then pushes the control rod forward so that the quantity of fuel injected and the engine speed are reduced.

The engine speed is therefore always proportional to the force on the governor spring, so that very precise speed control is ensured over the whole range of engine speeds.

Excess Fuel Device and Stop Control

The excess fuel device and stop control are incorporated in the top of the governor housing.

To engage the excess fuel device, the knob at the pivot of the shut-off lever is pressed in. The pump lever must then be brought to the position for maximum speed. The bellcrank for the maximum fuel supply stop is thereby disengaged from the stop on the control rod against the action of the return spring. The control rod is moved backwards by the governor spring acting through the rocking lever. In this position the edge of the stop on the control rod prevents the bellcrank returning to its original position. The pump plunger can then turn further and reach the position for excess fuel.

The engine must be started with the throttle lever fully open to maintain the control spring pressure.

When the engine starts, the speed increases until the centrifugal force on the governor weights exceeds the force of the governor spring and the rocking lever moves the control rod forward. The spring will then return the bellcrank to its initial position.

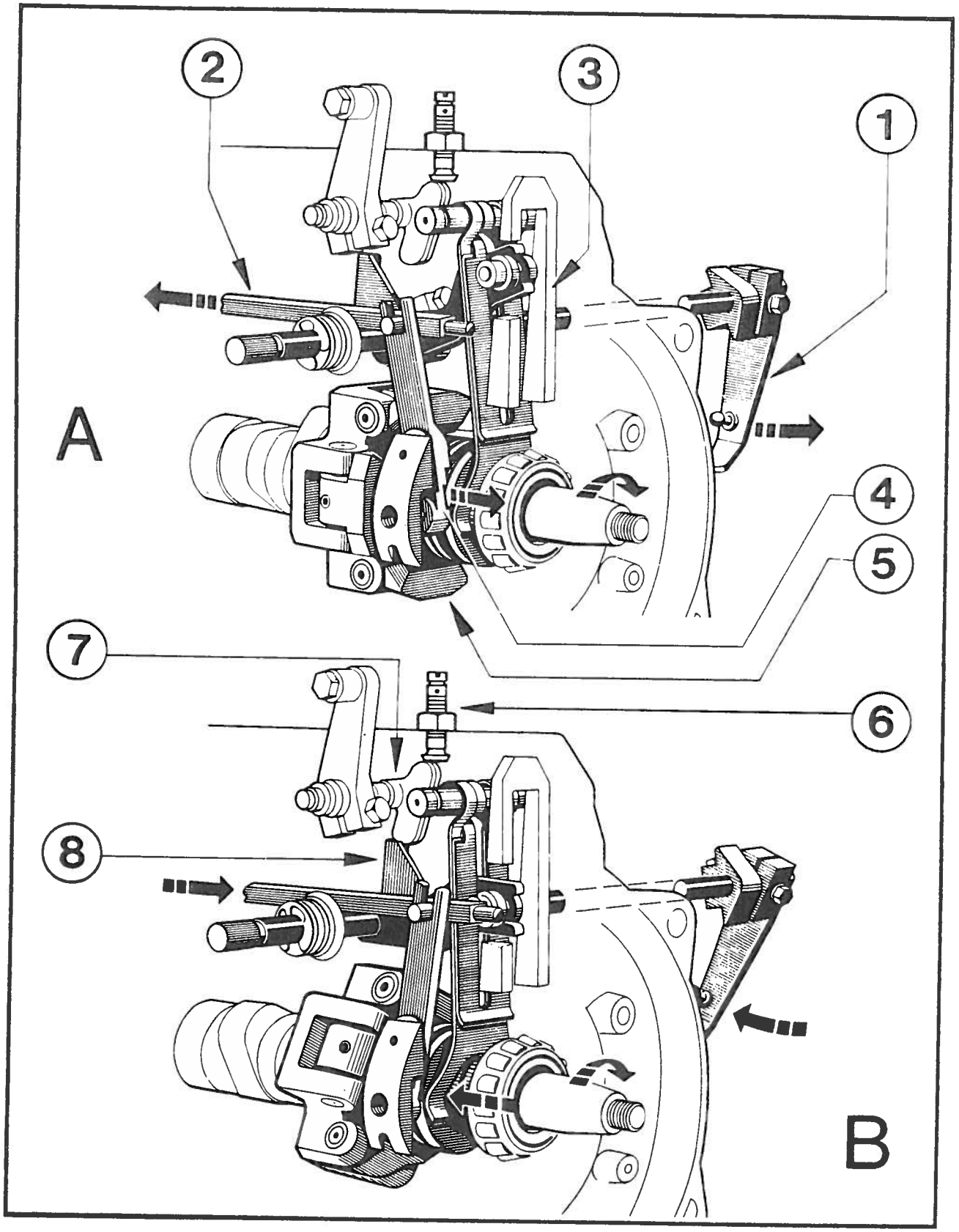


Fig. 5 GOVERNOR – OPERATION
A Throttle Lever – Idle Position
B Throttle Lever – Full Load

1 Throttle Lever
2 Control Rod
3 Ramp
4 Rocking Lever
5 Hub
6 Stop Screw, Fuel Supply
7 Bell Crank Lever
8 Control Rod Stop

The shut-off lever has a sleeve which rotates on the spindle of the excess fuel device with a control lever in the governor casing. If the shut-off lever is moved to the right, the control lever moves the control rod forwards until the pump plunger reaches a position where no more fuel is pumped. The engine then stops.

Lubrication

The camshaft and governor housing are filled with engine oil through a filler plug on top of the governor housing. Oilways in the front cover housing carry engine oil under pressure to and from the injection pump.

Automatic Advance Unit

The automatic advance unit is mounted on the front of the injection pump camshaft and is driven by the drive gear.

As the engine speed increases, centrifugal weights inside the unit advance the coupling flange and the camshaft so that injection commences further before top dead centre as the speed rises.

The centrifugal weights are connected to one another at their ends by tension springs (see Fig. 6 The springs are held by pins. The fly-weights are fixed to the drive flange through a recess on the back of the flyweights.

In each of the angled grooves, machined into the front of the flyweights there is a crosshead screw. The crosshead screws are fixed to two pins mounted on the inside of the drive hub. The drive hub has a bushed bore and runs on an extension of the pump drive flange.

When the engine is idling, the springs hold the weights in their position, When the engine speed is increased to a certain extent, centri-fugal force moves the weights outwards against the force of the spring. In doing so, the weights slide in the crossheads on the drive side and on

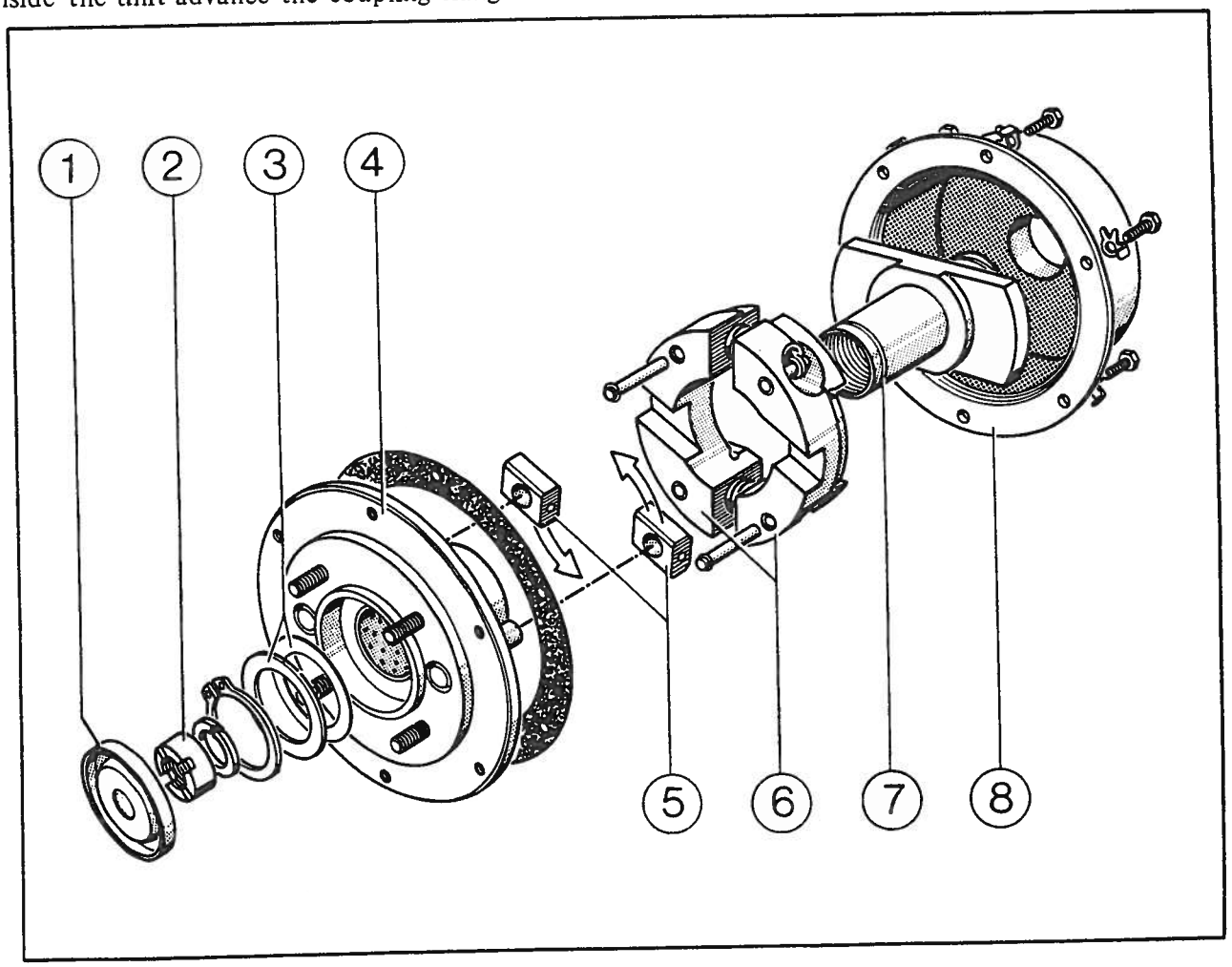


Fig. 6 AUTOMATIC ADVANCE UNIT

1 Cover
2 Nut
3 Shims
4 Flange
5 Crosshead
6 Fly Weights
7 Sleeve
8 Housing

the guides on the pump side. The angle of the grooves for the crossheads in the weights is so arranged that the weights and the pump flange turn clockwise in relation to the drive flange and the start of injection is advanced.

The automatic advance unit is sealed with two rubber rings to ensure good lubrication.

FAULT DIAGNOSIS

Introduction

The following charts have been devised to assist you in making the most accurate diagnosis of any fuel system problem with the least amount of trial and error work.

Reference should be made to the appropriate section to establish the technical data and how each repair should be carried out.

The fault diagnosis charts are divided into eight categories which represent the most common general problems which you are likely to encounter.

These problems are:–

1. Engine will not start or is difficult to start.
2. Excessive exhaust smoke.
3. Engine starts and then stops.
4. Incorrect engine idling and maximum speeds.
5. Uneven running/misfiring.
6. Lack of power/poor fuel consumption.
7. Engine Surge (with throttle in fixed position.)
8. Engine 'Knock' (with incorrect fuel metering).

To make the most effective use of these diagnosis charts, you should first of all test the vehicle to establish which problem or problems you have to contend with. Having defined the problem as one of the general terms listed above, simply refer to the relevant diagnosis chart to establish the cause of the problem and the relevant remedy.

Requirements for Easy Starting

An adequate quantity of properly atomised fuel delivered at the correct pressure, at the correct time, into the combustion chamber in which the compression of air has increased the temperature to readily ignite the fuel.

Requirements for Good Performance:

The most efficient generation of power is attained by the best possible combination of fuel and oxygen in the combustion chamber. Frictional losses throughout the vehicle must be kept to a minimum.

Requirements for Correct Speed Settings:

The specified idling and maximum no load speeds should be readily attained and held when the fuel pump control lever is in contact with the appropriate correctly set adjusting screw.

Requirements for Even Running:

All engine cylinders should give equal power output at evenly spaced intervals of the engine cycle at any given throttle opening and acceptable load. Engine mountings should hold the engine steady yet be sufficiently resilient to dampen normal engine vibration.

Requirements for Clean Exhaust:

If all the fuel and all the air in the combustion chamber were to be burnt this would be complete combustion. This ideal condition is approached but never realised in practice. However, no engine, if properly maintained and at its normal operating temperature, should emit more than a faint haze from the exhaust pipe.

Smoke is generated when combustion is unsatisfactory and therefore a proportion of the fuel is not doing useful work.

In the following notes it is assumed that the engine is in good condition and is therefore not burning excessive amounts of lubricating oil.

Black Smoke:

This consists of a large number of carbon particles which are produced when fuel is heated in "oxygen lean regions" of the combustion chamber.

Blue Smoke:

This consists of large numbers of fuel oil particles of about 0,5 microns diameter or less.

These particles are condensed droplets of partially burnt or unburnt fuel which have passed through 'low temperature regions' of the combustion chamber, and may also be caused by burning lubricating oil caused by some mechanical defect.

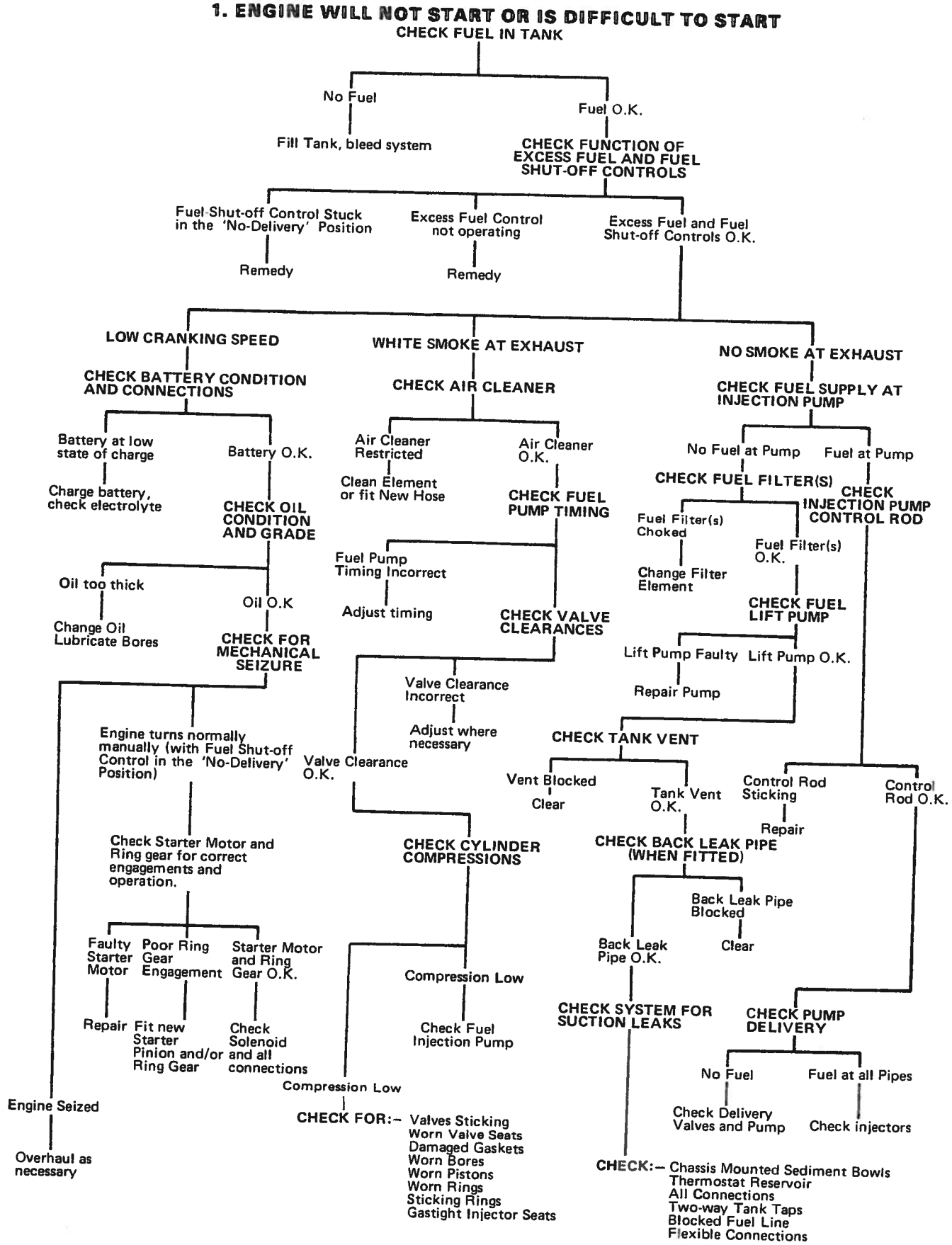
White Smoke:

This consists of a large number of condensed droplets of partially burnt or unburnt fuel larger than about 1,0 micron diameter. To produce white smoke the fuel will have had more time to condense than for blue smoke, e.g. a cold engine running at light load and low speed could produce white smoke. Retarded injection timing would not give the fuel suitable conditions to burn correctly, and this can also produce white smoke.

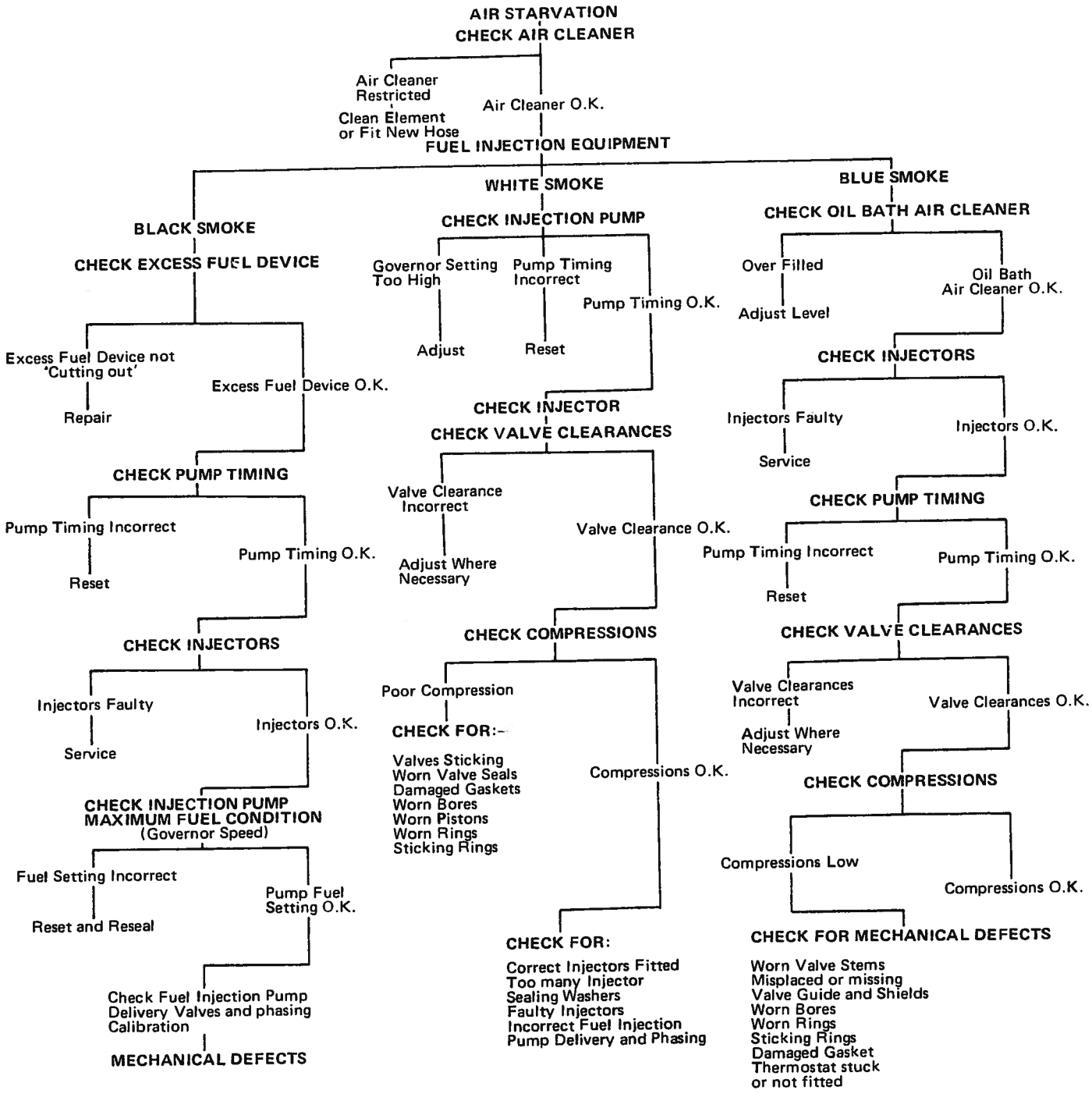
It is important to realise that the majority of the problems listed would not arise if the correct maintenance operations were carried out at the specified intervals.

Before any part of the fuel supply system is dismantled the surrounding area must be thoroughly cleaned. When the fuel system has been reassembled and all nuts tightened to the specified torque, it will be necessary to bleed the system.

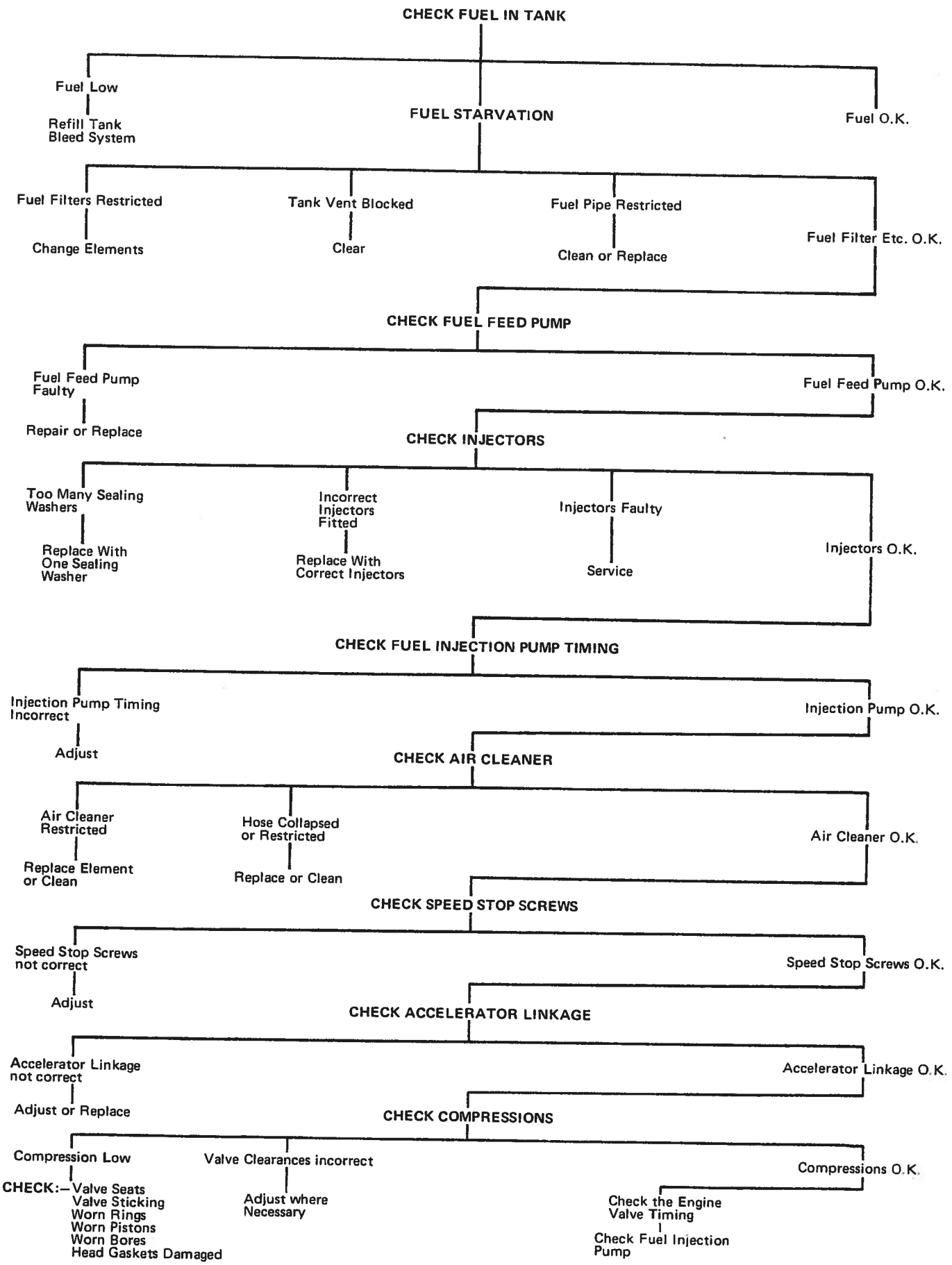
1. ENGINE WILL NOT START OR IS DIFFICULT TO START



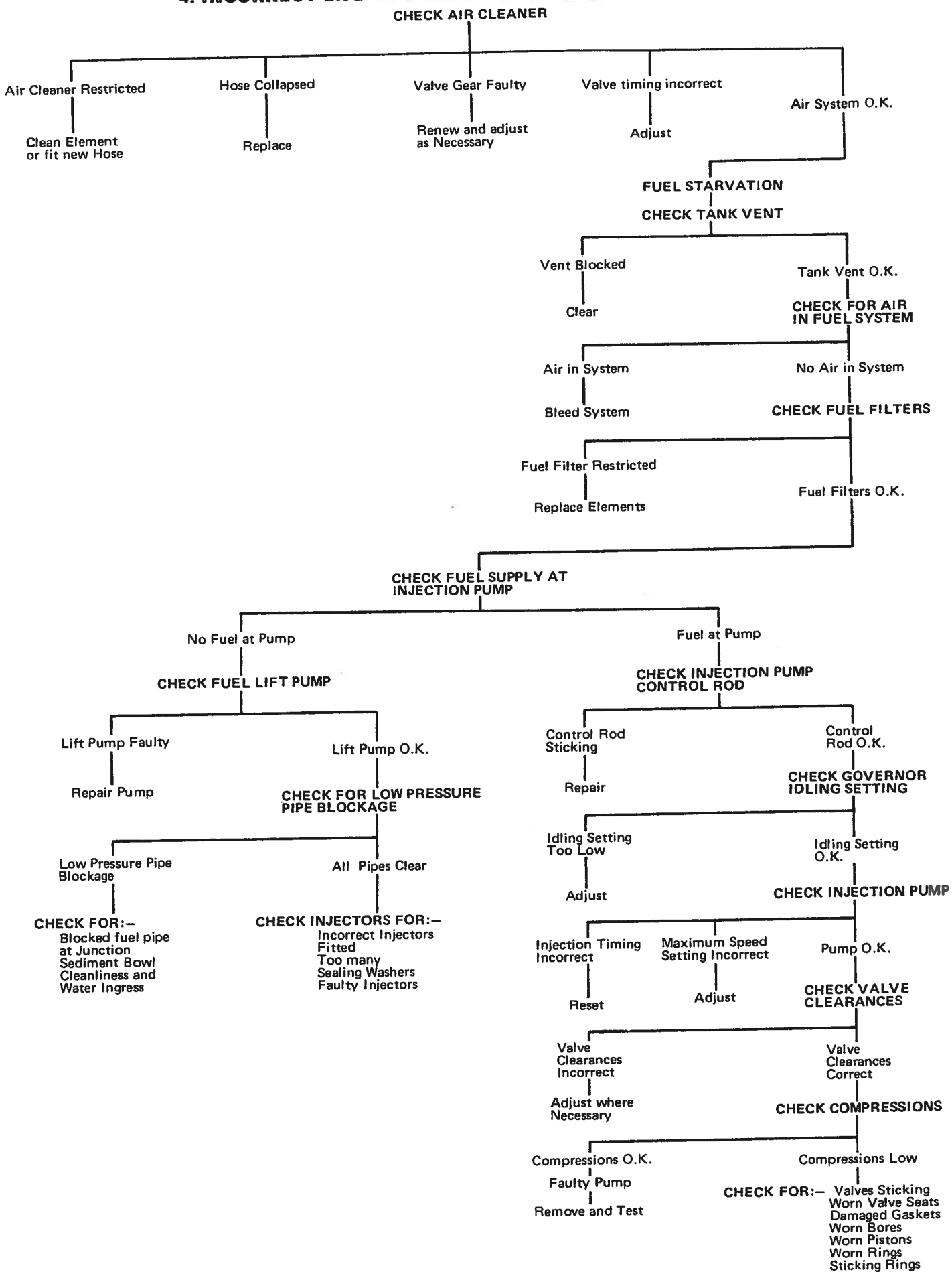
2. EXCESSIVE EXHAUST SMOKE



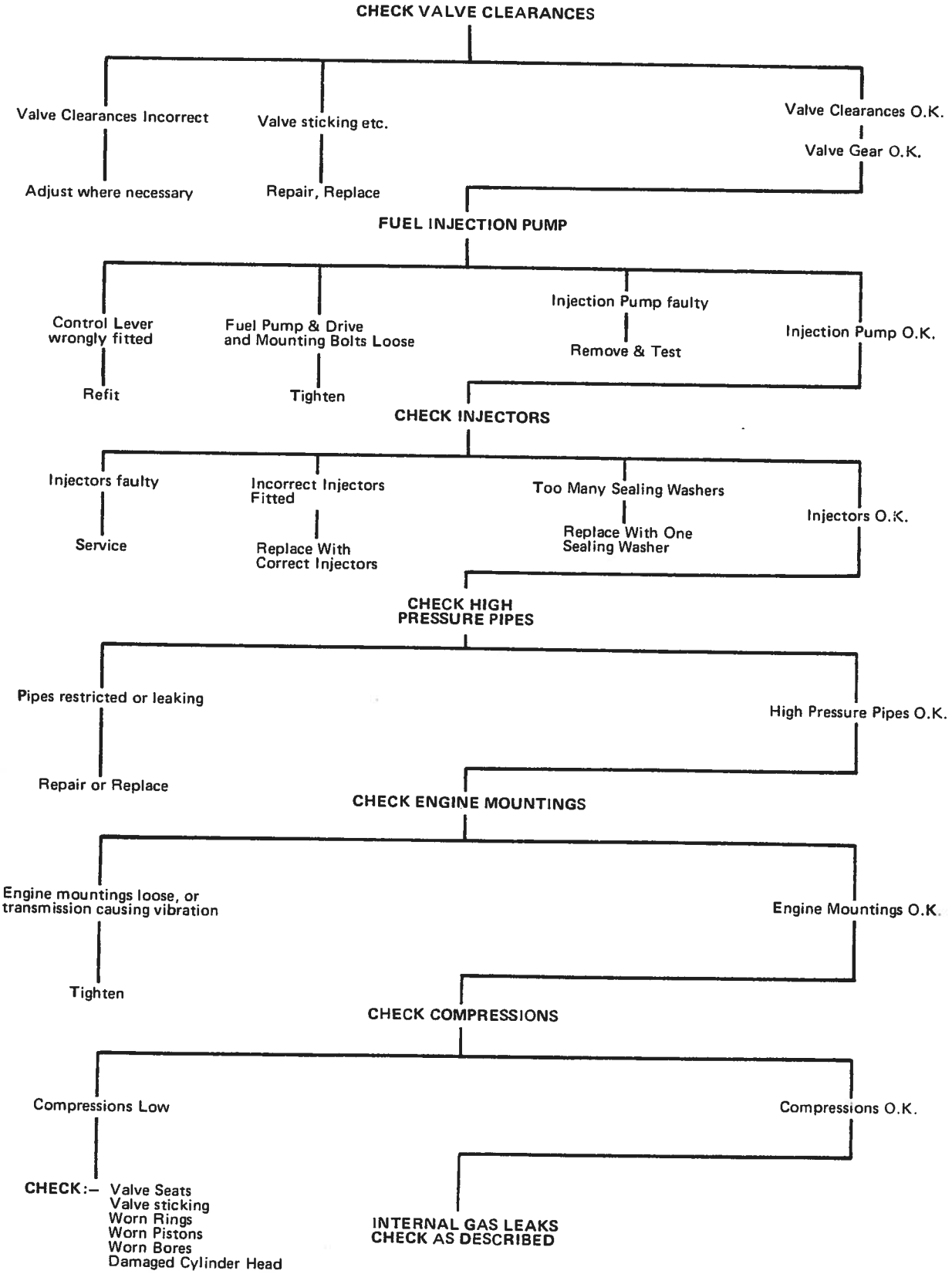
3. ENGINE STARTS AND THEN STOPS



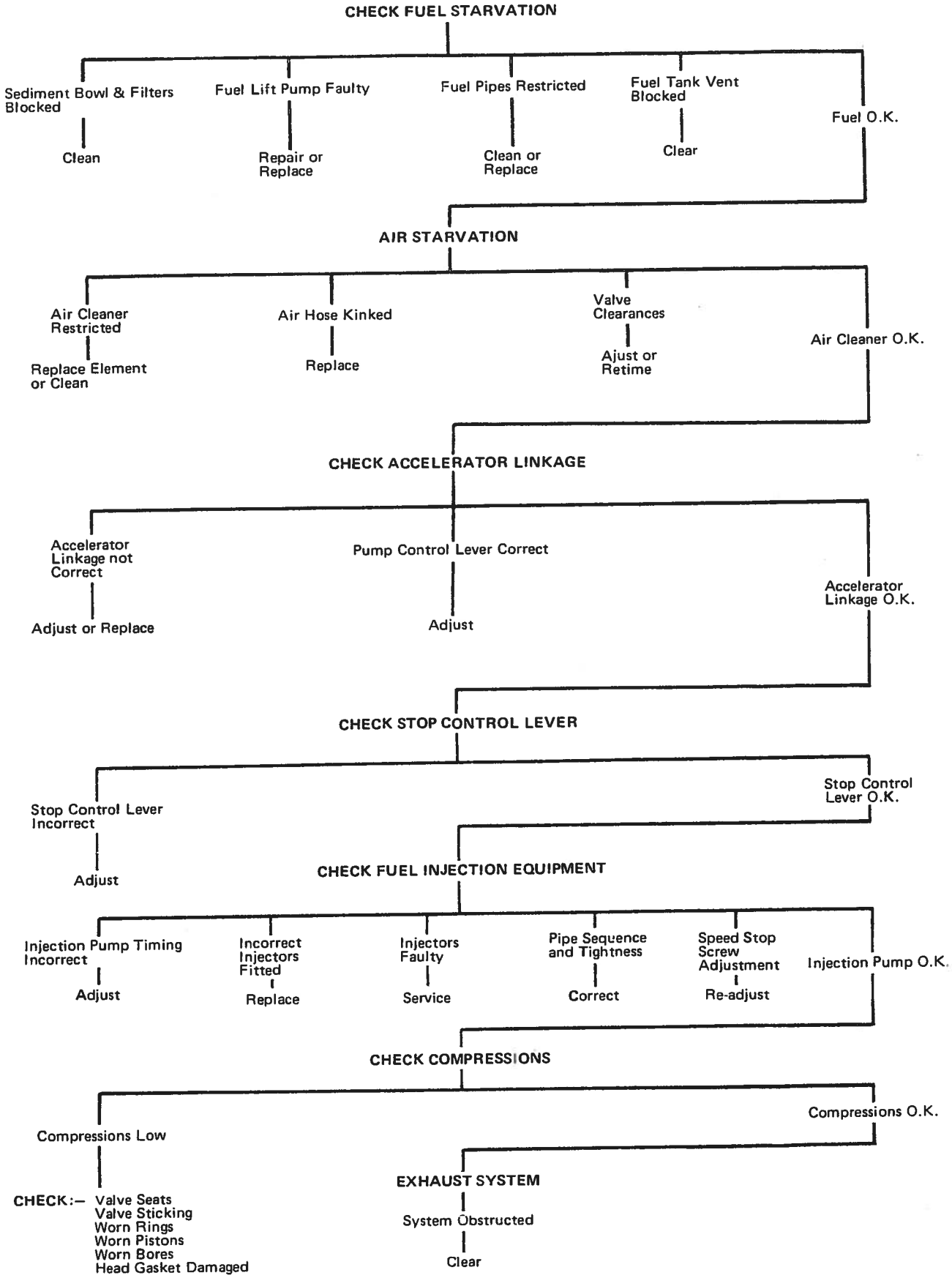
4. INCORRECT ENGINE IDLING AND MAXIMUM SPEEDS



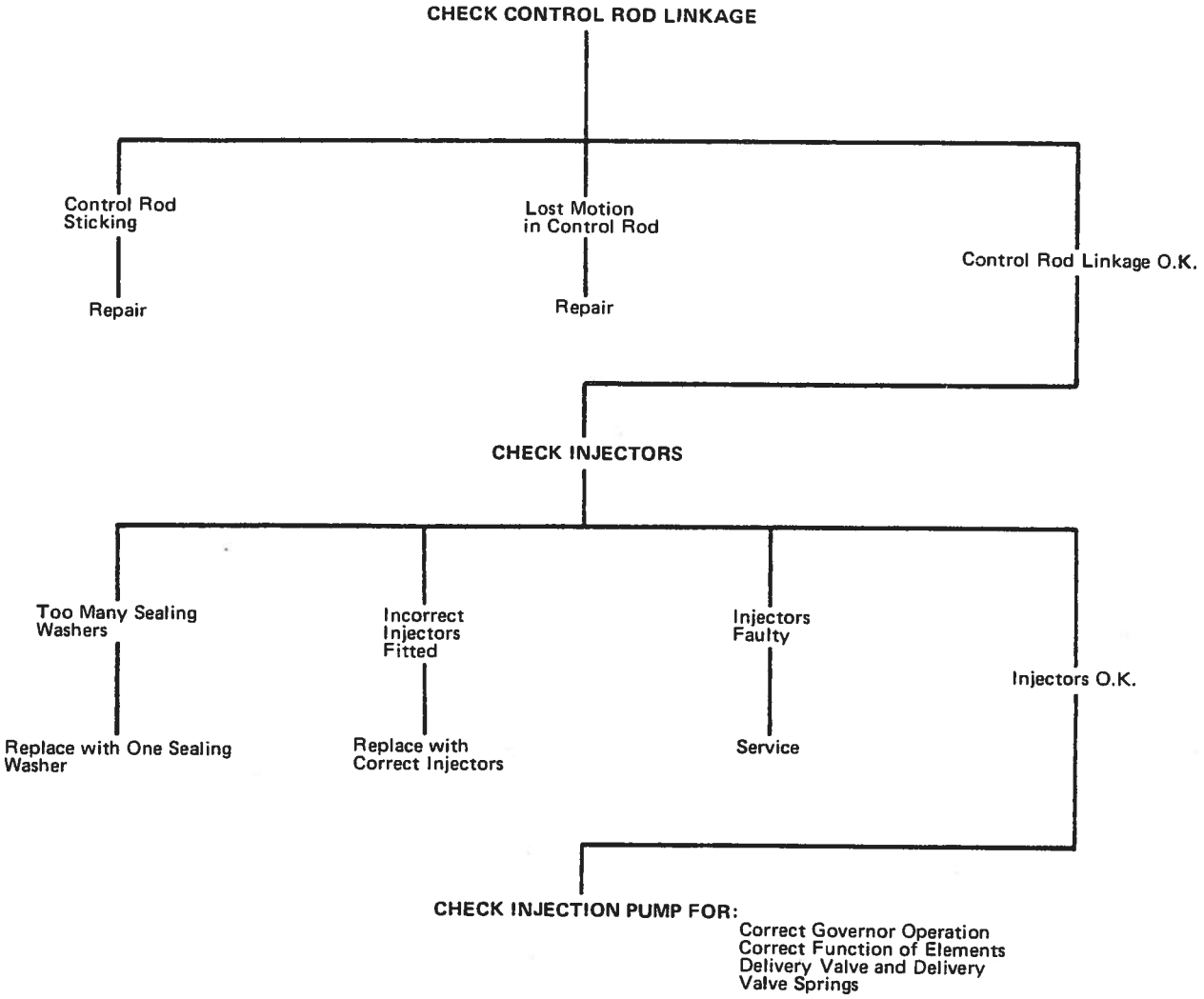
5. UNEVEN RUNNING/MISFIRING



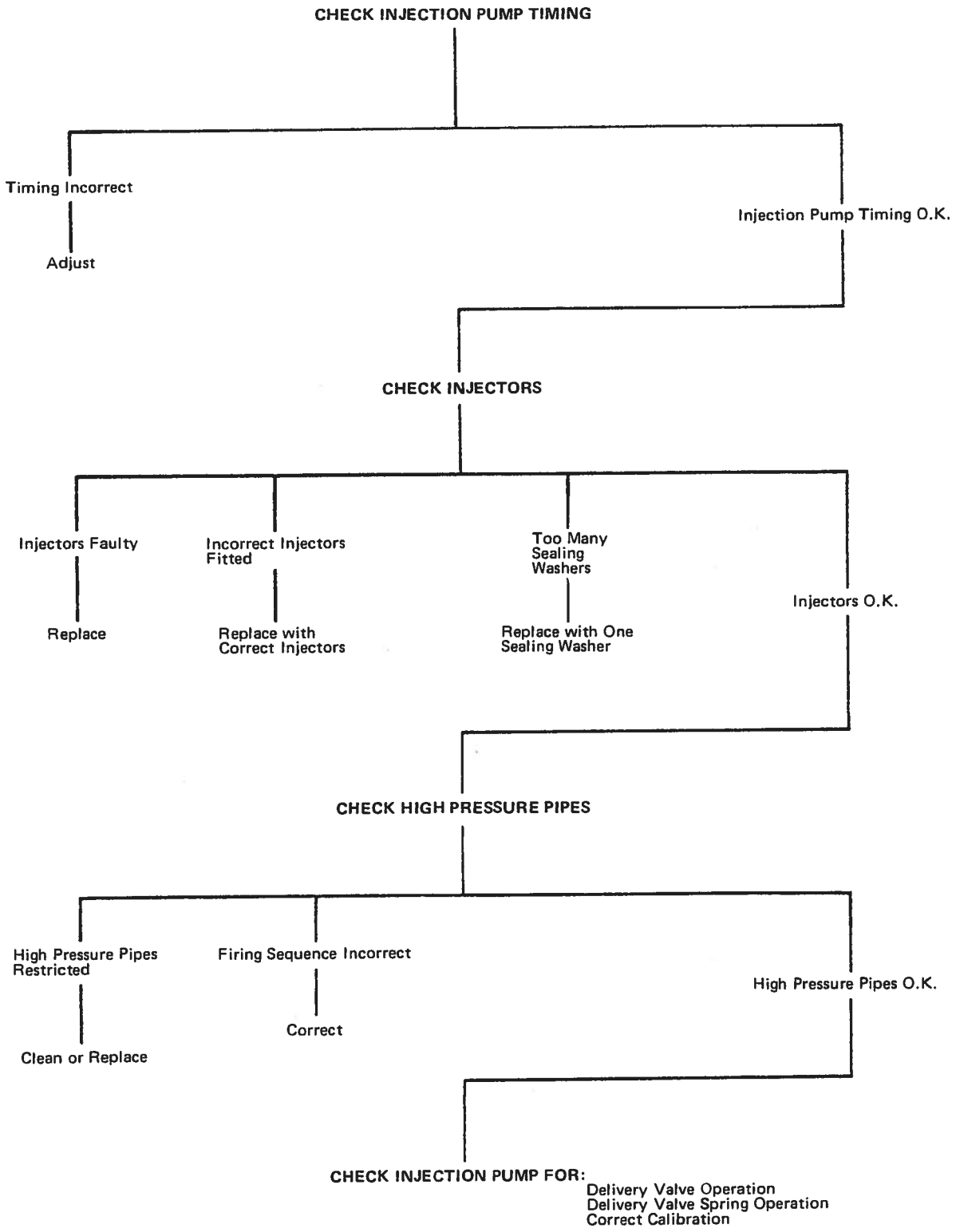
6. LACK OF POWER/POOR FUEL CONSUMPTION



7. ENGINE SURGE (WITH THROTTLE IN FIXED POSITION)



8. ENGINE KNOCK (WITH INCORRECT FUEL METERING)



SERVICE PRECAUTIONS

It should be stressed that as the fuel injection equipment is extremely accurate and finely finished, it is essential that every care be exercised to prevent damage when carrying out repairs or overhauls.

Special equipment must be used when phasing and calibrating the Minimec pump and resetting injector pressures. For all operations a dust-proof room must be available.

To protect the pump and injectors when they are removed prior to servicing, and to protect them before refitting to an engine, special dust caps and plugs, from kit Tool No. C.9080, should be used for blanking all fuel connections.

For cleaning and testing, a special test oil marketed for this purpose must be used, see Specifications.

In order to prevent skin irritation the mechanic should protect his hands with a good quality barrier cream prior to commencing any work of this nature, as a certain amount of fuel oil is bound to be present in pumps and injectors which have been in service.

Care should also be taken when testing injectors to prevent spray from the injectors coming into direct contact with the hands, as the working pressure is such that it will easily penetrate the skin.

REMEMBER! Cleanliness is essential.

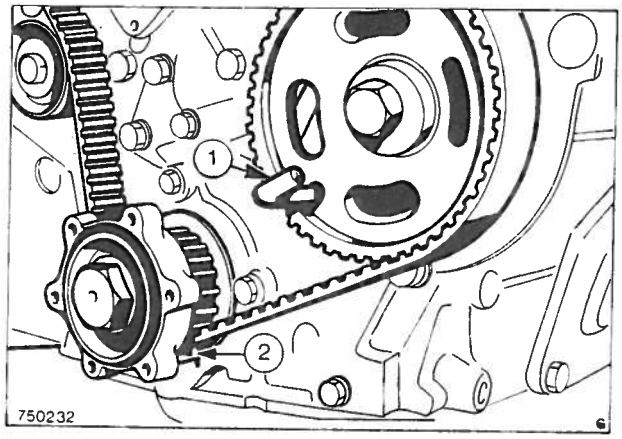


Fig. 7 The camshaft timing per Tool No. 21-016

REMOVAL FROM ENGINE

1. Slacken the alternator bolts and remove the fan belt, fan and water pump pulley. Remove the timing belt cover.
2. Align the crankshaft timing marks with No. 1 piston at T D C on the compression stroke and insert the camshaft gear timing pin, Fig. 7. Slacken the timing belt tensioner and remove the belt from the injection pump drive gear.
3. Disconnect the stop control cable and the accelerator linkage from the control lever.
4. Disconnect the injector pipes from the delivery valve holders and fit blanking plugs.
5. Remove the fuel pipes from the injection pump and the fuel lift pump. Fit blanking plugs to the pump.
6. Remove the four nuts retaining the injection pump drive gear and remove the gear.
7. Remove the injection pump retaining bolts and mounting bracket and remove the pump.

PRELIMINARY CHECKING

Before the injection pump is dismantled or a replacement unit is fitted to an engine, the pump that has been removed should be thoroughly cleaned and its operation checked on a calibrating machine.

It is also advisable to remove and check the operation of the fuel injection pump whenever the engine is undergoing major attention. Even pumps with minimal service should be checked for general performance to ascertain (a) if any faults exist, and (b) if a complete overhaul is necessary.

A preliminary check should be made to ensure that fuel oil entering the cylinder, by the injectors, commences to burn at the same point in the engine cycle for each cylinder. Each element must deliver the same amount of fuel oil as its companions to ensure equal power output from each cylinder of the engine. The operation for setting these characteristics is known as Phasing and Calibration respectively. Information is given in more detail in the appropriate pump sections.

DISMANTLING

1. Remove the fuel lift pump and drain the lubricating oil from the camshaft chamber.
2. Remove the retainers with Tool No. ST150 and slacken the delivery valve holders using Tool No. 23-500.
3. Remove evenly the screws securing the pump body to the housing and lay the pump at an angle on the bench. Remove the pump body in an arc as shown in Fig. 9, so that the plunger arms are disengaged from the control forks.
4. Remove the plungers, springs and lower spring seats from their barrels and lay them carefully in the dismantling tray, keeping them in their correct positions, Fig. 10. Remove the delivery valve holders. Extract the volume reducers, springs and delivery valves.
5. Lay the pump body on the bench, tap the barrels with a hide mallet to free them from the splines, and lift out the delivery valve guides, sealing washers and barrels.

   It is essential that all the mated parts of each pump element are kept together, on no account should parts such as plungers and barrels or delivery valves and guides be mixed.
6. Unscrew the bolts and remove the inspection cover, Fig. 11. Remove the screws locating the cover retainer plates and rotate the retainers through 90°, above the axles of the tapped holes to remove them.
7. Remove the tappet assemblies from the cambox, keeping them in their respective positions with the pumping elements. If the tappets are to be dismantled, push out the roller pin and remove the double rollers. Extract the circlip to enable the phasing spacer to be withdrawn from the tappet body, Fig. 12.
8. Before dismantling the pump further, check the camshaft end float, so that the thickness of shims behind the camshaft bearing inner races may, if necessary, be adjusted when reassembling.

   Remove the auto advance unit, using Tool No. 21-020.

   Use adaptor Tool No. ST89559/6 in conjunction with the dial gauge, by screwing the adaptor onto the threaded end of the camshaft and measure the end float in relation to the pump housing.

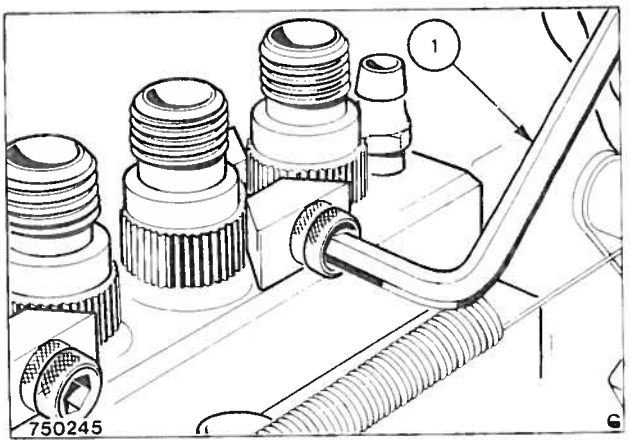


Fig. 8 Removing the delivery valve holder retainers
1. Tool No. ST150

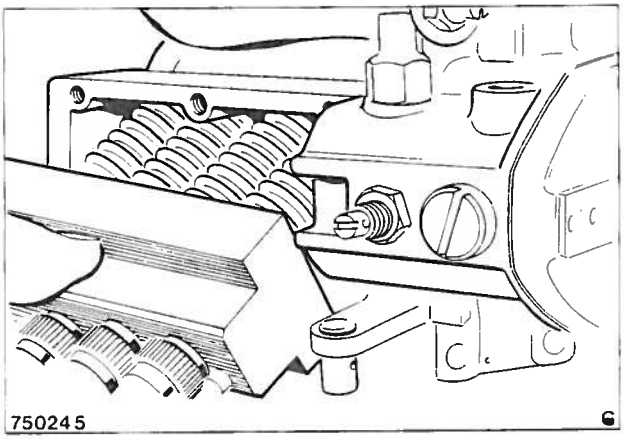


Fig. 9 Removing the pump body

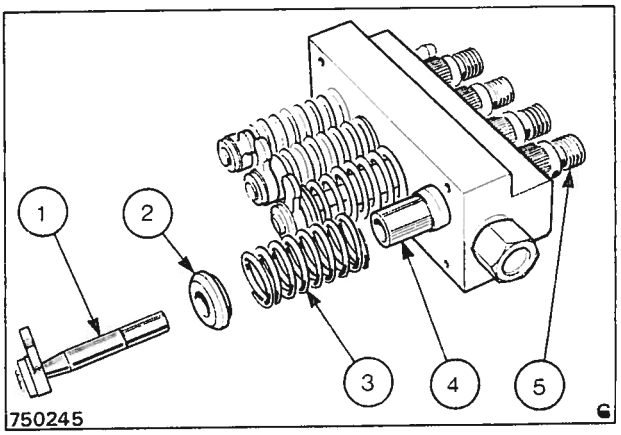


Fig. 10 Pump body

1	Plunger	4	Barrel
2	Seat	5	Delivery Valve Holder
3	Spring		

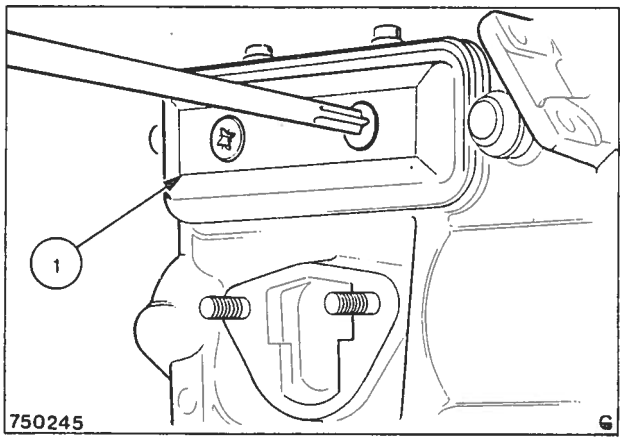


Fig. 11 Removing the inspection cover
1 Inspection Cover

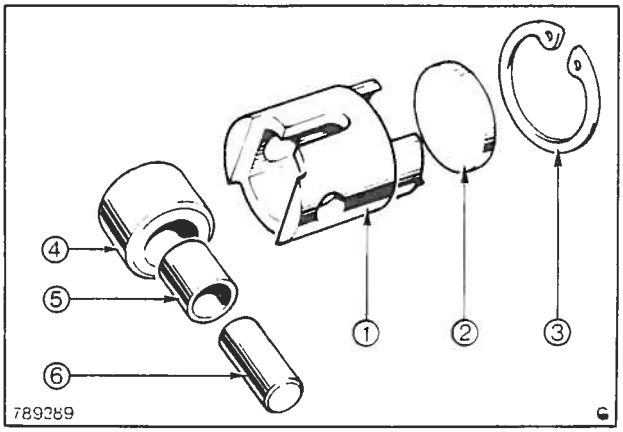


Fig. 12 Tappet assembly
1 Tappet Body
2 Phasing Spacer
3 Circlip
4 Cam Follower
5 Inner Roller
6 Tappet Pin

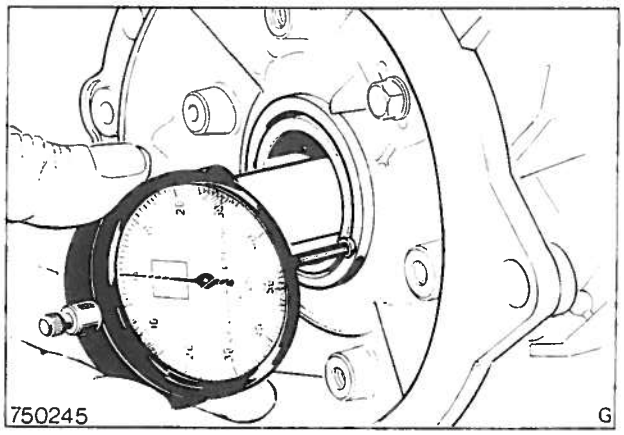


Fig. 13 Checking the camshaft end-float

NOTE: It is necessary to pack the gauge with a thick washer, to ensure that the anvil clears the ridge as shown in Fig. 13.

9. Remove the camshaft key and the screws securing the mounting flange cover to the governor housing. Ease the plate from its locations.
10. Remove the 'dumbell' shaped roller bearing from the throttle control lever cross-shaft fork (Fig. 14).
11. Press out the governor spring cross shaft to remove the governor springs.
12. Undo the two screws holding the rocking lever pivot shaft to the governor housing. Remove the circlip on the shaft inside the housing and remove the shaft and rocking lever.
13. Remove the circlip from the right-hand side of the control lever cross-shaft and then remove the washer, 'O' ring and oil seal.
14. Slacken the clamp bolt on the control lever cross-shaft fork, slide the fork along the shaft and remove the woodruff key. The fork can then be removed from the shaft as it is withdrawn from the governor housing.
15. Lift out the camshaft and governor mass as an assembly (Fig. 15).
16. Remove the camshaft bearing inner race using a suitable press, universal taper plate Tool No. 370, slave ring Tool No. CT9056 and adaptor Tool No. CT6085-1A, see Fig. 16.

    Note the thickness of shims fitted between each bearing race and the shoulder on the camshaft. These should be divided equally between each end of the shaft.
17. Slide off the thrust pad, needle bearing and sleeve, unscrew the four screws that hold the weight carrier to the camshaft and remove the weight carrier. This is located by a dowel to the camshaft.
18. Remove the rubber boot from the stop control lever and excess fuel device spindle. Slacken the stop control lever clamp bolt and slide the lever off the sleeve. Remove the circlip and washer fitted to the sleeve beneath the stop control lever.
19. Tap out the tension pin securing the maximum fuel stop bellcrank to the spindle, unscrew the threaded bush from the

governor housing and remove the return spring.

20. Withdraw the excess fuel device spindle and remove the maximum fuel stop bell-crank. Take care not to lose the two fibre washers fitted between the maximum fuel stop bellcrank and the stop control sleeve.
21. Slide the stop control sleeve and lever assembly into the governor housing and remove.
22. Slacken the screws securing the control forks to the control rod and slide out the control rod, disengaging the forks as the rod is withdrawn.
23. Remove the oil seal from the front cover, taking care not to damage the bore.
24. If the rear bearing cup is to be removed from the camshaft housing first tap out the expansion plug sealing this bore.
25. The camshaft bearing cups can be removed by using Tool No. CT9050, Fig. 17, in the following manner. Assemble the collet of the tool from the inside of the bearing, collapsing the sprung arms of the tool so that the lip passes through and locates on the outside of the bearing cup. Screw in and fully tighten the expander from the outside of the housing and then drive the assembly into the housing.

    The governor cover bearing cup is removed in a similar manner.

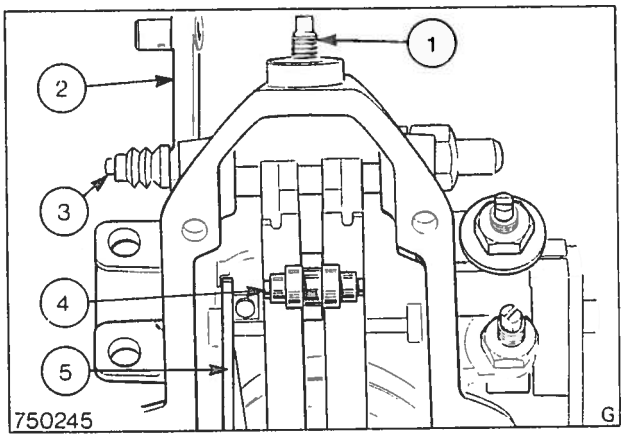


Fig. 14 Internal view of pump from drive end
1 'Max' Fuel Control Stop
2 Stop Control Lever
3 Excess Fuel Button
4 Spring Roller Assy.
5 Rocking Lever

COMPONENT INSPECTION & RENEWAL

Wash all components in test oil and inspect for wear and signs of seizure or tightness, paying particular attention to the plungers, delivery valves and governor. Examine the plungers for vertical line scoring, especially around the helix.

Renew all worn components, and pumping element and delivery valve guide assemblies which failed the preliminary check, if the pump is to be brought back to new condition. Barrels and plungers and delivery valves and guides are not interchangeable and can only be replaced as assemblies.

It should be noted that the control rod front bush is held in position by a small pin which locates in a drilling in the governor and camshaft housing directly above the bush, and protrudes from the housing just sufficiently to engage the wall of the bush. If it is necessary to remove this bush the pin must be driven downwards

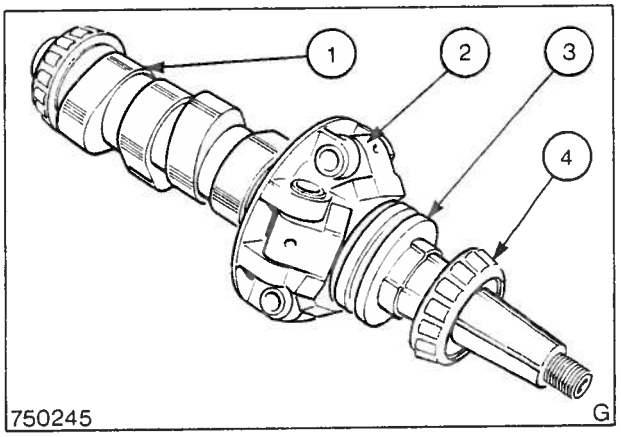


Fig. 15 The camshaft and governor mass assembly
1 Camshaft
2 Governor Mass
3 Thrust Pad
4 Bearing

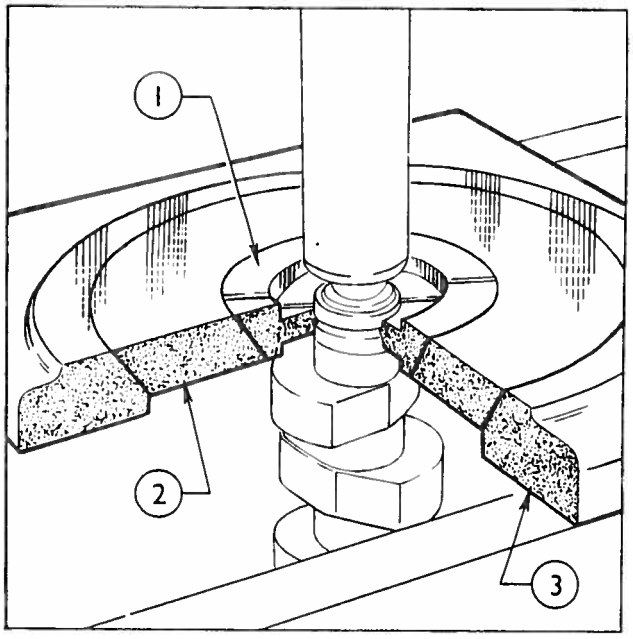


Fig. 16 Removing the camshaft bearing inner race
1 Adaptors CT.6085-1A
2 Slave Ring CT.9056
3 370 Universal Taper Base

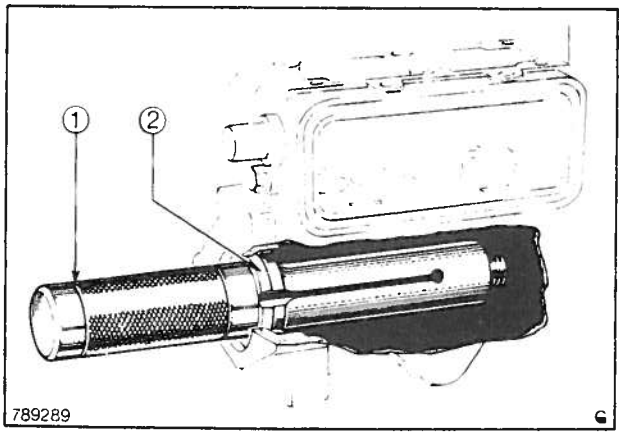


Fig. 17 Removing the camshaft bearing cups
1 Bearing Cup Remover Tool No. CT.9050
2 Bearing Cup

through the locating hole in the bush and extracted through the bore.

When replacing the bush it must be positioned with the pin hole facing upwards and in line with the drilling in the governor and camshaft housing. The pin must then be driven downwards through the drilling until its lower end locates in the wall of the bush. Care must be taken to see that the pin does not foul the control rod.

The control rod rear bush is located in the end cover and can only be replaced as an assembly. Seal the cover with EM-4G-47 jointing compound and apply EM-4G-52 plastic sealer to the screw threads.

The governor cross-shaft bushes are flanged, and thus must be removed by pulling or driving them outwards with a suitable tool. Coat the shanks of new bushes with EM-4G-47 jointing compound before reassembly.

Leave all components in the test oil until required for assembly when they should be fitted 'wet' to provide initial lubrication.

ASSEMBLY

1. Replace the camshaft bearing cups, using Tool No. CT9051 by first assembling the cup to the tool, then locating this assembly on the inside of the bearing bore. Assemble the washer and nut of the tool from the outside, and use a ring spanner to tighten the nut and draw the bearing into position, Fig. 18. When fitting the front bearing fit the oil seal at the same time, ensuring that the lip is inwards.

   On later engines, an improved oil seal of harder wearing silicon manufacture (Part No. 735F-9E596-AAA), has been fitted to all 'Minimec' pumps, and if replacement becomes necessary this latter type should always be fitted.

2. Fit a new expansion plug, coated around the periphery with a suitable sealing compound, into the housing from the inside. Press the expansion plug into the housing, using Tool No. C0982 fitted to handle Tool No. 550. This tool ensures that the base of the plug protrudes 3 mm (0,118 in).

3. Pass the control rod through the front bush in the housing, assemble the control forks and locate the end of the rod in the rear bush. Locate the rear control fork with its edge 0,5 mm (0,020 in) from the edge of the square section of the control rod and tighten the clamping screw. Fix

the other forks to the control rod at approximately equal distances apart.

4. Fit the stop control sleeve and lever assembly from inside the governor housing. Locate a new 'O' ring and add sufficient shims on the sleeve outside the governor housing to allow free rotation of the shaft without endfloat. Secure the sleeve in position with a washer and circlip.
5. Position the maximum fuel stop bellcrank in the governor housing. Insert the excess fuel device spindle, button end first, into the governor housing to pick up the maximum fuel stop bell crank, fibre washer and the stop control sleeve. Place the return spring in the threaded bush and screw the bush into the governor housing after coating the threads with EM-4G-47 jointing compound.
6. Align the holes in the maximum fuel stop bell crank and the excess fuel device spindle and carefully tap the tension pin into position, see Fig. 19.
7. Rotate the stop sleeve clockwise so that the internal stop lever is fully forward and position the stop control lever on the serrations so that the lever points forwards and is approximately 30° above the horizontal. Ensure that the lever moves easily and tighten the clamp bolt. Fit the rubber boot to the sleeve and spindle.
8. Locate a plain washer, the disheu washer, another plain washer, a new 'O' ring and an oil seal onto the control lever cross-shaft. Then insert it into the governor housing, passing it through the cross-shaft fork inside the housing. Fit a new oil seal and 'O' ring to the other end and fit the plain washer and circlip.
9. Fit the woodruff key to the control lever cross-shaft and slide the fork along the shaft over the key.
10. Centralise the fork on the cross-shaft and tighten the clamp bolt.
11. Place the camshaft in the vice with the drive end uppermost. Slide the weight carrier assembly over the camshaft with the governor weights uppermost, ensuring that the assembly is correctly positioned for the insertion of the dowel pin in the camshaft flange. Coat the four fixing screws with 'Loctite' (Part No. EM-4G-52) and secure the weight carrier in position with the four screws and washers. Tighten the screws to a torque of 12,2 Nm (9 lbf ft or 1,2 kgf m).

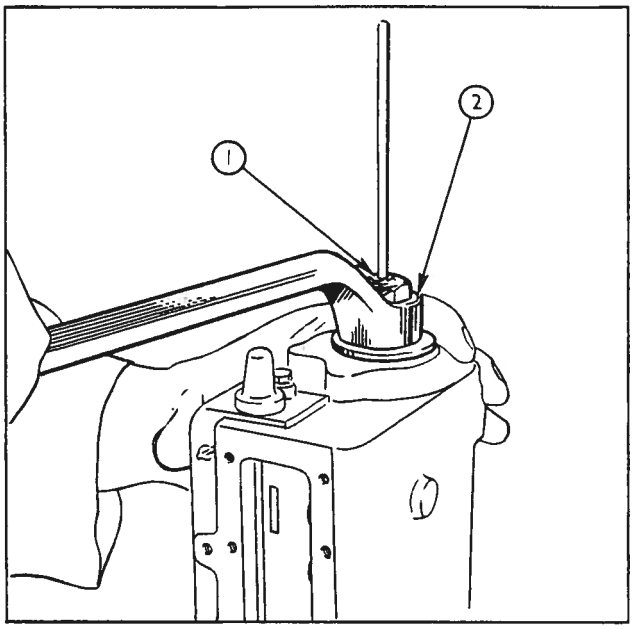


Fig. 18 Replacing the camshaft bearing cups
1 Bearing Cup Replacer Tool No. CT.9051
2 Spanner

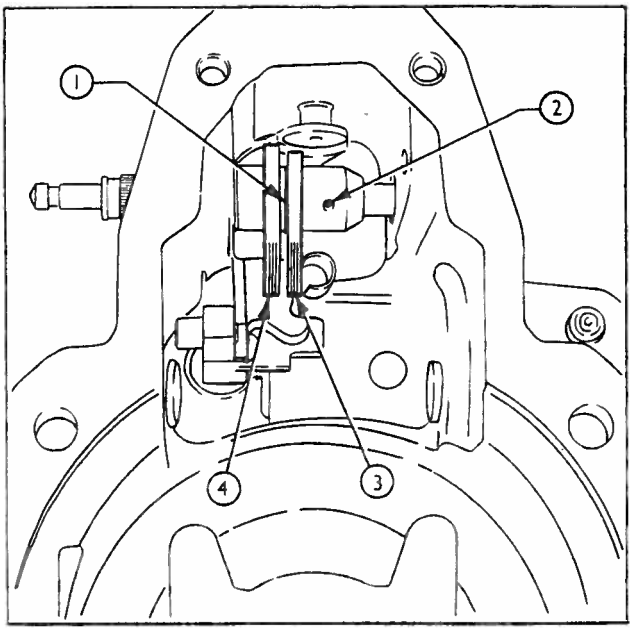


Fig. 19 Internal view of pump from drive end
1 Fibre Washer
2 Tension Pin
3 Maximum Fuel Stop Bell Crank
4 Stop Control Bell Crank

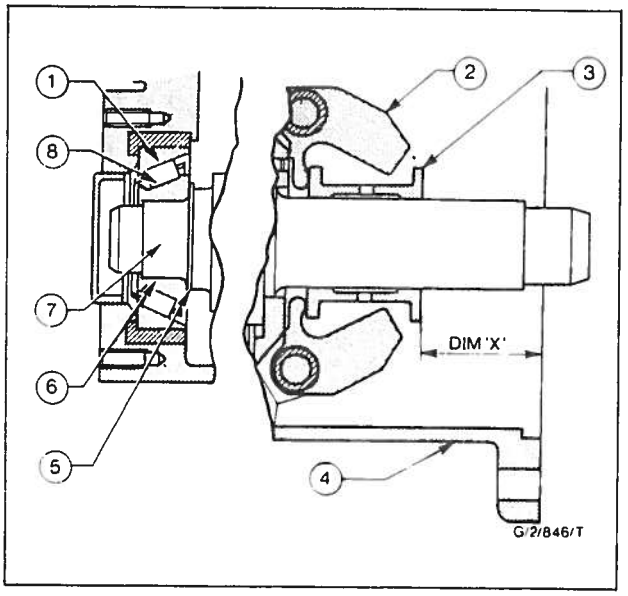


Fig. 20 Checking Dimension 'X'

1 Outer Race
2 Governor Weight Assembly
3 Thrust Sleeve
4 Pump Housing
5 One Thick, One Thin Shim
6 Inner Race
7 Camshaft
8 Rollers

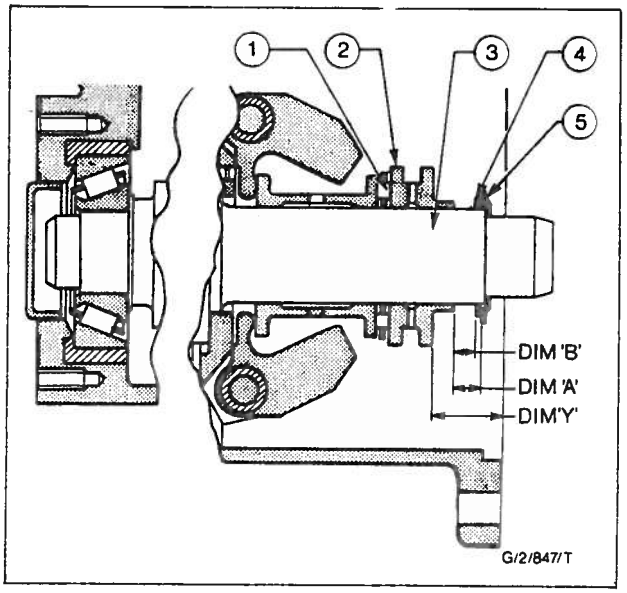


Fig. 21 Checking Dimensions 'Y', 'A' and 'B'

1 Needle Thrust Bearing
2 Selected Thrust Pad
3 Camshaft
4 Selected Spacing
5 Stop Disc

12. Slide the governor sleeve over the camshaft with the widest groove and flange uppermost. Engage the bottom groove of the sleeve with the heel of each governor weight and press down. Check to ensure that all weights pivot freely with the heel engaged in the governor sleeve. Fit the needle thrust race and thrust pad, ensuring that the machined face of the thrust pad is towards the thrust race.

    Now slide the spacer washer over the camshaft and fit the tapered roller race in position. Tap or press the roller race fully home against the spacer washer.

13. Remove the camshaft from the vice. Fit spacing shims on the opposite end ensuring that the same quantity and thickness of shims are used as previously noted on dismantling. Fit the tapered roller race over the camshaft. Tap or press the race fully home against the spacer shims.

14. Place the pump housing in the vice and position the assembled camshaft, with the drive end outwards, into the pump housing. Fit a new governor cover gasket and temporarily position the governor cover in place. Secure it in position with the three large securing screws and washers. Tighten the screws to a torque of 16,3 to 20,3 Nm (12 to 15 lbf ft or 1,7 to 2,1 kgf m).

15. Check the camshaft end float with the dial indicator. The end float should be within the limits of 0,05 to 0,13 mm (0,002 to 0,005 in). Adjustment is by means of spacing shims which are respectively 0,1 and 0,2 mm (0,004 to 0,008 in) thick.

    After achieving correct end float, remove the governor cover and gasket.

The following additional operations are necessary for the 'Minimec' injection pump.

Checking Dimensions

Fitting a new camshaft, pump housing, governor weight assembly or governor can affect the camshaft end float and any or all of the four dimensions shown (Figs. 20 and 21).

If readjustment is necessary the following procedure should be adopted.

1. Place one thick and one thin shim (Fig. 20) onto the camshaft and press on the inner race. Insert the camshaft complete with governor weight assembly and thrust sleeve

but without the governor end inner race, into the pump housing. Ensure that the rollers enter the outer race correctly. Check visually that the cam lobes are in the centre of the tappet bore; if necessary vary the amount of shimming behind the inner race until correct alignment is obtained. With the governor mass in the fully closed position shown, measure the distance 'X' between the end of the thrust sleeve and the face of the pump housing using Tool No. ST157 and a suitable depth gauge. Remember to subtract the thickness of that part of the tool lying on top of the housing flange before arriving at the final figure.

2. Refer to the thrust pad and spacing ring specification and select the thrust pad appropriate to the 'X' dimension obtained.

NOTE: The dimension 'X' must be measured without a gasket fitted and with the housing face clean and free from any jointing compound.

3. Assemble the needle thrust bearing (Fig. 21) and the selected thrust pad onto the camshaft. With the governor mass still in the closed position shown, dimension 'Y' should be between the limits of 19,90 and 20,60 mm (0,783 and 0,811 in). If it is not, then fit the next size thrust pad that will give the required 'Y' dimension.

4. Place the stop disc onto the camshaft the correct way round as shown. With the governor mass in the fully closed position and the stop disc held against the camshaft shoulder, measure dimensions 'A' using a vernier gauge.

5. Refer to the thrust pad and spacing ring, specification and select the appropriate spacing ring. Remove the stop disc, place the selected spacing ring (Fig. 21) in position and replace the stop disc. Dimension 'B' should be between the limits of 5,90 and 6,20 mm (0,23 and 0,24 in). If it is not, then fit the next size spacing ring that will give the required 'B' dimension.

NOTE: It may be necessary to remove the camshaft from the pump housing when measuring dimensions 'A' and 'B'.

6. Remove camshaft complete with all the parts already fitted, place one thick and one thin shim in position and press on the inner race. Insert the camshaft into pump housing and fit the governor cover complete with new gasket. Secure the cover with the small set screws tightened to the correct torque value of 5,4 to 8,1 Nm (4 to 6 lbf ft or 0,6 to 0,83 kgf m) and the large set screws 16,3 to 20,3 Nm (12 to 15 lbf ft or 1,7 to 2,1 kgf m).

DIM 'A' mm	SPACING RING No.	PACKING COLOUR
7,50 7,75	505353	RED
7,76 8,00	505354	WHITE
8,01 8,25	505355	BLUE
8,26 8,50	505356	YELLOW
8,51 8,75	505357	GREEN
8,76 9,00	505358	ORANGE
9,01 9,25	505359	PURPLE

DIM 'X' mm	THRUST PAD No.
31,10 31,50	2
31,51 32,00	3
32,01 32,50	4
32,51 33,00	5
33,01 33,50	6

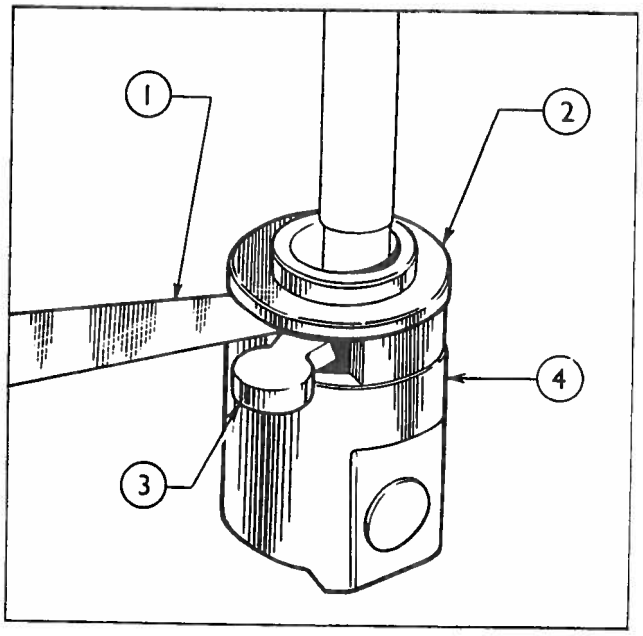


Fig. 22 Measuring the plunger vertical movement
1 Feeler Gauge
2 Spring Seat
3 Plunger Arm
4 Tappet Assembly

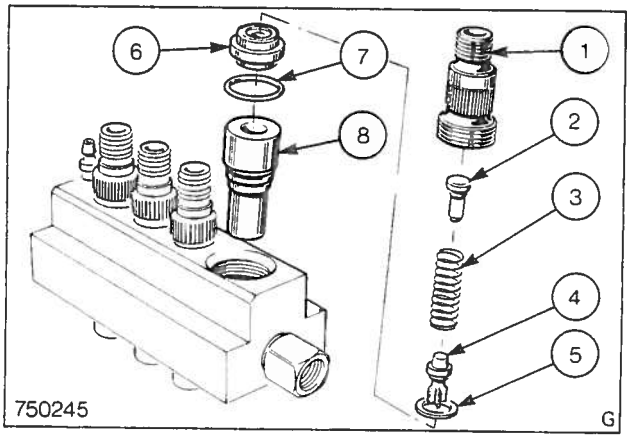


Fig. 23 Reassembling the pump body
1 Delivery Valve Holder
2 Volume Reducer
3 Spring
4 Washer
5 Delivery Valve
6 Delivery Valve Guide
7 Washer
8 Barrel

7. Turn the camshaft by hand to ensure full seating of bearings, then check the end float using Tool No. ST183 fitted with adaptor Tool No. P89559/8 and a suitable dial gauge such as Tool No. 23764. End float should be between 0,050 and 0,127 mm (0,002 and 0,005 in).

   If necessary remove the camshaft and alter the thickness of shims behind the inner race at the governor end. When the correct amount of end float is obtained remove the governor cover, leaving the camshaft in position. If it becomes necessary to alter the shimming at the other end of the camshaft, dimensions 'X' and 'Y' must be re-checked.

8. Locate the rocking lever in the governor housing with the pin in the thrust pad groove and the fork at the upper end of the lever engaging with the pin on the control rod.

9. Insert the rocking lever pivot shaft, fitted with a new 'O' ring, into the governor housing, locating the end of the shaft in the rocking lever pivot hole. Secure the shaft to the outside of the governor housing with the two screws, and replace the circlip on the shaft inside the governor housing.

10. Locate the governor spring in the housing with the curved feet of the spring bearing against the thrust pad.

11. Replace the governor spring cross-shaft. Fit a new 'O' ring to the shaft and insert it into the housing, passing it through the spring eyes. Fit the excess fuel lever support then replace and tighten the nut on the end of the shaft and refit the spring roller.

12. Replace the mounting flange cover plate on the governor housing, using a new gasket and secure with bolts and spring washers.

13. Assemble the tappets, using the original components or new phasing spacers if irregularities were noticed when checking prior to dismantling.

NOTE: Ensure that they are located fully within their dowels.

14. Pass the plungers through the lower spring seats, holding the seats on the tappet assemblies, check that the plungers have a vertical movement of 0,05 to 0,25 mm (0,002 to 0,010 in), Fig. 22. (Fit the steel 'T' pieces to their locations in the housing for the 'Minimec' pump.)

15. Locate the pump barrels in the body, ensuring that the master splines are fully engaged. Replace the delivery valve guides, delivery valves, sealing washers, delivery valve springs and volume reducers, Fig. 23.
16. Fit the springs, lower spring seats and plungers to the barrels, and fit the pump body to the camshaft housing, using EM-4G-47 jointing compound on the faces. This will be facilitated by laying the pump on its side with the plunger arms hanging downwards, Fig. 9, engaging the arms with the control rod forks and then rotating the pump body to the correct position.
17. Secure the pump body to the housing, tightening the eight Allen screws evenly in a diagonal sequence to 6,8 Nm (5 lbf ft or 0,7 kgf m) torque.
18. Phase and calibrate the pump as described in the section on Testing and Adjusting (see appropriate section).

OVERHAULING THE AUTO ADVANCE UNIT

To Dismantle

1. Bend the locking tabs away from the retaining bolt heads and remove the six retaining bolts.
2. Remove the cover and gasket. The retaining bolt holes in the cover will only align in one position on the driving flange.
3. Remove the circlip from the driven flange, washer and shims, Fig. 24.
4. Remove the driven flange from the weights, note the mating marks on the periphery of the driving and driven flanges to ensure correct assembly.
5. Remove the weights and slipper blocks from the driving flange.
6. Remove the spring retaining pins from the weights and springs. These pins are a slip fit, a circlip is fitted at one end which locates into a recess in the driving flange side of the weights, Fig. 25.
7. Clean and examine all parts.

Assembly

1. Hold the weights in the hand, enter one spring into its location in the weights, align the spring eyes, lubricate and fit the two spring retaining pins. Fit the other spring and retaining pins.

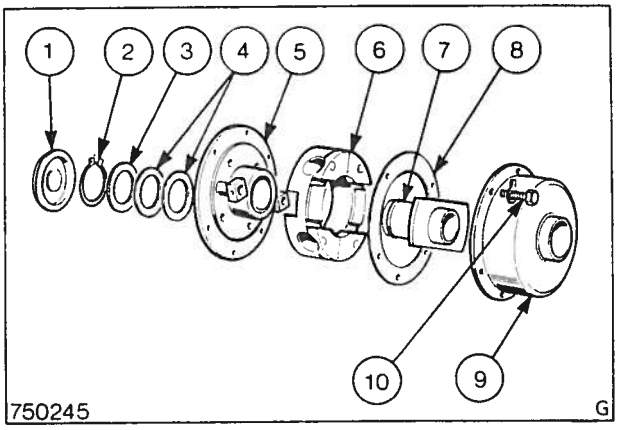


Fig. 24 Exploded view of auto-advance unit

1.	Core Plug	6.	Weight Assy.
2.	Circlip	7.	Driven Flange
3.	Seal	8.	Joint
4.	Shims	9.	Cover
5.	Driving Flange	10.	Bolt and locking tab

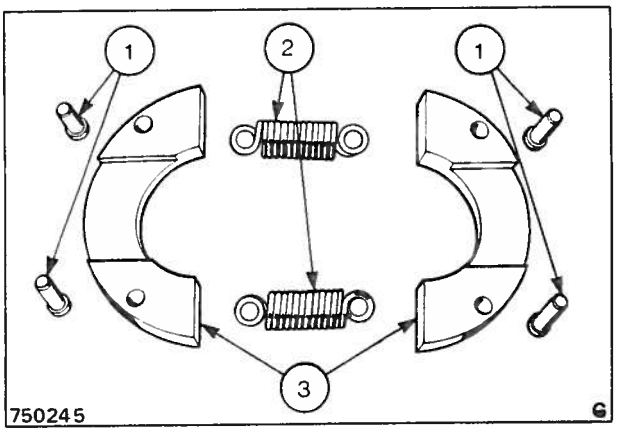


Fig. 25 Auto-advance unit weights and springs

1.	Spring Retaining Pins	2.	Springs
		3.	Weights

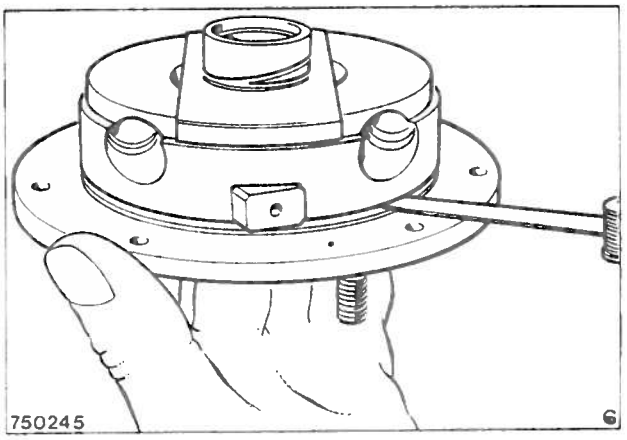


Fig. 26 Checking the end-float of the auto-advance unit

2. Lubricate the driven flange and position the flange on the weights. Lubricate the slipper blocks and fit onto the driving flange, fit the driven hub and weights onto the driving flange, aligning the slipper blocks and mating marks. Fit the shims, washer and circlip. Check between the driving flange and weight face using either a feeler gauge or the Auto-advance end float adaptor and dial gauge for the correct end float. Adjustment is made by adding or removing shims as necessary, Fig. 26.

NOTE: To check the angular movement use the advance gauge with the advance unit (less springs) mounted on a dummy camshaft.

3. Fit a new joint on to the driving flange and refit the cover, fit the retaining bolts with new lockwashers, tighten and secure the locking tabs, Fig. 24.

4. After the advance unit has been fitted on to the fuel pump camshaft and the retaining nut has been tightened, coat the outer edge of the new core plug (identified by the letters 'WT') with sealer A70SX-19554-AA.

   Tap the core plug, using a drift until it is level with the top of the plug location flange.

   Before replacing the automatic advance unit studs, Loctite sealer (Grade 241) should be applied to the threads.

TESTING & ADJUSTING THE INJECTION PUMP

The 'Micromec' and 'Minimec' injection pumps have a mechanical governor, and to completely test and adjust pumps of this kind, a variable speed testing machine is necessary.

The injection pump should be tested with the advance hub assembled as the timing marks are incorporated on the hub. A drive adaptor and special mounting brackets, where necessary for testing this injection pump are available from the test equipment manufacturers.

Test Equipment Specification

(a) Injectors BK B50SD19b fitted with BDN0SD6596 for 'Micromec' pumps and BDN12SD12 for 'Minimec' pumps, with nozzles set at the specified ATS opening pressure (refer to Specifications). Nozzle back leakage must not be less than 10 seconds for a drop from 150 to 100 atmospheres.

(b) High pressure pipes 6 mm by 2 mm by 760 mm (30 in) long. Ensure that the pipes are free from sharp bends, kinks and restricted ends.

(c) Gravity feed with test oil (see Specifications). Oil temperature 28° to 40°C (80° to 100°F).

Fuel injection pumps must be accurately calibrated and to ensure this it is essential that the master injectors fitted to the calibrating machine are maintained as an accurately balanced set. To ensure maximum life and efficiency from master injectors the following points should be strictly observed:–

1. The calibrating machine should be housed in a dustproof room, and suitably covered when not in use.
2. The fuel tank should be drained and cleaned out frequently, and after calibrating 200 pumps, the filter element renewed.
3. When calibration is not carried out frequently, an injection pump should be mounted on the machine and test fuel passed through the master injectors at least once a week.

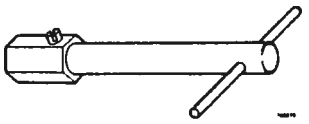
NOTE: It is advisable to use only test oil in the calibrating machine as the variation of the fuel is less than that of diesel fuel so that more accurate readings can be obtained. The test oil also gives better protection to the master injectors.

Mounting the Fuel Injection Pump on the Test Equipment

1. Mount the pump securely in position on the testing machine, using the brackets available from the equipment manufacturer.
2. Connect the fuel supply pipe from the test equipment to the fuel inlet on the pump body.
3. Fit the cleaning pipe tool to the delivery valve holders.
4. Fill the injection pump governor housing with the correct amount of engine oil. Do not overfill.
5. Turn on the fuel tap, slacken the bleed screw and allow fuel to flow from it. Tighten the screw, when all air bubbles in the fuel have disappeared (Figs. 40 and 41 'Micromec' and 'Minimec' respectively).
6. Run the pump for five minutes to flush it through, discharging the fuel to waste.

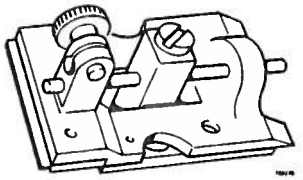
FUEL SYSTEM – BOSCH

1 681 440 011 Camshaft End-Float Gauge



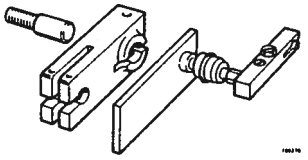
1 681 440 011

0 681 440 017 Pre-Stroke Gauge



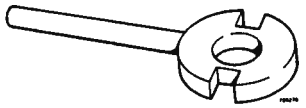
0 681 440 017

1 688 130 095
1 688 130 042 **Control Rod**
1 687 233 015 **Adjusting Device**
1 688 999 99M



1 688 130 095
1 688 130 042
1 687 233 015
1 688 999 99M

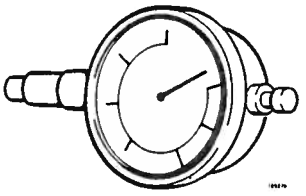
1 683 080 000 Slotted Ring Wrench



1 683 080 000

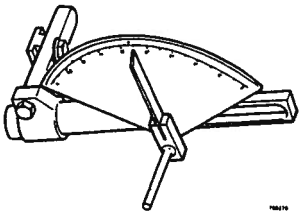
1 687 233 011 Dial Gauge

This tool is used for checking the camshaft end-float to determine that the thickness of shim behind the camshaft inner races is correct.



1 687 233 011

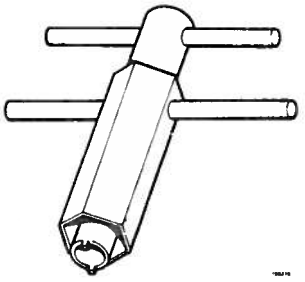
0 681 440 006 Control Lever Adjusting and Holding Device



0 681 440 006

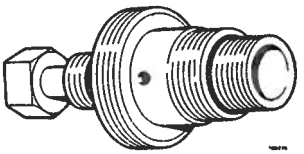
1687 950 013 Combination Wrench

For adjusting the maximum speed stop on the governor also adjusting the torque control spring.



1 687 950 013

0 681 342 002 Injection Pump Automatic Advance Unit Remover



0 681 342 002

89559/7

*** 89559/7 Adaptor**

Used with Tool No. ST183 for checking camshaft end-float.

23764

23764 Metric Dial Indicator Gauge

Used with Tool No. ST183 and appropriate adaptor for checking the end-float on camshaft and auto-advance unit. Also used with Tool No. 89558/4 for checking plunger head clearance.

ST167

ST167 Advance Gauge

This tool is comprised of scale plate and pointer to be used with Tool Nos. ST183, ST170 and appropriate adaptor to check total degree movement of auto-advance unit.

ST182

ST182 Pressure Test Device and Sealing Plate

For pressure testing the complete pump.

89558/4

89558/4 Plunger Head Clearance Gauge

In conjunction with Tool No. 23764 for checking the plunger head clearance on 'Minimec' injection pumps.

500445

500445 Allen Key Adaptor

For use on body securing screws.

ST119

ST119 Barrel Seat Cutter

Used for refacing barrel seats.

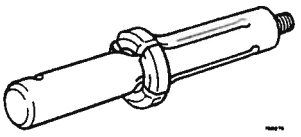
*** New Tools** – These tools are available from:-

Leslie Hartridge Ltd., Buckingham,
Buckinghamshire, England.

502-306 Camshaft Bearing Cup Remover

502-306

This tool consists of a collet and spindle. The spindle screws into the end of the collet and they are entered through the inside of the pump body until the collet snaps behind the bearing. The spindle is then screwed out of the collet and screwed into it again from the other end until the angle on the spindle contacts the inside taper on the collet, thus locking the collet in position. The spindle collet and bearing are then driven out of the pump body.



500-500/1 Camshaft Bearing Cap Replacer

500-500/1

This tool consists of a mandrel, special washer and nut. The cup is located on the mandrel with the lip on the cup abutting the end of the mandrel. Mandrel and cup are passed through the pump body, utilising the rod on the mandrel. When the cup is located, the special washer and nut are passed over the rod until the special washer abuts the pump body, the cup is then pulled into position with the nut.

ST89559/7 Auto Advance End-Float Adaptor

ST89559/7

This tool together with a dial gauge is used to ascertain the correct end-float is obtained between the driving flange and weights.

ST167

ST167

Used in conjunction with tool ST89559/7.

23-501 (CT9054) Socket Head Spanner

23-501 (CT9054)

This is an internally splined socket to fit the delivery valve holder for removal and replacement.

23-502 (CT9085) Key

23-502 (CT9085)

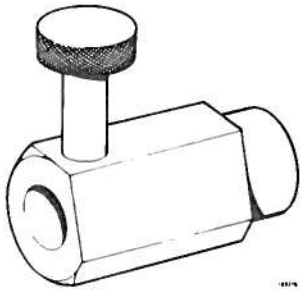
This tool is used for the removal and replacement of the auto advance unit retaining nut.

ST89599

ST89599 Camshaft End-Float Gauge

This tool will assist to check the camshaft end-float and ascertain the required shim thickness behind the camshaft bearing inner race.

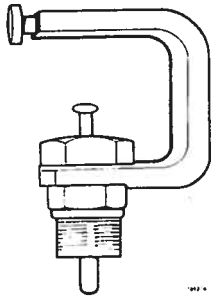
ST89599/2



ST89599/2 Adaptor

Used in conjunction with tool ST89599.

ST89558



ST89558 Plunger Head Clearance Gauge

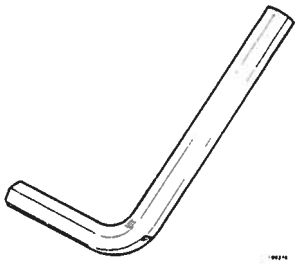
Used in conjunction with the camshaft end-float gauge to check the plunger stroke and ensure correct injection characteristics.

ST89558/11

ST89558/11 Adaptor

Used in conjunction with tool ST89558.

ST150

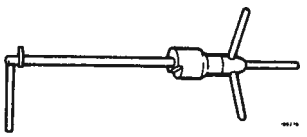


ST150 Delivery Valve Holder Socket

ST166

ST166 Valve Seat Cutter

21-022 Camshaft Bearing Remover/Replacer



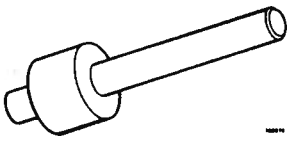
21-022

21-022-01/02 Camshaft Bearing Remover/ Replacer Adaptors

These tools are used with 21-022 main tool. Full instructions for use are included with the main tool.

21-022-01/02

21-045 Flywheel Bearing Installer



21-045

21-036 Flywheel Bearing Remover

21-036

COOLING SYSTEM

P8000-4 Water Pump Overhaul Adaptors

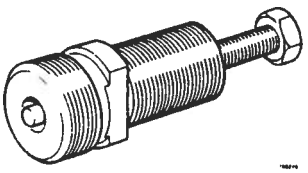
P8000-4

CPT-8000/2A Water Pump Overhaul Adaptors

CPT-8000/2A

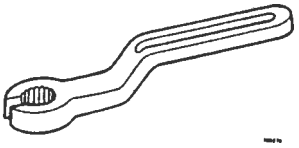
FUEL SYSTEM CAV/SIMMS

21-020 Injection Pump Automatic Advance Unit Remover



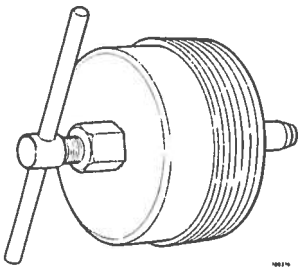
21-020

21-041 Injector Pipe Nut Wrench



21-041

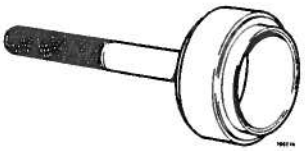
21-010



21-010 Crankshaft Rear Seal Remover

Removes oil seal without damage to the seal bore.

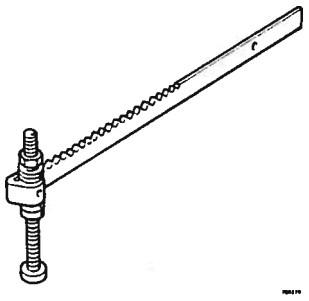
21-011A



21-011A Crankshaft Rear Seal Installer/Aligner

Ensures that on installation the new seal is 'square' in its housing and is undamaged.

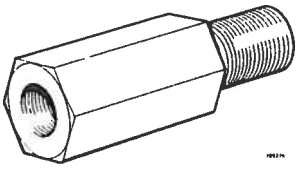
21-024



21-024 Valve Spring Compressor

The adaptor 21-024-01 screws into one of the rocker shaft bolt holes and the post of the main tool screws into the adaptor to give a rigid mounting. The height of the arm is adjusted by screwing the two adjusting nuts up and down the post. The two legs which fit on the valve spring retainer, slide along the arm and are retained in position by a knurled locknut. The valve spring is then depressed by pulling the arm down.

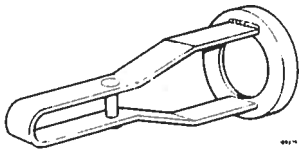
21-024-01



21-024-01 Valve Spring Compressor Stud Adaptor

For use with main toll 21-024 to fit the metric thread on the cylinder head.

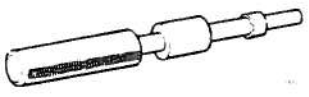
21-024-02



21-024-02 Valve Spring Compressor Adaptor

For use with main toll 21-024

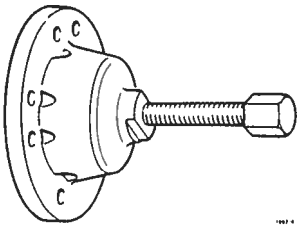
21-021



21-021 Valve Guide Remover/Installer

Damaged or worn guides can be pressed out with this tool. The same tool is used to press in new guides from the top until the legs of the tool attachment just touch the head. The guide is then set to the correct protrusion.

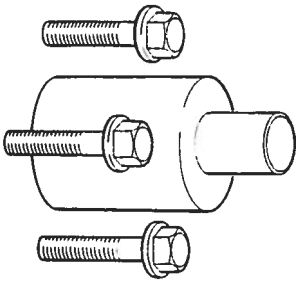
15-038 Crankshaft Pulley Remover



15-038

15-038-51 Crankshaft Pulley Thrust Pad and Bolts

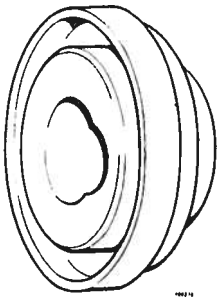
Used in conjunction with Tool No. 15-038. (Bolts can also be used with Tool No. 21-502).



15-038-51

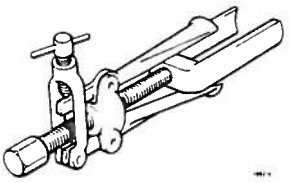
21-017 Camshaft/Crankshaft Oil Seal Remover/ Installer

For installation of crankshaft and camshaft oil seals. Also aligns front cover and camshaft oil seal to camshaft.



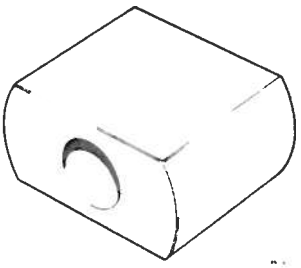
21-017

15-048 Camshaft Front Seal Remover



15-048

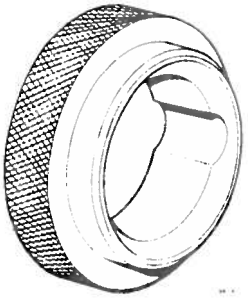
15-048-01 Camshaft Front Seal Remover Adaptor



15-048-51

21-025 Crankshaft Oil Seal Aligner

For correct alignment of the oil seal and carrier to the crankshaft.



21-025

case studs as it may twist relative to the crankcase causing the compressor to malfunction.

13. Place the cylinder head gasket on the cylinder, locate the marks made previously, fit the head and tighten the retaining nuts.

Renewing the Cylinder and Piston Rings

1. Proceed as for 'Reconditioning the cylinder head' numbers 1 and 2.
2. Tap the cylinder to break the joint and slide the cylinder out of the crankcase, supporting the piston until the cylinder is clear to avoid skirt damage.
3. Remove the piston rings and thoroughly clean all carbon from the ring grooves. Clean the cylinder recess in the crankcase removing all particles of carbon and old gasket. Discard the old cylinder and piston rings.
4. Check that the gudgeon pin clearance in the small end bush does not exceed 0,381 mm (0,0015 in). If a new bush has to be fitted, mark the piston and gudgeon pin in relation to the connecting rod, before dismantling the piston and connecting rod assembly.
5. If the bush is a plain one press in and drill the oil holes before reaming to size. If the bush is pre-drilled ensure that the oil holes are lined up with the holes in the connecting rod before pressing in the bush.
6. Refit the piston to the connecting rod using the marks previously made.
7. Fit the new piston rings ensuring that all rings are fitted with the internal recesses or the word top facing towards the piston crown. Space the ring gaps at approximately 120° to each other avoiding placing any ring gap opposite a gudgeon pin end.
8. Apply a good quality engine oil to the piston rings. Position a new sealing ring in the crankcase recess, and compressing the piston rings with a suitable ring clamp, slide the new cylinder into position.
9. After cleaning replace the cylinder head as detailed in 'Reconditioning the cylinder head' number 13.

MAJOR OVERHAUL

If a major overhaul is required this consists of the work carried out in 'Reconditioning the cylinder head' and 'Renewing the cylinder and piston rings' together with 'crankshaft, crankcase bearings and cover bearing inspection and renewal as required.' In the event of a major overhaul the compressor will have to be removed from the engine.

To Remove the Compressor

1. Disconnect the air pipes at the compressor cylinder head, governor valve and reservoir.
2. Remove the drive belt, the compressor pulley retaining nut and lockwasher. Using a two legged puller remove the pulley from the shaft. Then remove the woodruff key and the seal housing and seal assembly.
3. Remove the bolts retaining the compressor to the front cover housing and withdraw the compressor.

Crankshaft, crankcase Bearings and Cover Bearing Inspection and Renewal as Required

1. With the compressor removed from the engine remove the cylinder head and cylinder as described in 'Reconditioning the cylinder head' and 'Renewing the cylinder and piston rings'.
2. Mark the end cover and crankshaft in relation to the crankcase and note the way any locking straps are fitted. Remove the end cover.
3. Remove the sump plate and mark the big end bearing cap in relation to the connecting rod and then dismantle, removing the big end shell bearings.

NOTE: It is recommended that new shell bearings should always be fitted on reassembly.

4. Remove the smaller of the bearing retaining circlips from the drive end of the crankshaft and withdraw the crankshaft.
5. Remove the remaining larger bearing retaining circlip from the crankcase and extract the bearing race.
6. Thoroughly clean all parts, particularly oilways and check all threads for damage.
7. Test the running smoothness of the bearing race and renew if faulty.
8. Examine the crankshaft journals for scores or excessive wear. If badly scored or oval more than 0,381 mm (0,0015 in) nominal the crankshaft should be renewed.
9. Check that the plain bearings in the crankcase and end cover are a neat sliding fit on the crankshaft with no signs of

escape of air during the compressor stroke.

Excessive leakage will indicate a faulty inlet valve spring, inlet valve or seat. Replace the inlet connection after test. If the oil carry-over and the air leakage tests prove to be negative, remove the cylinder head as described under 'Reconditioning the cylinder head' and connect a separate air line at 6,9 bar (100 lbf/in² or 7 kgf/cm²) to the delivery port. An excessive amount of excaping air indicates defective delivery valve, valve spring or seat. If the compressor does not compress air at all see if the unloader plunger is stuck down and holding the inlet valve off its seat.

OVERHAUL

The following repairs, detailed under 'Reconditioning the cylinder head' and 'Renewing the cylinder and piston rings' are intended to be carried out without removing the compressor from the engine, obviating unnecessary dismantling.

Reconditioning the Cylinder Head

1. Disconnect the air pipes at the compressor, cylinder head, governor valve and reservoir.
2. Mark the cylinder head in relation to the cylinder. Remove the cylinder head nuts and, holding the cylinder hard down to avoid spoiling the crankcase seal, tap the cylinder head to break the joint.
3. Remove the set screws and separate the two halves. The valves and springs are now accessible.
4. Remove the old gasket and scrape off all particles of carbon from the affected areas including the piston crown, if necessary.
5. Inspect the head for cracks and damaged threads and reface the valve seats if they show signs of pitting. Ensure that the seating reamer cuts parallel to the machined surfaces of the baseplate or cylinder head.
6. Check the fit of the unloader plunger in the bush as any sloppiness may cause sticking.

It is assumed that during the reassembly new valves and springs will be fitted and that new seals, plugs and gaskets will be used where applicable.

7. Position the gasket on the baseplate and screw the springs into their tapered recesses in the baseplate and cylinder head.
8. Place the delivery valve in its recess in the baseplate and balance the inlet valve on its spring.
9. Insert a dowel of suitable length down the unloader plunger bore in the cylinder head and press the inlet valve into its cavity in the baseplate to avoid trapping the valve disc.
10. Line up the holes for the setscrews and exert pressure to depress the delivery valve spring and screw in the setscrews.
11. Smear the sliding surfaces of the unloader plunger and bush with 'Dow-Corning M.S. 200' fluid. Fit the circlips, sealing ring and spring on the plunger and slide the plunger into the bush.
12. Fit the sealing washer on the unloader cap and screw in the cap.

NOTE: The cap should not be tightened to its full torque with the head held solely by the cylinder head to crank-

Fig. 2

1. Nut
2. Washer
3. Stud
4. Cap
5. Washer
6. Circlip
7. Spring
8. Unloader Plunger
9. Sealing Ring
10. Cylinder Head
11. Gasket
12. Valve Disc
13. Valve Spring
14. Baseplate
15. Compression Ring
16. Piston
17. Gudgeon Pin
18. Circlip
19. Oil Scraper Ring
20. Bush
21. Connecting Rod and Cap
22. Big-end Bearing
23. Sealing Ring
24. Cylinder Liners
25. Sealing Ring
26. Crankcase
27. Locking Tab
28. Big-end Bolt
29. Gasket
30. Sump Plate
31. Washer
32. Setscrew
33. Bush
34. Bearing Pin
35. Bearing Assy.
36. Circlip
37. Circlip
38. Crankshaft
39. Bush
40. Gasket
41. Cover
42. Screw
43. Stud
44. Washer
45. Nut
46. Screw

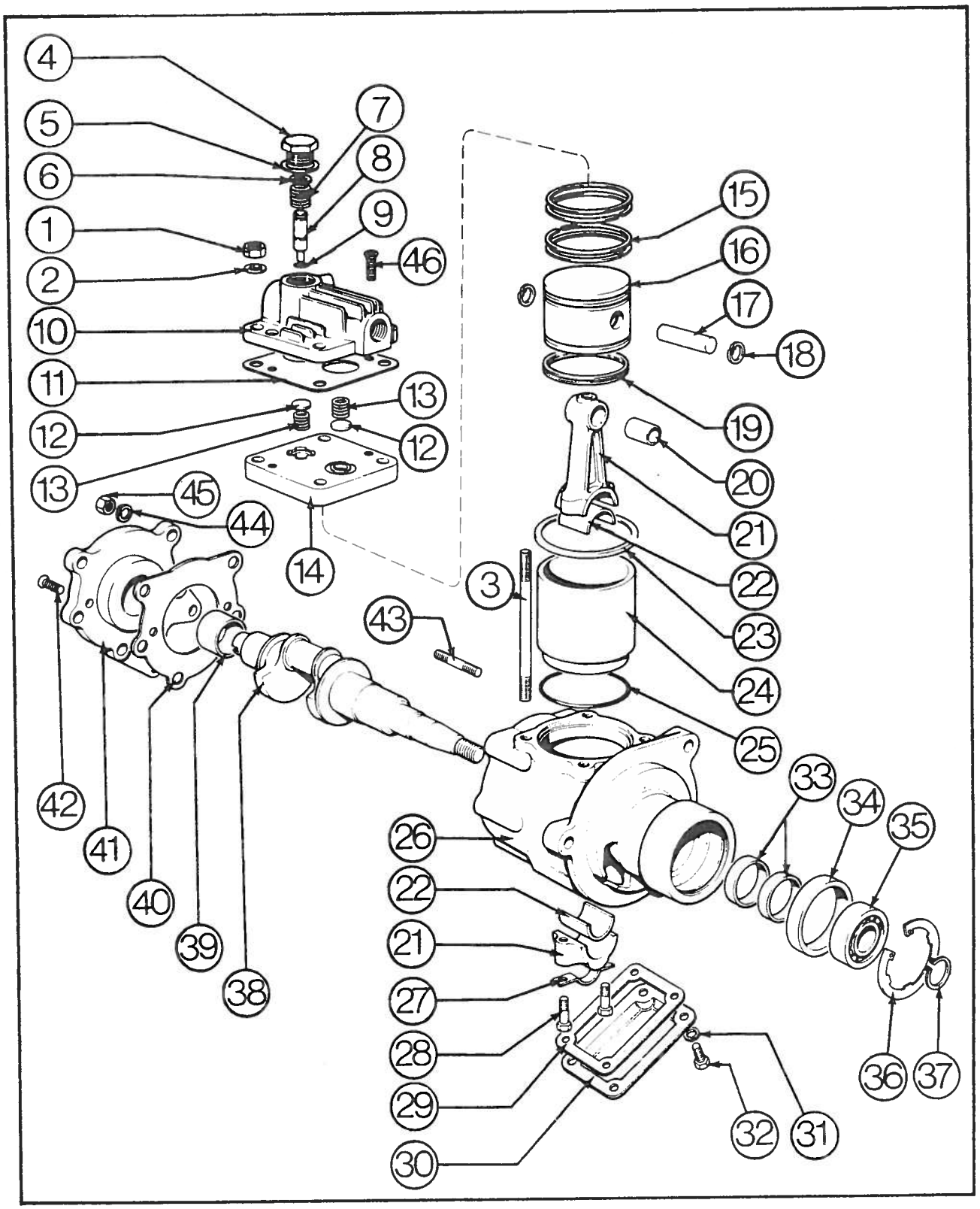


Fig. 2 The Compressor

THE EXHAUSTER

GENERAL

The exhauster is fitted to the rear of the front cover housing on the lower right hand side of the cylinder block and is retained by a stud and two bolts. It is belt driven by the crankshaft at engine speed. Oil is pressure fed to the exhauster from the engine lubricating system via an oilway in the front cover. The oil passes through the motorshaft to the bearings, blades and housing. It is then pumped back with the air from the exhauster into the timing case and returned to the sump.

Before dismantling the exhauster, a suitable repair kit should be obtained.

TO DISMANTLE THE EXHAUSTER – FIG. 1

1. Extract the circlips and remove the roller bearing, seal and spacer.
2. Unscrew the four end plate retaining bolts and remove the end plate.
3. Withdraw the shaft blades.
4. Check the shaft journals and housing for wear or damage. If either of these conditions is evident, the complete pump must be replaced.

TO REASSEMBLE THE EXHAUSTER

1. Ensure that all components are clean, including the oilways through the rotor shaft.
2. Fit the shaft and blades to the housing and then fit the spacer, seal (with the cup facing outwards) and bearing. Secure with the circlips.
3. Fit the rear cover gasket and with a straight edge placed across the housing, check the clearance between the straight edge and the rotor blades. This should be 0,102 mm minimum to 0,230 mm maximum (0,04 to 0,08 in).
4. Remove the rear cover gasket and coat both sides evenly with a proprietary sealing compound.
5. Refit the rear cover gaskets, locate the dowel in the exhauster body and replace the rear cover, bolts and washers.

THE AIR COMPRESSOR

GENERAL

The air compressor (Fig. 2) is a single cylinder air cooled unit. It is mounted beneath the fuel injection pump and is bolted to the rear of the front cover housing. The compressor is belt driven from the crankshaft pulley at engine speed. Oil is fed from the engine lubricating system via oilways in the front cover. It then passes through drillings in the compressor crankshaft to the connecting rod bearing bushes. The piston and bore are splash lubricated by oil thrown off the crankshaft. The oil drains back to the sump via. the front cover.

The compression crankshaft runs in steel backed white metal bearing bushes. Its detachable cylinder head contains the inlet and delivery valve assemblies. The valves and springs are held between the machined surfaces of the cylinder head the baseplate.

OPERATION

During the downstroke of the piston, a partial vacuum is created above the piston which unseats the inlet valve allowing air to enter the cylinder above the piston. On the upstroke, the air pressure under the valve, plus the effort of the inlet valve spring, closes the inlet valve and then opens the delivery valve discharging the air. At the start of the downstroke the delivery valve reseats and the cycle is repeated.

OPERATING TEST

Failure of the compressor to maintain adequate air in the system, or to change the system in a reasonable time, usually denotes loss of efficiency due to wear. This wear could be in the cylinder head (valves, valve springs and seats) or cylinder (piston assemblies).

To determine which part of the compressor is malfunctioning, release the air from the system and remove the delivery part fitting. Run the compressor for a short time to clear any collected oil and then hold a sheet of white card 50 mm (2 in) from the delivery port for 10 seconds.

The formation of a large patch of oil will indicate wear in the cylinder bore on piston assembly. A light mist of oil should be apparent, indicating correct lubrication is taking place. After carrying out the above test, check the cylinder head serviceability by reconnecting the delivery line and changing the system to governor valve cut-out pressure, or failing this, to the maximum pressure the compressor will attain. Slow the engine down to idling speed and remove the inlet port fitting. Feel, by means of a hand held close to the inlet port, for any

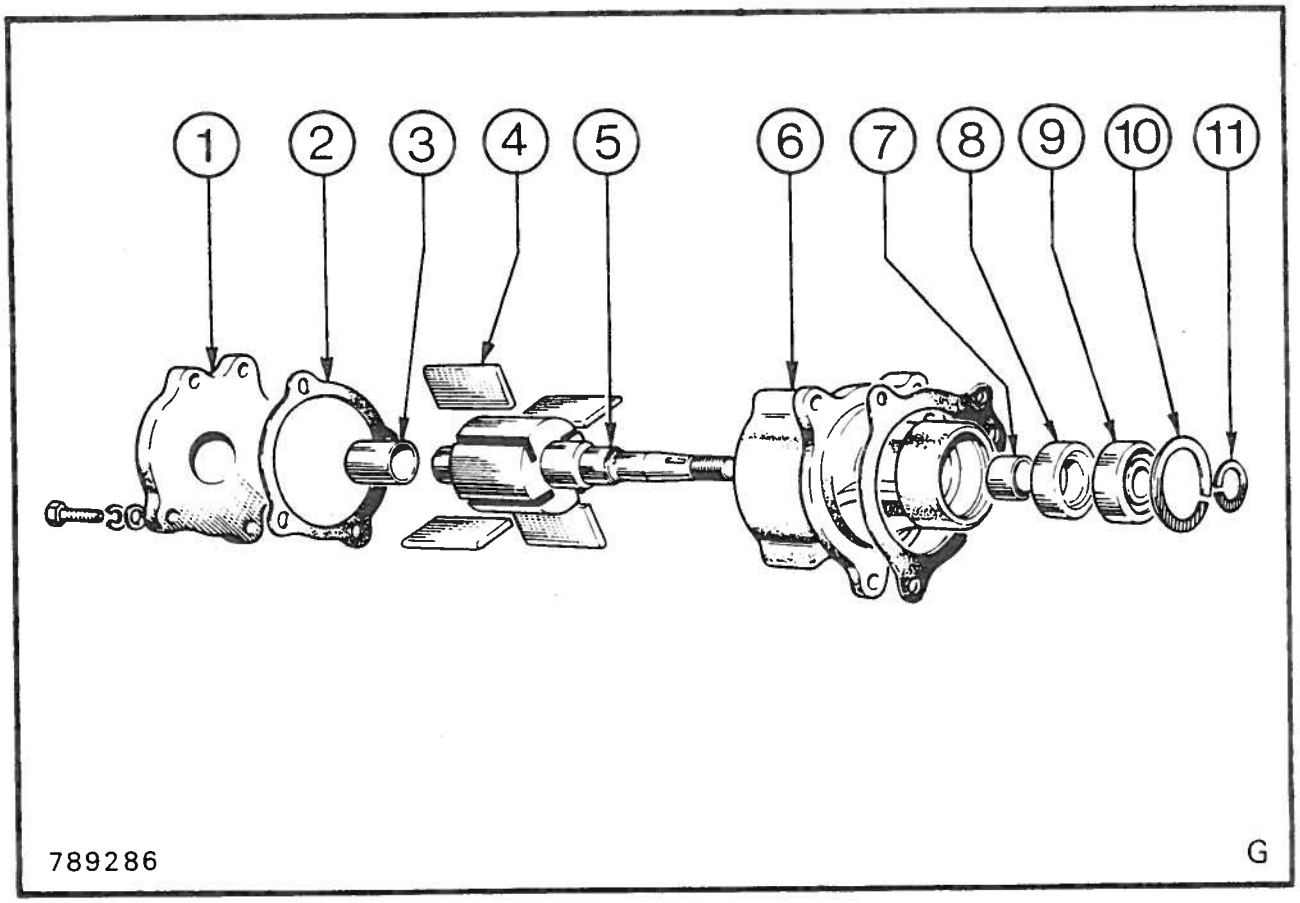


Fig. 1 The Exhauster

1. End Plate
2.* Gasket
3. Bearing
4.* Rotor Blade
5. Rotor Shaft
6. Rotor Housing
7. Spacer
3.* Seal
9. Bearing
10. Circlip
11. Circlip

* Parts marked * thus part of kit 2K362. Refer to Parts List.

SECTION 5

ADDITIONAL EQUIPMENT

CONTENTS

7. Fit the through bolts in their insulating sleeves and tighten them down. Check the armature end float. It will be necessary to fit the outer shim and horse shoe clip to the armature shaft to carry out this check. The axial movement of the armature should not exceed 0,1 to 0,3 mm (0,004 to 0,012 in).

8. Insert all the brushes in their holders using a suitable wire hook. The brush spring pressure should be 9,8 to 12,9 N (2,2 to 2,9 lbf or 1 to 1,3 kgf).

9. Remove the through bolts to allow the commutator end cover to be fitted. The cover locks the horseshoe clip and shims in place.

10. Make a wire hook as shown in Fig. 96 to hold the drive engagement lever bush whilst the solenoid plunger is pushed in and over the engagement lever Fig. 97.

    Withdraw the hook, fit the solenoid body and secure it with the three screws. Attach the flexible yoke terminal lead to the solenoid main terminal.

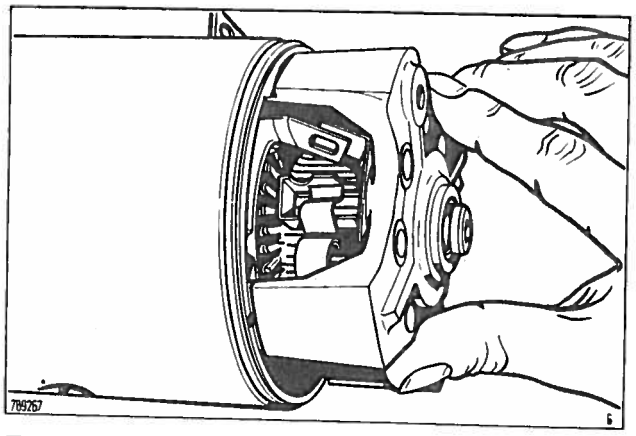


Fig. 95 Fitment of commutator end plate

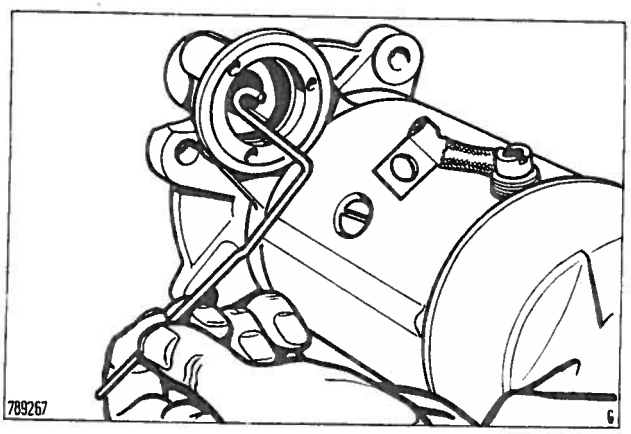


Fig. 96 Wire hook

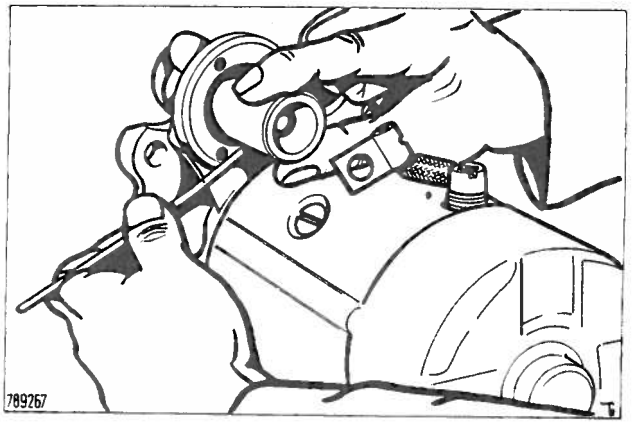


Fig. 97 Holding drive engagement lever bush with wire hook

TECHNICAL DATA

Type (Bosch 3.3ps)	Self indexing
Number of teeth on Pinion	12
Number of brushes	4
Minimum length of brushes	15,5 mm (0,06 in)
Brush spring pressure	9,8 to 12,9 N (2,2 to 2,9 lbf or 1 to 1,3 kgf)
Armature end float	0,1 to 0,3 mm (0,004 to 0,012 in)

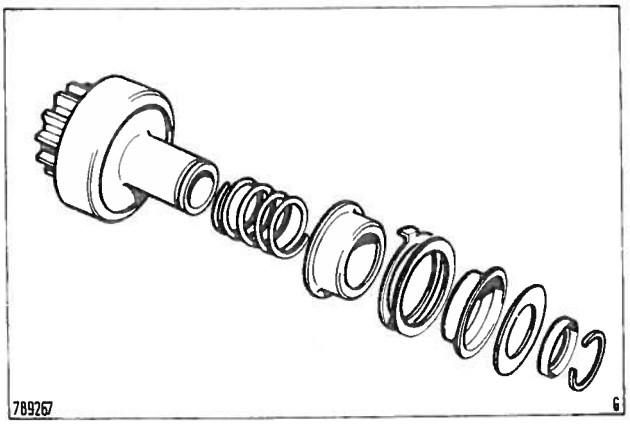


Fig. 89 Clutch and pinion assembly

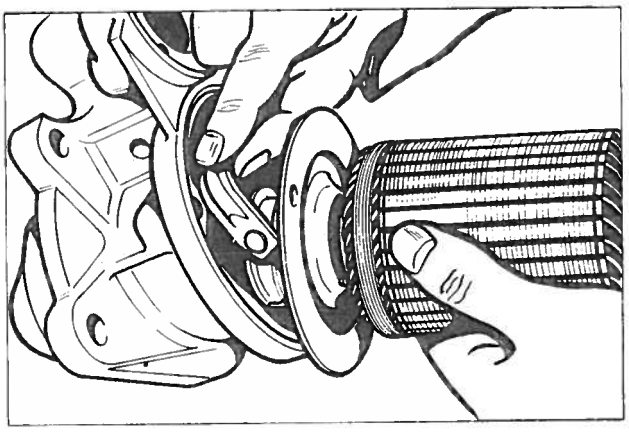


Fig. 92 Insertion of drive engagement lever

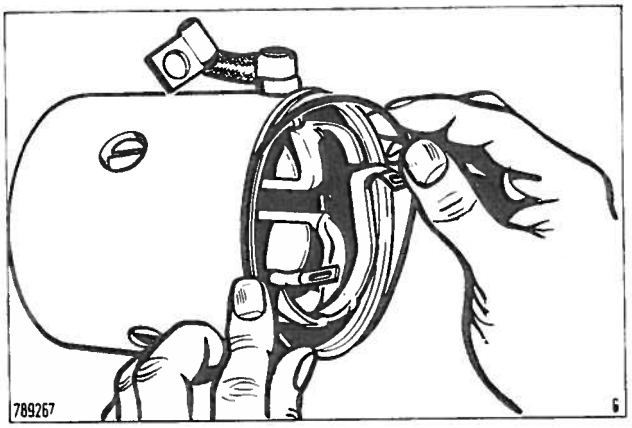


Fig. 90 Replacing rubber seals

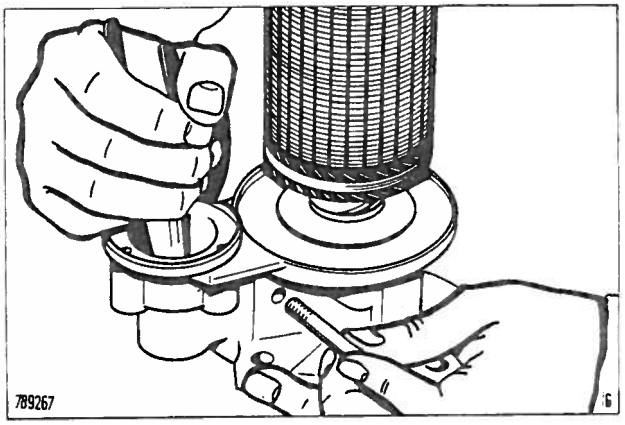


Fig. 93 Fitment of drive engagement lever pivot pin

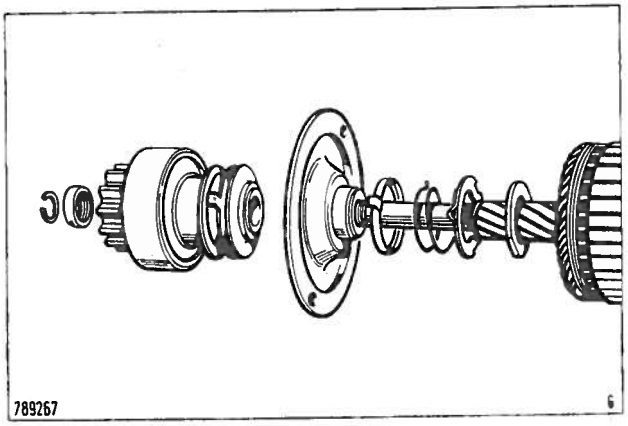


Fig. 91 Fitment of brake fibre washer, spring assembly and intermediate plate

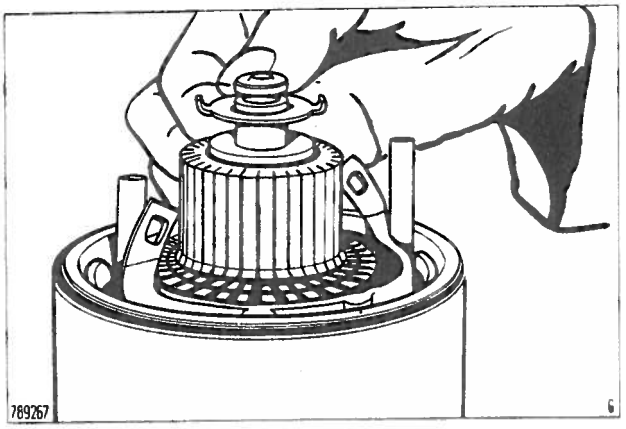


Fig. 94 Fitment of fibre and tabbed thrust washers

shouldered spacer, the fibre washer, tab washer (tab towards the clutch) the thick cup shaped spacer and spring.

Reverse the procedure for reassembly Fig. 89.

Examine the solenoid plunger/drive engagement lever link and replace any worn or damaged parts.

Under normal operating conditions the solenoid will operate satisfactorily for the life of the starter motor. Therefore apart from the engagement lever links, the solenoid is serviced as an assembly.

To ensure proper sealing of the starter motor, replace all rubber seals and coat all joints with a sealing component Fig. 90.

Reassembly

1. Fit the brake fibre washer to the armature, followed by the spring assembly and intermediate plate Fig. 91.

   Coat the rubber seal with sealing compound and insert it under the intermediate bearing plate.

2. Fit the drive pinion assembly on to the armature shaft, followed by the jump ring collar and a new jump ring.

   Using a suitable puller, carefully pull the jump ring collar over the jump ring until it locks in place.

3. Slide the drive end plate over the pinion and insert the drive engagement lever Fig. 92, ensuring that the studs on the engagement lever enter the channel between the metal washer and the thick cup on the pinion assembly.

   Fit the drive engagement lever pivot pin Fig. 93.

4. Fit the yoke ensuring that the locating pip coincides with the drive end plate and intermediate bearing plate.

5. Fit the through bolts together with the insulating tubes. Fit the fibre and tabbed thrust washers respectively onto the commutator end of the armature shaft. The tabs should face away from the commutator Fig. 94.

6. Fit the commutator end plate complete with a new pair of earthed brushes Fig. 95, making sure that the end plate location groove aligns with the yoke pip. Ensure that the field coil terminals line up with the insulated brush screw holes. Fit the new insulated brushes.

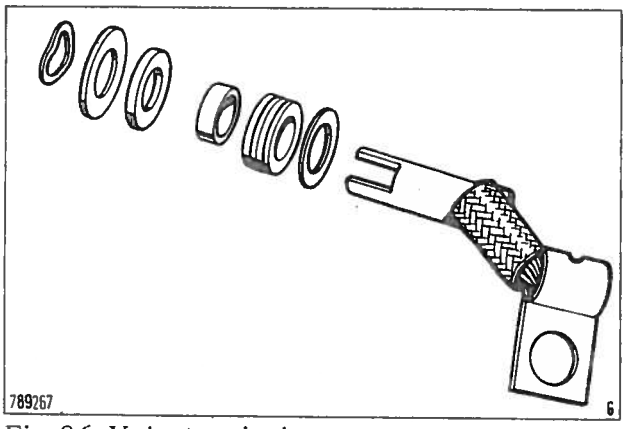


Fig. 86 Yoke terminal

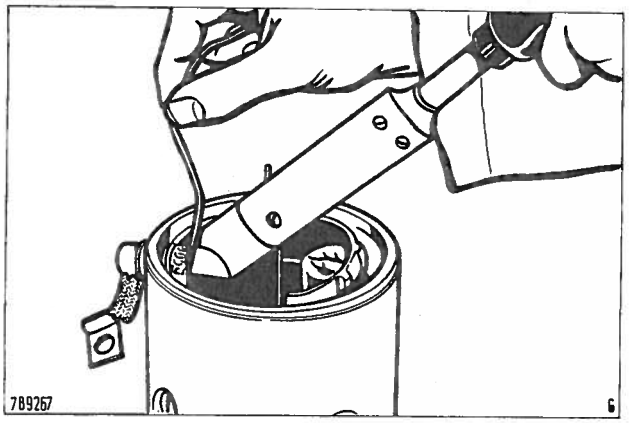


Fig. 87 Soldering new field coil connection between terminal forks

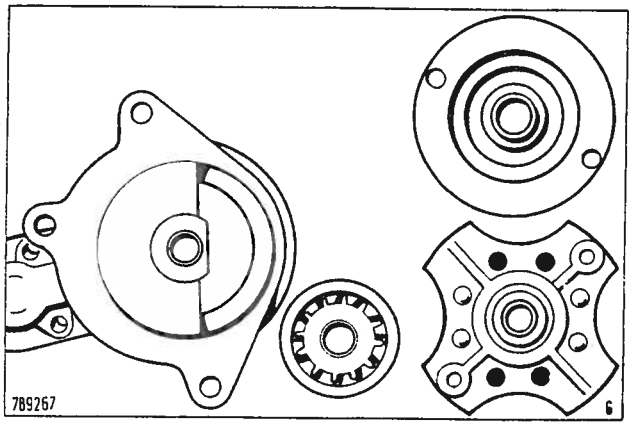
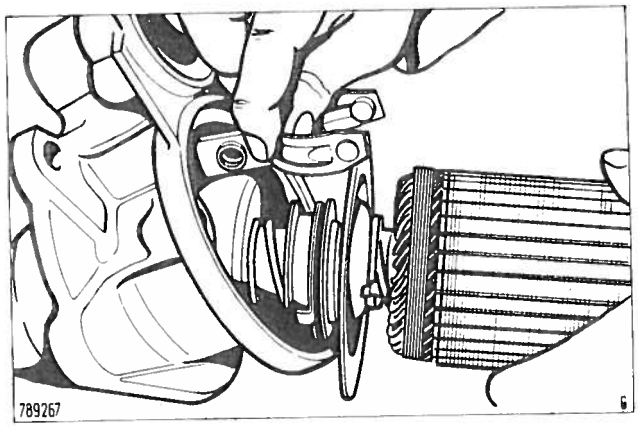


Fig. 88 Self lubricating bushes



83. Removing engagement lever

Fig. 84 Removing jump ring

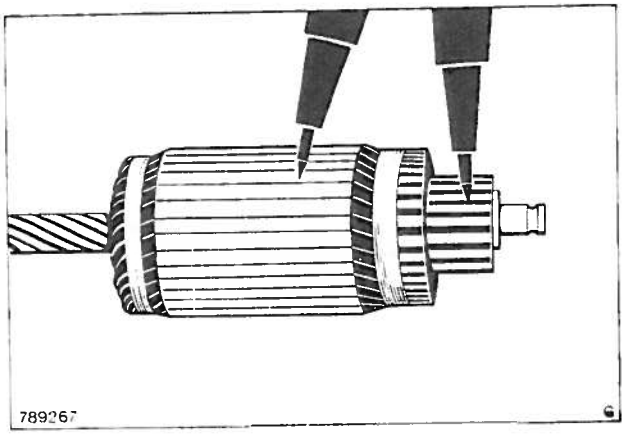


Fig. 85 Testing armature insulation

instantaneous take up in the other direction. If any fault is evident it will be necessary to replace the clutch and pinion as an assembly.

The field coils are serviced as an assembly. To renew them, unsolder and remove the yoke terminal taking note of its position in the yoke and the location of insulating and metal washers Fig. 86.

To remove the field coils, mount the yoke and pole piece screwdriver in a vice, the pole piece screws can then be slackened off and finally removed.

Remove the pole piece expander and withdraw the field coil assembly from the yoke. Fit the new coils, complete with new insulating cards between the coils and yoke. Take care that the insulator with the hole for the yoke terminal is correctly positioned to align with the hole in the yoke.

Refit the yoke terminal, noting that the washers are fitted as follows:-

Inside the yoke hole fit the fibre ring. Fit one large flat metal washer and four insulating washers to the terminal and insert it into the yoke.

Inside the yoke fit the small and the large insulating washers respectively, followed by a small thin metal washer.

Finally solder the new field coil connections between the terminal forks Fig. 87. Insert the pole piece expander and tighten the pole piece screws.

The brushes must move freely in their guides. Renew damaged or annealed brush springs. Set in correctly. The brush spring pressure should be 9,8 to 12,9 N (2,2 to 2,9 lbf or 1 to 1,3 kgf).

There are four self lubricating bushes in the starter motor. One in each of the following positions, the pinion/clutch assembly, the brush holder assembly, the drive end plate assembly and the intermediate plate assembly Fig. 88.

All bushes are pressed into position and can be renewed, using the conventional press techniques.

Before fitting new bushes, soak them in engine oil for at least 24 hours (at room temperature) or 2 hours at 100°C (212°F). Allow the oil to cool before removing the bushes.

To dismantle the brake on the clutch and pinion assembly, compress the spring and remove the jump ring. The whole assembly can now be released by decompressing the spring. Remove the jump ring cup, the thick flat washer, the thin

THE BOSCH 3.3PS STARTER MOTOR

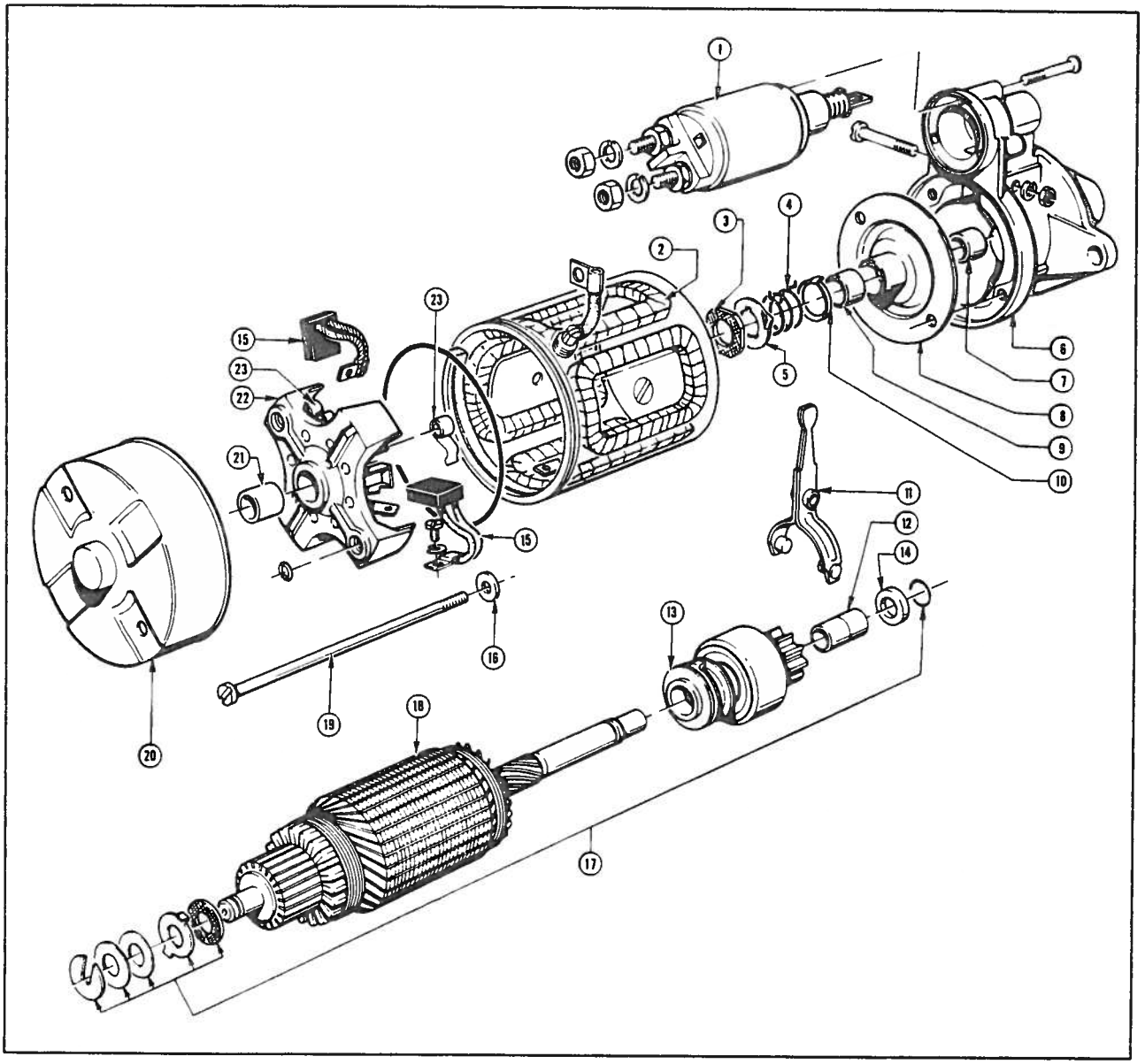


Fig. 76 – The Bosch Starter Motor Exploded

1. Solenoid Assy.
2. Coil Assy.
3. Insulating washer
4. Stop Spring
5. Stop
6. Cover Assy. Front
7. End Cover Brush Front
8. Intermediate Bearing
9. End Cover Bush
10. Stop Spring Retainer
11. Actuating Lever
12. Armature Shaft Seal
13. Drive Assy.
14. Seal
15. Brushes
16. Gasket
17. Armature Kit
18. Armature Assy.
19. Through Bolt
20. Cover Assy. -- Rear
21. End Cover Brush -- Rear
22. Brush Holder
23. Brush Springs

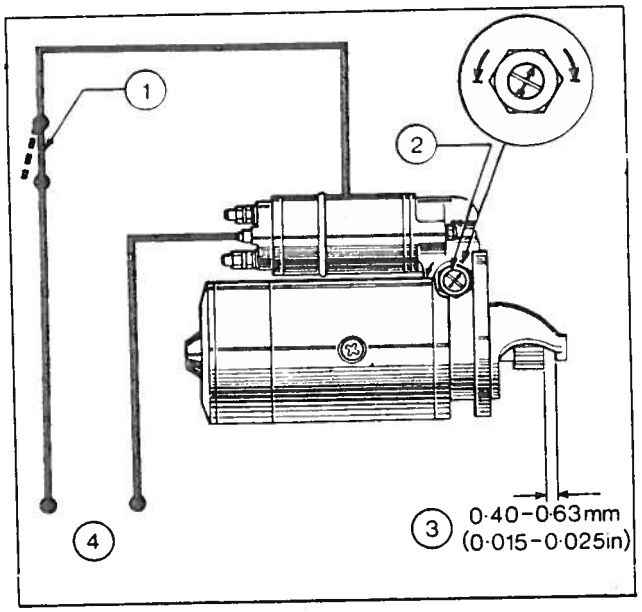


Fig. 75 Setting the Pinion Movement

1. Switch
2. Eccentric Pivot Pin
3. Dimension when the Solenoid is Energised
4. To 6 volt Test supply

To check or carry out the adjustment, connect a 6 volt supply between the solenoid 'Lucar' terminal and the starter frame (Fig. 75). (This will move the drive forward to the fully engaged position.) With the pinion pressed lightly back, measure the space between the front pinion and the thrust collar on the armature shaft. This should be 0,40 to 0,63 mm (0,015 to 0,025 in).

NOTE: On marine starters, connect the 6V supply between the solenoid positive and negative 'Lucar' blade terminals.

TECHNICAL DATA

Type (Lucas M50)	Self Indexing
Gear Ratio	12:1
Number of teeth on Pinion	10
Number of brushes	4
Lock Torque	46,1 Nm (34 lbf ft or 4,7 kgf m) with 980 ampere at 5,0 terminal volts (max.)
Torque at 1000 rpm	21,7 Nm (16 lbf ft or 2,2 kgf m) with 590 ampere at 7,5 terminal volts, (max.)

NOTE: All amperage figures are inclusive of the solenoid hold-on coil current.

Solenoid–Closing coil resistance, measured between terminal 'S2' and 'push-on' terminal 0,13 to 0,15 ohm. Hold on coil resistance, measured between 'push-on' terminal and the solenoid outer case 0,63 to 0,73 ohm.

Tightening Torques

Through Bolts	10,8 Nm (8 lbf ft or 1,1 kgf m)
Brushgear Securing Screws in Commutator End Cover	3,4 Nm (2,5 lbf ft or 0,35 kgf m)
Solenoid Unit Fixing Stud Nuts	6,1 Nm (4,5 lbf ft or 0,6 kgf m)
Solenoid Upper Terminal Nuts S1 and S2	3,4 Nm (2,5 lbf ft or 0,35 kgf m)
Solenoid Main Battery Connection Terminal Nut	4,1 Nm (3,0 lbf ft or 0,4 kgf m)
Starter Earthing Stud Nut in Commutator	8,1 Nm (6 lbf ft or 0,8 kgf m)
Marine Starter negative terminal nut	5 Nm (3,5 lbf ft or 0,45 kgf m)

Check the armature for short-circuit windings, using "GROWLER" equipment brush gear.

Brushes should move freely in the brushboxes. Sticking brushes should be cleaned with a petrol moistened cloth.

Brushes which are worn to approximately 8 mm (0,313 in) in length must be renewed. Service brushes are preformed and do not require "bedding" to the commutator.

Renewing the Field Coil Brushes

Place the yoke assembly on its end, with the brush and terminal arrangement uppermost, Fig. 72. Cut the worn brush flexible lead as near as possible to the field coil conductor. Carefully prise the brush flexible jointing part of the conductors away from the yolk, to provide sufficient space for soldering new brushes in position. Separate the ends of the two brush flexibles and position one each side of the conductor. Pinch the ends of the flexibles and conductor together with long nosed pliers and bend the brush and flexibles over the edge of the yoke to help hold the flexibles in position during soldering, Fig. 72. Solder the brush flexibles to the field coil conductor, using an iron of sufficient size to make a good quick joint without overheating the components. Repeat the operation for the second brush.

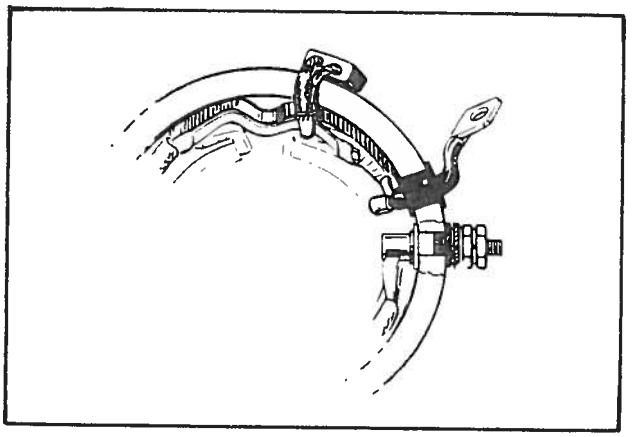


Fig. 72 Brush and terminal arrangement (field coils)

Renewing Earth Brushes on Standard Starter

Place a hot soldering iron on the roller over contact holding the brush flexible joint. When the solder is molten, using a small screwdriver, prise up the metal sufficiently to allow removal of the old brush lead. Insert the new brush lead and solder it in place.

Renewing Negative Brushes on Marine Starter

The negative terminal and brush assembly must be replaced as a complete unit.

Checking the Spring Pressure

Brush spring pressure should be checked with the whole of the brush gear loosely assembled to the commutator (i.e. all four brushes assembled in their working position). Hold the brush gear assembly firmly centralised on the commutator and apply a pull-type spring gauge to each spring in turn, Fig. 73. The reading should be 11,7 N (1,2 kgf or 42 ozf) when the spring just leaves the brush.

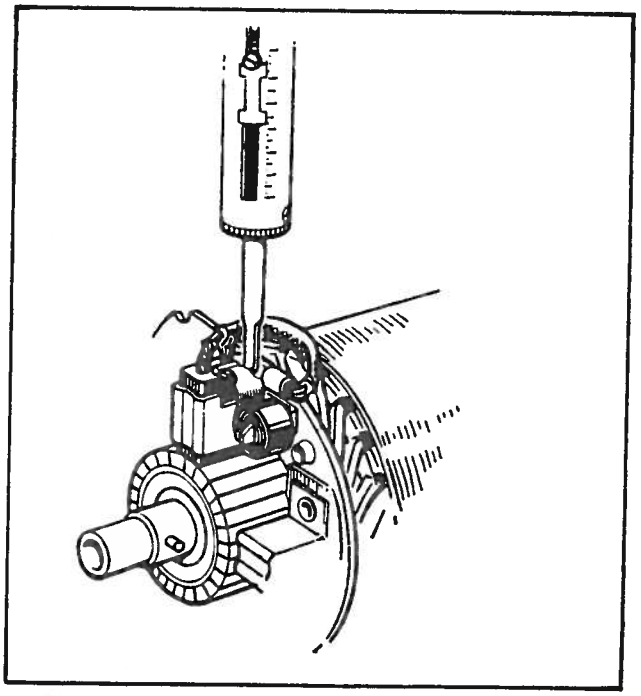


Fig. 73 Checking brush spring pressure

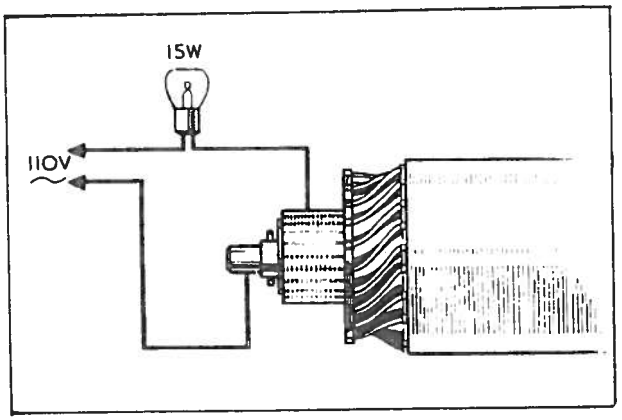


Fig. 71 Armature insulation test

8. Withdraw the yoke assembly from the armature and drive end bracket. Remove the sealing ring between the yoke and intermediate bracket.

9. Unscrew the eccentric pivot pin from the fixing bracket and remove the drive end fixing bracket drive engagement lever, armature complete with roller clutch drive and intermediate bracket.

NOTE: Separation of the fixing and intermediate bracket may cause two small sealing washers to become dislodged from a recess in the through bolt holes of the fixing bracket. Ensure these are retrieved.

10. Dismantle the armature assembly roller clutch and intermediate bracket using a tubular tool (e.g. box spanner). Remove the thrust collar from the armature shaft, ensuring that if any packing shims have been fitted these are retrieved.

Bench Inspection

The surface of the commutator should be clean and free from burnt spots. Clean the commutator with a petrol moistened cloth. If necessary, use very fine glass paper or emery cloth, prior to using the petrol moistened cloth.

The commutator may be skimmed to a minimum diameter of 38 mm (1,5 in) before a replacement armature becomes necessary. If the skimming operation has been carried out the commutator surface must be polished with very fine glass paper or emery cloth. The insulation slots must not be under cut.

If there are signs of thrown solder or the conductors have lifted from the commutator segments, the motor has probably been over speeding. Check the operation of the roller clutch drive.

If the armature fouls the pole shoes, it indicates worn bearings, loose pole shoes, or the armature shaft is distorted. Check the armature in a lathe, if it is out of true, renew. If the armature is satisfactory, renew the bearings in both end brackets.

Check armature insulation with a 110V ac 15W test lamp connected between one of the commutator segments and the armature shaft, Fig. 71.

If the lamp lights, the insulation is unsatisfactory.

OVERHAULING THE STARTER MOTOR

To Dismantle

1. Remove copper link which connects the solenoid terminal S2 to the yoke terminal.
2. Disconnect the flexible link connecting the solenoid terminal S1 to the first stage field coil inside the yoke.
3. Remove the solenoid securing nuts, washers and seals and withdraw the solenoid unit complete with gasket from the drive end fixing bracket. Also the small sealing washer from the solenoid fixing studs.

NOTE: The solenoid plunger will be left attached to the starter when the main part of the solenoid is withdrawn.

To remove the solenoid plunger, grip plunger by hand and lift up the front end of the plunger. Withdraw the plunger from the fork in which it pivots at the top of the drive engagement lever.

4. Remove the sealing grommet which is wedged between the fixing bracket and yoke. This is not fitted to marine versions.
5. Remove the through bolts complete with washers and sealing washers.
6. Remove the two screws from the outer face of the commutator end cover. (These screws secure the brush gear to the inner face of the end cover).

   On marine starter motors, remove the negative terminal nut, spring washer, plain washer and insulating washer.

   The commutator end cover assembly, comprising sealing ring, brake shoe assembly, steel thrust washer, fibre packing washer and bearing bush can now be removed, leaving the brush gear in position on the commutator.

   On marine starter motors, the negative terminal and insulating bush will also be left in position.

7. To remove the brushgear assembly, grip the commutator end of the armature shaft and pull the armature forward so as to fully expose commutator and brushgear. Using a wire hook or a small screwdriver, lever up the brush springs so that the brushes can be disengaged from their brushboxes. Remove the brushgear assembly.

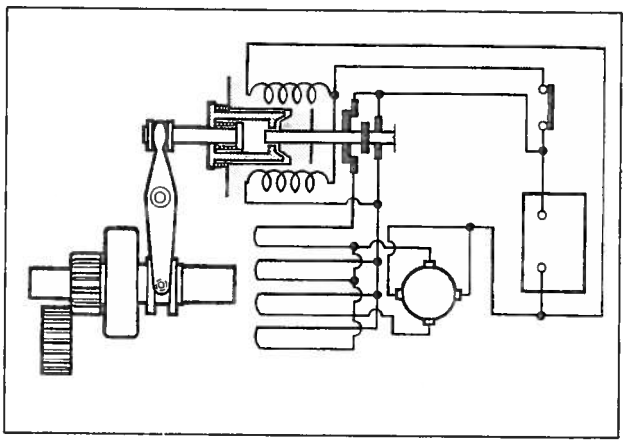


Fig. 70 Insulated return wiring system

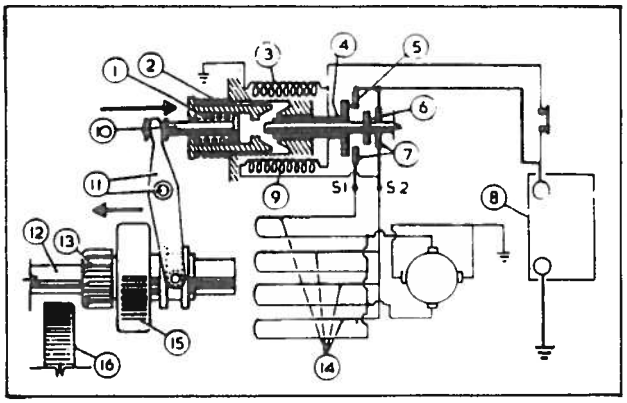


Fig. 67 – Explanation of two-stage switching

1. Engagement spring
2. Return spring
3. Solenoid hold-on winding
4. Switch operating spindles (concentric)
5. First Switch contacts
6. Second switch contacts
7. Fixed contacts
8. Battery
9. Solenoid operating winding
10. Plunger
11. Operating lever and pivot
12. Armature shaft
13. Pinion
14. Field system: Four field coils in parallel
15. Roller clutch
16. Gear ring

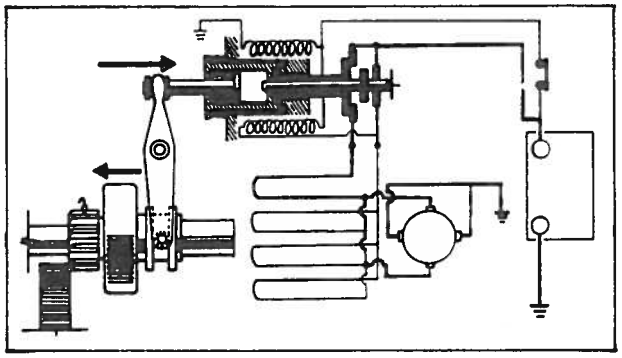


Fig. 68 Showing tooth to tooth abutment

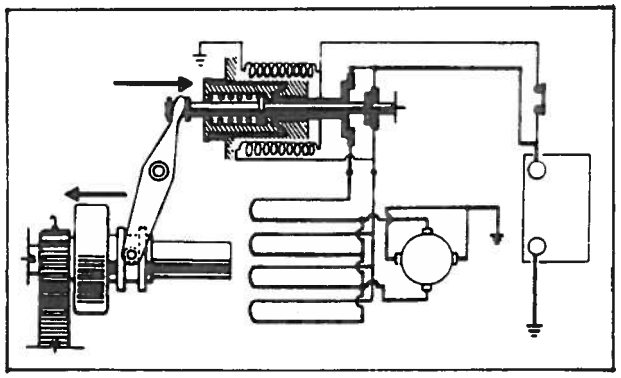


Fig. 69 Showing meshing position

when the tooth-to-tooth abutment occurs, the solenoid plunger continues to move by compressing a drive engagement spring inside the plunger. This plunger movement causes the first stage contacts to close, connecting one of the field coils to the battery. The starter armature now turns at low speed and the pressure of the drive engagement spring, combined with push screw assistance from the drive helix causes the pinion to move into mesh.

When the pinion is fully engaged, the solenoid second stage contacts close, and the remaining three field coils are connected to the battery. (Figs. 67, 68 & 69).

NOTE: The wiring shown in Figs. 67, 68 and 69 is for the standard earth return system. Fig. 70 shows the insulated return system wiring used on marine starter applications.

The solenoid is energised in the conventional manner to move the pinion towards the gear ring on the engine flywheel.

The roller clutch prevents the armature from rotating excessively if the drive remains in mesh with the flywheel after the engine has started.

The starter motor is oil and watertight (except from the bell housing) the seals are located as follows:–

1. Between the commutator end cover and yolk.
2. Between the intermediate bracket and yoke.
3. Between the solenoid and drive-end bracket.
4. At both ends of the through bolts, at the earthing stud, solenoid fixing studs and brush gear plate securing screws in the outer face of the commutator end cover see Fig. 66.

Routine Maintenance

No routine maintenance is necessary, the tightness of the electrical connections should however be checked periodically.

The starter motor should be dismantled for detailed inspection during major engine overhaul.

The commutator should also be examined and the bearing bushes renewed; refer to section on Bench Testing.

THE STARTING SYSTEM

INTRODUCTION

Two makes of starter motors are used on the 2400 range of engines. These are:

1. **The Lucas M50 Starter Motor**
2. **The Bosch 3.3PS Starter Motor**

NOTE: A marine version of the Lucas M50 starter motor is also used. This is similar to the standard machine but is suitable for insulated return wiring systems and has marine finished components for greater protection against corrosion. Lucas marine finished starter motors can be readily identified by the special white marine paint finish.

LUCAS M50 & M50 MARINE STARTER MOTORS

DESCRIPTION

Where differences between the two types exist, these will be pointed out in the following text.

The pre-engaged starter (Fig. 66) is a four pole four brush machine of 127 mm (5 in) diameter, having a solenoid operated, roller clutch drive. The solenoid incorporates two sets of contacts which provide two-stage switching. When the starter is operated the pinion moves into full engagement with the engine flywheel ring-gear and the first and second stage contacts of the solenoid close simultaneously, connecting all four field coils of the starter to the battery; full cranking torque then develops. On occasions

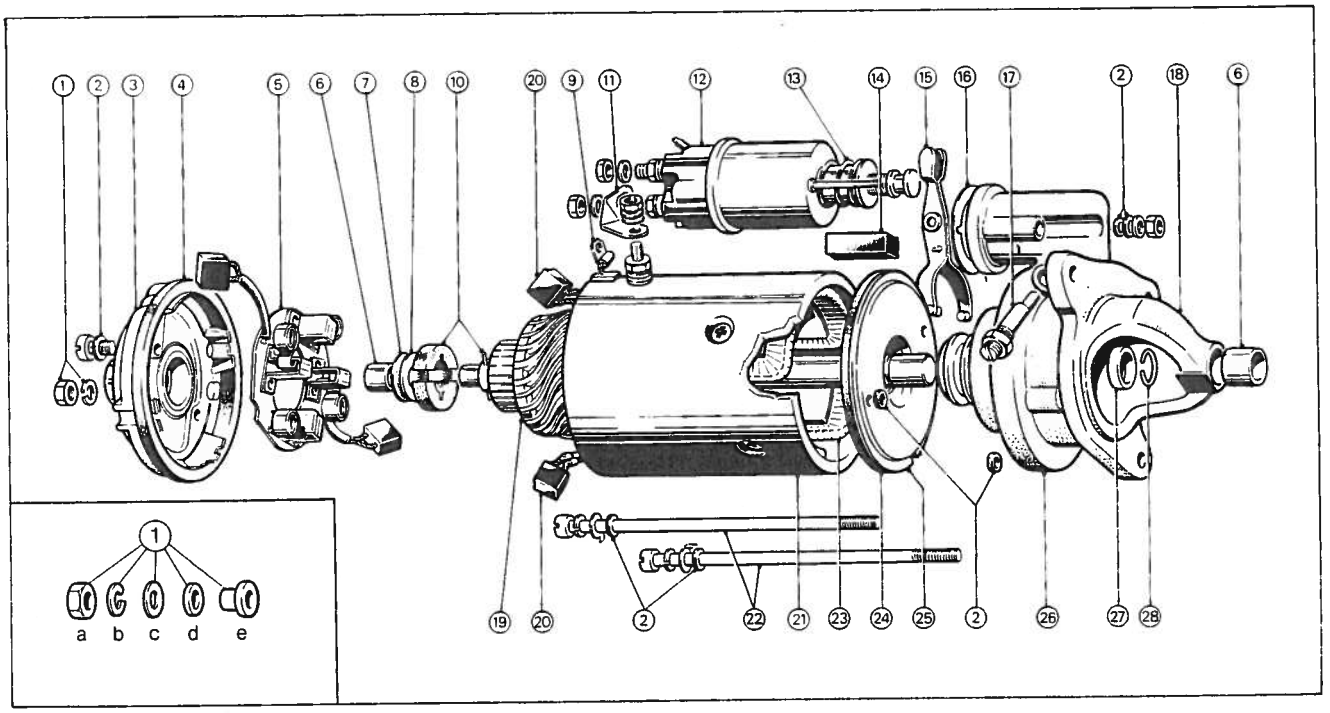


Fig. 66 Starter, dismantled. Inset shows different negative terminal components for marine version

1. Nut & spring washer (C/E cover earth stud)
2. Sealing washers
3. Commutator end cover
4. Sealing ring
5. Brushgear assembly comprising, earth brushes and springs } insulated negative brushes on marine version
6. Bearing bush
7. Fibre washer
8. Steel thrust washer
9. Flexible link
10. Brake shoes and cross peg
11. Copper link
12. Solenoid unit
13. Return spring
14. Sealing grommet (deleted on marine versions)
15. Engagement lever
16. Gasket
17. Eccentric pivot pin
18. Drive end fixing bracket
19. Armature
20. Insulated Brushes (field coils)
21. Yoke
22. Through bolts
23. Field coils
24. Sealing ring
25. Intermediate bracket
26. Drive assembly
27. Thrust collar
28. Jump ring

(a) nut
(b) spring washer
(c) plain washer
(d) insulated washer (outside cover)
(e) insulated bush (inside cover)

the stator connection lead must project over the edge of the negative diodes heat sink. Clamp the connection firmly ensuring that a minimum isolation distance of 3 mm (0,125 in) exists between the leads and the housing and also that the insulation sleeve protrudes at least 3 mm (0,125 in) over the soldered connections.

6. Rub a molycote type paste into the ball bearing seat of the slip-ring end frame and install the claw pole rotor with the drive end frame.

   Check the position of the stator relative to the end frame. Fit the brush holder plate.

7. Fit the fan belt pulley and tighten the retaining nut to 34 to 39,3 Nm (25 to 29 lbf ft or 3,5 to 4,0 kgf m).

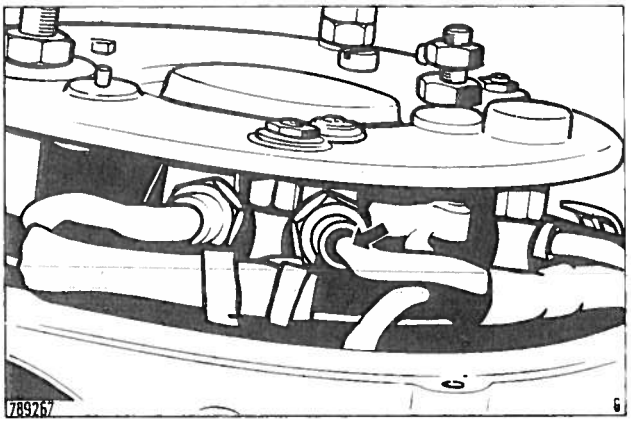


Fig. 65 Showing insulating sleeve fitted over exciter diode lead and stator connection cable

TECHNICAL DATA

Nominal dc output at 12 volt	35 ampere
Resistance of stator windings +10%	3,4 ohm
Resistance of exciter winding (rotor) +10%	4,0 ohm
Run-out of slip-rings	0,3 mm (0,001 in) max.
Run-out of rotor pole wheel (claw pole type)	0,05 mm (0,002 in) max.
Minimum length of carbon brush	14 mm (0,563 in)
Brush spring pressure	2,9 to 3,9 N (10,7 to 14,1 ozf)
Minimum diameter of slip rings	31,5 mm (1,25 in)
Assembly torques	
Pulley nut	34 to 39,3 Nm (25 to 29 lbf ft or 3,5 to 4,0 kgf m)
Exciter diodes	1,4 to 1,8 Nm (1,0 to 1,3 lbf ft or 0,1 go 0,2 kgf m)

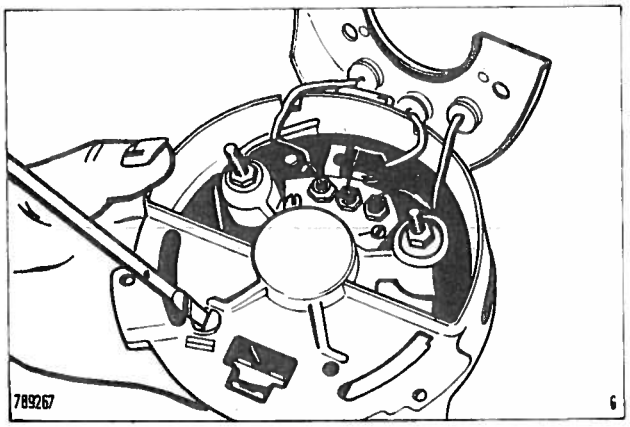


Fig. 57 Disconnecting conductor

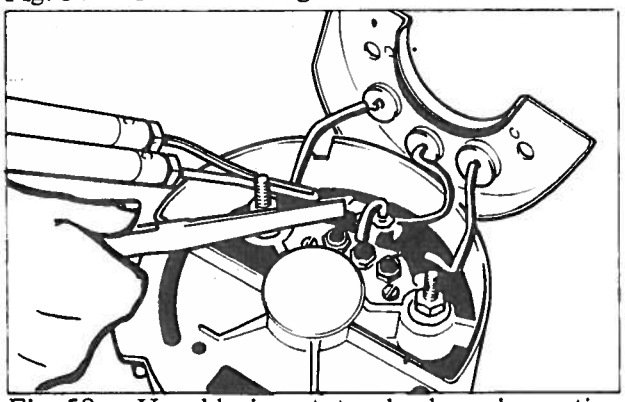


Fig. 58 Unsoldering stator leads and negative diode connections

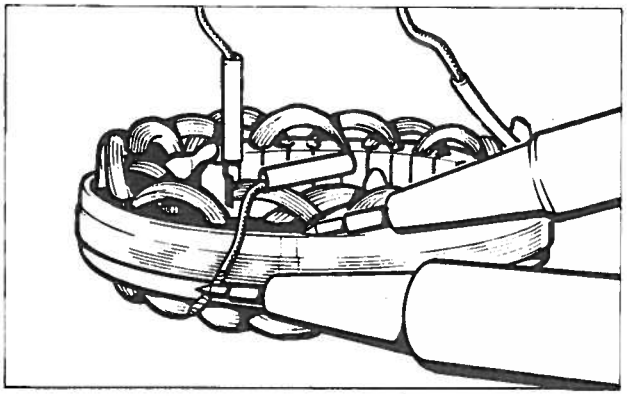


Fig. 59 Testing stator for short circuit

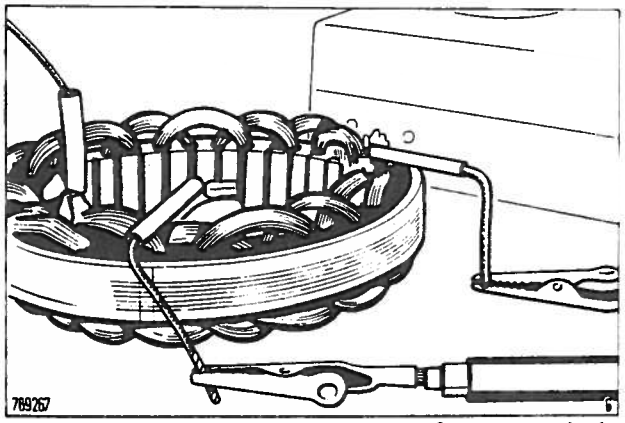


Fig. 60 Measuring resistance of stator windings between phase connections

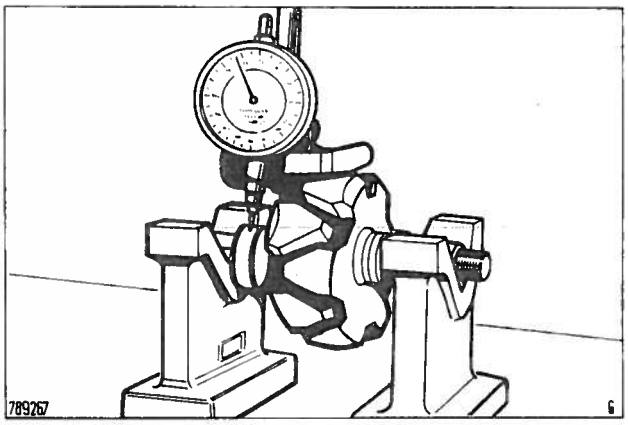


Fig. 61 Checking rotor run-out

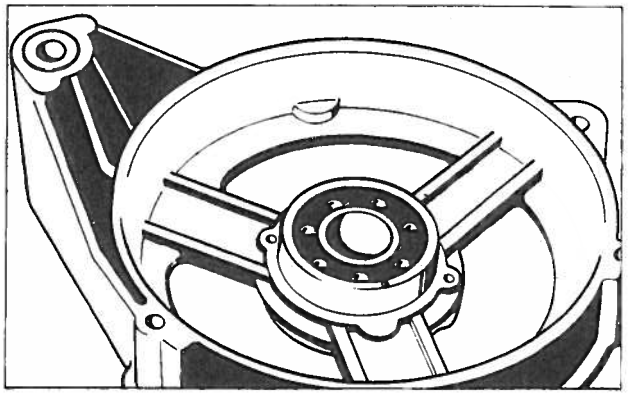


Fig. 62 Drive end frame bearing

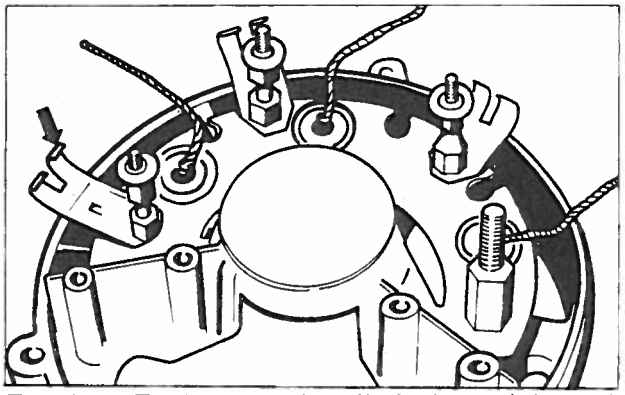


Fig. 63 Fitting negative diode heat sinks and clamps

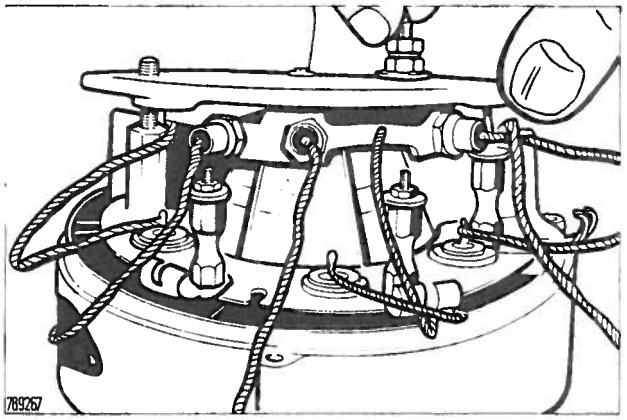


Fig. 64 Fitting positive diode heat sink

in the rotor with an ohmmeter, this should be 4,0 ohm + 10%.

14. Turn down the slip-ring on a lathe. After turning, check the concentricity of the slip-rings. Run-out should not exceed 0,03 mm (0,001 in). Minimum diameter of slip-rings 31,5 mm (1,25 in). Maximum run-out of the pole wheel 0,05 mm (0,002 in).

    To check the run-out, place the rotor in 'v' blocks Fig. 61.

15. To press out the output diodes, set the diode plate on a press die and force out the diode with a plunger. Before replacing the output diodes, first smear the seals with silicon oil, press in the diode up to the stop with the press plunger. Test diodes.

16. Check the bearings in the drive end frame Fig. 62. If necessary replace them. Press the drive end frame onto the rotor, ensuring that dirt does not enter the bearings. Press the ball bearing onto the slip-ring end of the rotor.

REASSEMBLING THE ALTERNATOR

1. Fit the negative diodes heat sink and clamps, ensuring the longer clamp is fitted on the left hand side of the housing. Screw in the double ended bolts, shorter thread facing outwards. Fit the insulating washers and bushings correctly Fig. 63.

2. Test the B+ terminal bolt for short circuit to earth. Test voltage 80V ac.

3. Fit the positive diodes heat sink securing it with the insulating and spring washers Fig. 64.

4. Fit the stator in the slip-ring end frame. Draw the positive and negative diode leads together and slip through an insulating sleeve. Push the insulating sleeve over the lead of the exciter diode and stator connection cable Fig. 65.

   Hold the cable leads temporarily together with adhesive tape, crimp with a metal ring and solder.

NOTE: Do not allow the solder to flow down the leads.

After soldering, cut off the protruding lead ends at the metal ring. Remove the adhesive tape and slide over the insulating sleeve. Bend the lead retaining clamps over.

5. Slide the insulating sleeve over the exciter diode terminal. The insulating sleeves of

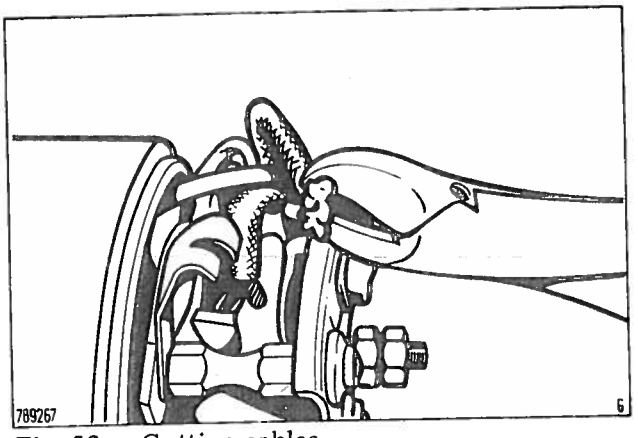


Fig. 53 Cutting cables

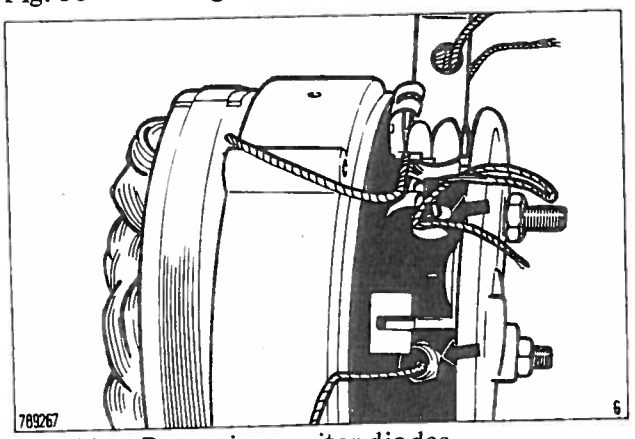


Fig. 54 Removing exciter diodes

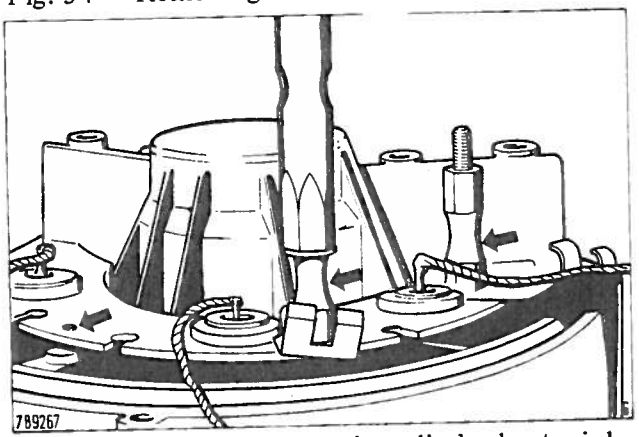


Fig. 55 Removing negative diode heat sink

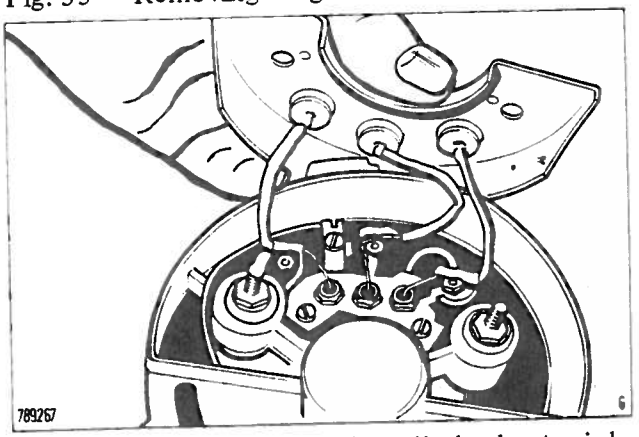


Fig. 56 Removing positive diode heat sink

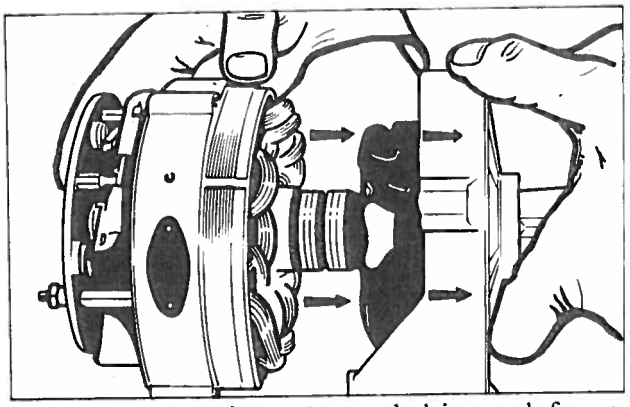


Fig. 49 Removing rotor and drive end frame assembly

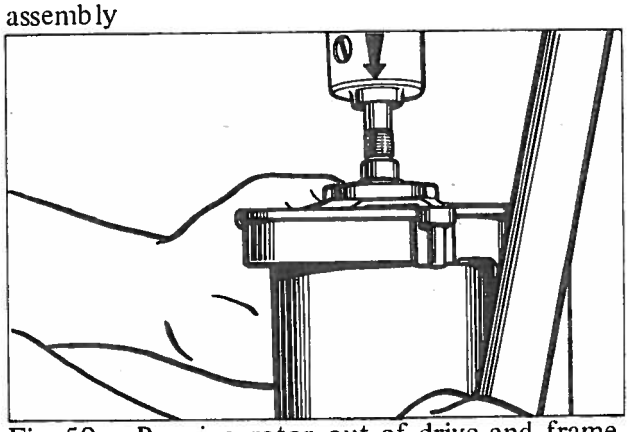


Fig. 50 Pressing rotor out of drive end frame assembly

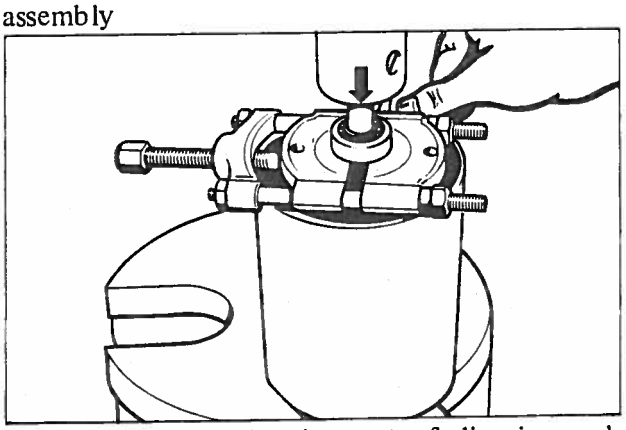


Fig. 51 Pressing bearing out of slip ring end

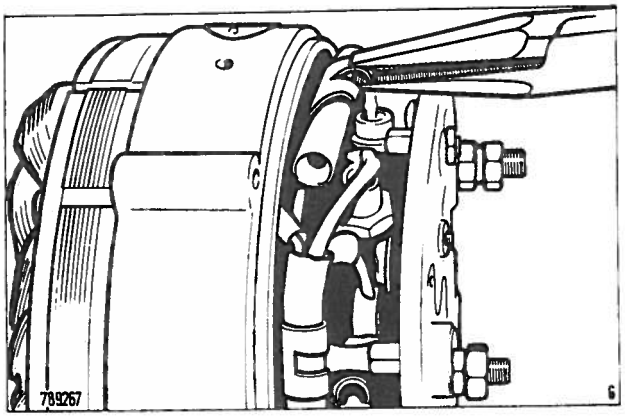


Fig. 52 Bending open lead clamps

5. Press the ball bearing out of the slip-ring end with the arbor press and an appropriate device Fig. 51.

NOTE: The ball bearing can also be pulled off with a claw extractor applied to the inner race. If the bearing is extracted by gripping the outer race damage will occur, necessitating bearing replacement.

6. Carefully bend open the clamps securing the positive and negative diode leads Fig. 52. Pull off the insulating sleeve and cut the cables as close as possible to the soldering joint Fig. 53.

NOTE: If only exciter diodes are defective, further dismantling is not necessary.

7. To remove the exciter diodes, screw out with socket wrench Fig. 54. If it is necessary to replace the output diodes, the slip-ring end frame must be dismantled further.

   When dismantling, take care not to lose or damage the insulating bushings under the positive diodes heat sink.

   To remove the negative diodes heat sink, unscrew the bolts with a socket wrench Fig. 55.

8. Unscrew the nuts on both B+ terminal bolts and lift the positive diodes' heat sink Fig. 56. Disconnect the conductor from D+ to the exciter diodes Fig. 57.

   Unscrew the spring and brush holder and remove the brush holder.

9. Unsolder the stator leads and negative diode connections Fig. 58 then unscrew the exciter diodes' heat sink and remove together with the positive diodes' heat sink.

10. Clean all individual parts of the alternator with clean petrol or trichlorethylene for a short period only.

11. Test the stator for short circuits to earth Fig. 59.
    Test voltage – 40V ac

    Measure the resistance of the stator windings between the phase connection Fig. 60. Refer to Technical Data resistance values.

12. Test the claw-pole rotor for short circuits to earth. Test voltage 40V ac

13. Measure the resistance of the exciter coil

BOSCH ALTERNATOR — 35 AMPERE

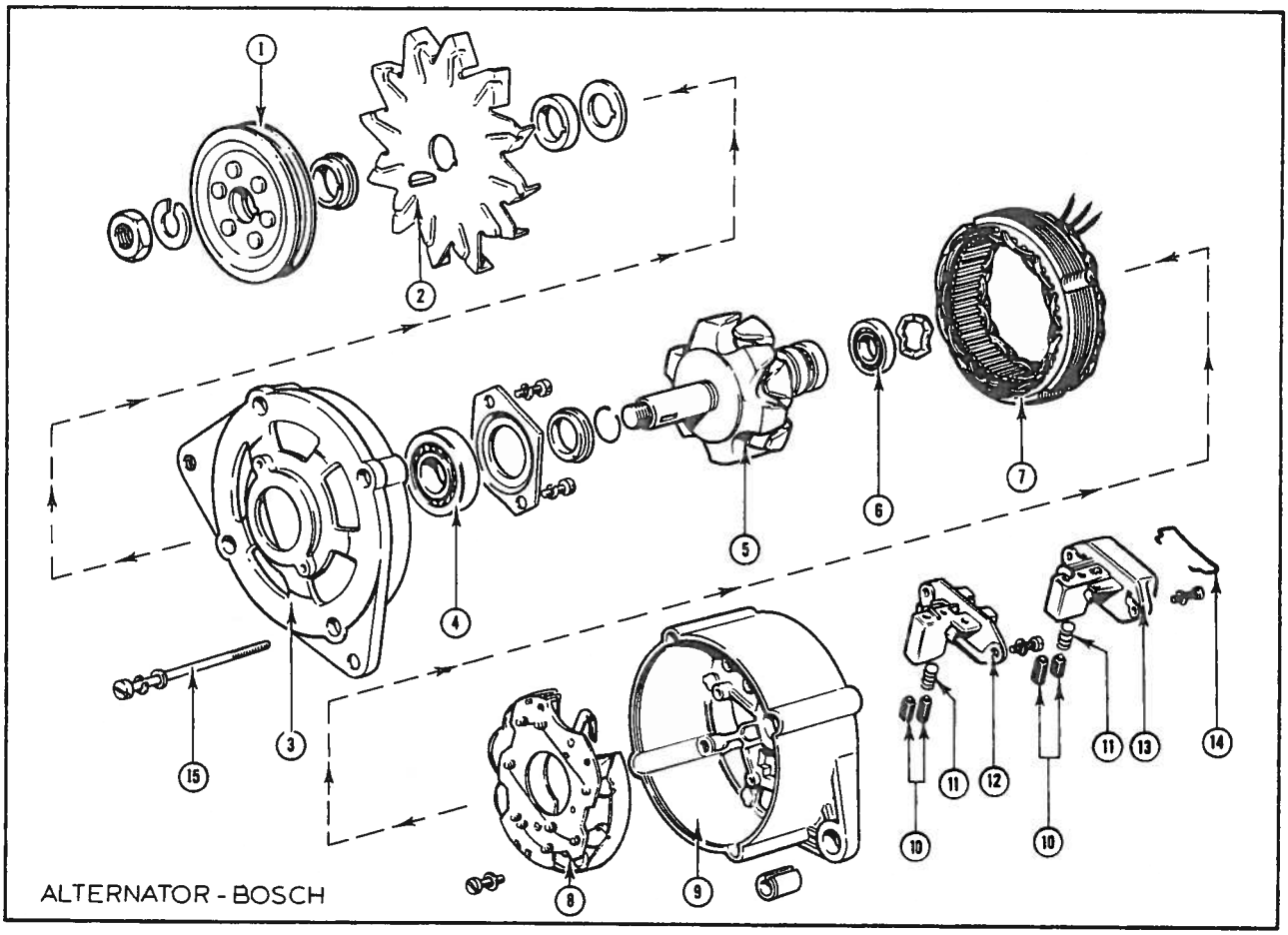


Fig. 47

1. Alternator Pulley
2. Fan
3. Drive End Plate
4. Bearing
5. Rotor Assy.
6. Bearing
7. Stator Assy.
8. Rectifier Assy.
9. Housing
10. Brushes
11. Brush Springs
12. Brush Holder Assy.
13. Regulator and Brush Holder Assy.
14. Terminal Retaining Clip
15. Through Bolt

DISMANTLING THE ALTERNATOR

1. Unscrew the pulley retaining nut with an open end 22 mm wrench and remove the pulley from the rotor shaft with a suitable puller.
2. Mark the position of the stator relative to the end frame. Unscrew the brush holder plate complete with the carbon brushes Fig. 48.
3. Release the fastening screws at the drive end frame and carefully withdraw the claw-pole rotor and the drive end frame assembly from the stator Fig. 49.
4. Using a suitable support and arbor, press the rotor out of the drive end frame, holding the rotor securely Fig. 50

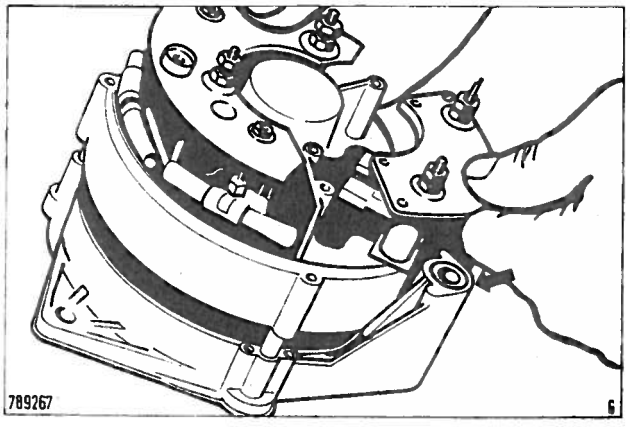


Fig. 48 Brush holder plate

SPECIFICATIONS

Wiring	Negative earth return (17ACR) Insulated return (17ACR'M')
Nominal voltage	12V
Nominal d.c. output (hot, at 14V and 6000 rpm)	36A
Alternator controlled voltage (measured across the battery terminals with alternator current stabilised below 10A)	13,6 to 14,4V
Max. permissible speed	15000 rpm
Rotor field winding resistance (approx.)	4,2 ohm (17ACR rotors with PINK windings.) 3,2 ohm (17ACR rotors with GREEN windings.) 3 to 3,5 ohm (17ACR 'M' rotors.)
Brush spring pressure (measured with brush depressed flush with brushbox moulding)	2,5 to 3,6 N (255 to 369 gf or 9 to 13 ozf)
New brush length:	12 mm (0,5 in)
Renew when worn to:	8 mm (0,3 in)

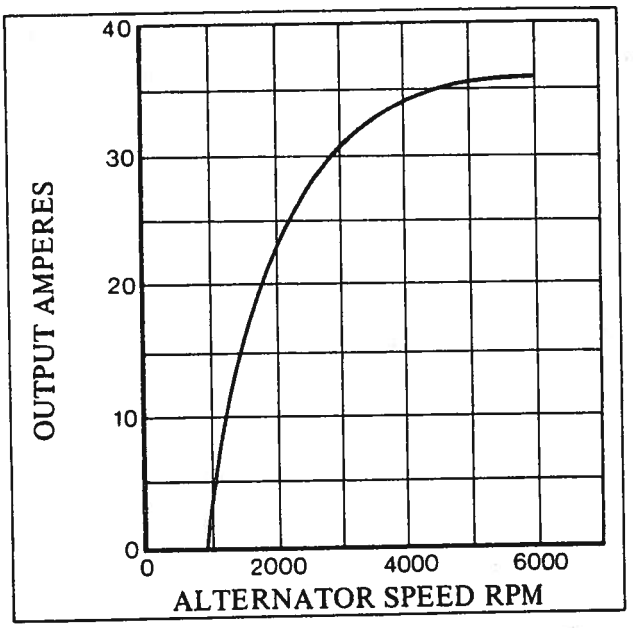


Fig. 46 Typical performance curve (alternator hot)

Slip Ring End Bearing Renewal

Unsolder the field winding connections from the slip rings using a light weight soldering iron eg, 25W.

Withdraw the slip rings from the rotor shaft using a suitable puller.

Position the two halves of a bench press support plate beneath the shoulder of the nylon distance piece and press the rotor shaft from the bearing. Alternatively, use a suitably-sized claw-type bearing extractor tool (position claws behind the shoulder of the nylon distance-piece) and pull the bearing from the shaft.

Ensure that the new nylon distance piece is in position and that the field coil leads are correctly located.

Press the new bearing into position.

NOTE: When refitting a 'standard' bearing, ensure that the shielded side of the bearing faces the slip-ring moulding.

Press the slip ring moulding into position, ensuring that the spring retainer is fitted inside it.

Re-solder the field coil leads to the slip rings using a light weight soldering iron, eg. 25W and resin cored solder only.

Drive End Bearing Renewal

After removing the bearing retaining circlip and plate, the drive-end bearing can either be pressed or carefully tapped from the bracket with a suitably-sized mandrel inserted in the outer-face aperture of the bearing housing.

When refitting the bearing, ensure correct sequence of assembly of sundry parts associated with the bearing – see Fig. 27 or Fig. 28 as appropriate.

NOTE: On some earlier machines the bearing is retained by a triangular plate secured by three bolts.

ASSEMBLY

Position the rotor spacing collar on the shaft. Press the rotor shaft through the drive end bearing and (where applicable) slide the fan spacer onto the shaft, recess side towards bearing.

Fit the 'Woodruff' key to the shaft and place the fan and drive pulley in position. Secure pulley with the spring washer and nut.

Fit the stator assembly in the drive-end bracket so that the stator connecting leads are centrally positioned between the alternator fixing lugs, then assemble the slip-ring end bracket to the stator laminations and finally secure into a sub-assembly by fitting the through bolts.

Avoid overtightening the through bolts, the maximum tightening torque is 6,2 Nm (55 lbf in or 0,6 kgf m).

The remaining assembly must be carried out by reversing the dismantling sequence given under the heading 'Partial Dismantling – 17ACR Alternator' or 'Partial Dismantling – 17ACR 'M' Alternator' whichever is appropriate.

NOTE: Use only 'M' grade 45-55 resin-cored solder to attach the stator cables to the diode connecting pins. Carry out the operation as quickly as possible, using a thermal shunt to avoid damaging the diode(s). (Long-nosed pliers are suitable as a thermal shunt, (see Fig. 45).

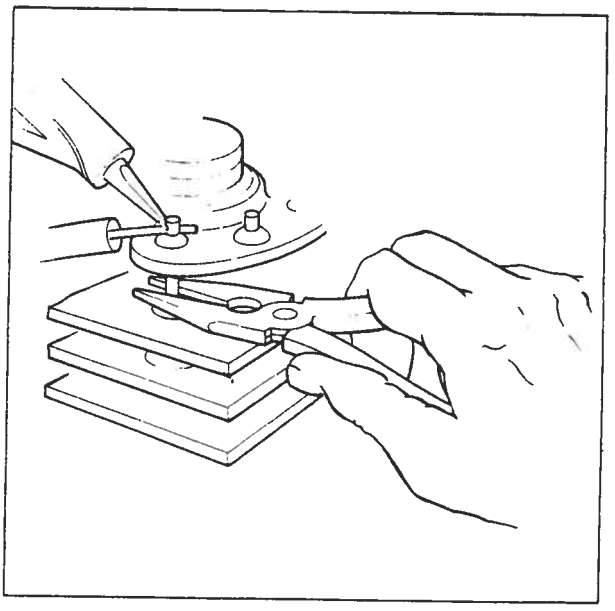


Fig. 45 Use of thermal shunt when soldering diode connections

Regulator

Individual testing of the regulator can only be carried out with special test equipment and unless this is available the regulator must be proved by substitution.

The surge protection diode and suppression capacitor(s) can be tested for faults by disconnecting each one in turn during bench testing – refer to operation 6 under 'Test Procedure'.

FURTHER DISMANTLING

Remove the three 'through' bolts.

Grip both ends of the alternator in the hands, pull apart the end brackets from the stator laminations and separate the alternator into the following major parts.

Slip-ring end bracket

Stator laminations-and-windings

Sub-assembly comprising:

(a) Fan and pulley

(b) Drive-end bracket and bearing

(c) Rotor complete with slip-ring end bearing

If difficulty is experienced in separating the above parts, suspend the alternator gripped by the pulley in one hand and apply a series of light blows with a hide, plastic, or wooden mallet in turn to the shoulders of the through bolt housings of the slip-ring end bracket.

Separate the rotor assembly from the drive-end bracket. First remove the driving pulley, fan and shaft key and, where applicable, the fan spacer, then press the rotor shaft from the bearing using a suitable bench press.

BEARINGS

Check whether the bearings need renewing. Determine this by first inspecting the rotor and stator poles for signs of rubbing. If so, excessively worn bearings are indicated and both should be renewed. If there is no visible evidence of worn bearings, check whether the bearings are worn to the extent of allowing perceptible side movement of the rotor shaft and if so the bearing(s) should be renewed – see under 'Slip Ring End Bearing Renewal' or 'Drive End Bearing Renewal' as appropriate.

Bearing Lubrication

During major overhaul of the alternator, providing the bearings have been checked and found not to be excessively worn, 'standard-type' bearings can be serviced by re-packing with Shell Alvania 'RA' grease lubricant, or equivalent.

To re-pack the slip-ring end bearing with grease it will be necessary to gain access to the unshielded (open) side of the bearing, by removing first the slip-ring moulding and then the bearing from the rotor shaft – see under 'Slip Ring End Bearing Renewal'.

Heavy-duty alternators are fitted with fully-sealed bearings. This type of bearing cannot be serviced by re-packing with grease but providing the bearing is not worn to the extent of allowing perceptible side movement of the rotor shaft, and providing also the bearing rotates smoothly, it should be allowed to continue in use, (except when the alternator has been dismantled for the purpose of fully-reconditioning it for a further period of long service, in which case it is then advisable to renew the bearing).

A fully-sealed bearing should not be confused with a 'standard-type' shielded bearing fitted to the slip-ring end of alternators of standard specification. A standard-type shielded bearing incorporates a metal shield in one side of the bearing only (facing slip-ring moulding), whereas a fully-sealed bearing incorporates a plastic shield in both sides of the bearing.

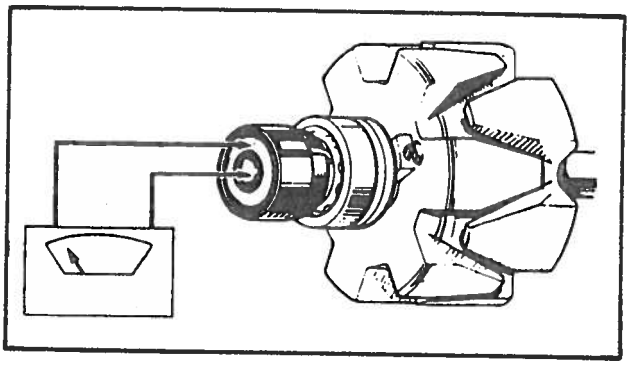


Fig. 40 Measuring rotor field winding resistance

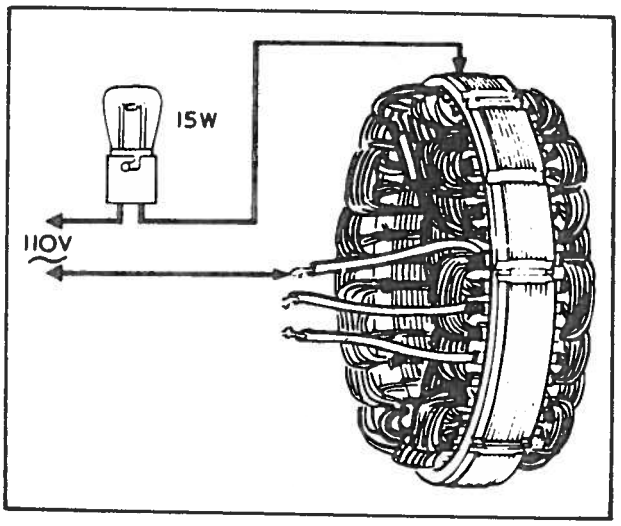


Fig. 43 Stator winding insulation test

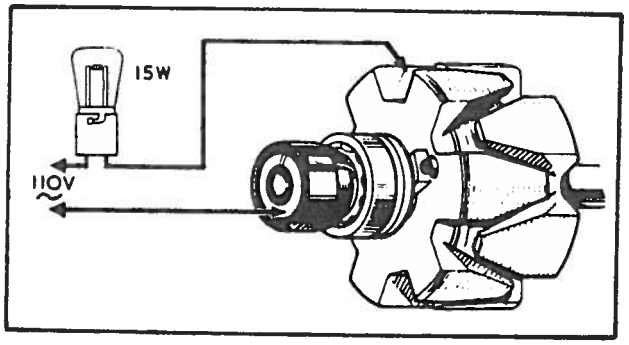


Fig. 41 Insulation test of rotor field winding

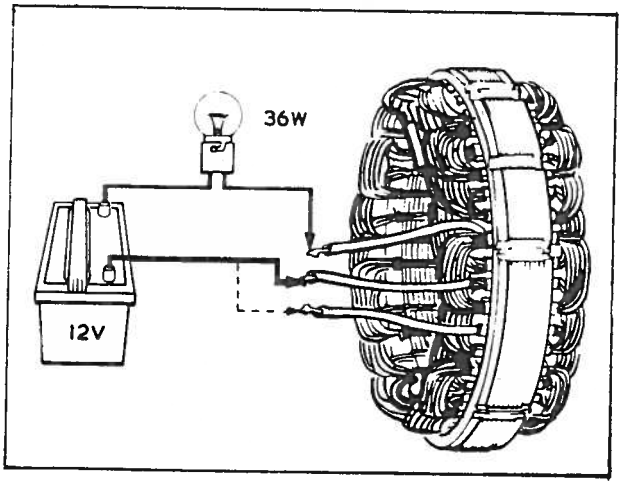


Fig. 42 Stator winding continuity test

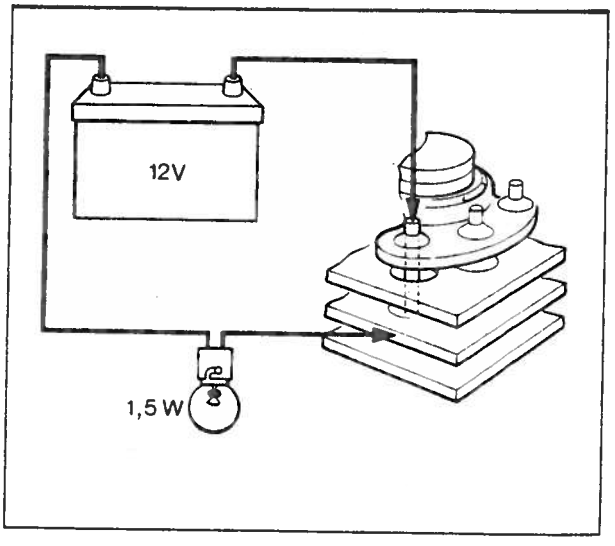


Fig. 44 Simple test for diodes

COMPONENT TESTING AND RENEWAL

Brushes and Springs

Renew the brush-and-spring assemblies if the overall length of the brushes are worn to, or approaching 8 mm (0,3 in). If the brushes are satisfactory but require cleaning, use a petrol-moistened cloth.

Check the brush spring pressure. With the brush-and-spring assemblies fitted in the brush-box moulding, apply a push-type spring gauge to the end-face of each brush in turn until the end-face of the brush is flush with the moulding. The spring pressure should then be 2,5 to 3,6 N (255 to 369 gf or 9 to 13 ozf).

Rotor Slip Rings

The slip-rings should be clean and smooth. If necessary, clean the slip-rings with a petrol-moistened cloth. If the slip rings are burnt and require refinishing, use very fine glass paper (not emery cloth, or similar abrasives) and afterwards wipe clean with a petrol-moistened cloth.

NOTE: It is essential that the refinishing glass paper is sufficiently fine to produce a highly-polished slip-ring surface, otherwise excessive brush wear will occur.

If the slip-rings are excessively worn, they should be renewed – see under 'Bearings'.

Rotor Field Windings

Check field winding continuity and resistance simultaneously, by connecting a resistance meter between the slip rings – see Fig. 40. The indicated resistance should be in accordance with the appropriate value given in Specifications.

Test the insulation with a 110V 15W lamp wired as shown in Fig. 41; the lamp should not illuminate if the insulation is correct. If the lamp lights, renew the rotor.

Stator Windings

Check continuity of stator windings, by first connecting any two of the three stator winding connecting cables in series with a 12V battery-operated test lamp, of not less than 36 watt (see Fig. 42). The test lamp should light. If not, renew the stator assembly. Providing the first part of the test is satisfactory, transfer one of the test lamp leads to the other (third) cable. Again the test lamp should light. If so, proceed to insulation test.

Check insulation of stator windings, by connecting a 110V a.c. 15-watt test lamp between the stator laminations and any one of the three connecting cables (see Fig. 43). The lamp should not light.

Due to the very low resistance of the stator windings, a practical test to determine the presence of short-circuited turns cannot be carried out without the use of special instruments. However, in practice inter-winding short-circuiting is usually indicated by obvious signs of burning of the insulating varnish covering the windings. This cannot be checked until the alternator is completely dismantled – see under 'Further Dismantling'.

If short circuiting is apparent, renew the stator assembly.

Rectifier Diodes

Test each of the nine diodes separately, as follows:

Connect a 12V battery and a 15 watt bulb in series with one of the diodes, one test lead being applied to the diode connecting pin and the other to the particular heat sink plate in which the diode is soldered (see Fig. 44). Note whether lamp lights, then reverse the test lead connections. The lamp should light during one half of the test only. If any one diode test is unsatisfactory, renew the rectifier assembly.

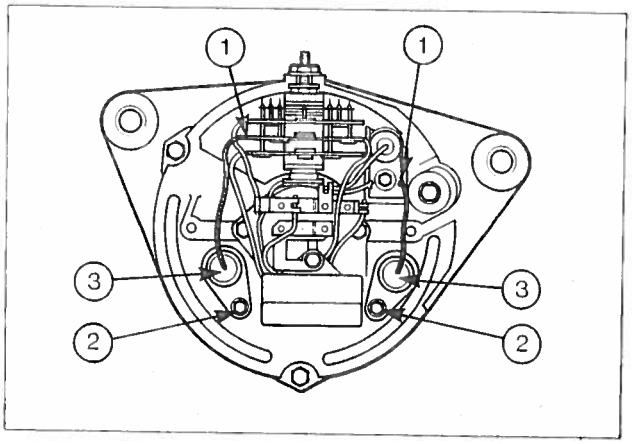


Fig. 35 Removing suppression capacitors

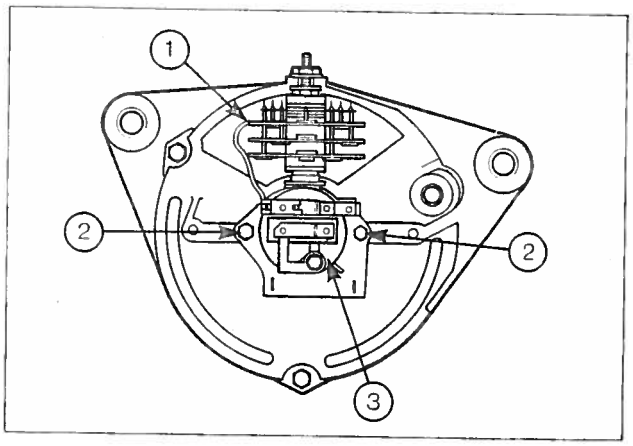


Fig. 38. Removing the brush box

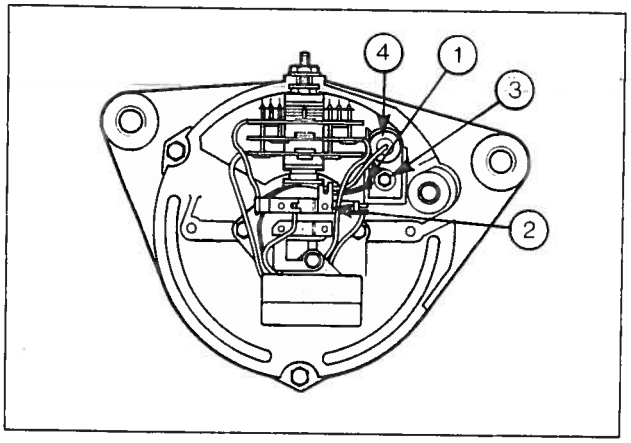


Fig. 36 Removing surge diode

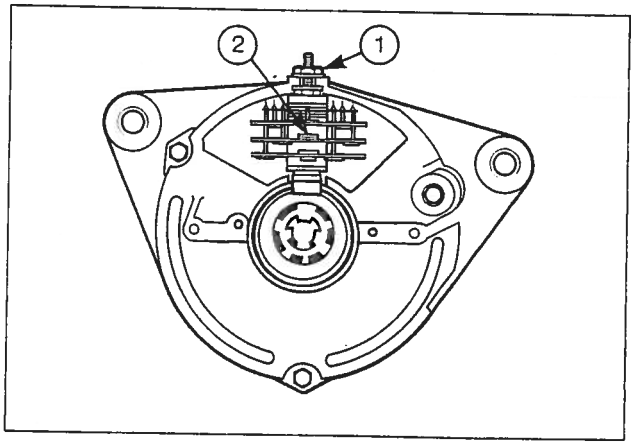


Fig. 39 Removing the rectifier

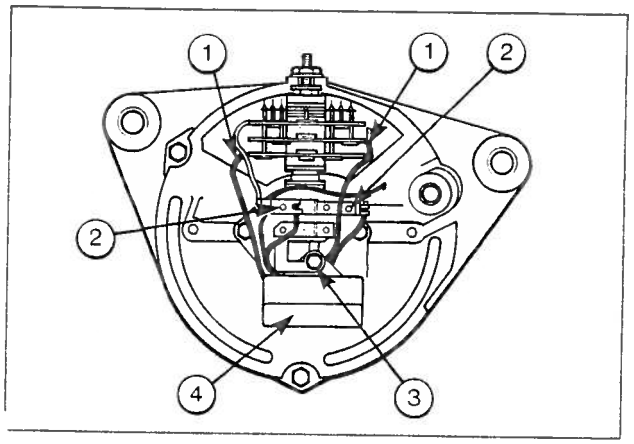


Fig. 37. Removing regulator

PARTIAL DISMANTLING – 17 ACR ALTERNATOR

The following information covers minimum dismantling of the alternator to enable the brushgear and slip-rings to be inspected, and the rotor and stator windings and rectifier diodes to be electrically tested. If inspection and testing determines the need to extend dismantling in order to renew a faulty part, refer to 'Further Dismantling'.

1. Remove the moulded slip-ring end cover (if not already removed).

2. Note the arrangement of the stator winding connections to the rectifier diode connecting pins, and then using a thermal shunt (see Fig. 45) and a light-weight soldering iron (e.g. 25-watt) unsolder the connections to the rectifier.

   Refer to Fig. 27 and identify the arrangement of the cable connections to the rectifier plates. (This ensures correct refitting of the rectifier cables during reassembly). These cables can now be disconnected from the rectifier.

3. Remove the three hexagon-headed screws, securing the brushbox moulding and regulator to the end-face of the slip-ring end bracket. The brushgear-and-regulator sub-assembly can now be detached from the rest of the alternator.

4. Slacken the rectifier securing nut and detach the rectifier from the rest of the alternator.

   The alternator is now sufficiently dismantled to allow inspection and electrical testing of components.

PARTIAL DISMANTLING – 17ACR 'M' ALTERNATOR

The following information covers minimum dismantling of the alternator to enable the brushgear and slip-rings to be inspected, and the rotor and stator windings and rectifier diodes to be electrically tested. If inspection and testing determines the need to extend dismantling in order to renew a faulty part, refer to 'Further Dismantling'.

1. Remove the two hexagon headed screws and detach the moulded slip ring end cover.

2. Disconnect the leads (1) at the surge diode and rectifier. Remove the two screws (2) and detach both suppression capacitors (3) – see Fig. 35.

3. Disconnect the lead (1), then remove screw (2) securing the surge diode lead. Remove screw (3) and detach surge diode (4) – see Fig. 36.

4. Make a note of the regulator leads terminations, then disconnect leads (1) from the rectifier. Remove screws (2) securing remaining two regulator leads. Remove screw (3) and detach regulator (4) – see Fig. 37.

5. Disconnect lead (1) from the rectifier. Remove the two screws (2) and detach the brush box assembly (3) – see Fig. 38.

6. Clamp the alternator securely. Unsolder the stator leads from the rectifier. Slacken the securing nut (1) and remove the rectifier pack (2) – see Fig. 39.

FAULT SYMPTOMS

Warning Light	Alternator			Probable Fault (Associated Damage)
	Temperature	Noise	Output	
Illuminated at stand-still, extinguished at cut-in speed (1500 rpm) but higher speeds becomes partially illuminated again and gets progressively brighter.	High	Normal	Higher than normal at 6000 rpm Approximately: 38A	Positive side main output diode open-circuit. (May damage rotor field winding and regulator, overheat brushboxes, and fuse warning light bulb).
Not illuminated between zero and 1500 rpm	High	Excessive	Very low at 6000 rpm Approximately: 10A	Positive-side main output diode short-circuit. (May damage associated 'field' diode).
Illuminated at stand-still, dims appreciably at cut-in speed (1500 rpm) and gets progressively dimmer or may be extinguished at higher speeds.	Normal	Excessive	Poor at low speed. Slightly below normal at 6000 rpm Approximately: 30A	Earth (or negative) side main output diode open-circuit.
Illuminated at stand-still dims appreciably at cut-in speed (1500 rpm) and gets progressively dimmer or may be extinguished at higher speeds.	Normal	Normal	Lower than normal at 6000 rpm Approximately: 29A	'Field' diode open-circuit.
Illuminated at Stand-still, dims at cut-in speed (1500 rpm) and remains dim, but may be extinguished at very high speeds.	Normal	Excessive	Very low at all speeds above cut-in (1500 rpm). Approximately: 7A	Earth (or negative) side main output diode short-circuit, to earth.
Illuminated at stand-still dims at cut-in speed (1500 rpm) and remains dim, but may be extinguished at very high speeds.	Normal	Excessive	Very low at 6000 rpm Approximately: 7A	'Field' diode short-circuit

4. While the brushbox moulding is removed, check rotor field winding continuity by connecting a resistance meter between the two slip rings. Check the reading obtained with the correct risistance value given in Specifications. If the resistance is incorrect or no reading can be obtained, renew the rotor – refer to heading 'Dismantling' – then proceed with operations Nos. 5 and onwards.

5. Render the regulator inoperative by linking its 'F' terminal to earth or negative terminal – refer to operation 1 or 2 as appropriate.

6. Run the alternator in the test rig at a slowly-increasing speed. At the cutting-in speed of 1550 rpm max. and with 13,5V indicated, the warning light should be extinguished; proceed with operation No. 7.

   If the warning light is not extinguished, the suppression capacitor(s) and/or surge protection device (when fitted) should be proved by repeating the test with each of these items disconnected in turn.

NOTE: Do NOT disconnect any wiring while the alternator is running.

If the result is still unsatisfactory, the alternator is faulty and must be dismantled for detailed inspection to determine and rectify the fault.

7. Providing the first half of the test is satisfactory (warning light extinguished), increase alternator speed to 6000 rpm and adjust the variable load resistor until the voltmeter registers 13,6V. The ammeter should register the maximum rated output of the alternator – refer to Specifications.

   If this second half of the test is unsatisfactory, the suppression capacitor(s) and/or surge protection device (when fitted) should be proved by repeating the test with each of these items disconnected in turn.

   If the result is still unsatisfactory, the alternator is faulty and it must be dismantled for detailed inspection to determine and rectify the fault.

NOTE: Failure of one or more of the diodes will be indicated by the effect on alternator output, and in some instances by abnormally high alternator temperature and noise level. The fault symptons table shows how diode failure will influence alternator output test results.

8. This test assumes the alternator output test (Op. 7) has previously been carried out and found to be satisfactory.

   Remove the variable load resistor from the battery terminals and also the test link connecting the regulator 'F' terminal connection to alternator frame or negative terminal.

   Run the alternator at 6000 rpm, until the ammeter registers less than 10A. If the voltmeter registers 13,6 to 14,4V, the regulator is working normally. If the voltmeter reading is outside the limits specified, the regulator must be renewed.

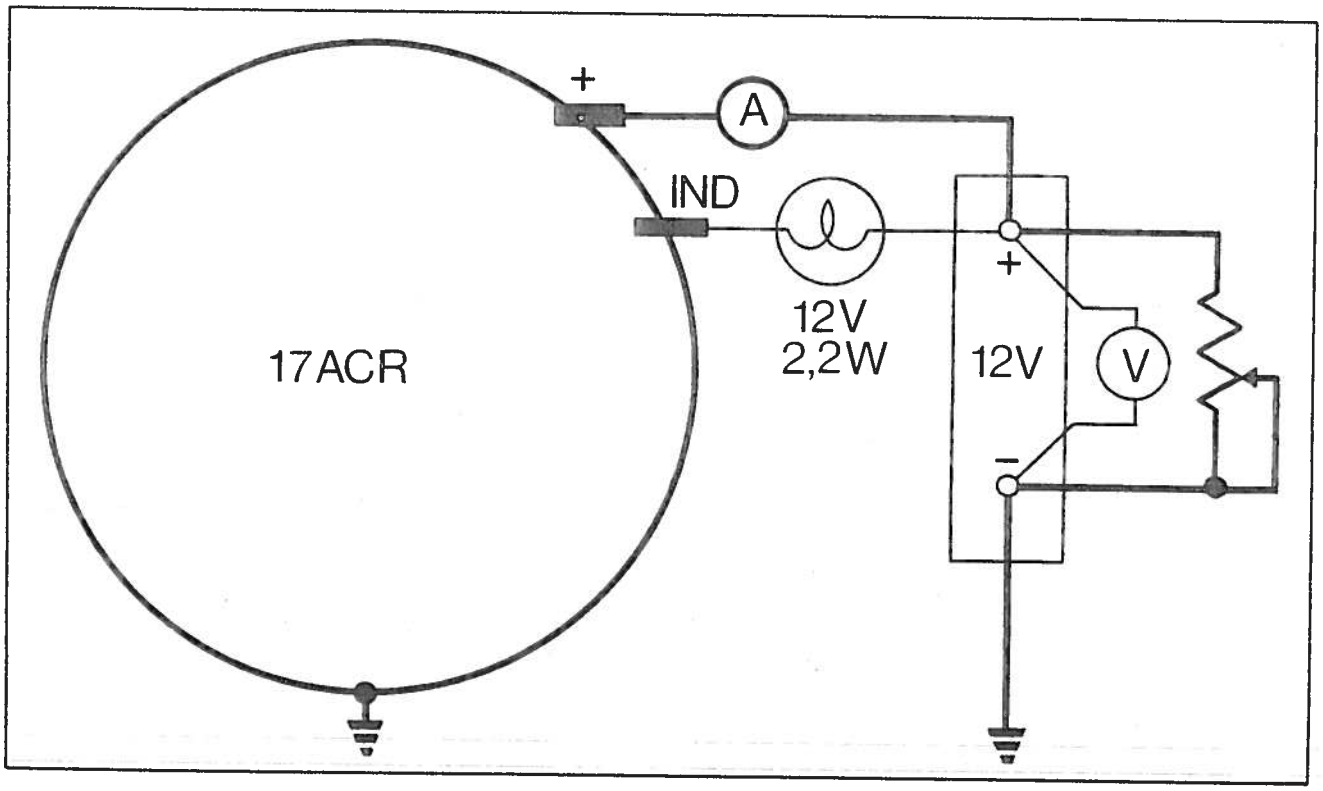


Fig. 33 17ACR Bench test circuit

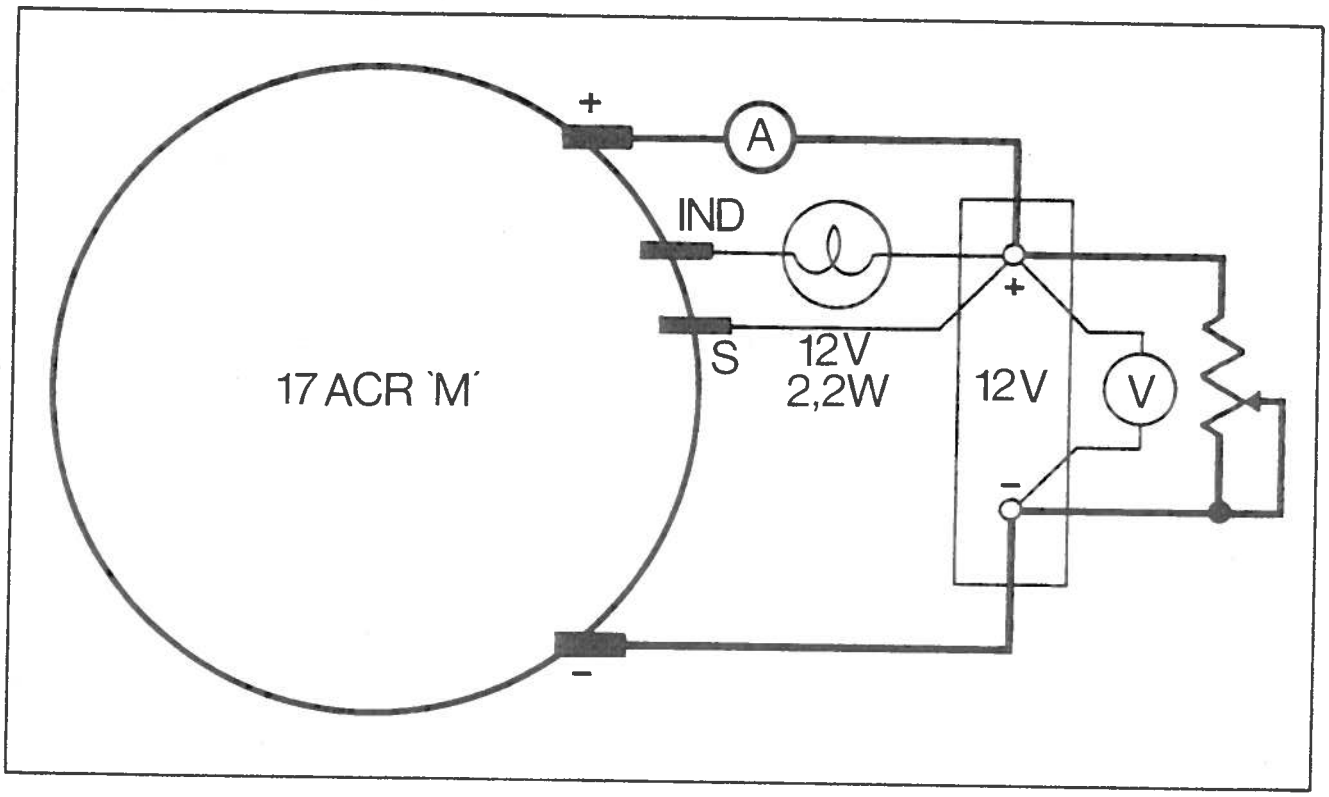


Fig. 34 17 ACR 'M' Bench test circuit

BENCH TESTING

Equipment Required

The test rig must be capable of varying the alternator speed from zero to 6000 rpm. To avoid overheating of the alternator it should be fitted with a fan and driven in the correct direction-of-rotation. (Correct rotation of the alternator can be determined by an arrow marking on the face of the fan, or, alternatively, by the angle of the fan blades which are inclined in the opposite direction to that in which the alternator must be rotated when viewed from the drive-end). Wiring used in the test circuit must be of equivalent grade to that used in vehicle alternator installations ie, 14/010 (14/0,25 mm) grade for the 'IND' and 'S' terminal cables and 120/012 (120/0,30 mm) grade for the main positive and earth or positive and negative terminal cables.

Clamp the alternator in the test rig, with the alternator moulded slip-ring end cover removed to expose the regulator connections. Connect a test circuit as shown in Fig. 33 for 17ACR machines or Fig. 34 for 17ACR 'M' machines.

The ammeter should be a moving coil type with a range of 0 to 50A.

The volt meter should be a moving coil type with a range of 0 to 20V.

The variable resistor should have a value of 15 ohm and must be capable of handling a current of 36A at system voltage.

Test Procedure

With the alternator wired into the appropriate test circuit, the warning lamp should be illuminated; in this case proceed direct to operation No. 5.

If the warning light is not illuminated (providing the warning light bulb is known to be good) non-continuity of the rotor field winding circuit is indicated. Carry out operation 1 on 17ACR machines or operation 2 on 17ACR 'M' machines.

1. Regulator – 17 ACR machine

   Connect the regulator 'F' terminal to alternator frame. If this results in the warning light now being illuminated, the regulator is faulty and it must be renewed. If the regulator is not faulty, proceed with operation No. 3.

   In all cases except a model 14TR regulator, the regulator 'F' terminal is a green coloured lead. In the case of a 14TR regulator, the 'F' terminal connection is via the regulator case, connected to the brushbox by a metal connecting strip (see Fig. 31).

2. Regulator – 18ACR 'M' machine

   Connect a link between the regulator 'F' and '–' terminals (metal strip and black leads). If this results in the warning light now being illuminated, the regulator is faulty and it must be renewed. If the regulator is not faulty, proceed with operation 3.

3. Remove the brushbox moulding. Check whether brushes and slip-rings are free of oil and grease. If necessary, the brushes and springs can be cleaned with a petrol-moistened cloth. Check brush-and-spring assemblies for freedom-of-movement in the brushbox moulding. If the visible length of the brushes in the free position is less than 6 mm (0,25 in) this is the probable cause of non-continuity of the field circuit. In any case, the brush-and-spring assemblies should now be renewed if the overall length of the brushes has become worn to 8 mm (0,3 in) or less.

   Check brush spring pressure as detailed under 'Component Testing and Renewal (sub heading 'Brushes and Springs').

   If brushes and spring pressures are correct, carry out operation No. 4.

If the test is unsatisfactory, the continuity fault in the external cable circuit(s) must be traced and remedied – refer to Fig. 31 or 32 as appropriate.

If the test is satisfactory, refit connector plug to the alternator and proceed to operation 6.

Charging Current and Controlled Voltage at Battery Terminals

NOTE: In addition to the voltmeter used in the previous test (op. 5), unless the installation is fitted with an ammeter, it will be necessary to connect a test-ammeter, 0 to 60A range, in series with the cable(s) connected to the main output '+' terminal of the alternator.

6. Connect the voltmeter across the battery terminals, so that battery voltage is registered.

7. Start engine, increase speed (ignore voltmeter at this stage) and observe the ammeter reading. If ammeter registers zero current, the alternator is faulty and must be removed from the vehicle for individual testing (proceed to 'Bench Testing').

   If ammeter registers a charging current in excess of 10A, continue running the engine until ammeter reading falls below 10A, and observe the voltmeter reading; 13,6 to 14,4V should be registered (alternator-controlled voltage), in which case the charging system is working normally.

   If the voltmeter reading exceeds 14,4V, the alternator should be removed from the vehicle and the regulator renewed, otherwise the battery will be subjected to overcharging and the alternator will be overworked and damaged.

8. If voltmeter reading is below 13,6V, a faulty alternator (regulator) or a high-resistance fault in the external connections of the charging system is indicated. Proceed to operation 8. If the volt drop tests are satisfactory, remove the alternator from the vehicle and proceed to 'Bench Testing'.

Volt Drop Test

9. Check for a high resistance fault in the charging system, by carrying out two separate volt drop tests on the positive and earth (or negative) side of the charging circuit. Test must be carried out with all the alternator cables connected. (The connector plug is open-ended to facilitate testing).

10. Switch on the head-lamps or other electrical equipment to load the charging system and run the engine at a fairly high speed (simulating normal working speed), and connect the voltmeter as follows:

11. **Positive-side volt drop test**

    Connect voltmeter between the alternator main output '+' terminal(s) and the '+' terminal of the battery. (Voltmeter red lead to alternator and black lead to battery).

    The test is satisfactory if the voltmeter registers 0 to 0,5V.

    If the test is unsatisfactory, a high-resistance fault between the positive side of the battery and the alternator '+' terminal(s) must be traced and remedied.

12. **Earth or nagative-side volt drop test**

    Connect a voltmeter between the alternator frame (or negative terminal on 17ACR 'M' unit and the negative terminal of the battery. (Voltmeter black lead to alternator and red lead to battery).

    The test is satisfactory if the voltmeter registeres 0 to 0,25V.

    If the test is unsatisfactory, a high-resistance fault on the earth or negative-side of the charging circuit must be traced and remedied.

to maintain the alternator output voltage (and so the current) at a predetermined and safe working limit. The alternator-controlled voltage, measured at the battery terminals, is normally 13,6-14,4V. The type of sensing system used on the 17ACR alternator is machine sensing.

The regulator senses the alternator generated output voltage, via the regulator connections inside the alternator.

On the 17ACR 'M' alternator, a separate terminal allows direct connection to be made to the battery for sensing battery voltage.

SERVICE PRECAUTIONS

(i) Ensure that no connection in the charging circuit, including the battery, is made or broken while the engine is running.

(ii) Observe correct polarity when refitting the vehicle battery, using a slave battery to start the engine, or when using a battery charger (connect positive to positive, negative to negative).

ROUTINE MAINTENANCE

Occasionally check the general condition and tightness of the fan belt. If necessary, the fan belt tension should be adjusted to obtain approximately 16 mm (0,6 in) deflection of the belt when pressed at the longest point between pulleys.

NOTE: When adjusting the fan belt, leverage must only be applied to the alternator drive-end bracket and the lever should preferably be of wood.

TESTING THE CHARGING SYSTEM

Battery Condition

1. Check with a hydrometer the specific gravity of the electrolyte in each of the battery cells. If the cells readings vary by more than 40 points (0,040), the battery is suspect. Specific gravity readings should be:–

State of charge	Specified gravity readings correct to 15°C (60°F)	
	Climates normally below 25°C (77°F)	Climates normally above 25°C (77°F)
Fully-charged	1,270 - 1,290	1,210 - 1,230
70% charged	1,230 - 1,250	1,170 - 1,190
Discharged	1,100 - 1,120	1,050 - 1,070

For every 10°C (18°F) below 15°C (60°F) subtract 0,007

For every 10°C (18°F) above 15°C (60°F) add 0,007

2. If the battery is found to be discharged it should be independently recharged, renewed, or substituted for the following tests. If the battery is found to be satisfactory, check for tightness of its terminal connections.

Warning Light Operation

3. Switch on the Isolation switch, (do not at this stage start the engine). The warning light should be fully illuminated. If the warning light is not illuminated, check the bulb. If the bulb is not the cause of the fault, proceed direct to operation 5.

   If the warning light is illuminated, start the engine and run it above idling speed. The warning light should be extinguished. If the warning light is not extinguished, the driving belt may be broken or slipping (refer to operation 4).

4. Stop the engine, then check whether the driving belt is broken or slipping, With the driving belt depressed by hand at the longest point between pulleys, deflection of the belt should be approximately 13 mm (0,5 in).

   If the driving belt is not the cause of the fault, remove the alternator 'IND'/MAIN terminals connector plug. If warning light remains illuminated, check for short-circuit to frame or negative line between the 'IND' cable-end and warning light. If warning light is now extinguished, refit the alternator connector plug and proceed direct to operation 5.

Alternator Connections

NOTE: A moving coil voltmeter 0-20V range is required.

5. Move ignition switch or equivalent control switch to 'ON'.

   Remove connector plug from alternator and connect voltmeter positive lead to the 'IND' and '+' socket in turn while the voltmeter negative lead is connected to earth (or negative lead). Battery voltage should be indicated in each case.

illuminated and the rotor is partially-magnetised. When the engine is started and the partially-magnetised rotor rotates within the stator windings, 3-phase alternating current (a.c.) and rapidly rising voltage is generated.

A small portion of generated alternating current (a.c.) is rectified to direct current (d.c.) by the three field diodes incorporated in the rectifier pack. Output current from the field diodes supplements the initial current flowing through the rotor field winding from the battery, causing an increase in the magnetic influence of the rotor and resulting in self-excitation of the alternator. As rotor speed and generated current and voltage increases, the rotor field current increases correspondingly until the alternator becomes fully-excited.

During the rise in generated output voltage (reflected at terminal 'IND') the rising voltage influences the warning light so that its functions as a 'Charge-Indicator Warning Light', as follows: When the generated voltage applied to one side of the warning light (via the 'IND' terminal) rises to, or above, the battery voltage applied to the other side of the warning light, the warning light is extinguished and this normally indicates that the alternator is developing its main battery-charging current.

The main battery-charging current is rectified from a.c. to d.c. by the other six diodes in the rectifier pack (main output diodes) which function in a full-wave bridge rectifier circuit.

Alternator output is controlled by a voltage-sensing regulator unit, attached to the brushbox moulding and the outer-face of the slip-ring end bracket. The regulator functions as an electronic control switch in the earth-side of the rotor field winding circuit, switching the circuit 'OFF' and 'ON' at very high frequency

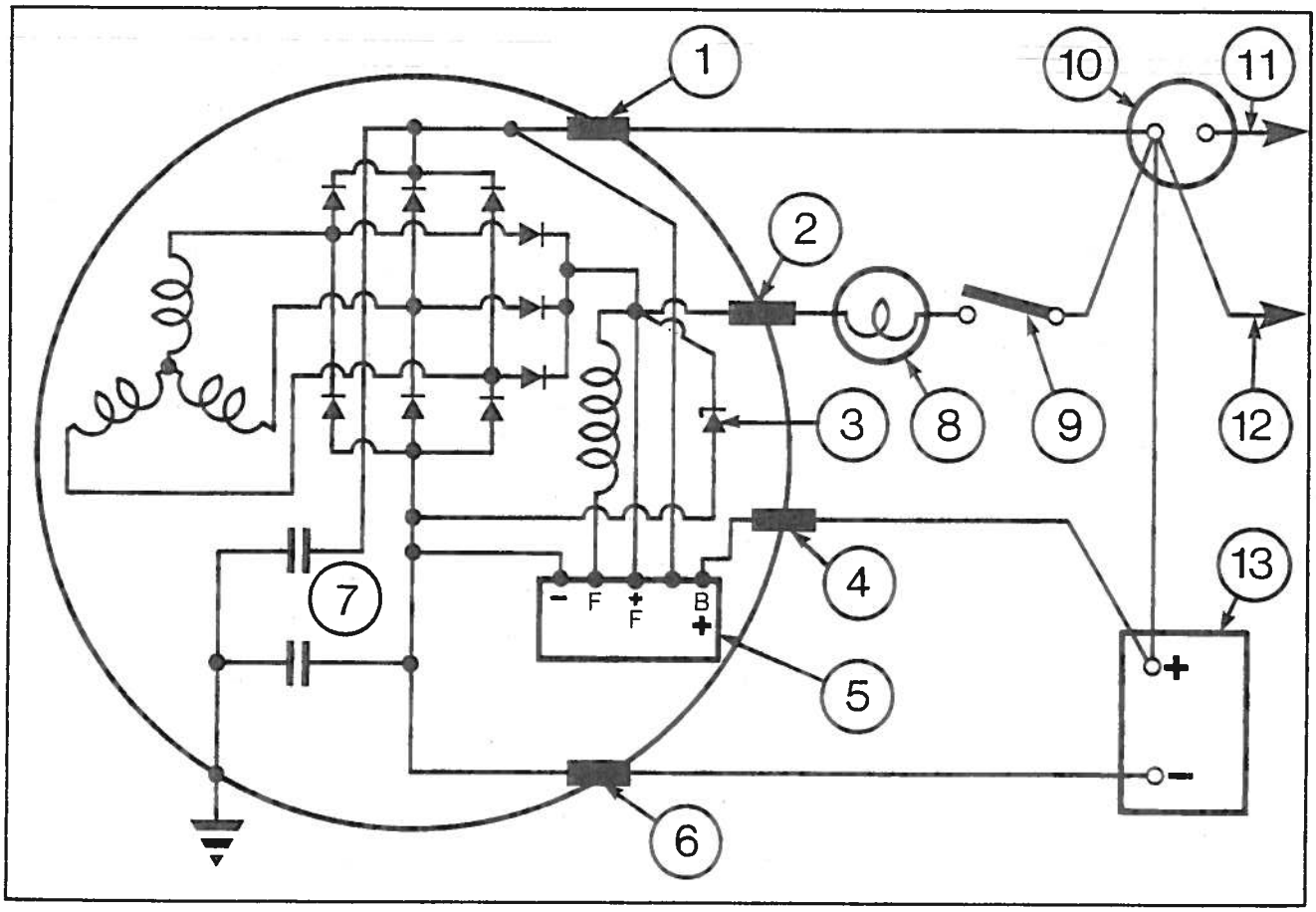


Fig. 32 – Battery-sensing system, 17ACR 'M' marine alternator

1. Main '+' terminal
2. 'IND' terminal
3. Surge protection device (avalanche diode)
4. 'S' terminal (sensing)
5. Regulator
6. Main '–' terminal
7. Suppression capacitors
8. Warning light
9. Ign switch
10. Solenoid
11. Starter
12. Load
13. Battery

Surge Protection Device

The surge protection device is a special avalanche-diode, fitted to the outer-face of the slip-ring end bracket (not to be confused with a suppression capacitor, similarly fitted in the end bracket). The avalanche-diode is connected between terminal 'IND' and frame on the 17ACR machine and between 'IND' and negative terminal on the 17ACR 'M' unit; its purpose is to protect the regulator from damage by absorbing high transient voltages which occur in the charging system due to faulty cable connections, or if the cables are temporarily disconnected at the battery whilst the engine is running. (The surge protection device is intended to provide limited protection for the regulator under normal working conditions and therefore the service precautions not to disconnect any of the charging system cables, particularly those at the battery, while the engine is running, should still be observed).

OPERATION – Refer to Fig. 31 or 32

When the isolation switch is switched 'ON', a small current flows from the battery and through the rotor field winding, the circuit being completed via the warning light, alternator terminal 'IND' and the carbon brushes contacting the rotor slip-rings, the alternator regulator and earth or negative return line. At this stage, the warning light is

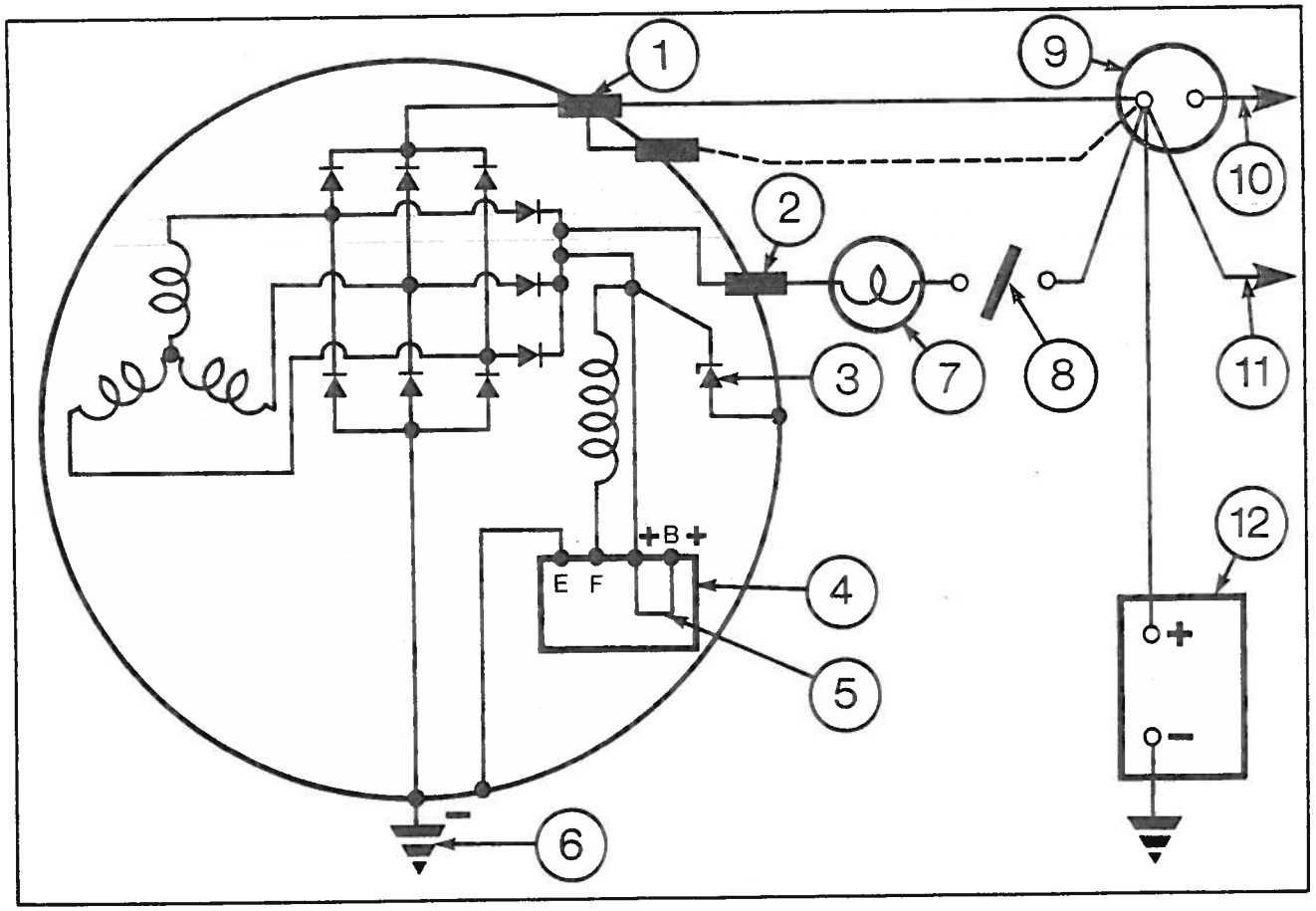


Fig. 31 – Machine-sensing system, 17ACR alternator

1. Main terminal
2. 'IND' terminal
3. Surge protection device (avalanche diode)
4. Regulator (see note) 8TR
5. Internal B+ connection
6. Earth return
7. Warning light
8. Ign switch
9. Solenoid
10. To Starter
11. To Load
12. Battery

NOTE: If a 3-lead model 11TR regulator is fitted, the 'B+' terminal and internal link will not apply.

If a later production 2-lead model 14TR regulator is fitted, the 'F' connection will be via the regulator case (connected to the brush box via a metal connection link) and the 'B+' terminal and internal link will not apply.

LUCAS 17 ACR & 17 ACR 'M' ALTERNATORS — 36 AMPERE

INTRODUCTION

These two alternators are similar in construction and generate current in exactly the same way. The 17ACR machine is intended for automotive and similar applications where an earth return wiring system is employed.

The 17ACR 'M' machine is intended for marine applications using an insulated return wiring system; it has marine finished components offering greater resistance to corrosion and can be readily identified by its special white marine paint finish.

DESCRIPTION

Mechanical Construction

Both machines are of the revolving field and stationary armature type and have built-in rectifiers and voltage regulators. The field coil is contained within the 'claw' type rotor which is supported by a sealed bearing at each end. Fig. 27 shows an exploded view of the 17ACR alternator and Fig. 28 the 17ACR 'M' alternator.

Terminal Arrangement

Figs. 29 and 30 show the terminal arrangements of the 17ACR and 17ACR 'M' machines respectively. The 17ACR 'M' has an additional sensing terminal 'S' which when connected to the battery '+' terminal, senses the actual battery voltage.

Alternator Output Control

Integral electronic voltage regulator unit of micro-circuit construction.

NOTE: The 17ACR machine can be fitted with any of the three following types – see Fig. 27 for further details.

(i) 8TR or 11TR 4-lead regulator
(ii) 8TR or 11TR 3-lead regulator
(iii) 14TR 2-lead regulator

Rectifier

Plate-type rectifier pack comprising nine silicon diodes (three field diodes and six main output diodes).

Rotor

Press claw type.

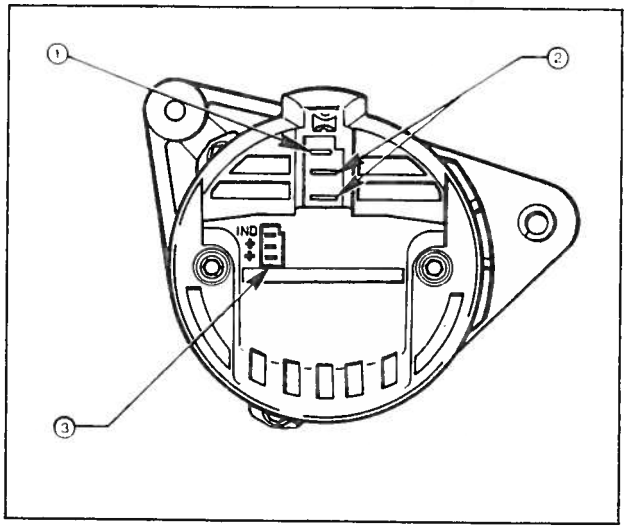


Fig. 29 – 17ACR alternator
(machine-sensed European terminations)

1. 'Ind' Connection to Warning Light
2. Main '+' Terminals (Lower Terminal for Physical Retention of Plug Only)
3. Signifies Polarity of Main Terminals

Note: Connection through frame.

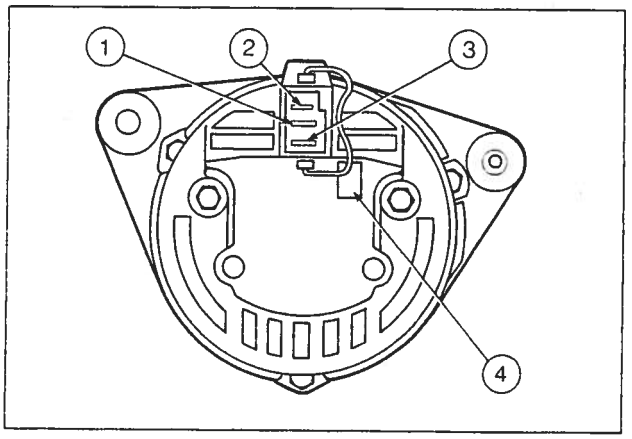


Fig. 30 – 17ACR 'M' alternator
(battery-sensed European terminations)

1. Main '+' Terminal
2. 'Ind' Connection to Warning Light
3. Main '–' Terminal
4. 'S' Terminal for Battery Sensing

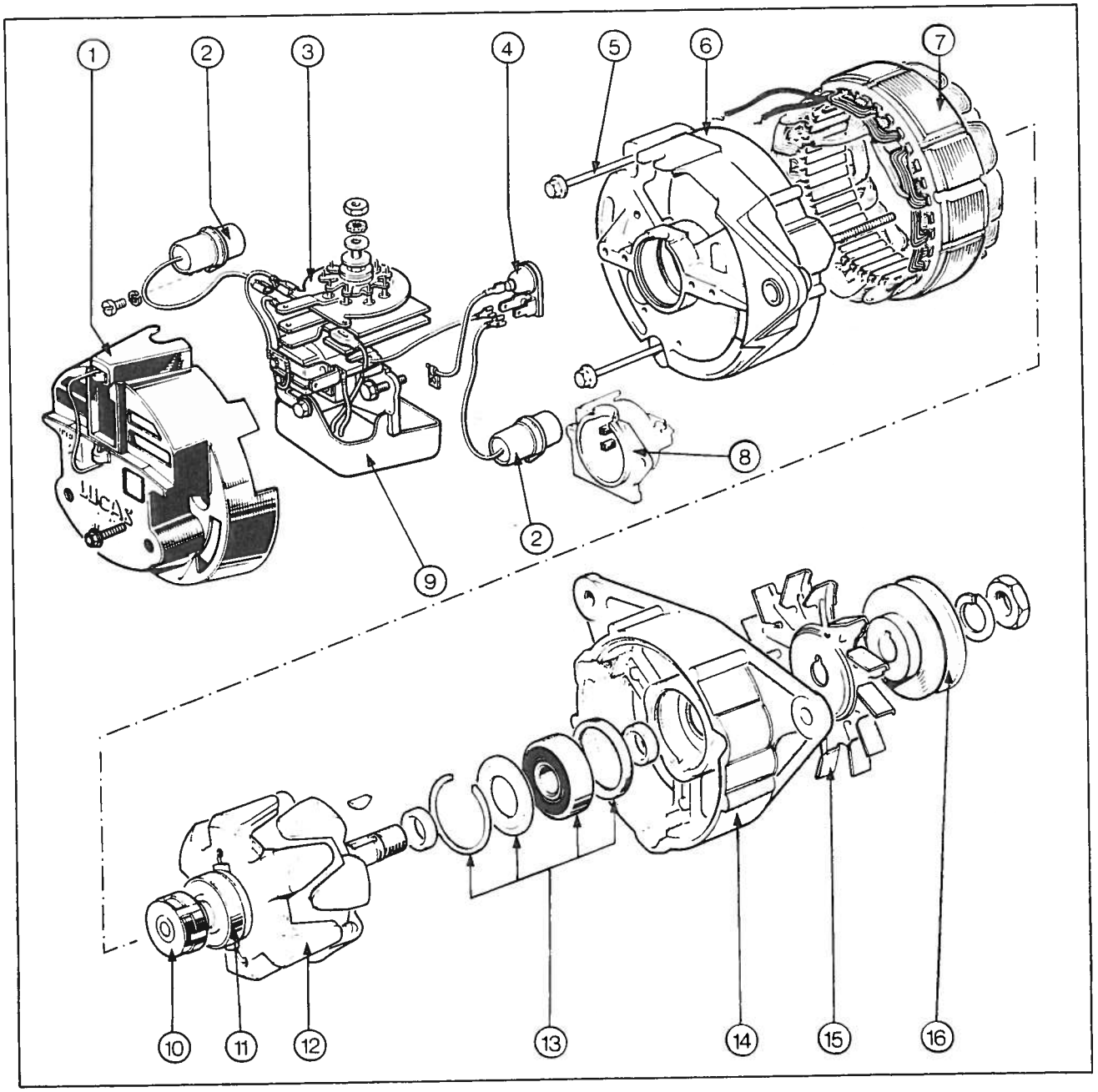


Fig. 28 Exploded view of 17ACR'M' marine alternator

1. Cover
2. Suppression capacitor
3. Rectifier
4. Anti-surge diode
5. Through bolts
6. Slip ring end bracket
7. Stator assembly
8. Brush box assembly
9. Regulator
10. Slip ring assembly
11. Slip ring end bearing
12. Rotor assembly
13. Drive end bearing assembly
14. Drive end bracket
15. Fan
16. Drive pulley

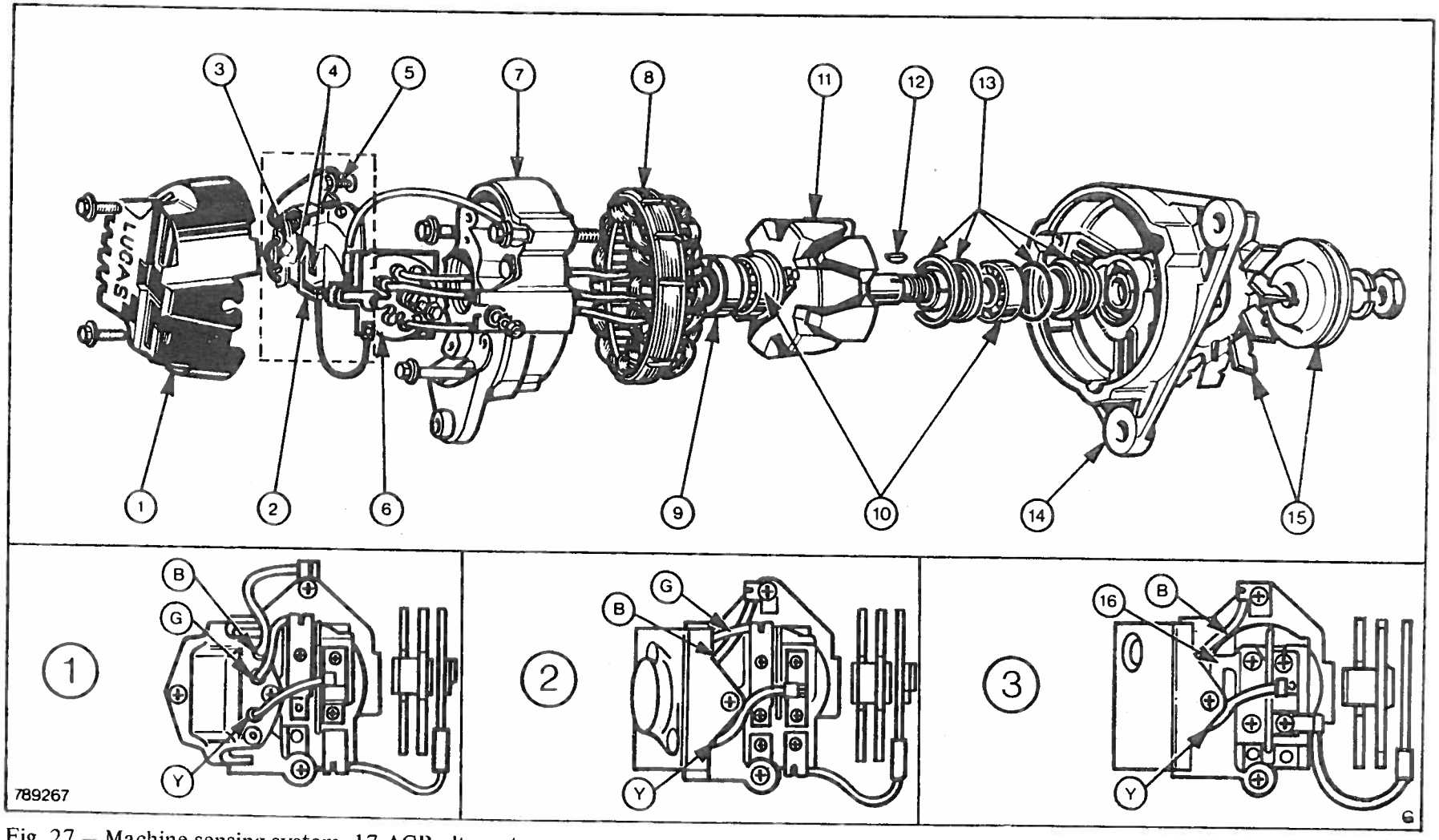


Fig. 27 – Machine sensing system, 17 ACR alternator

1. Cover
2. Brushgear and regulatory assembly
3. Built-in output regulator in heat sink
4. Brush and spring assembly
5. Regulator earthing screw
6. Rectifier
7. Slip ring end bracket
8. Stator winding assembly
9. Slip ring moulding
10. Ball bearing(s)
11. Rotor and field winding
12. Woodruffe shaft key (fan and pulley fixing)
13. Bearing assembly parts
14. Drive-end bracket
15. Fan and pulley (fixing nut and spring washer)
16. Alternative connections for surge protection device (where fitted)

Wiring Colour Code:

B – Black
G – Green
Y – Yellow
R – Red

4. Start the engine and run the alternator at approximately 3000 rpm for at least eight minutes. (This will ensure that the system voltage has stabilised). If the charging current is still greater than 10 ampere, continue to run the engine until this figure is reached. The voltmeter should now give a reading of 13,9 to 14,3 volt.

   If, however, the voltmeter reading remains unchanged (at open-circuit battery terminal voltage) or, conversely, increases in an uncontrolled manner, then the control unit is faulty and a replacement unit must be fitted. Component parts are not serviced individually.

FIELD ISOLATING RELAY TYPE 16RA

The purpose of the Alternator Field Relay is to extinguish a no-charge warning light as the alternator voltage rises, and to switch it on should the alternator voltage fail for any reason.

The relay has a pair of normally open contacts, while its low-voltage-sensitive operating winding is connected between the mid-point of one pair of the alternator output diodes and earth. The warning light bulb (12 volt 2,2 watt) is connected in parallel with a resistor (60 ohm) built into the relay, see Fig. 26.

Initially, the alternator field circuit is fed with a reduced current from the battery by way of a field switch and the warning light-resistor combination—the return path from the alternator field winding being to earth through the 4TR regulator. At this stage the warning light is illuminated.

The reduced excitation is sufficient to cause the alternator output voltage to begin building up.

When the voltage at the diode mid-point attains a potential of approximately 3 volt, the relay cuts in. The relay contacts closing short out the warning light-resistor combination and connect the field directly to the battery.

The relay has five terminals, W1, W2, C1, C2 and R—The resistor being connected between the latter two terminals. The complete circuit is shown in Fig. 26.
Electrical adjustments are effected by a cam adjuster for cut-in settings, while drop-off settings are obtained by adjusting the height of the fixed contact.

Setting Data

Cut-in voltage—2,5 to 3,0V
Drop-off voltage -1,5 to 2,0V

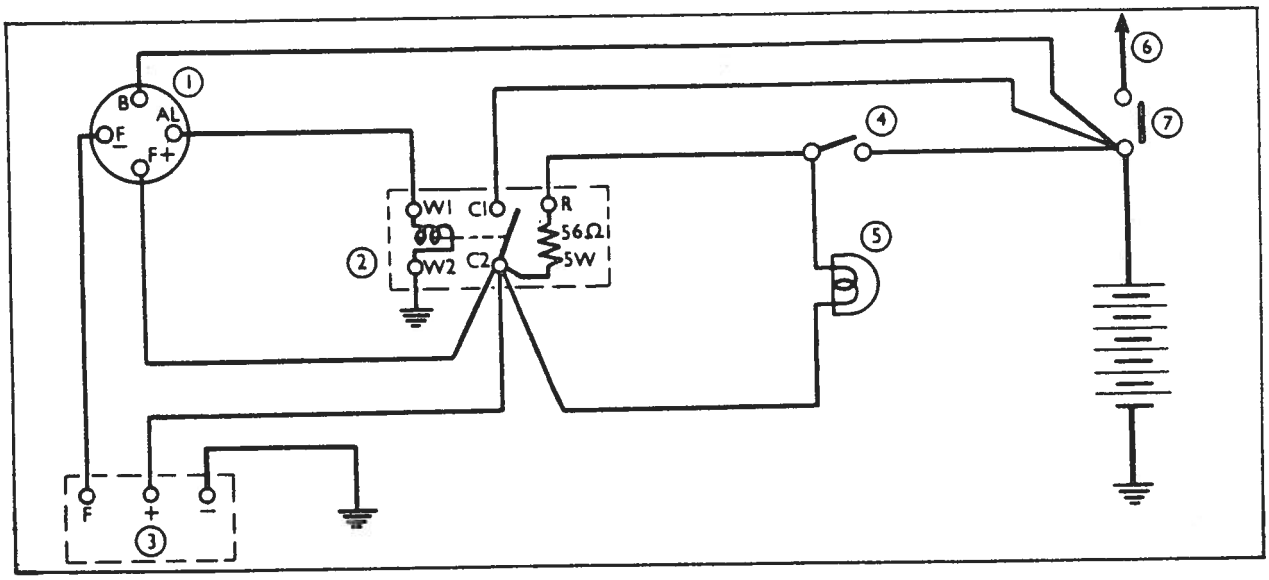


Fig. 26—Typical Circuit Diagram showing Type 16RA Relay

1. Alternator
2. Low Voltage Relay
3. Regulator
4. Field Switch
5. No-charge Warning Lamp
6. To Starter Motor
7. Starter Switch

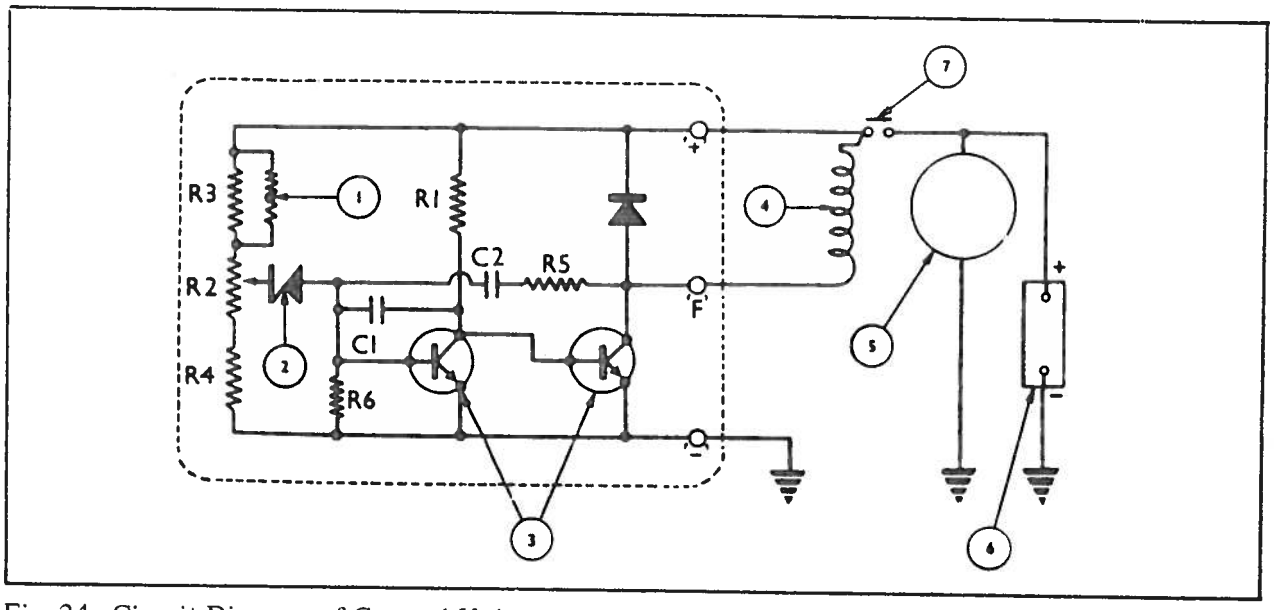


Fig. 24—Circuit Diagram of Control Unit

1. Thermistor
2. Zener Diode
3. Transistors
4. Rotor Field Winding
5. Alternator
6. Battery
7. Field Isolating Device

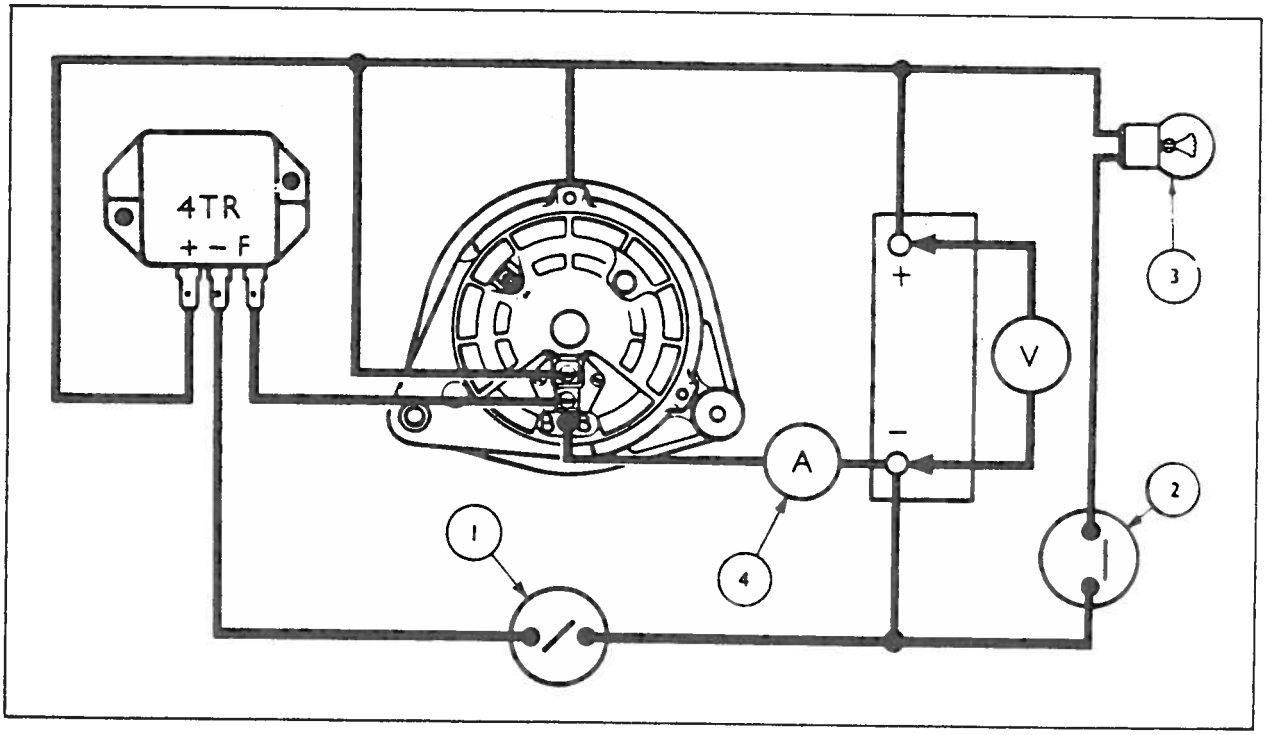


Fig. 25—Control Unit Test Circuit

1. Field Isolating Device
2. Load Circuit Switch
3. Testing Lamp Load
4. Ammeter

TECHNICAL DATA

Nominal dc output at 12 volt	43 ampere
Resistance of field coil at 20°C (68° F)	3,8 ohm ± 5%
Maximum rotor speed	12500 rpm
Stator	3 phase star conencted
Slip-ring brushes	
Length new	15,9 mm (0,625 in)
Replace at	4 mm (0,156 in)
Brush spring loading	2,2 to 4,4 N (227 to 454 gf or 8 to 16 ozf)
Assembly torques	
Maximum permissible tightening torques	
Brushbox fixing screws	1,13 Nm (10 lbf in or 0,1 kgf m)
Diode heat sink fixings	2,8 Nm (25 lbf in or 0,3 kgf m)
"Through" bolts	5,1 to 5,7 Nm (45 to 50 lbf in or 0,5 to 0,6 kgf m)

CONTROL UNIT TYPE 4TR

Description

The effect of the electronic control unit is similar to that of the vibrating type of voltage control unit, but switching of the field circuit is achieved by transistors instead of vibrating contacts, while a Zener diode provides the voltage reference in place of the voltage coil and tension spring system. No cut-out is required since the diodes incorporated in the alternator prevent reverse currents from flowing. No current regulator is required as the inherent self-regulating properties of the alternator limit the output current to a safe value.

A temperature compensation device is fitted. This takes the form of a thermistor connected in parallel with one of the Zener-biasing resistors. The thermistor is a device whose resistance increases as the temperature falls and vice versa. Any alteration in its ohmic value will cause the Zener diode to begin to conduct at a modified value of alternator output voltage, so matching the changes which take place in "on charge" battery terminals voltage due to temperature change. The control unit and the alternator field windings are isolated from the battery when the engine is stationary, by means of the normally-open contacts of a model 16RA relay.

WARNING: THE BATTERY MUST NEVER BE DISCONNECTED WHILE THE ALTERNATOR IS RUNNING. FAILURE TO OBSERVE THIS RULING WILL CAUSE THE CONTROL UNIT TO BE IRREPARABLY DAMAGED.

Care must be taken at all times to ensure that the battery, alternator and control unit are correctly connected. Reversed connections will damage the semiconductor devices employed in the alternator and control unit.

Routine Maintenance

The output control unit does not require any regular maintenance but the moulded cover should be occasionally wiped clean and a check made that the terminal connector is secure.

Checking and Adjusting the Control Unit

A circuit diagram of the control unit is shown in Fig. 24.

IMPORTANT: The following voltage checking and setting procedure must be carried out only:—

(a) providing the alternator and associated wiring circuits have first been tested and found satisfactory; and

(b) in conjunction with a well-charged battery, i.e. with the charging current not exceeding 10 ampere.

Voltage Checking

1. Leave the existing connections to the alternator and control unit undisturbed. Connect a high-quality voltmeter between control unit terminals '+' and '—'. If available, use a voltmeter of the supressed-zero type, reading 15 volt maximum.
2. Unless an ammeter is already fitted, insert one of suitable range in series with the alternator main output cable.
3. Switch on an electrical load of approximately 2 ampere. The test circuit is shown in Fig. 25.

(e) Replace the retaining circlip on eposition the retaining plate and locate in position with the three set-screws/ rivets.

2. If required, place the slip-ring end bearing as follows:–

(a) Immerse the new felt pad in light oil and leave to soak.

(b) Remove the rear housing as previously described.

(c) Position the rear housing on the bed of a press and, using a bar of suitable diameter, carefully press out the bearing complete with old felt pad and washers.

NOTE: Support the rear housing at the area directly below the bearing boss to prevent breakage or distortion of the housing.

(d) Using a pilot bar press the new bearing into its location in the rear housing. Use a suitable plate beneath the press ram so that the bearing face is flush with the housing.

(e) Fit a new plain washer, the new felt seal and a new retaining washer, in the order given.

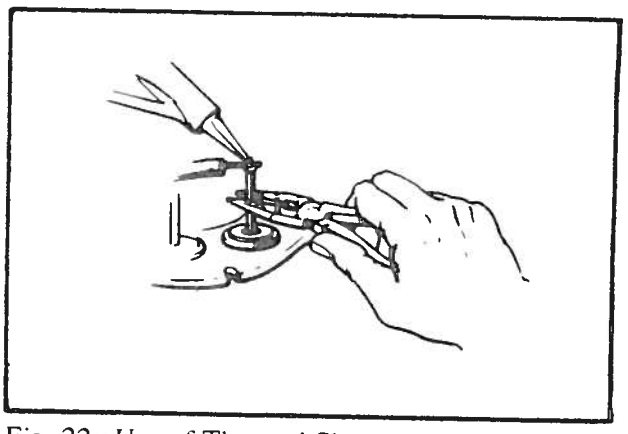


Fig. 22–Use of Thermal Shunt when soldering Diode connections

Re-assembling the Alternator

1. Reassembly of the alternator is the reversal of the dismantling procedure.

2. Take care to align the two end brackets with the lamination pack and then fit the three 'through' bolts which should be tightened evenly.

N.B. If the rotor and drive-end bracket have been separated, the inner journal of the drive-end bearing must be supported by a suitably dimensioned tube for the re-assembly operation. Do not use the drive-end bracket as a support for the bearing whilst fitting the rotor.

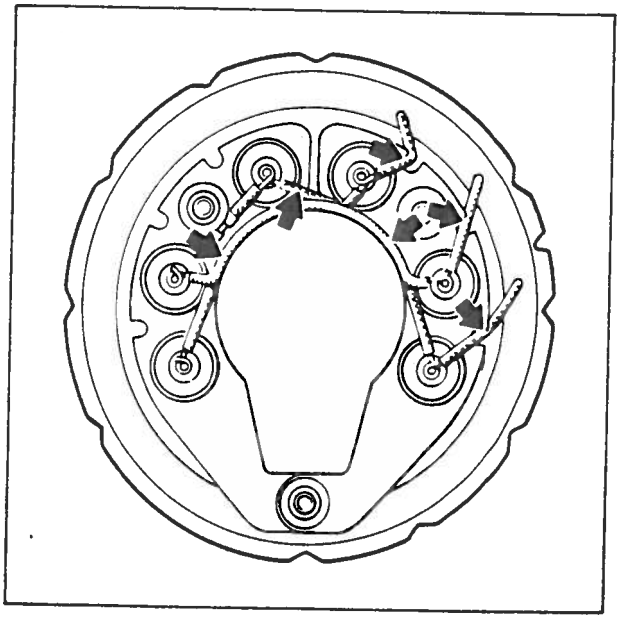


Fig. 23–Heat Sink Cable securing points

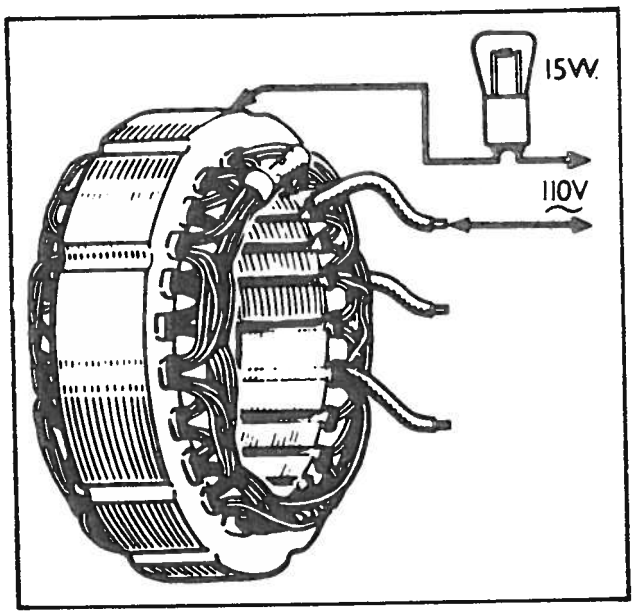


Fig. 20–Stator Winding Insulation Test

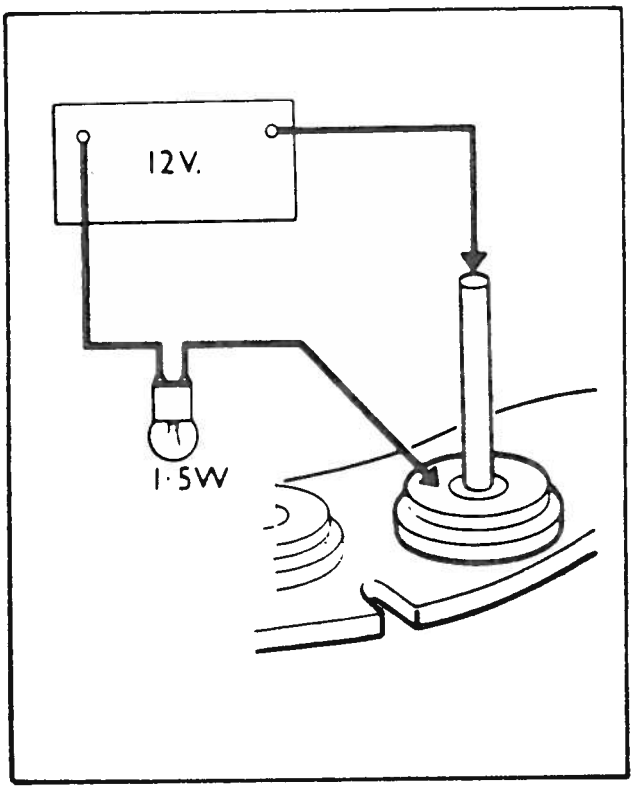


Fig. 21–Simple Diode Test

service purposes. Any accurate measurement of diode resistance requires factory equipment. Since the forward resistance of a diode varies with the voltage applied, no realistic readings can be obtained with battery-powered ohmmeters.

Warning: Ohmmeters of the type incorporating a hand-driven generator must never be used for checking diodes.

Diode heat sink

The alternator heat sink assembly consists of two parts, one of positive polarity and the other negative (see Fig. 34). The positive portion carries three cathode base diodes marked red, and the negative portion three anode base diodes marked black. The diodes are not individually replaceable, but, for service purposes, are supplied already pressed into the appropriate heat sink portion.

Great care must be taken to avoid overheating the diodes or bending the diode pins. The diode pin should be lightly gripped with a pair of suitable long-nosed pliers (which act as a thermal shunt) and soldering must be carried out as quickly as possible. The operation is shown in Fig. 22.

After soldering, the connections must be neatly arranged around the heat sinks, to ensure adequate clearance for the rotor, and be tacked down with a suitable adhesive where indicated in Fig. 23. The stator connections must pass through the appropriate notches at the edge of the heat sink.

Bearings

Bearings which are worn to the extent that they allow excessive side movement of the rotor shaft must be renewed. (Service replacement bearings are pre-packed with grease ready for use).

1. If required, replace the drive end bearing as follows
   - (a) Remove the front housing as previously described.
   - (b) Remove the bearing retaining circlip or the three retaining screws/rivets and bearing retaining plate.
   - (c) The bearing can now be pressed from its location.
   - (d) Press the new bearing into its location, applying pressure to the outer race only.

Rotor

1. Test the rotor winding by connecting either an ohmmeter (Fig. 16) or the appropriate battery supply (Fig. 17) between the slip-rings. The reading of resistance should be 3,8 ohm. If the alternative test has been made, the value of the current should be approximately 3,2 ampere.
2. Test for defective insulation between one of the slip-rings and one of the rotor poles using a 100 volt ac mains supply and a 15-watt test lamp (Fig. 18). If the lamp lights the coil is earthing and a replacement rotor/slip-ring assembly must be fitted.
3. No attempt should be made to machine the rotor poles or to true a distorted shaft.

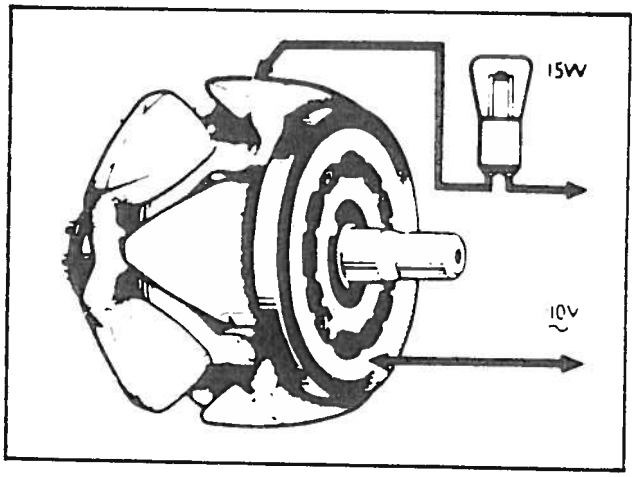


Fig. 18–Insulation Test
Rotor Winding

Stator

1. Unsolder the three stator cables from the heat sink assembly, taking care not to overheat the diodes–(refer to "Heat Sink Replacement"). Check the continuity of the stator windings by first connecting any two of the three stator cables in series with a test lamp of not less than 36 watt and a 12-volt battery as shown in Fig. 19. Repeat the test, replacing one of the two cables by the third cable. Failure of the test lamp to light on either occasion means that part of the stator winding is open-circuit and a replacement stator must be fitted.
2. Test for defective insulation between stator coils and lamination pack with the mains test lamp (see Fig. 20). Connect the test probes between any one of the three cable ends and the lamination pack. If the lamp lights, the stator coils are earthing and a replacement stator must be fitted.
3. Before re-soldering the stator cable ends to the diode pins carry out the following test.

Diodes

Each diode can be checked by connecting it in series with the 1,5-watt test bulb across a 12 volt dc supply and then reversing the connections, (Fig. 21).

Current should flow, and the bulb light, in one direction only. Should the bulb light up in both tests or not light up in either, the diode is defective and the appropriate heat sink assembly must be replaced.

NOTE: The above procedure is adequate for

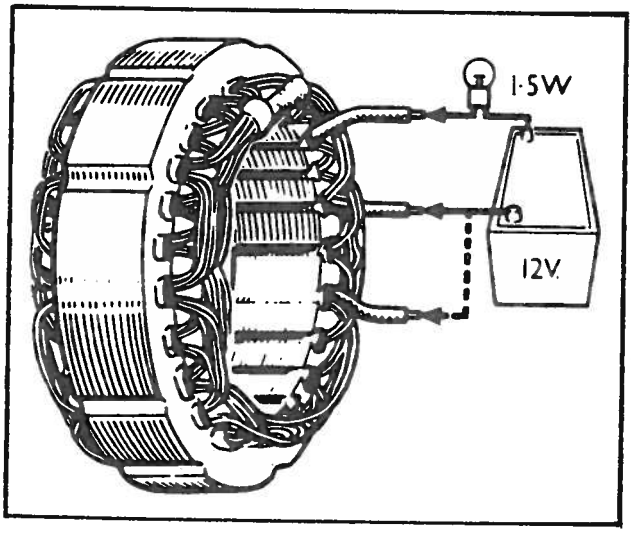


Fig. 19–Stator Winding
Continuity Test

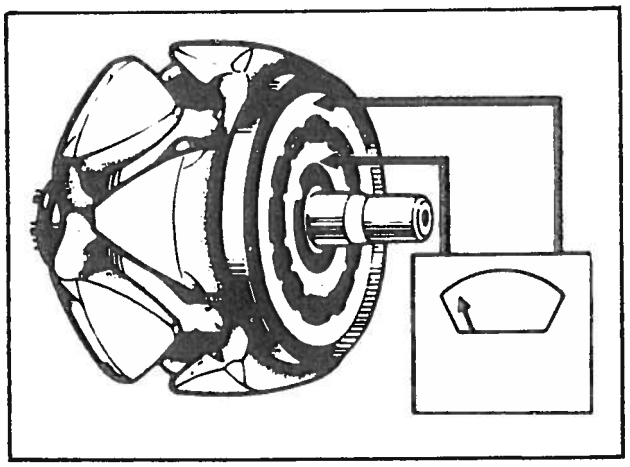


Fig. 16–Measuring Rotor Winding Resistance with Ohmmeter (Alternator dismantled)

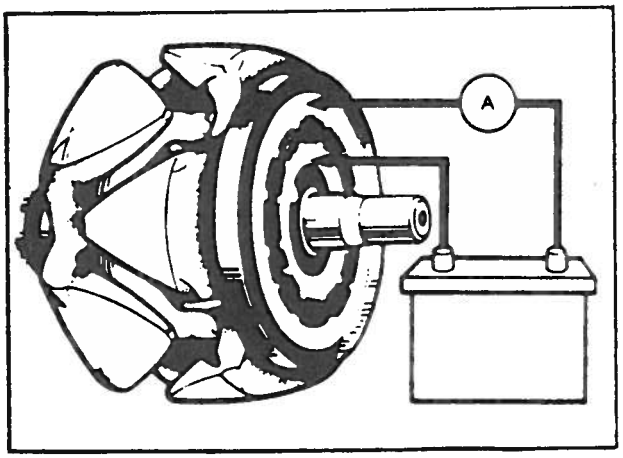


Fig. 17–Measuring Rotor Winding Resistance with Battery and Ammeter (Alternator dismantled)

Brushgear

1. Measure the brush length. A new brush is 15,9 mm (0,625 in) long: a fully worn brush in 4 mm (0,156 in) long and must be renewed at, or approaching, this length. The new brush is supplied complete with brush spring and terminal blade and has merely to be pushed in until the tongue registers. To ensure that the terminal is properly retained, carefully lever up the retaining tongue with a fine screwdriver blade, so that the tongue makes an angle of about 30° with the terminal blade.
2. Check the brush spring pressure using a push type spring gauge. Push each brush in turn back against its spring until the brush face is flush with the housing. The gauge should then indicate 2,2 to 4,4 N (227 to 454 gf or 8 to 16 ozf). Replace the brush assembly which gives a reading appreciably outside these limits where this is not due to the brush movement being impeded for any reason.
3. Check that the brushes move freely in their holders. If at all sluggish, clean the brush sides with a petrol-moistened cloth or, if this fails to effect a cure, lightly polish the brush sides on a smooth file. Remove all traces of brush dust before re-housing the brushes in their holders.

NOTE: The brush which bears on the inner slip-ring is always associated with the positive pole of the electrical system, since the lower linear speed of the inner ring results in reduced mechanical wear and helps to offset the higher rate of electrical wear peculiar to the positive-connected brush.

Slip-rings

The surfaces of the slip-rings should be smooth and uncontaminated by oil or other foreign matter. Clean the surfaces using a petrol-moistened cloth, or if there is any evidence of burning, very fine glass paper. On no account must emery cloth or similar abrasives be used. No attempt should be made to machine the slip-rings, as any eccentricity in the machining may adversely affect the high-speed performance of the alternator. The small current carried by the rotor winding, and the unbroken surface of the slip-rings mean that the likelihood of scored or pitted slip-rings is almost negligible.

7. A low output current reading will indicate either a faulty alternator or poor circuit wiring connections. Check the latter while keeping the alternator connected and running as described above; connect a good-quality voltmeter, or low range if available, between the alternator output terminal and the battery insulated terminal (see Fig. 14) and note the voltmeter reading.
8. Now transfer the meter connections to the alternator frame and battery earth terminal, Fig. 15 and again note the reading.

   If either of these readings exceed 0,5 volt there is high resistance in the charging circuit which must be traced and remedied.

   If, however, these tests show that there is no undue resistance in the charging circuit (although the alternator output is low) proceed to dismantle the alternator as described below.

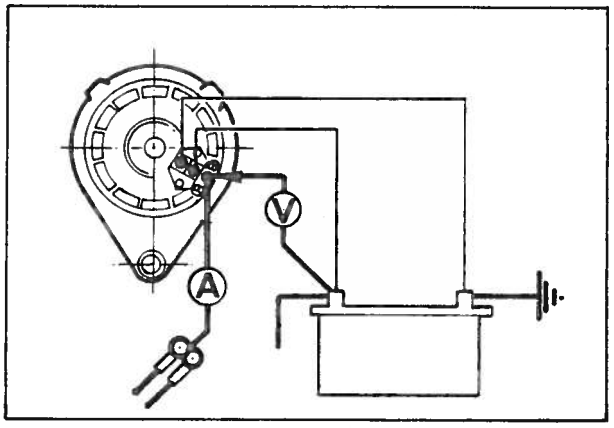


Fig. 14—Charging Circuit Voltage Drop Test (insulated side)

OVERHAULING THE ALTERNATOR

Dismantling

1. ENSURE THAT THE BATTERY EARTH CABLE IS DISCONNECTED, then remove the alternator from the engine.
2. Unscrew and remove the pulley retaining nut and washer and remove the pulley from the rotor shaft with a suitable puller.
3. Mark the relative position of the front and rear housings relative to the lamination pack, unscrew and remove the three through bolts and then lift the front housing and rotor assembly from the stator.

NOTE: The drive and bracket and rotor need not be separated unless the drive end bearing or rotor is to be replaced.

4. In this event the rotor should be removed from the drive end bracket by means of a hand press, the shaft key having first been removed.
5. From the slip-ring end bracket remove the terminal nuts, washers, insulating pieces, brushbox screws and the 2BA hexagonal-headed bolt.
6. Withdraw the stator and heat sink assemblies from the slip-ring end bracket.
7. Close up the retaining tongue at the root of each field terminal blade and withdraw the brush spring and terminal assemblies from the moulded brushbox.

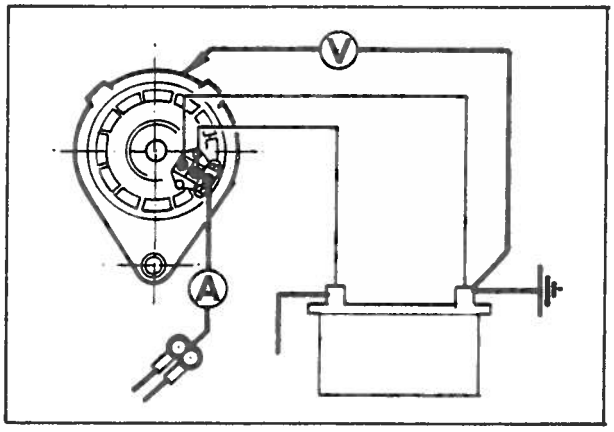


Fig. 15—Charging Circuit Voltage Drop Test (earth side)

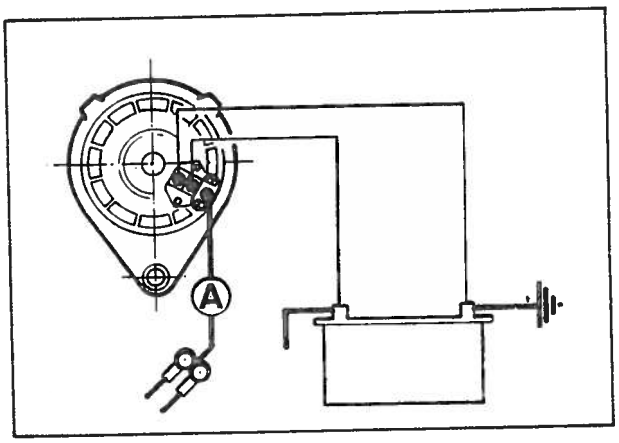


Fig. 13—Alternator Output Test

TESTING THE ALTERNATOR IN POSITION

In the event of a fault developing in the charging circuit, such as:—

(a) The charge Indicator Light remaining on at high engine speeds.

(b) The battery using an excessive amount of water although the charging system appears to be working satisfactorily.

(c) The electrical components (such as light bulbs) having a short service life.

(d) The ammeter showing a discharge or low charging rate.

The following procedure should be adopted to locate the cause of the trouble.

1. Inspect the driving belt for wear and tension.
2. Start the engine and check that battery voltage is being applied to the rotor winding by connecting a voltmeter between the cable ends normally attached to the field terminals. Stop the engine.
3. Disconnect the battery earth cable.
4. Disconnect the cables from the alternator output terminal and connect a good quality moving-coil ammeter of appropriate range between the output terminal and the disconnected cables.
5. Withdraw the cables from the alternator field terminals and, using a suitable pair of auxiliary cables, connect these terminals directly to the battery.

   For this test polarity matching is unimportant.

   Fig. 13 shows the alternator output test circuit.
6. Re-connect the battery earth lead. Start the engine and slowly open the throttle until the alternator speed is approximately 4000 rpm. At this speed the reading on the ammeter should be approximately 40 ampere.

   If a zero reading results, stop the engine and disconnect the cables from the field terminals. Withdraw the two brushbox moulding retaining screws and remove the brushgear for examination as described later in this chapter.

   Fit new brush and spring assemblies if necessary and re-test the alternator output. If the zero reading persists, the alternator must be removed from the engine and dismantled for detailed inspection.

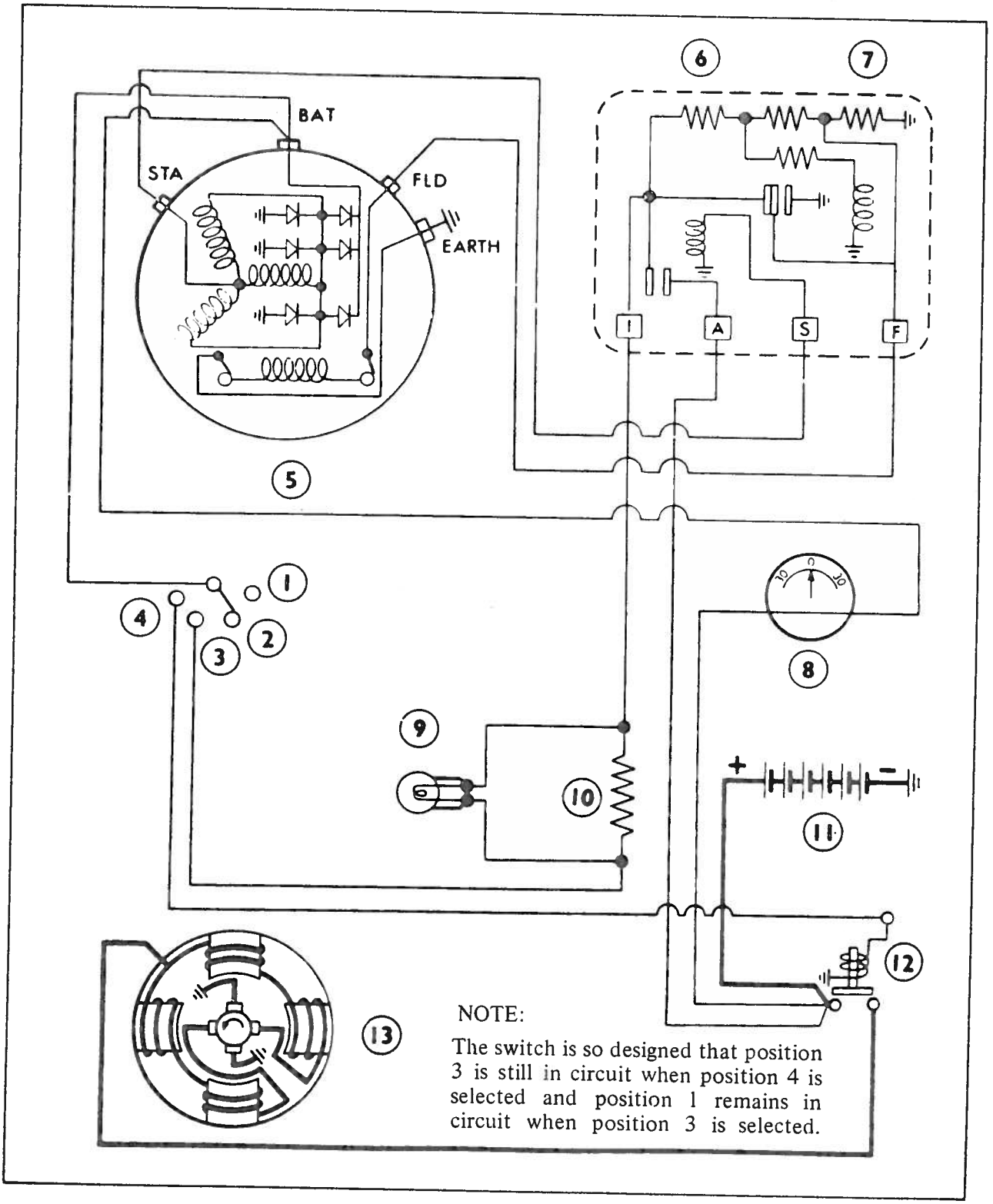


Fig. 12–Typical Wiring Diagram–Alternator

Isolating Switch
1. Auxiliary Circuits
2. Off
3. On
4. Start
5. Alternator
6. Regulator–Field Relay
7. Regulator–Voltage Limiter
8. Ammeter
9. Charge Indicator
10. Harness Resistor (15Ω)
11. Battery
12. Starter Solenoid Switch
13. Starter Motor

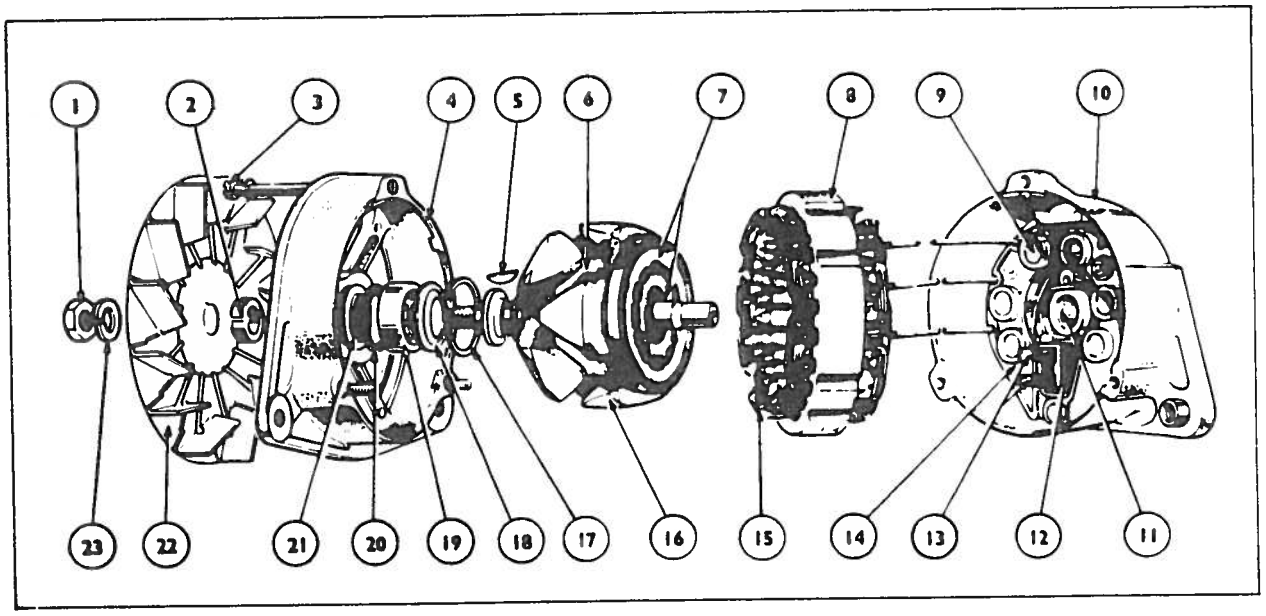


Fig. 10 – The 11 AC Alternator Exploded

1. Shaft Nut
2. Key
3. Through Bolt
4. Drive End Bracket
5. Key
6. Rotor (Field) Winding
7. Slip Rings
8. Stator Laminations
9. Diodes
10. Slip-ring end Bracket
11. Needle Roller Bearing
12. Brush Box Moulding
13. Brushes
14. Diode Heat Sink
15. Stator Winding
16. Rotor
17. Circlip
18. Bearing Retaining Plate
19. Ball Bearing
20. 'O' Ring Oil Seal
21. 'O' Ring Retaining washer
22. Fan
23. Spring Washer

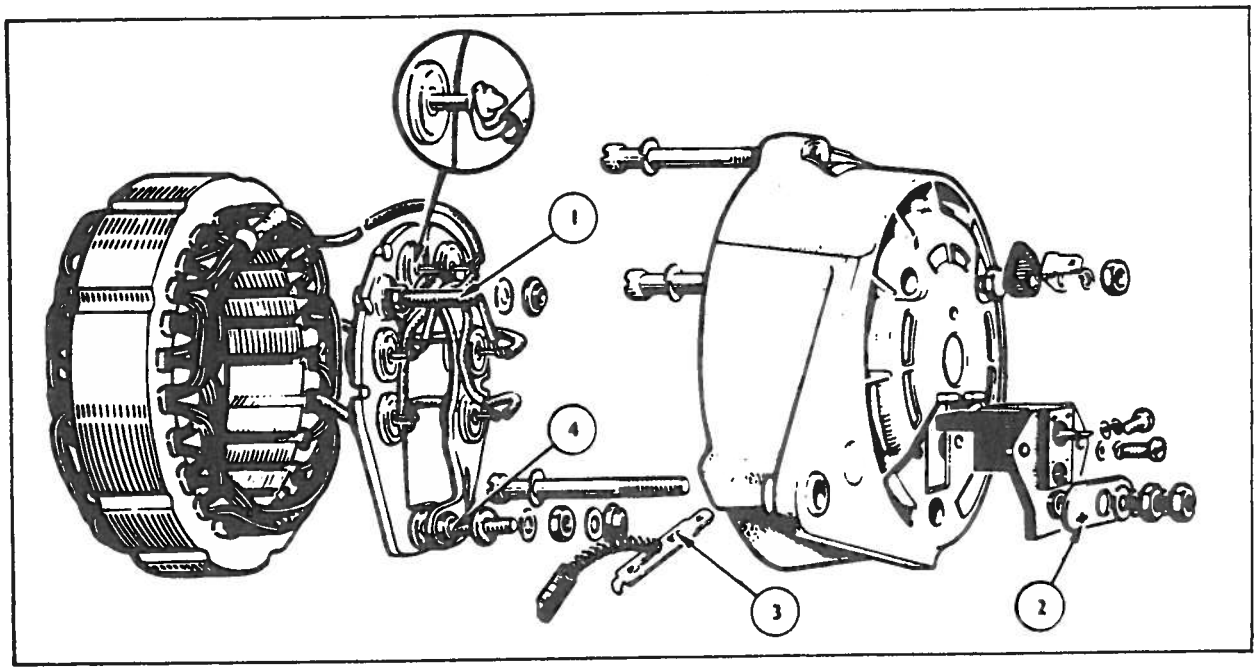


Fig. 11–Slip-Ring End, showing Heat Sink withdrawn

1. Warning Light Terminal 'AL'
2. Output Terminal Plastic Strip
3. Terminal Blade Retaining Tongue
4. Output Terminal

THE LUCAS 11AC ALTERNATOR 43 AMPERE

GENERAL

The alternator (Fig. 10) is belt-driven from the engine and has a rated output of 43 ampere. Power is produced in the form of alternating current which is rectified to direct current by six diodes situated within the alternator casing. (Fig. 11)

The A.C. Charging System (Fig. 12) is a negative earth system and consists of an alternator, a regulator, a charge indicator, an ammeter (if fitted), a battery and associated wiring.

The regulator consists of:–

(a) The Field Relay, (type 16RA) which connects the battery and alternator output to the alternator field circuit when the engine is running, and

(b) The Voltage Limiter, (type 4TR) which is a temperature compensated double contact unit. The upper contacts operate at low engine speeds and high loads and the lower contacts operate at high engine speeds and light loads.

The charge indicator circuit consists of:–

(a) A charge indicator light shunted by a 15 ohm resistor wire located in the harness. On closing the ignition switch, battery current flows through the lamp and the 15 ohm resistor and through the voltage limiter to the field coil. This small current is enough to allow the alternator to start generating. The lamp is shunted by the 15 ohm resistor to supply adequate starting field current.

(b) An ammeter (if fitted). This is connected between the positive terminal of the battery, and the power side of the isolation switch.

GENERAL PRECAUTIONS

(a) NEVER disconnect battery cables from the battery, charging or control circuit, while the engine is running.

(b) NEVER "flash" any charging or control cables to earth.

(c) NEVER use a high voltage resistance tester ('Megger') for testing alternator circuits.

(d) ALWAYS connect a slave battery in parallel, i.e. positive to positive, negative to negative.

(e) ALWAYS disconnect the battery earth lead before carrying out any work on the alternator. Note the alternator output lead is live.

(f) ALWAYS disconnect the battery leads before connecting a battery charger.

(g) ALWAYS disconnect the battery and alternator leads before arc welding on any part of the vehicle.

(h) NEVER run an alternator with an open circuit with the rotor fields energised.

(i) NEVER use high voltages to test diodes (use a 12 volt maximum).

(j) NEVER use a lever on the stator or rear housing when adjusting the fan belt.

(k) ALWAYS note the polarity of connections to battery, alternator and voltage regulator. Incorrect connections may result in irreparable damage to semi-conductor devices.

(l) ALWAYS check battery polarity before installing, as it may be reverse charged (Use a voltmeter for the check.)

(m) NEVER attempt to polarise or motor an alternator.

ROUTINE MAINTENANCE

Cleaning

Wipe away any dirt or oil which may have collected around the slip-ring end cover ventilating apertures.

Belt Adjustment

Occasionally inspect the driving belt, for wear and tension. It should be possible to move the belt laterally 13 mm (0,5 in) at a point midway along its longest run between pulleys. See that the alternator is properly aligned with respect to the drive, otherwise the rotor bearings will be unduly loaded.

Lubrication

The bearings are packed with grease during assembly and do not require periodic attention.

Terminal Connections

Ensure that all terminal connections are tight.

Cut-in Voltage Adjustment

1. Keep the voltmeter connected as described in the previous section. Turn the cut-out relay adjustment screw (clockwise to raise the setting or anti-clockwise to lower it) until the current setting is obtained.
2. Recheck the setting by increasing the engine speed slowly from zero.

Drop-off Adjustment

1. Remove the cable from the 'A' terminal.
2. Connect the voltmeter between the 'A' terminal and earth.
3. Start the engine and run up to charging speed.
4. Slowly decelerate and observe the voltmeter pointer. Opening of the contacts indicated by the voltmeter pointer dropping to zero should occur between the limits 8,5 to 11,0 volt.

   If the voltmeter reading is within the limits, stop the engine and restore the original connections. If the drop-off occurs outside these limits, the regulator must be changed.

Technical Data

Resistance Values at 20°C (68°F)	
Carbon Resistors	60-75 ohm
Wire Wound Resistors	55-65 ohm
Shunt Winding Resistors	56-60 ohm

(Check between terminals 'D' and 'E')

The Shunt (or voltage) winding is connected directly across the generator armature (between terminal 'D' and earth). The series winding which carries generator output (battery charge and any load current), is wound on the bobbin in the same direction as the 'Shunt' winding.

Compensation is by means of the series winding which assists the shunt winding to make and break the regulator contacts.

The cut-out is an automatic switch which disconnects the generator from the battery when the generator terminal voltage is lower than that of the battery.

Testing and Adjusting the Regulator

1. Disconnect the cable from the 'A' terminal and ensure that the end of the cable does not contact any earthed part of the equipment.
2. Start and run the engine so that the generator is driven at 3000 rpm, observe the voltmeter reading. This should lie between the following limits of 16,0 to 16,5 volt.
3. Remove the linked rubber blanks from the control box cover, and use test prods to measure the voltage between the exposed head of one of the adjustment screws and a good earth Fig. 9.
4. Restart the engine and run the generator at 3000 rpm. Turn the voltage regulator adjusting screw (clockwise to raise the setting or anti-clockwise to lower it), until the correct setting is obtained. Check the setting by reducing the generator speed (engine at tickover) and then raise again to 3000 rpm.
5. Connect the cable to the 'A' terminal and replace the rubber blanks.

Checking Cut-out Relay Electrical Setting

1. Connect a 0-20V moving coil voltmeter between the terminals 'D' and 'E'. Remove the rubber blanks and use test prods to measure the voltage between the exposed head of one of the adjustment screws and a good earth. Switch on lights (where fitted) to load the charging system, this will give a more recognisable flick back of the voltmeter pointer at the instant of contact closure.
2. Start the engine and while slowly increasing its speed observe the voltmeter pointer. The flick back should occur within the limits of 12,75 to 13,25 volt. If not an adjustment must be made.

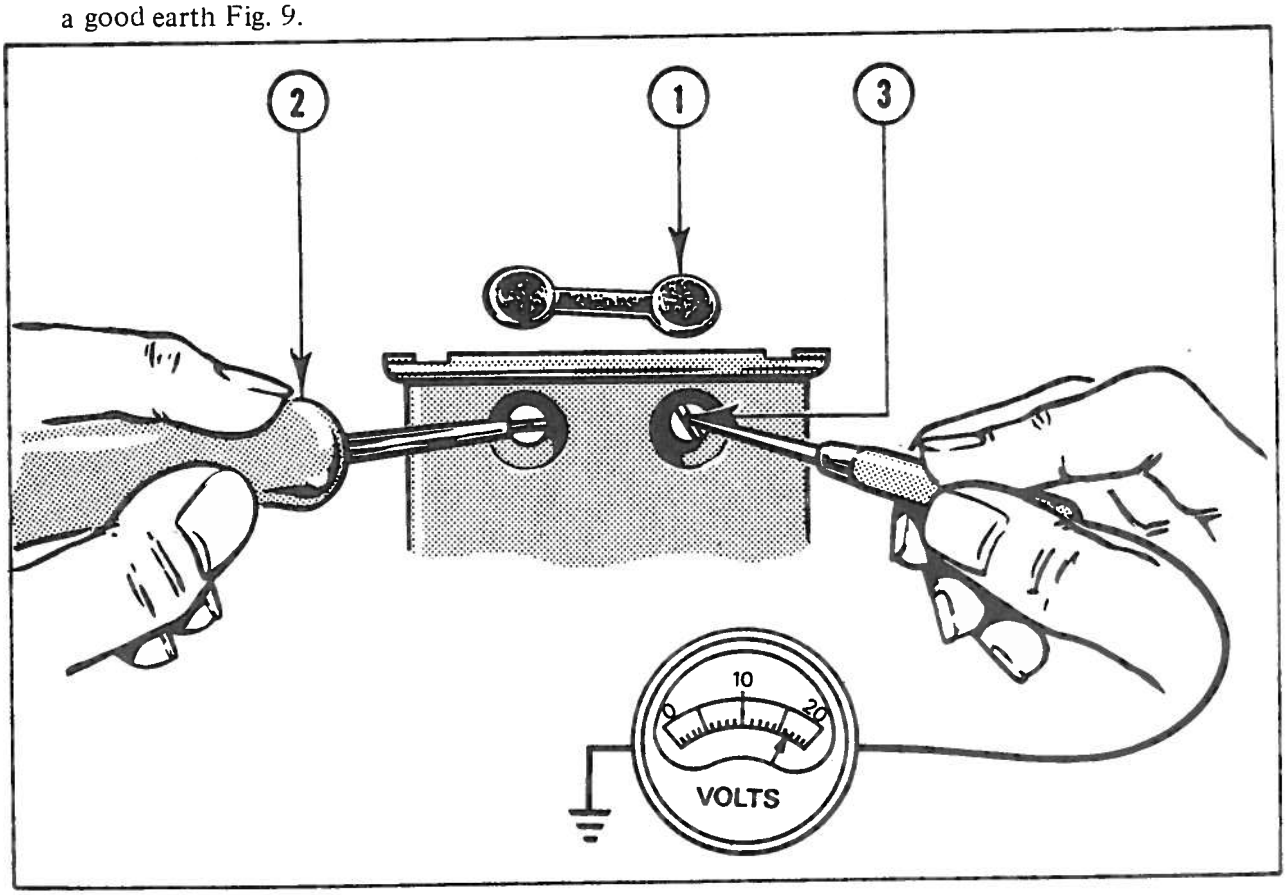


Fig. 9 Use of test prods to measure voltages

the end bracket taking care not to trap the brush connector pigtails. See that the dowel on the end bracket locates with the groove in the yoke.

5. Refit the two through bolts, pulley spacer and shaft key.
6. After reassembly lubricate the commutator end bearing.

PERFORMANCE DATA

Cutting-in Speed	1100 rpm (max.) at 13,0 generator volt
Max. Output	10,5 ampere at 1700 rpm (max.) with 13,5 generator volt and a resistance load of 1,23 ohm
Field Resistance	6,0 ohm

VOLTAGE CONTROL REGULATOR & CUT-OUT

The two 'bobbin' regulator incorporates a combined cut-out and voltage regulator. Normally the regulator requires very little attention in service.

Should, however, it be suspected that it is not functioning correctly, tests should be made to ensure that the rest of the electrical circuits are in good condition and are not affecting the operation of the regulator.

Preliminary Checks

Important points which can give a false indication of a regulator fault are given below, and should be carefully checked before attempting to effect any replacements.

1. Fan Belt

   Make certain that the generator support brackets are securely tightened in position. Check the fan belt and ensure that it is adjusted correctly without the slightest suspicion of belt 'slip'. A slipping belt may cause an erratic or low charging rate. Ensure that the fan belt is correctly aligned and that the pulleys are not damaged.

2. Battery

   Check the battery as previously outlined.

   Clean off any corrosion from the battery lugs and cable ends and make certain that the top of the battery is dry.

   A sulphated battery or corroded lugs will cause a low output even though the open circuit setting of the regulator may be correct. Both these conditions will probably be indicated by unsatisfactory starter motor operation.

   If a battery has a short-circuited cell, or the top of the battery has become soaked with acid, or is in a poor condition due to abuse or prolonged service, it will cause a high generator output.

   Check the earth connections from the battery and from the regulator, to ensure that they are tight and in good condition, as a poor earth will cause a rise in voltage.

3. Generator and Connections

   Check that the generator is functioning satisfactorily and ensure that the leads D and F are not crossed either at the regulator or generator. If the leads are crossed, the regulator points will have 'welded together' the moment the engine was started. Make sure that the leads are not broken or damaged and that the connections are tight.

   Check the generator by disconnecting the cables from the two terminals on the commutator end bracket and using an ammeter, link the larger terminal 'D' to the small terminal 'F'. Connect a voltmeter between terminal 'D' and earth.

   Run the engine, slowly increasing the speed until the voltmeter reads battery volts. Ammeter should read 2-3 ampere. If this is satisfactory test the regulator.

   The voltage regulator is a sealed unit. If a fault is diagnosed which cannot be corrected by simple adjustment (See 'Testing and adjusting the regulator') the voltage regulator must be renewed.

Operation of Regulator

The generator, which is a shunt wound machine, produces a variable output depending upon its speed and the magnetic field strength of the generator field coils.

The regulator automatically controls the generator output to safe limits by varying the strength of the field circuit.

This is effected by the action of opening and closing a pair of contacts to insert a resistance in the field circuit.

The voltage regulator has two regulating windings (one shunt and one series) wound on the voltage regulator bobbin.

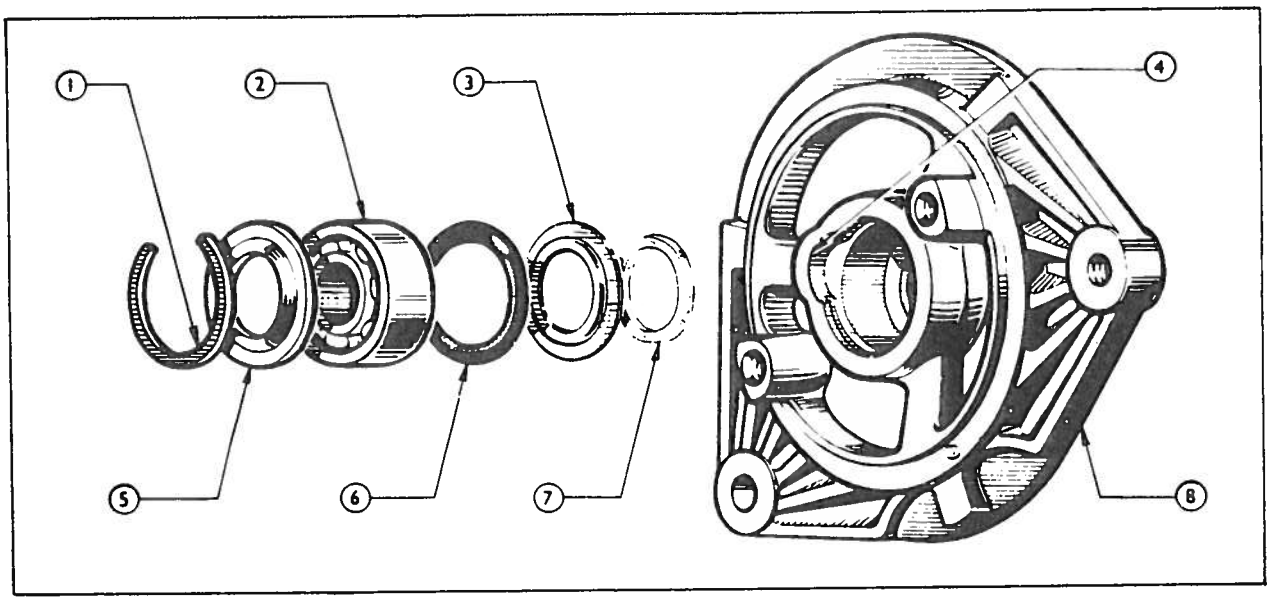


Fig. 8—Exploded view of Circlip Retained Bearing

1. Circlip Retainer
2. Front Bearing
3. Felt Retaining Washer
4. Circlip Extractor Notch
5. Bearing Retainer Plate
6. Rubber 'O' Ring
7. Felt Ring
8. Drive End Bracket

4. Thoroughly clean the bearing housing and then clean and re-locate the felt ring, retaining plate and the rubber rings in the housing.
5. Pack the new bearing with high melting point grease and then press it home using a driver of sufficient diameter to apply the bearing outer race.
6. Locate the bearing retainer plate with its concave side towards the bearing and then locate the retaining circlip in its housing groove.

To Reassemble the Generator

1. Replace the shaft collar retaining cup and then fit the drive end bracket to the armature shaft. The inner journal of the bearing must be supported by a tube approximately 10 cm (4 in) long, 3,18 mm (0,125 in) thick and with an internal diameter of 15,9 mm (0,625 in).

   Do not use the drive end brackets as a support for the bearing whilst fitting the armature.
2. Fit the yoke to the drive end bracket.
3. Push the brushes up into the brush boxes and secure them in that position by positioning each brush spring at the side of its brush. (see Fig. 2)
4. Fit the commutator end bracket to within 13 mm (0,5 in) of the yoke. Release the brushes so that they partly engage with the commutator. Then complete the fitting of

immersed in thin engine oil. This is a porous bronze type bush and the pre-soaking will allow the bush pores to fill with lubricant.

1. Remove the old bearing bush from the end bracket. This is best done by screwing a 15,875 mm (0,625 in) tap a few turns into the bush and then extracting it by pulling on a suitable bolt screwed into the tapped thread.
2. Withdraw and clean the lubricating felt pad and the felt retainer and replace them in the housing.
3. Using Tool No. CP.9507, press the new bush into its location so that the end of the bush in flush with the bottom of the chamber.

NOTE: This bush is supplied finished size and should not be opened out by reaming or its porosity will be impaired.

Renewing Drive End Bracket Bearing – Plate Retained Bearing

Plate Retained Bearing

1. File down or drill out and remove the rivets securing the bearing retainer plate and remove the plate.
2. Press the bearing from its housing.
3. Remove the corrugated washer and felt ring located behind the bearing.
4. Thoroughly clean the bearing housing and then clean and re-locate the felt ring and corrugated washer in the housing.
5. Pack the new bearing to the maximum that it can contain with high-melting-point grease. Locate the bearing in the housing and press it home, using a driver of sufficient diameter to apply the thrust to the bearing outer race.
6. Locate the bearing retaining plate over the bearing and securely rivet in position.

Renewing Drive End Bracket Bearing – Circlip Retained Bearing (see Fig. 8)

1. Remove the circlip retainer from its locating groove in the drive end bracket boss.
2. Remove the dished bearing retaining plate and then press the bearing from the housing.
3. Remove the rubber pressure ring, felt retaining plate and the felt ring located behind the bearing.

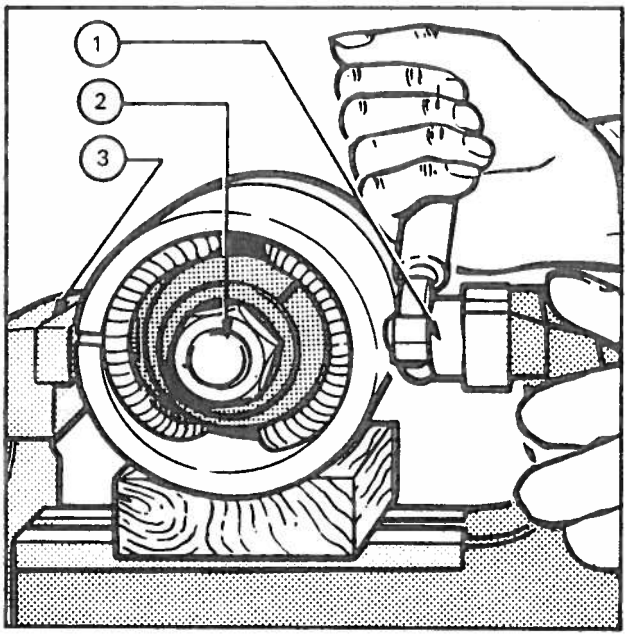


Fig. 7 Removing and replacing the pole shoes

1. Pole piece screwdriver
2. Pole expander
3. Vice

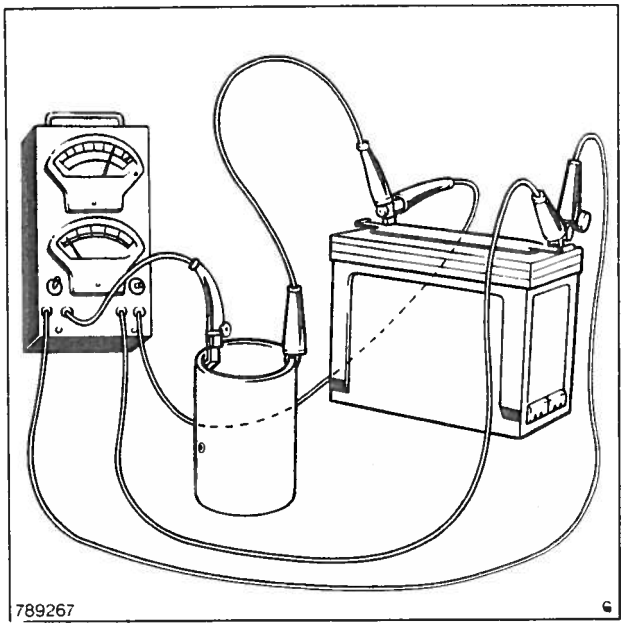


Fig. 5—Testing the Generator Field Coils

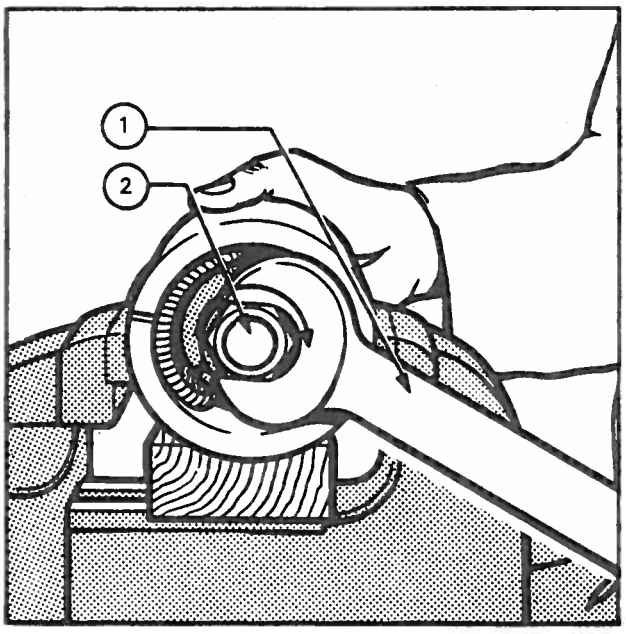


Fig. 6—Removing the Generator Field Coils

1. Turn to open expander
2. Pole expander

To Renew the Field Coils

1. Drill out the rivet securing the field coil terminal assembly to the yoke.
2. Remove the insulation strip which is provided to prevent the junction of the field coils from contacting the yoke.
3. Mark the yoke and pole shoes so that the latter can be refitted in their original positions.
4. Locate the pole piece expander Tool No. CP.9509 inside the yoke and securely tighten the end nut—see Fig. 6.
5. Mount the yoke and pole piece screwdriver in a vice, as shown in Fig. 7, the pole piece screws can then be slackened off and finally removed.
6. Remove the pole piece expander and withdraw the pole pieces and field coils from the generator yoke.
7. Place the new field coils over the pole pieces and position them in the generator yoke. The pole pieces must be refitted in the same position from which they were removed and the field coil wires must point towards the apertures in the yoke and be on the same side at the terminal. Take care not to trap the wires between the pole pieces and the yoke.
8. Replace the pole piece screws, tightening them up to retain the field coils in position.
9. Insert the pole piece expander and open it up to its fullest extent, tightening the pole piece screws as much as possible.
10. Mount the yoke and pole piece screwdriver in a vice, as shown in Fig. 7, and tighten the screws fully.
11. Remove the pole piece expander.
12. Replace the insulator strip between the field coil connection and the yoke.

NOTE: It may be necessary to provide residual magnetism in the field coils after the generator has been replaced, by flicking the cut-out points together with the generator connected and with the fan belt disconnected.

To Renew the Commutator End Bracket Bush

If the bush is worn to such an extent that slight movement of the armature shaft is possible, the bush should be renewed.

NOTE: Before fitting the new bush it should be allowed to stand for about 24 hours

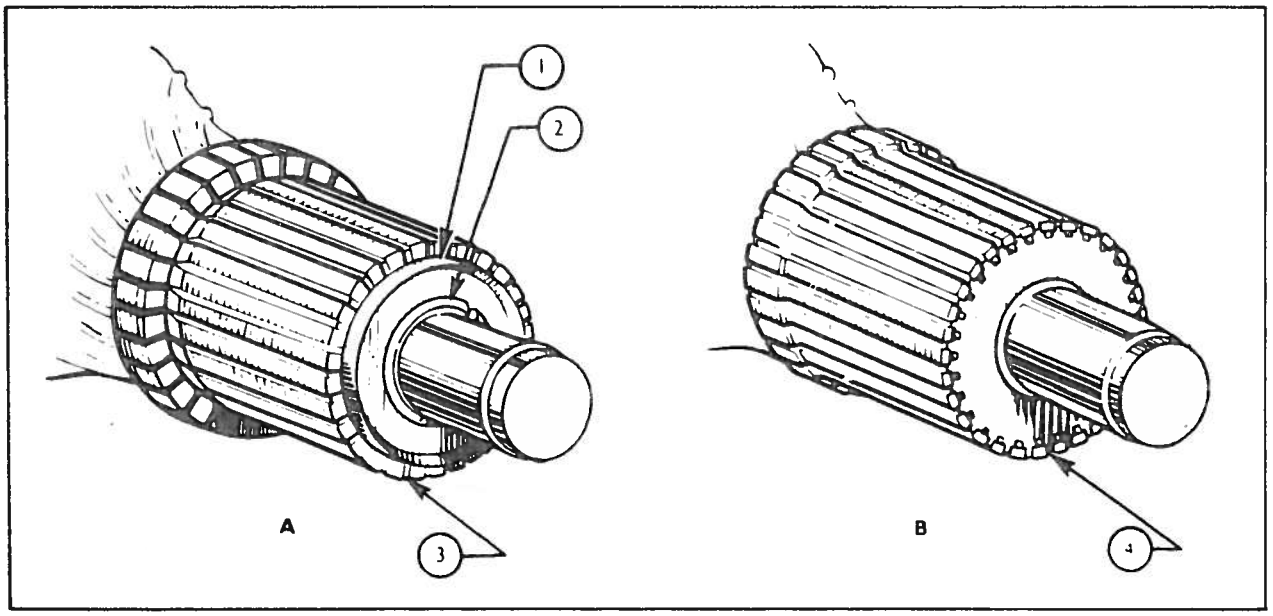


Fig. 3—The Commutator

A. Fabricated Commutator
1. Insulating Cone
2. Metal Roll-over
3. Slot Depth 0,79 mm (0,031 in) max.

B. Moulded Commutator
4. Slot Depth 0,51 mm–0,89 mm (0,020 in–0,035 in)

means of an ohm meter connected between the field terminal and the yoke.

If an ohm meter is not available connect a 12 volt battery between the terminal ends of the field coils, i.e. between the 'F' terminal and the generator casing and insert an ammeter in series (see Fig. 5). Observe the current reading. Connect a suitable voltmeter also between the generator 'F' terminal and the casing and observe the value of the applied voltage.

The field coil resistance can be calculated from Ohm's Law, viz:–

$$R = \frac{E}{I}$$

where R=the field coil resistance in ohms.
E=the applied voltage.
I=the current reading on the ammeter.

The correct field coil resistance at 20°C. (68°F) is 6,0 ohm i.e. the ammeter reading should be approximately 2 ampere. If the current reading is much more than 2 ampere, it is an indication that the insulation of one of the field coils has broken down.

Zero ammeter reading indicates an open circuit in the field winding.

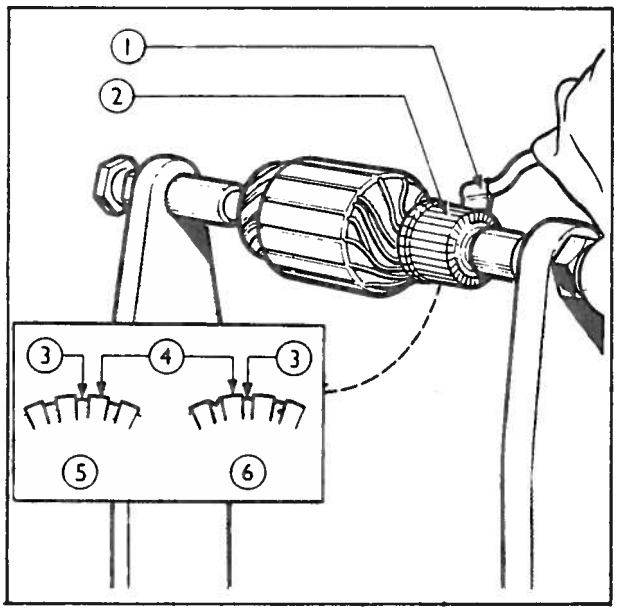


Fig. 4—Undercutting the Commutator segments

1. Hand Tool
2. Commutator
3. Mica
4. Segments
5. Correct
6. Wrong

2. Unscrew and withdraw the two through bolts.
3. Withdraw the commutator end bracket from the yoke.
4. Lift the driving end bracket and armature assembly from the yoke. Take care not to lose the fibre thrust washer(s) (when fitted) from the commutator end of the shaft.

NOTE: The driving end bracket, which on removal from the yoke has withdrawn with it the armature and armature shaft ball-bearing, need not be separated from the shaft unless the bearing is suspect and requires examination, or the armature is to be replaced: in this event the armature should be removed from the end bracket by means of a hand press, having first removed the shaft key. Remove the shaft collar retaining cup.

Checking the Brush Gear

(with the yoke removed)

1. Lift the brushes up into the brush boxes and secure them in that position by positioning the springs at the sides of the brushes–see Fig. 2.
2. Fit the commutator end bracket over the commutator and release the brushes.
3. Hold back each of the brush springs and move the brushes by pulling gently on their flexible connectors. If the movement is sluggish, remove the brushes from their holders and ease the sides by lightly polishing on a smooth file. Always refit brushes in their original positions. If the brushes are badly worn, new brushes must be fitted and bedded to the commutator. The minimum permissible length of brush is 7 mm (0,28 in).

   Test the brush springs pressures using a spring balance held radially to the commutator. With a commutator diameter of 37,6 to 37,73 mm (1,480 to 1,485 in) these pressures should be 850 gram (30 oz), maximum when exerted on a new brush and 368 gram (13 oz) minimum, on a brush worn to 7 mm (0,28 in). Fit new springs if the tension is low.

The Commutator

A commutator in good condition will be smooth and free from pits or burned spots.

Whilst this generator was designed to accommodate a commutator of moulded construction, production also includes machines having commutators of the fabricated type. Moulded commutators can be recognised by the exposed end being quite smooth unlike that of fabricated commutators from which a metal roll-over and an insulating cone protrude–see Fig. 3.

A moulded commutator can be re-skimmed during service, but care must be exercised to ensure that the finished diameter is not less than 36,3 mm (1,430 in).

The week and year of manufacture are stamped on the armature bearing collar, e.g. 26 – 72 indicates the 26 week 1972.

The process of re-skimming consists of rough turning (if necessary) and diamond turning. Whether or not rough turning is carried out depends upon the severity and unevenness of wear which has taken place. If a moulded commutator cannot be completely cleaned up without going below the specified diameter, the armature should be replaced. A moulded commutator requires no undercutting in service the production undercut being of sufficient depth to obviate any further need for this. The insulation slots should, however, be kept clear of copper and carbon residue.

To remedy a worn fabricated commutator, undercut the insulators between the segments to a depth of 0,8 mm (0,031 in) see Fig. 4, then take a light skim with a very sharp (preferably diamond-tipped) tool. If a non-diamond-tipped tool is used for machining, the commutator should afterwards be lightly polished with a very fine glass-paper–NEVER USE EMERY CLOTH.

Armature

Indication of an open-circuited armature winding will be given by burnt commutator segments. If armature testing facilities are not available, an armature can be checked by substituiton. To separate the armature shaft from the drive end bracket, press the shaft out of the drive end bracket bearing. When fitting the new armature, support the inner journal of the bearing using a mild steel tube of suitable diameter, whilst pressing the armature shaft firmly home. See also 'To Reassemble'.

Field Coils

Measure the resistance of the field coils, without removing them from the generator yoke, by

3. Pull off the connectors from the terminal blades of the generator and connect the two blades with a short length of wire.
4. Start the engine and set to run at normal idling speed.
5. Clip the positive lead of a moving coil voltmeter, calibrated 0–20 volt, to one generator terminal and the negative lead to a good earthing point on the yoke.
6. Gradually increase the engine speed, when the voltmeter reading should rise rapidly without fluctuation. Do not allow the voltmeter reading to reach 20 volt and do not race the engine in an attempt to increase the voltage. It is sufficient to run the generator up to a speed of 1000 rpm. If the voltage does not rise rapidly and without fluctuation the unit must be dismantled for internal examination.

Motoring Test

If the output reading is incorrect, but does not indicate the cause of the trouble, remove the fan belt by slackening the generator mounting bolts and moving the generator in towards the engine. Connect a 0–30A ammeter between the joined terminals of the generator and the positive battery post.

The generator should now motor and the current consumption should be 4 to 6 ampere.

NOTES: A high reading on the ammeter is an indication of tight generator bearings.

An excessively high reading will indicate a short circuit.

A low reading is a general indication of bad commutation.

Dead Segment Test

Slacken the generator mounting bolts and remove the fan belt.

Connect together the 'D' and 'F' terminals on the generator and connect a 0 to 50A ammeter between the joined terminals and the 'live' battery post.

Rotate the generator pulley very slowly against the pull of the magnets. The reading should not vary more than 5 ampere.

NOTE: If this condition is not fulfilled, examine the commutator for dirt, high micas, etc., clean if necessary and re-test. If the reading on the meter still varies, the armature windings are probably faulty. If the reading suddenly rises, it indicates a short circuit on a commutator segment and if it falls, a dead or open circuit on one or more segments may be suspected and the faulty segments will now be opposite one brush of the commutator and will probably show evidence of arcing.

If the brushes are worn or damaged, they must be renewed.

OVERHAULING THE GENERATOR

To Dismantle

1. Secure the pulley and unscrew the pulley nut and spring washer. If the pulley is tight on the shaft, it may be removed using the universal pulley puller (Tool No. CP.6041). Detach the key and spacer.

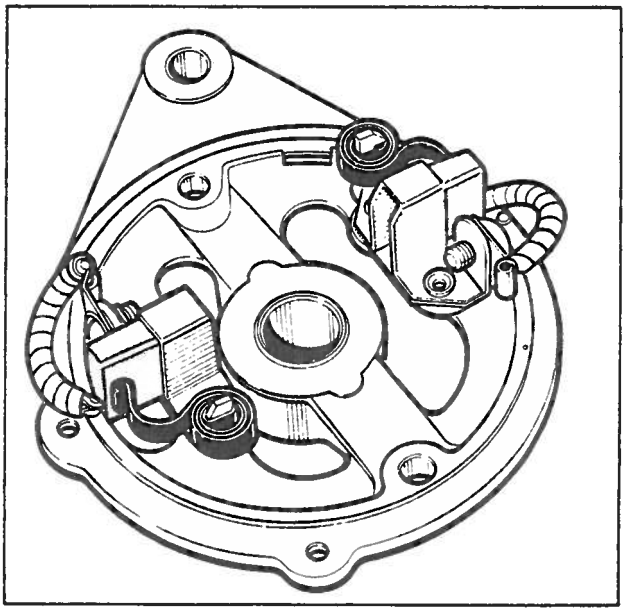


Fig. 2 Brushes held in the raised position

ROUTINE MAINTENANCE

Lubrication

Every 200 running hours remove the neoprene plug (if fitted) and inject a few drops of S.A.E. 30 engine oil into the hole marked 'OIL' at the end of the generator housing. Replace the plug.

Belt Adjustment

After the first 15 running hours and subsequently every 200 running hours, adjust the fan belt tension to give 13 mm (0,5 in) total movement at the slackest part of the belt. Check also that the belt and pulleys are correctly aligned by placing a straight edge along the front face of the generator pulley and measure the distance between the straight edge and the forward edge of the fan belt at points adjacent to all three pulleys (generator, water pump and crankshaft). If the difference between the measurements taken adjacent to the generator and that adjacent to either of the other two pulleys exceeds 1,6 mm (0,06 in) correct this mis-alignment by slackening off the generator mounting bracket bolts and adjusting the position within the tolerances of the bolt holes.

Inspect the Brush Gear

Every 1000 running hours, or once a year, the generator should be removed from the engine and the brush gear serviced as outlined later in this chapter.

TESTING THE GENERATOR

In the event of a fault in the charging circuit, adopt the following procedure to locate the cause of trouble.

Output Test

1. Inspect the driving belt and adjust if necessary.
2. Check the connections on the commutator end bracket. The larger connector carries the main generator output, the smaller connector the field current.

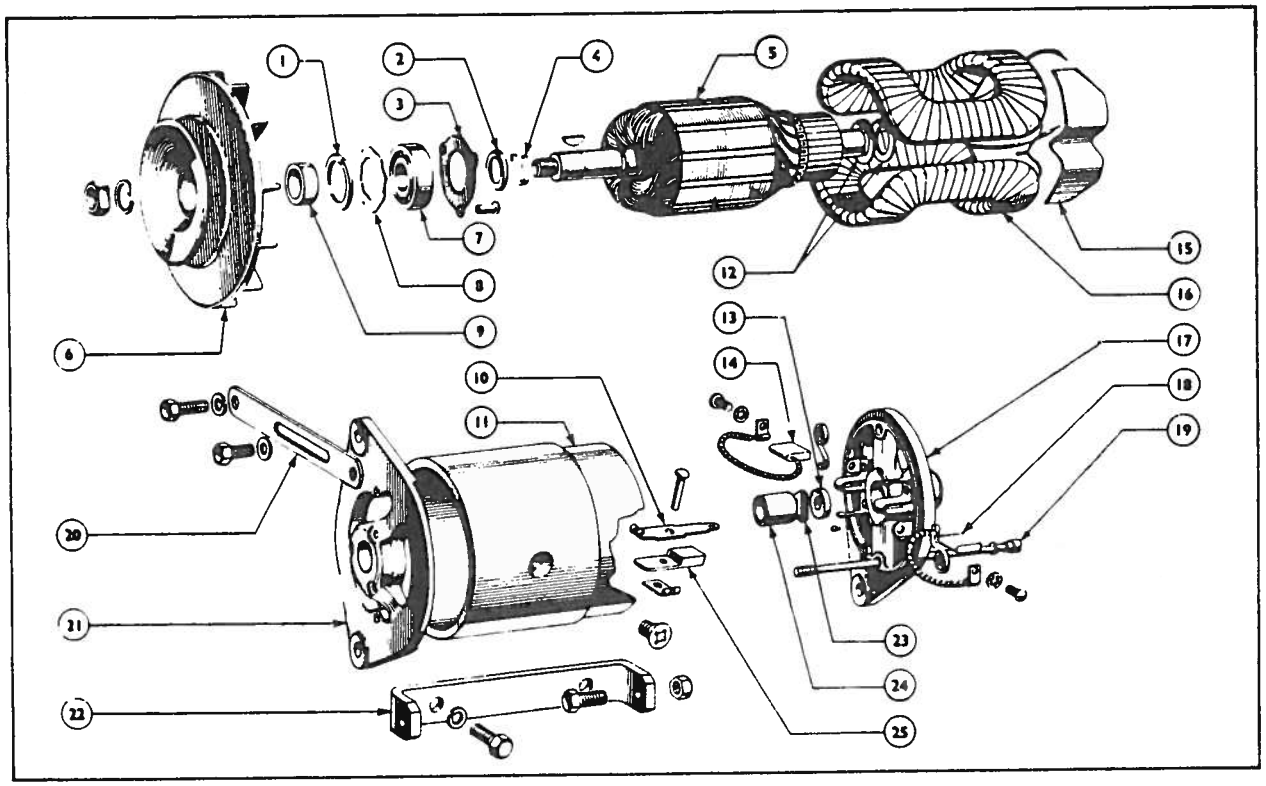


Fig. 1—The 11 ampere Generator—Exploded

1. Felt Ring
2. Ring Retainer
3. Bearing Retainer Plate
4. 'U' Ring
5. Armature
6. Generator Pulley
7. Front Bearing
8. Corrugated Washer
9. Pulley Spacer
10. Field Terminal
11. Yoke
12. Thrust Washers
13. Lubricating Felt
14. Insulated Brush
15. Insulator
16. Field Coils
17. Commutator End Bracket
18. Insulated Brush
19. Through Bolt
20. Felt Adjusting Strap
21. Drive End Bracket
22. Mounting Bracket
23. Felt Retainer
24. Bracket Bush
25. Insulator

THE BATTERY

GENERAL

In cold ambient temperatures, the battery should conform to the appropriate one of the following Specifications, with a total resistance in the starting circuit NOT EXCEEDING 0,0012 ohm;
6 cyl. engines (all temperatures) 2 x 6 volt 242 ah
4 cyl. engines (down to −10°C) 1 x 12 volt 68 ah
4 cyl. engines (down to −20°C) 2 x 12 volt 68 ah

Any deficiences in battery Specifications should be referred back to the Original Equipment Manufacturer.

A negative earth system is used on all diesel engines in this range.

Ensure that the correct battery terminal is connected to a good earth on the framework of the equipment.

Distilled water for battery use should be kept in clean, covered, non corrodible vessels. In cold weather, add water only immediately before running the engine, so that the charging will mix the water and electrolyte: this will prevent freezing.

If the battery is allowed to stand in frosty weather in an unduly discharged condition there is the possibility that it may freeze, causing damage to the container. Take care, therefore, to keep the battery as fully charged as possible– specific gravity 1,275 at 21°C. (70°F.) since then it is unlikely to be affected by frost.

Special precautions should be taken when operating in cold climates to prevent the battery state from falling below the conditions indicated by the following specific gravities:

1,200 specific gravity at − 18°C. (0°F.)
1,245 specific gravity at − 29°C. (−20°F.)
1,265 specific gravity at − 35°C. (−30°F.)

The battery should not be allowed to become unduly discharged, or to stand in a run-down condition.

Keep the battery filler plugs and connections tight, and the top of the battery clean. Wiping the battery with a rag moistened with ammonia will counteract the effect of any of the solution which may be on the outside of the battery. A coating of a good grade of petroleum jelly will protect the terminals from corrosion.

BATTERY CABLES

To reduce starting failure risks, the recommended battery cable sizes are:
Up to 122 cm (48 in) long, 61/0,91 mm (0,0036 in). From 122 cm (48 in) to 183 cm (72 in) long, 61/0,102 mm (0,004 in).

The MAXIMUM voltage drop should NOT EXCEED:

at 700 ampere	0,8 volt
at 550 ampere	0,6 volt

Any deficiences in battery cable Specifications should be referred back to the Original Equipment Manufacturer.

CHARGING FROM AN EXTERNAL SOURCE

Before starting the charge, the electrolyte level should be topped-up with distilled water to 6 mm (0,25 in) above the separators.

The normal bench charge rates for the various batteries specified are as follows:–

Battery	Normal Bench Charge Rate
1. – 12 volt 120 ah	12 ampere
2. – 12 volts in parallel 240 ah	12 ampere
3. – 6 volts in series 185 ah	18 ampere

THE CHARGING SYSTEM

One of the following charging systems may be incorporated.

(a) Generator – 11 ampere – 12 volt (Type Lucas.
(b) Alternator – 43 ampere – 12 volt (Type Lucas 11AC)
(c) Alternator – 36 ampere – 12 volt (Type Lucas 17ACR)
(d) Alternator 36 ampere – 12 volt (Type Lucas 17 ACR 'M')
(e) Alternator – 35 ampere – 12 volt (Type Bosch)

A description of each system with relevant servicing and adjustment information follows:–

LUCAS 11 AMPERE GENERATOR — See Fig. 1

The generator is a shunt-wound, two-pole, two-brush, non ventilated 11 ampere machine, arranged to work in conjunction with a regulator unit. The output of the generator is controlled by the regulator unit and is dependent on the stator of charge of the battery and the loading of the electrical equipment in use. When the battery is in a low state of charge, the generator gives a high output, whereas if the battery is fully charged, the generator gives only sufficient output to keep the battery in good condition without any possibility of overcharging.

SECTION 4
ELECTRICAL SYSTEM

CONTENTS

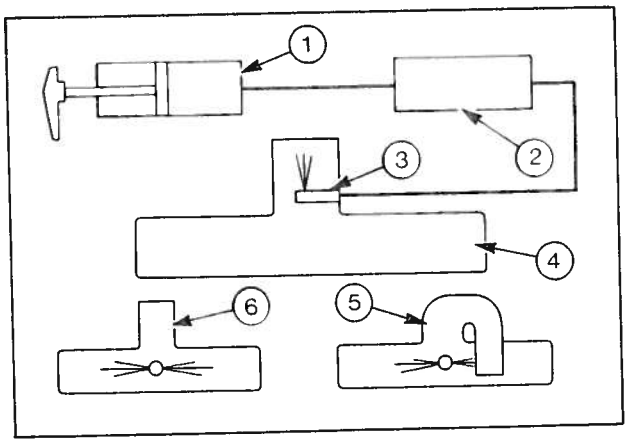


Fig. 82 Start Pilot System
1. Hand Pump
2. Reservoir
3. Nozzle
4. 4 cylinder Inlet Manifold
5. 6 cylinder Inlet Manifold (Top Intake)
6. 6 cylinder Inlet Manifold (Side Intake)

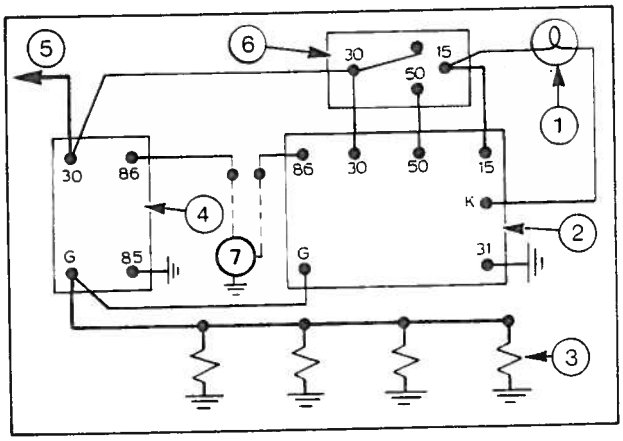


Fig. 83 Glow Plug system
1. Warning Light
2. Control Box
3. Glow Plugs
4. Relay
5. To Positive Battery Supply
6. Starter Switch
7. Switch (fitted to Engine Block Left Hand Side)

enough, the timer will energise the relay for the correct length of time. The glow plugs will be energised and will heat up the pre-combustion chambers. A warning light on the instrument panel will illuminate while the glow plugs are energised. When the light is extinguished, a normal start is made using the excess fuel device.

NOTE: No other starting aids will be available with the engines fitted with this system.

Fig. 83 shows diagramatically the complete glow plug system.

COLD START PROCEDURES

All engines:–

1. Where possible, disconnect the driven equipment.
2. Set engine speed control to maximum position.
3. Ensure stop control is fully disengaged.

To Start a Cold Engine – 6 Cylinder Engines & 4 Cylinder Engines without Glow Plug Cylinder Heads

1. Close the radiator shutters (if fitted).
2. Depress excess fuel button (CAV injection pump only).
3. Pre-heat with Thermostart for 25 secs (4 cyl), or 30 sec. (6 cyl).
4. Crank engine for 10 sec. whilst still operating Thermostart.
5. If engine does NOT start, continue to operate Thermostart.
6. Stop cranking for 15 sec., then recrank for a further 10 sec.
7. Continue to operate Thermostart until engine runs unaided.
8. Open radiator shutters (where fitted) when engine reaches normal operating temperature.

To Start a Cold Engine – 4 Cylinder Engines with Glow Plug Cylinder Heads

1. Close the radiator shutters (where fitted).
2. Depress excess fuel button (CAV injection pumps only).
3. Turn key to 'Run' position, the glow plug warning light should illuminate.

COLD STARTING EQUIPMENT

In order to acheive reliable and consistent starting at low temperatures, various types of starting aids have been introduced for both the 4 cylinder and 6 cylinder engines. The exact type fitted depends on the particular engine and the minimum temperature likely to be encountered.

The purpose of this sub-section is to describe briefly each of the systems used and to explain its correct operation.

In addition to cold start devices, later engines incorporate a self purging fuel system which materially assists reliable starting. Engines fitted with this system can be readily identified by the air bleed banjo installed on the fuel injection pump. The conversion of earlier engines to this system is covered by the Service Letter No. 3, March 1977.

THERMOSTART SYSTEM

This consists of electrically ignited fuel burners installed in the inlet manifold – two on 4 cylinder engines and three on 6 cylinder engines. The Thermostarts are energised manually by means of an electrical push button normally mounted on the instrument panel and are supplied with fuel from a separate reservoir. The reservoir is connected to the fuel injection pump. Figs 80 and 81 show the installation diagramatically.

THE START PILOT SYSTEM

This system is available on all 6 cylinder engines and pre-glow plug head 4 cylinder engines and consists of a nozzle installed in the inlet manifold which sprays an ether based starting fluid. The exact location of the nozzle depends upon the size of engine and the type of manifold fitted. The ether is pumped from a reservoir to the nozzle by means of a small manually operated pump normally mounted on the instrument panel. Fig. 82 shows the installation diagramatically.

GLOW PLUG SYSTEM

This recently introduced system will be included on all 2401E 4 cylinder engines as standard equipment. It will not be available for 6 cylinder engines.

One glow plug is fitted into each of the four precombustion chambers and is supplied electrically from the battery via a relay. The relay is controlled by a timer which is temperature sensitive. When the ignition key is turned to the 'Run' position then providing the temperature is low

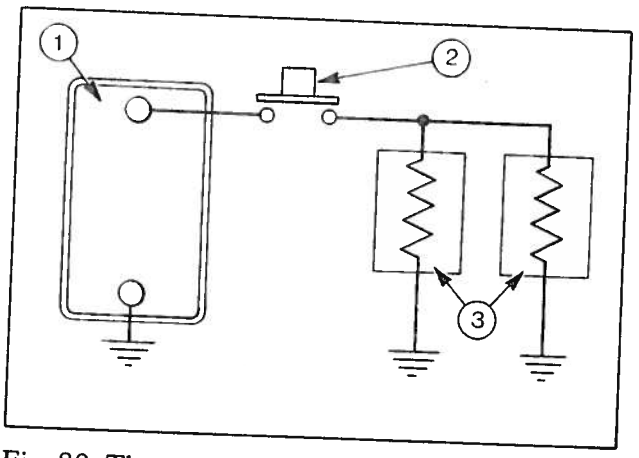


Fig. 80 Thermostart system Electrical Circuit
1. Battery
2. Push Button
3. Thermostarts

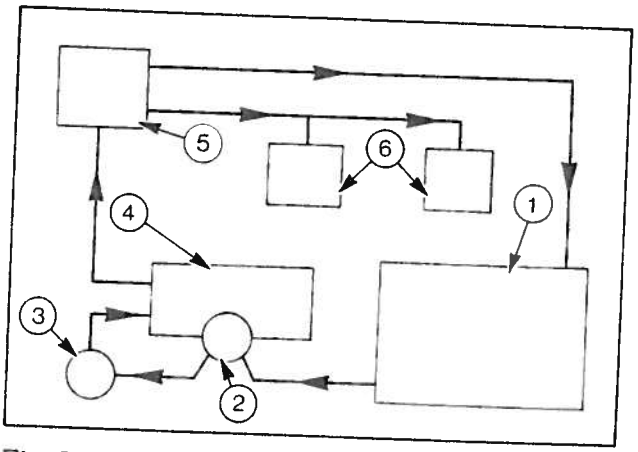


Fig. 81 Thermostart system Fuel Circuit
1. Fuel Tank
2. Lift Pump
3. Filter
4. Injection Pump
5. Reservoir
6. Thermostarts

The characteristics of the 'pintle' type nozzle differ from the normal in that the spray, with slow hand pumping, presents rather an inefficient appearance in comparison. It is inclined to be more 'ragged', 'wet' or 'soft' than with the normal four hole injector.

Testing of the opening pressure or re-adjustment should only be carried out with the Injector Tester, Fig. 79.

By screwing the adjusting screw in, the force of the compression spring is raised and with it the injection pressure. Conversely by screwing the adjusting screw out, the pressure is reduced.

It is usually better to set the injection pressure slightly higher than specified since the setting usually alters when the locknut is tightened. Hold the adjusting screw with the Allen Key when tightening the locknut (Bosch injectors only).

To test for nozzle jamming, press the hand lever of the Nozzle Tester down vigorously (approximately 6 to 8 downward movements per second) with the pressure gauge out of circuit. With the nozzle needle moving properly, the nozzle should chatter with a high whistling tone.

With the pressure gauge in circuit, slowly depress the hand lever until the nozzle ejects with slight chattering. Take a reading on the pressure gauge of the opening pressure. If this pressure differs from the specified opening pressure, turn the adjusting screw in the necessary direction to adjust.

CAUTION: When the pressure gauge is in circuit, increase or decrease the pressure slowly, otherwise the gauge may be damaged.

Depress the pump lever until the pointer on the gauge is about 1960 kN/m² (300 lbf/in² or 21,0 kgf/cm²) below the set opening pressure. The injector is satisfactory if no drop in pressure apepars within 10 seconds.

Fuel Pipes

Check that the olives are undamaged. Injector pipe olives must not be renewed. If an olive is leaking or shows signs of damage, the pipe assembly must be replaced.

Check that the end of the pipe has not closed up, using a 2 mm drill. If the pipe end has closed up the pipe should preferably be renewed, but as a temporary measure the pipe end may be opened by using a 2 mm drill to a depth of 10 mm.

Ensure that the pipe is thoroughly cleaned afterwards.

Normally injector pipes should not be reset, but if this has to be done, care should be taken to ensure that scale, which may have become loosened inside the pipe, is removed by compressed air and rinsing.

When pipes are removed from an engine, blanking plugs must be fitted to the pipe nuts and caps fitted to the appropriate delivery valve holders and injector inlet adaptors.

The pipes must not be bent when removing or refitting and should be loosened at both ends when removing the injectors. When refitting the pipes ensure that all clips are correctly located and fully tightened.

Fuel Pipe Adaptors

If fuel leaks are evident at the mounting of the inlet adaptor to the injector pump on Bosch installations, the latest type of seal (Part No. E 830435-S) should be fitted.

of caustic soda exceed 15%, then the needle valve bore and joint face on the nozzle body may be roughened, making the injector unserviceable.

3. Remove the nozzles after treatment, and wash in running water to remove all traces of caustic soda. After washing immerse the nozzle in a de-watering oil, then remove the surplus oil by draining.
4. The carbon can now be easily removed with a wire brush and a standard pricker wire.
5. Flush out the interior of the nozzle using a suitable reverse wash adaptor fitted to the injector testing machine. Inspect all parts. If the tip of the needle is blued from overheating, or if the seat is scored or damaged, the nozzle and needle valve are unfit for further service. Check that the spring is not broken or rusty and that the ends are perfectly square. Inspect all the components for wear or damage and check all joint faces for scratches or trapped foreign particles. Ensure that the needle is free to fall under its own weight in the nozzle, when wet with substitute oil, and falls freely from the nozzle seat when inverted. If any of the components are faulty, the injector must be renewed.

Injector Testing

Care should be taken when testing injectors to ensure that the fuel spray does not come into contact with the hands of the personnel operating the test equipment.

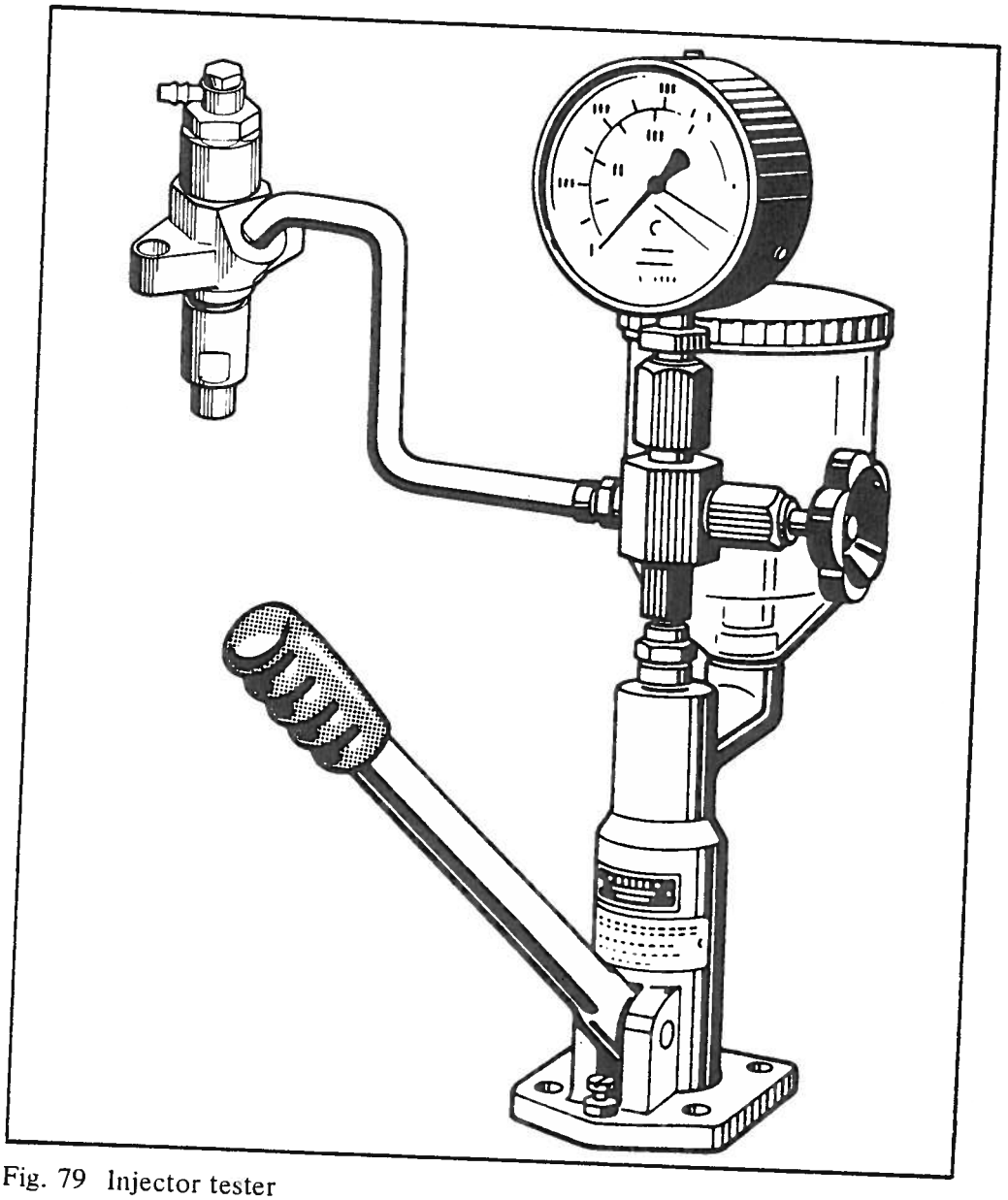


Fig. 79 Injector tester

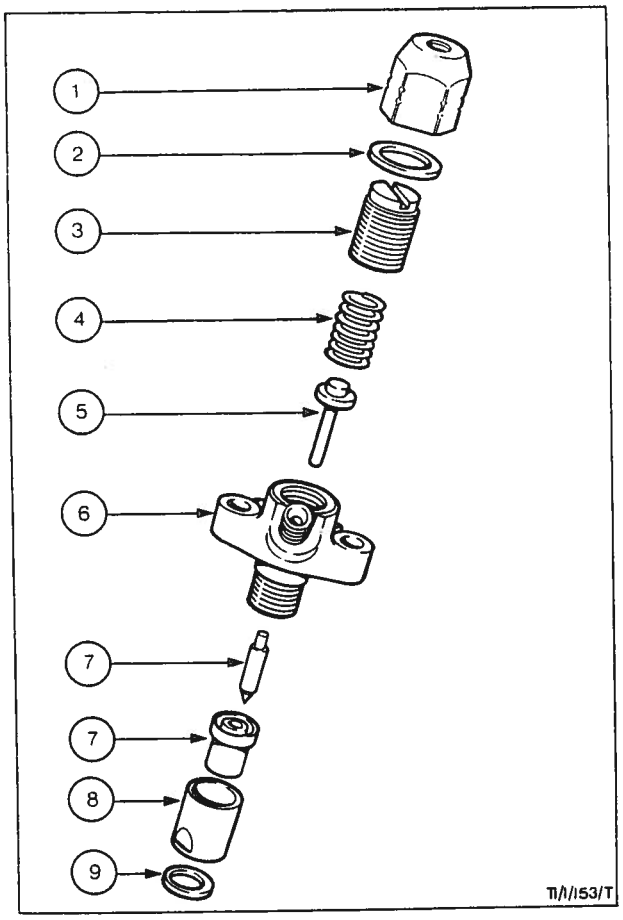


Fig. 77 Simms Injector

1. Cap nut
2. Washer
3. Adjusting screw
4. Spring
5. Spindle
6. Holder
7. Nozzle
8. Nozzle nut
9. Washer

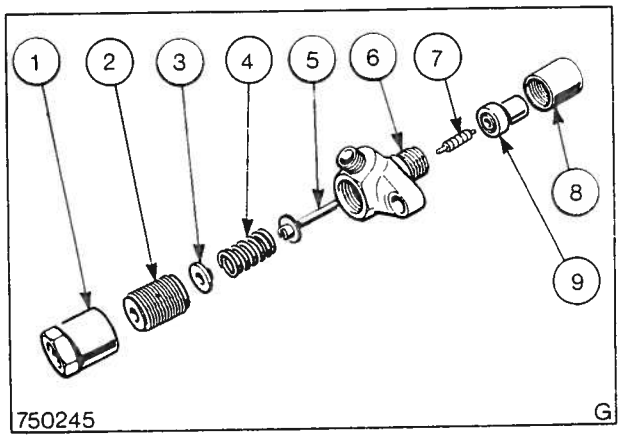


Fig. 78 Bosch Injector

1. Cap nut
2. Adjusting screw
3. Seat
4. Spring
5. Spindle
6. Holder
7. Needle
8. Nozzle
9. Nozzle nut

NOTE: It is essential that the specified torque figure is not exceeded otherwise serious distortion of the nozzle assembly may occur.

3. Fit the injector spindle, spring and spring adjusting nut. Screw down the adjusting nut until pressure can be felt on the spring.
4. Connect the injector to the testing pipe. Adjust the nozzle opening pressure, refer to Specifications.
5. Fit the injector cap nut, tighten securely and check the nozzle opening pressure.
6. Fully test the injector, as described on page 35.

NOTE: If, after cleaning, the injector fails to pass these tests, it should be replaced by a serviceable injector and the faulty one reconditioned. On no account should attempts be made to reclaim injector nozzles and valves through hand-lapping with metal polish or any other abrasive.

Cleaning Injectors

Use the tools in the injector cleaning kit, to remove all carbon from the interior of the nozzle.

When a hard carbon deposit is formed, it may be softened by immersing the nozzle in 'Acetone' for a short period. Up to half an hour is normally sufficient.

WARNING: 'Acetone' is a highly inflammable liquid and must not be brought near a naked flame.

NOTE: It is important that immediately the nozzle is removed from the fluid it must be rinsed in clean fuel oil or substitute fuel oil to prevent corrosion of the finely-finished surfaces.

Alternatively, the nozzle may be treated as follows:–

1. Dissolve 55 gm (2 oz) of caustic soda in 0,6 litre (1 pint) of water. Also add 14 gm (½ oz) of detergent.
2. Place the nozzle in the liquid and boil for a minimum period of 1 hour and not more than 1½ hours.

NOTE: The concentration of caustic soda must not exceed 15% and water should be added to replace that lost by evaporation. Should the concentration

INJECTORS

The injector consists of a nozzle assembly and a nozzle holder clamped together axially by the nozzle nut. The steel nozzle holder body incorporates lugs for clamping the injector to the cylinder head and contains a spring, adjusting screw and spindle. The nozzle consists of a nozzle body and 'Pintle' type needle valve.

Fuel from the injection pump enters the injector inlet and passes through the injector body before reaching the needle valve seat. The needle valve is held on its seat by the spring pressure acting through the spindle. The pressure of the fuel when the ports in the injection pump barrel are closed causes the needle valve to open against the action of the injector spring. Fuel is then forced, in a highly atomised state through the 'Pintle' nozzle. At the end of injection the spring returns the needle valve on its seat. The spring pressure can be adjusted by the adjusting screw, to give a nozzle opening pressure of the specified number of atmospheres.

The needle valve stem is a very accurate fit in the body, but a small quantity of fuel leaks past the stem to provide lubrication, and is returned to the fuel tank by a leak-off pipe.

TO REMOVE THE INJECTORS

Where difficulty is experienced in obtaining replacement Bosch fuel injector nozzle and holder assemblies (Part No. 715F-9K546-CAA), it is permissible to replace with CAV/Simms assemblies (Part No. 715F-9K546-AAB).

1. Remove the bolt on top of the injector securing the leak-off banjo union to the injector body.
2. Remove the high pressure pipe clips.
3. Unscrew the union nuts at each end of the high pressure pipe and remove the pipe.
4. Unscrew the injector retaining bolts and remove the injector.
5. Remove the sealing washer and the corrugated injector seat washer.
6. Blank off the delivery and leak-off connections and thoroughly clean the injector externally. Overhaul, test or replace the injector as required.

TO REPLACE THE INJECTORS

1. Install a new injector corrugated seat washer (red side uppermost), also sealing washer into the heat shield in the cylinder head.

NOTE: If the heat shield comes out with the injector, a new heat shield to cylinder head sealing washer must be fitted, Fig. 76.

2. Remove the blanking plugs from the injector, install the injector in the recess and replace the retaining bolts. Tighten the bolts down evenly to the specified torque.
3. Position the fuel high pressure pipe/s between the injection pump and injector/s, and tighten the union nuts evenly. Fit the high pressure pipe clips.

NOTE: Ensure the clamping jaws of the delivery valve nuts are correctly fitted before fitting the pipes. Any additional torque to that specified will adversely affect the sealing.

4. Fit a washer either side of the leak-off pipe banjo union. Fit the banjo union bolt and tighten to the specified torque.
5. Bleed the fuel system as described on page 20r or 31r as appropriate.

INJECTOR OVERHAUL

To Dismantle – CAV/Simms Type

1. Fit the injector to a dismantling jig.
2. Remove the injector cap nut, then with a screwdriver, unscrew the spring adjusting nut and remove the injector spring and spindle, See Fig. 77.
3. Unscrew the nozzle nut, and remove the nozzle and needle valve.

NOTE: As nozzles and needle valves are a selected fit, they should never be interchanged.

To Dismantle – Bosch Type

1. Fit the injectors to a dismantling jig.
2. Remove the injector cap nut and unscrew the spring adjusting nut using a 5 mm Allen key. Remove the spring, spindle and spacer, Fig. 78.
3. Unscrew the nozzle nut, and remove the nozzle and needle valve.

NOTE: As nozzles and needle valves are a selective fit, they should never be interchanged.

To Assemble

1. All injector parts should be assembled wet, after rinsing in clean fuel oil or test oil. Do not use rag to clean any of the internal parts.
2. Fit the nozzle and the needle valve to the injector body. Screw on the nozzle nut and tighten securely to the specified torque, see Specifications.

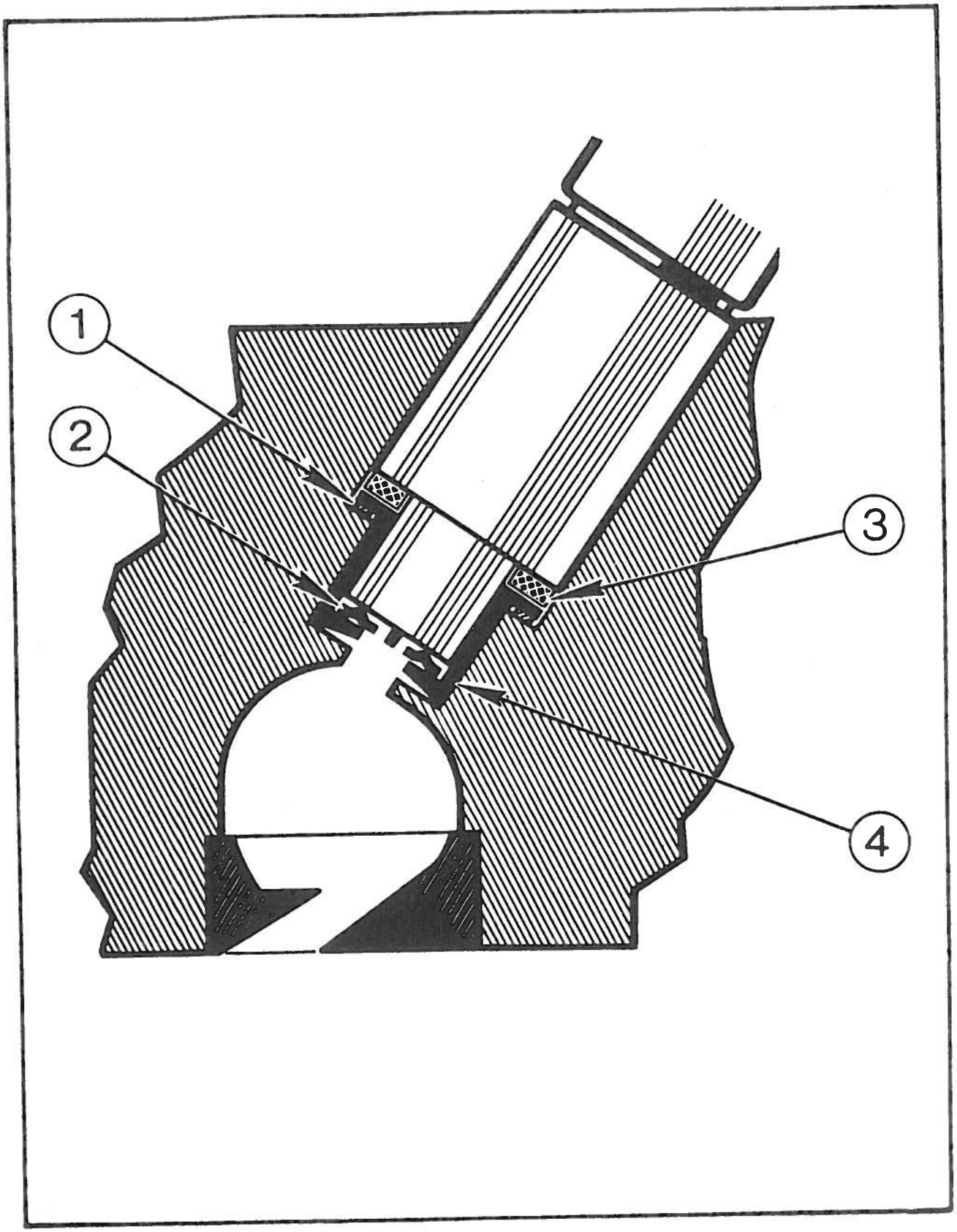


Fig. 76 – Injector Installation
1. Sealing ring – Heat shield
2. Heat sink plate
3. Sealing ring – Injector holder
4. Heat shield

Fuel Injector

Injectors .	11,7 to 14,9 Nm (8,6 to 11 lbf ft or 1,2 to 1,5 kgf m)
Injector leak-off pipe	17,7 to 20,3 Nm (13 to 15 lbf ft or 1,8 to 2,1 kgf m)

Fuel Filter

Mounting bracket bolt	31,2 to 39,3 Nm (23 to 29 lbf ft or 3,2 to 4,0 kgf m)
Mounting bolt	14,9 to 20,3 Nm (11 to 15 lbf ft or 1,5 to 2,1 kgf m)

Fuel Lines

Banjo bolts	14,9 to 20,3 Nm (11 to 15 lbf ft or 1,5 to 2,1 kgf m)
Fuel line union bolts	6,6 to 9,5 Nm (4,9 to 7 lbf ft or 0,7 to 0,9 kgf m)
Solneoid engine stop control	14,9 to 20,3 Nm (11 to 15 lbf ft or 1,5 to 2,1 kgf m)

Fuel Injectors

Type	Pintle type
Injector nozzle number	DN 05027
Nozzle opening pressure	175 ± 2,5 atmospheres

Camshaft protrusion	19,5 mm ± 1 mm (0,7677 ± 0,0394 in)
Governor sleeve protrusion	19,0 mm ± 0,02 mm (0,7480 ± 0,008 in)
Plunger head clearance	Minimum 0,3 mm (0,0118 in)
Plunger foot in spring rest clearance	0,05 to 0,18 mm (0,002 to 0,007 in)
Lubricant	As for engine
Initial pump fill quantity	0,284 litre (0,5 pint)

Test Oil

Shell	Calibration 'B'
Bosch Oil	0161V11
Oil Temperature	40° ± 5°C (104° ± 9°F)

Test Equipment Specification

Type	Variable speed
Master injector nozzle	DN 12SD12
Nozzle opening pressure	17150 kN/m² + 3,00 − 0,0
Leak post needle must be	20 to 50 cm³/min when under pressure of 1960 kN/m² Nitrogen Gas
High pressure pipes	6 mm O.D. x 2 mm I.D. x 600 mm long

Injector Testing

Back leak test time for pressure to drop from	100 to 75 atmospheres
	6 to 22 secs
New injectors	Nozzle tip to be dry after operating the injector and after holding the pressure at 10 atmospheres below opening pressure for 10 secs
Service injectors	Hold the pressure at 10 atmospheres below opening pressure for 60 secs when leakage should not cause a blot larger than 38,1 mm (1,5 in) diameter on filter paper (Whatmans 541).

Injector Tightening Torques

Nozzle nut	58,3 to 78,6 Nm (43 to 58 lbf ft or 5,9 to 8,0 kgf m)
Cap nut	14,9 to 24,4 Nm (11 to 18 lbf ft or 1,5 to 2,5 kgf m)
Injector bolt	14,9 to 19,7 Nm (11 to 14,5 lbf ft or 1,5 to 2,0 kgf m)

Fuel Injection Pump Tightening Torques

Cap nuts	24,4 Nm (18 lbf ft or 2,5 kgf m)
Delivery valve "holders"	Tighten to 24,4 Nm (18 lbf ft or 2,5 kgf m). Release to zero torque. Retighten to 24,4 Nm (18 lbf ft or 2,5 kgf m). Release to zero torque again. Finally tighten to 27,1 to 28,7 Nm (20 to 21,5 lbf ft or 2,8 to kgf m)
Governor housing fixing screws	9,5 to 10,8 Nm (7 to 8 lbf ft or 0,9 to 1,1 kgf m)
Control rod bush	39,3 to 58,3 Nm (29 to 43 lbf ft or 4,0 to 5,9 kgf m)
Governor cover screws	5,4 to 6,8 Nm (4 to 5 lbf ft or 0,6 to 0,7 kgf m)
Governor flyweight retaining nut	48,8 to 58,3 Nm (36 to 43 lbf ft or 5 to 5,9 kgf m)
Tappet guide and retaining screws	6,8 to 8,13 Nm (5 to 6 lbf ft or 0,7 or 0,8 kgf m)
Bleed screw assembly	19,7 Nm (14,5 lbf ft or 2,0 kgf m)
Camshaft end plate screws	6,8 to 8,13 Nm (5 to 6 lbf ft or 0,7 to 0,8 kgf m)
Engine mounting plate to pump bolts	12,8 to 15,6 Nm (9,4 to 11,6 lbf ft or 1,3 to 1,6 kgf m)
Injection pump pulley to auto advance unit	14,9 to 20,3 Nm (11 to 15 lbf ft or 1,5 to 2,1 kgf m)

SPECIFICATIONS

Fuel Injection Pumps

	Automotive	General Purpose	Class 'A'	
Ford Part No.	715F-9A543-AFB	725F-9A543-GBA	715F-9A543-EEB	715F-9A543-EDB
Bosch Part No.	0400084012	0400084013	0400084011	0400084010
Fuel delivery for 200 shots (cc) with BDN12SD12 nozzles				
With Bosch Machine				
at 1800rpm	37,5-41-5	39,0-43,0	—	36,0-40,0
1600rpm	—	—	—	—
1500rpm	—	—	35,0-39,0	—
1400rpm	—	—	—	—
1000rpm	35,5-41,5	36,5-42,5	—	—
Except Bosch Machine				
at 1800rpm	7,2-8,2	7,2-8,2	—	—
1600rpm	—	—	—	6,3-7,3
1500rpm	—	—	—	—
1400rpm	—	—	6,3-7,3	—
1000rpm	7,0-8,0	7,1-8,1	—	—
Full Load Speed rpm	3600	3600	3000	3600
No Load Speed rpm	4040/4060	3880/3900	3130/3140	3755/3765
Start Spring Rate	0,004 kg/mm	0,004 kg/mm	0,0046 kg/mm	0,0046 kg/mm
Governor Spring	10,5 kg/mm	10,5 kg/mm	4,08 kg/mm	4,08 kg/mm
Free Length	52,8 mm	52,8 mm	50,0 mm	50,0 mm
Damper Spring Rate	3,5 kg/mm	3,5 kg/mm	1,2 kg/mm	1,2 kg/mm
Idling rpm	600/650	600/650	500/550	500/550
Control Rod Starts to Move rpm	1820/1840	1810/1820	1500/1510	1800/1810
No Delivery	2100/2180	1880/1930	1550/1575	1860/1895

Injection Pump Specification

Type	Multi-element operated by an enclosed camshaft	
Rotation	Clockwise form drive end	
Governor	Mechanical	
Cold Starting Device	Automatic	
Pump Timing	12° BTDC (11° BTDC on later 6 cyl engines)	
Plunger bore stroke and helix slope	7 mm diameter x 8,0 mm x 13 mm	
Camshaft end-float	0,02 to 0,06 mm (0,00079 to 0,00236 in)	
Camshaft end-float shims	Governor End	Drive Gear End
	0,1 mm (0,0039 in)	0,1 mm (0,0039 in)
	0,12 mm (0,0047 in)	0,12 mm (0,0047 in)
	0,14 mm (0,0059 in)	0,14 mm (0,0059 in)
	0,16 mm (0,0063 in)	0,16 mm (0,0063 in)
	0,18 mm (0,0071 in)	0,18 mm (0,0071 in)
	0,3 mm (0,0118 in)	0,3 mm (0,0118 in)
	0,5 mm (0,0197 in)	0,5 mm (0,0197 in)
	1,0 mm (0,0394 in)	
Phasing tolerance	± 1° Pump	
Timing tolerance	± ½° Pump	
Stroke to close inlet port	2,6 to 2,8 mm (0,10232 to 0,11020 in)	
Roller (diameters)	14,52 mm (0,5716 in), 14,64 mm (0,5753 in)	
	14,70 mm (0,5801 in), 14,88 mm (0,5849 in)	
	15,00 mm (0,5905 in), 15,06 mm (0,5928 in)	
	15,12 mm (0,5952 in), 15,18 mm (0,5976 in)	
	15,24 mm (0,5999 in), 15,30 mm (0,6023 in)	
	15,36 mm (0,6047 in), 15,48 mm (0,6094 in)	
	15,60 mm (0,6141 in)	

FUEL FILTER MAINTENANCE

It must be emphasised that fuel oil must be kept clean at all times. Contamination by dirt and/or water will result in premature wear and possible failure of the finely machined components in the injection pump and injectors.

When filling the fuel tank, the fuel must not be poured from or have been stored in a dirty container.

Even when operating under the most favourable conditions a certain amount of dirt may be present in the fuel oil, and to prevent this reaching the injection pump and injectors, filters are provided in the fuel system.

Fuel is drawn from the tank by the fuel lift pump, and then passes through a renewable element type filter.

To Renew the Filter Element

1. Using a strap wrench, unscrew the filter canister.
2. Remove the rubber ring gasket from the filter head.
3. Install a new rubber ring gasket in the filter head.
4. Screw in by hand a new filter canister until it just touches the gasket.
5. Turn the canister through 180°.
6. Bleed the fuel system.

BLEEDING THE FUEL SYSTEM

1. Ensure that all fuel pipe connections are tight and that there is sufficient fuel in the tank.
2. Loosen the bleed screw on top of the filter two or three turns, Fig. 74, and operate the priming pump on the fuel lift pump, Fig. 75. Continue pumping until a stream of fuel, free of air bubbles, issues from the filter.
3. Tighten the bleed screw on the filter.
4. Loosen the bleed screw on the injection pump body, two or three turns and operate the priming pump as before.

NOTE: Under no circumstances should the injection pump plungers be levered up and down to prime the injector pipes or test the injectors, as the plunger arms may be seriously damaged.

5. When the fuel, free from air bubbles, issues from the bleed screw, tighten the screw.
6. Wipe all surplus fuel oil from the exterior of the filter and injection pump.
7. Start the engine and check for leaks.

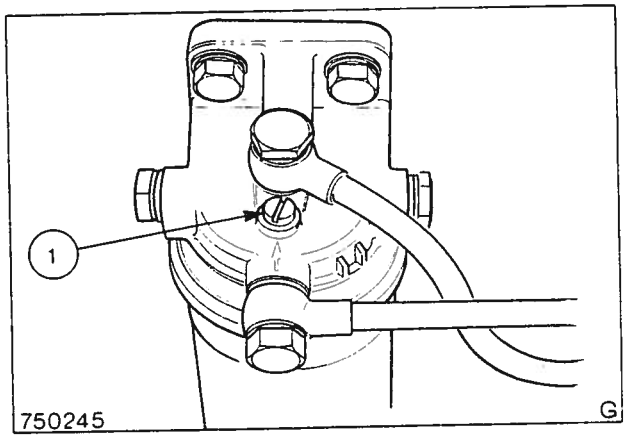


Fig. 74
1. Bleed screw

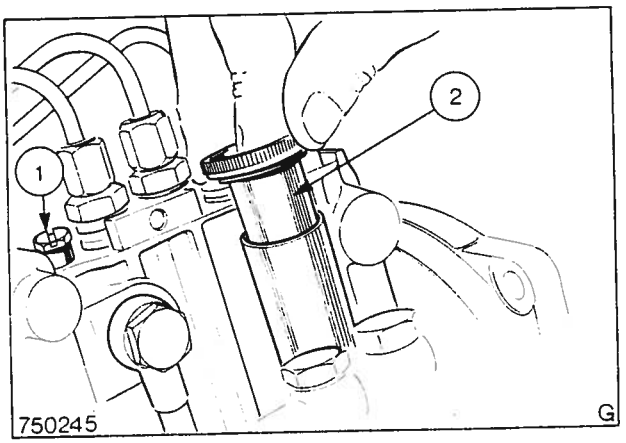


Fig. 75
1. Bleed Screw 2. Priming plunger

OVERHAULING THE FUEL LIFT PUMP

The fuel lift pump is mounted on the injection pump and is driven by a cam on the injection pump camshaft. This pump also incorporates a hand priming plunger to enable the fuel system to be bled.

On rotation of the injection pump camshaft, the eccentric cam forces the tappet, link and plunger in the direction of the suction chamber. Fuel is therefore forced out of the suction chamber through the delivery valve and the balancing channel into the compression chamber, At the same time the plunger spring is compressed. Further movement of the camshaft eccentric, e.g. beyond the highest point, causes the plunger to be forced back by the plunger spring. The fuel is now forced out of the compression chamber through the balancing channel to the fuel filter/s and the injection pump. At the same time, the receding plunger creates a vacuum in the suction chamber, whereby 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 forward toward the camshaft eccentric thus reducing the amount of fuel flow.

VISUAL INSPECTION OF THE FUEL LIFT PUMP

1. Using a socket wrench unscrew the union nuts. Check that the valves seat correctly and that the valve springs are in order, Fig. 73.
2. If necessary the plug should be removed to check if the roller tappet, plunger spindle and plunger can be moved backwards and forwards easily without any visible play.
3. Check for any damage to the tappet, bearing and roller, and renew if necessary.
4. Check valve and plug seals for damage.

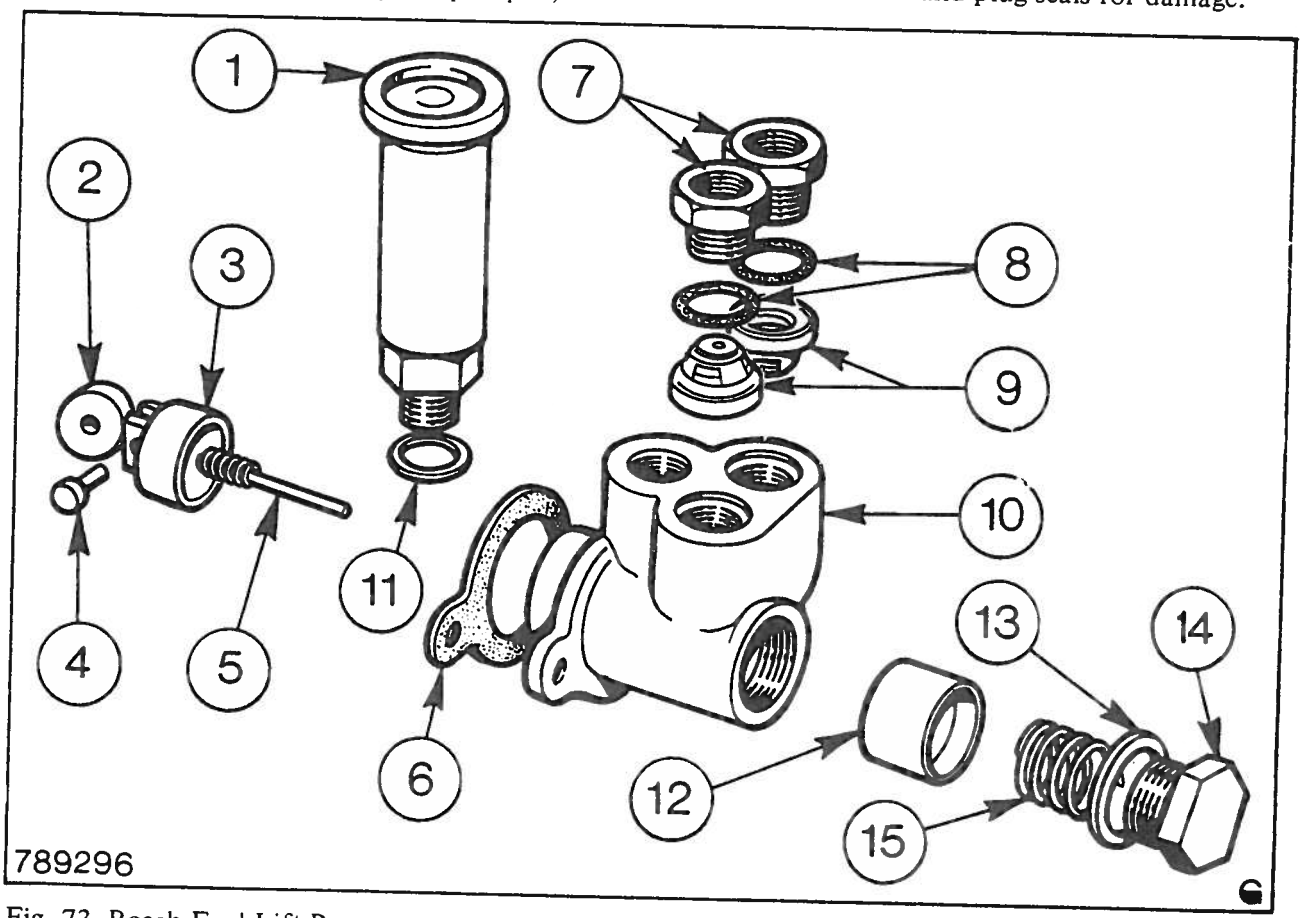


Fig. 73 Bosch Fuel Lift Pump

1. Primer assy.
2. Bearing
3. Tappet
4. Roller
5. Spring and Plunger
6. Gasket
7. Union nuts
8. Seals
9. Valves
10. Pump body
11. Seal
12. Sleeve
13. Seal
14. Plug
15. Spring

8. Screw in the supplementary/bumper spring idling screw until the engine rpm just start to increase and then screw out about 1/8 of a turn. Tighten the locknut.

9. Open the throttle several times allowing it to release sharply to ensure it is returning correctly and the engine is not stalling.

10. If the engine stalls under these conditions raise the idling rpm slightly by releasing the supplementary/bumper spring idling screw locknut and screwing in the adjusting screw a small amount to ensure a stable idling condition and relock the retaining nut.

11. Recheck the engine idling as in 9 and refit the cover nuts.

NOTE: No attempt should be made to adjust the slow running speed by screwing in the supplementary/bumper spring idling adjustment screw only. Any attempt to adjust the idling speed by this screw may result in damage to the engine. The supplementary/bumper spring idling screw is set on the test bench and may only be used as a very fine adjustment to stop stalling at the correct engine slow running speed.

refit the retaining bolts and tighten. Secure the maximum speed stop screw plastic cover, fit sealing wire through the hole in the body and plastic cover and secure with a lead seal. Seal the slow running, supplementary idling/bumper adjustment screw with wire and a lead seal, Fig. 69. Remove the control rod travel measuring device. Refit the plunger spring cover plate. Fill the pump to the correct level with lubricating oil through the oil filler (see Specifications) and refit the level plug.

Remove the injection pump and governor from the test bench.

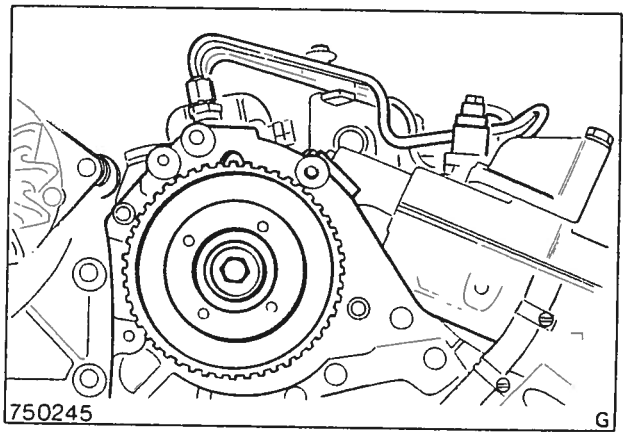


Fig. 70 Refitting Injection Pump

REPLACING THE INJECTION PUMP

To refit the pump to the engine, first ensure the governor housing has been topped up with 0,284 litre (0,5 pint) of engine oil, then refit the pump in position on the front cover and secure the retaining bolts and the mounting bracket, Fig. 70. Refit the drive gear and plate and install the nuts finger tight. Ensure that the crankshaft timing marks are aligned and that the camshaft gear locking pin is installed. Time the injection pump to 12° BTDC (timing marks are scribed on the automatic advance unit housing).

NOTE: The injection pump hub can be turned slightly within the limits of the drive gear elongated stud holes to give a fine adjustment.

Injection Pump – Adjust Idle Speed on Engine

To adjust slow running.

1. Run the engine until operating temperature is reached.
2. Remove the cover nuts and release the locknut retaining the supplementary/bumper spring idling screw.
3. Screw out the supplementary/bumper spring idling screw until it ceases to affect the idling speed, Fig. 71.
4. Release the idling screw retaining locknut, Fig. 72.
5. Adjust the idling screw to obtain 680 to 750 rpm.
6. Lock the idling screw by tightening the locknut and recheck the idling speed.
7. Check to ensure that the supplementary/bumper spring idling screw is not affecting the idling speed; if still affecting the idling speed repeat operations 3 to 6.

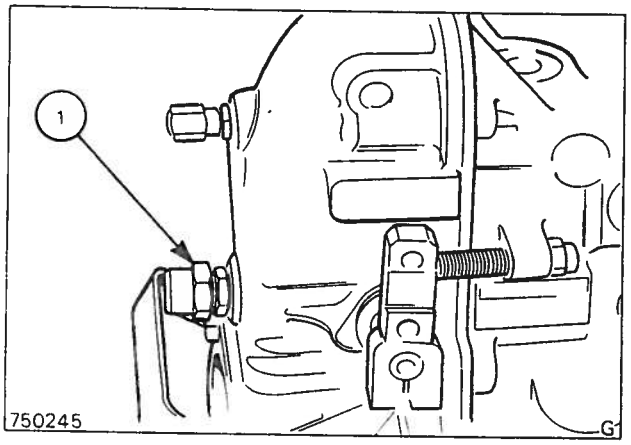


Fig. 71 Location of supplementary idling screw
1. Cover nut

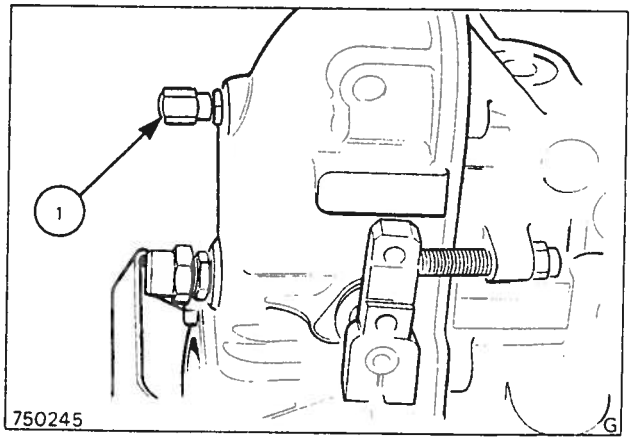


Fig. 72 Location of idling screw
1. Idling screw retaining locknut

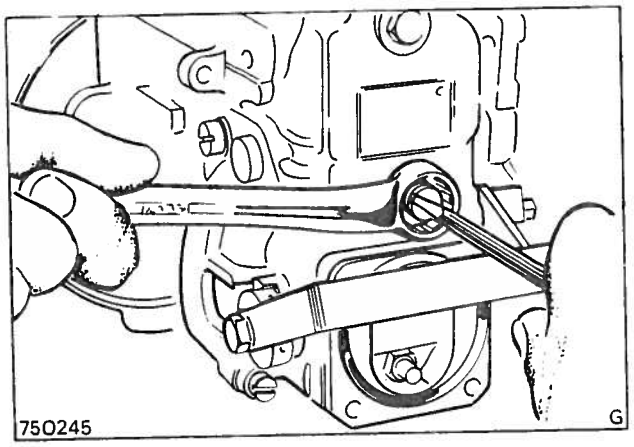


Fig. 67 Adjusting the supplementary idling spring

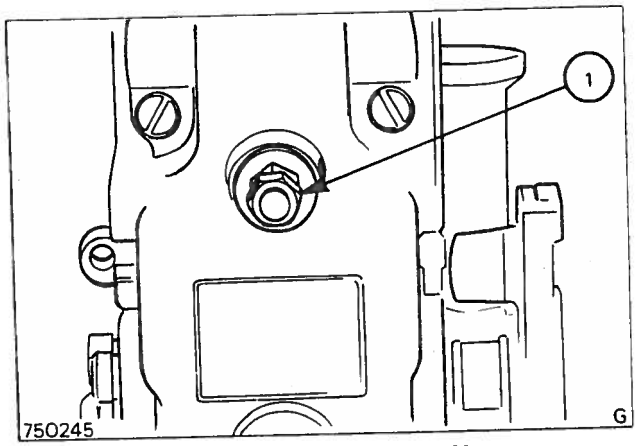


Fig. 68 Location of the shut-off stop screw
1. Shut-off screw

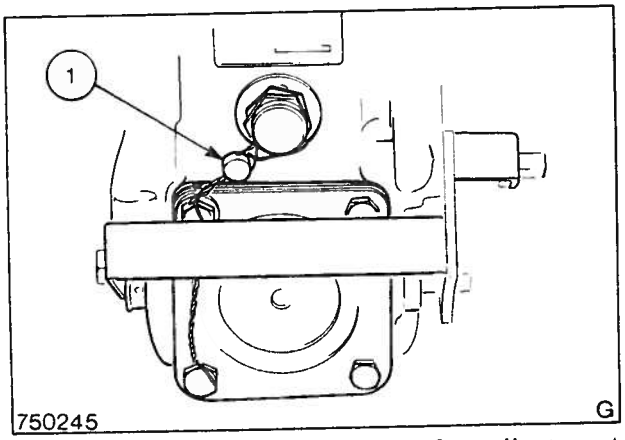


Fig. 69 Sealing injection pump after adjustment
1. Lead seal

6. Adjusting the supplementary idling spring.

   Drive the governor at the idling speed and set the control rod by means of the control lever to 1 to 1,5 mm less than the specification.

   Then screw in the supplementary idling spring and adjust until the value for the control rod travel (see Specifications) is obtained. Tighten the locknut slightly, Fig. 67.

7. Testing the control rod travel at the idling speed.

   The control lever is kept in the position described under (6). Then test the control rod travel at the prescribed speeds. It should correspond in each case with the mean of the values which are given. If this is not so, the control lever must be adjusted accordingly and tests 6 and 7 repeated.

8. Testing the control travel at the upper rated speed.

   Hold the control lever against the maximum speed stop. Drive the pump at the prescribed speeds and check the control rod movements are correct (see Specifications).

9. Setting the idling stop screw.

   Allow the pump to run at the specified speed and set the prescribed control rod travel with the control lever (see Specifications). Screw the shut off stop screw forward until it touches the control rod and secure with a locknut, Fig. 68.

10. Testing the quantity delivered for starting.

    Drive the pump at the prescribed speeds and check whether the correct values are obtained (see Specifications).

11. Final adjustment of break-away speed.

    Drive the pump at the upper rated speed.

    Hold the control lever against the maximum speed stop.

    Increase the speed and watch the control rod travel measuring device carefully. The governor must break-away at the correct speed (see Specifications) otherwise the maximum speed stop requires adjustment. Once the adjustments have been made, secure the stop slightly with the locknut.

12. Check zero delivery (see Specifications).

13. Securing and sealing.

    Once the adjustments and tests have been completed, place the cover in position and

must be adjusted accordingly and the initial tension of the governor main spring corrected with the adjusting screw. Then the maximum speed stop must be readjusted to the new lever position. (Setting the adjusting screw = rough adjustment: adjusting the maximum speed stop = fine adjustment.) Now check whether the control rod remains stationary from 1.5 times idling speed to the break-away speed (about full-load speed 0,2 mm reduction in control rod travel is still permissible.

3. Adjusting the full load delivery

   Hold the control lever against the maximum speed stop. Allow the pump to run at the prescribed speed. Set the full load stop screw with a spanner and screwdriver, so that the prescribed full load delivery is achieved, Fig. 64. (While adjusting, remove the load from the screw, i.e. set the control lever to STOP.)

   After each adjustment tighten the locknut well. After carrying out the adjustment to the full load delivery, read off the control rod travel and note it for subsequent torque control adjustments, Fig. 65.

   If no full load quantity is indicated, the control rod travel must be limited with the full load stop screw to half the control rod travel. The final speed limitation is only set when the whole test is complete.

4. Adjust the torque control.

   Screw the spring capsule, adjusted at the factory before delivery, into the tensioning lever. Press the control lever against the maximum speed stop and hold it in this position. Drive the governor at the top rated speed. Read the control rod position indicated on the adjusting tool and use the value for subsequent tests. Check the speeds and associated control rod travel. If the values indicated in the test sheet are not attained, the spring capsule must be adjusted using the pin spanner. If the values are still not attained replace the spring capsule. Once the adjustments have been made, tighten the locknut on the spring capsule, Fig. 66.

5. Testing the delivery characteristics.

   Allow the pump to run at the prescribed speed and check whether the correct values are obtained (see Specifications). If this is not the case, the spring capsule must be adjusted and then secured with the locknut.

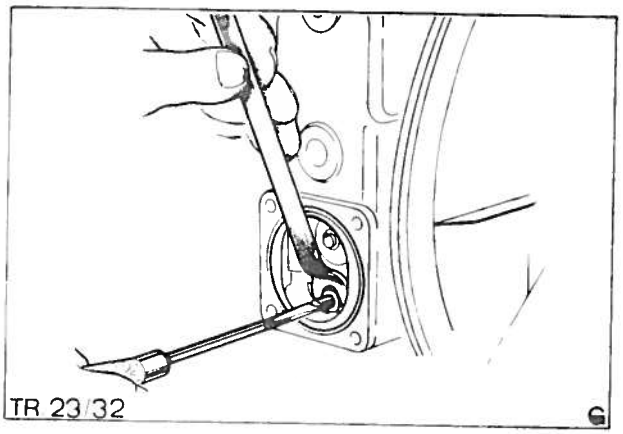


Fig. 64 Adjusting the full load stop

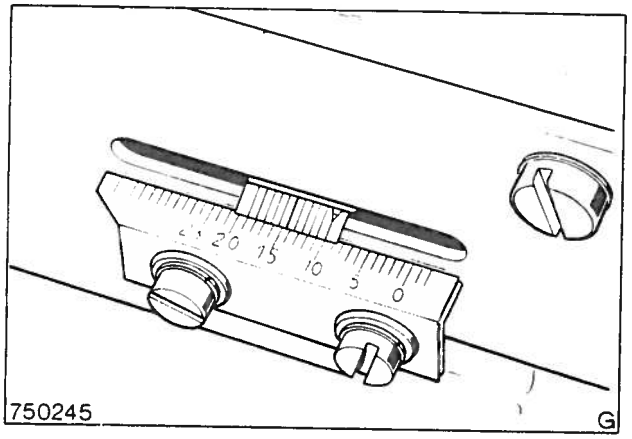


Fig. 65 Control rod travel indicator

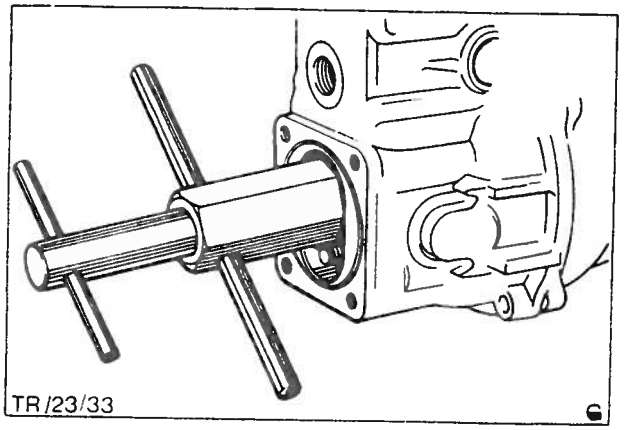


Fig. 66 Adjusting the spring capsule

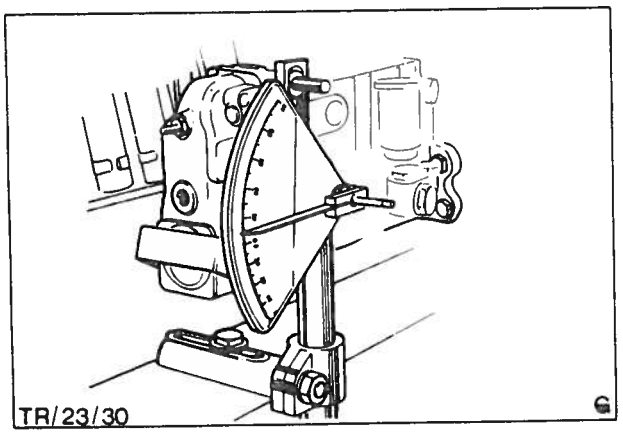


Fig. 61 The control rod adjusting and holding device

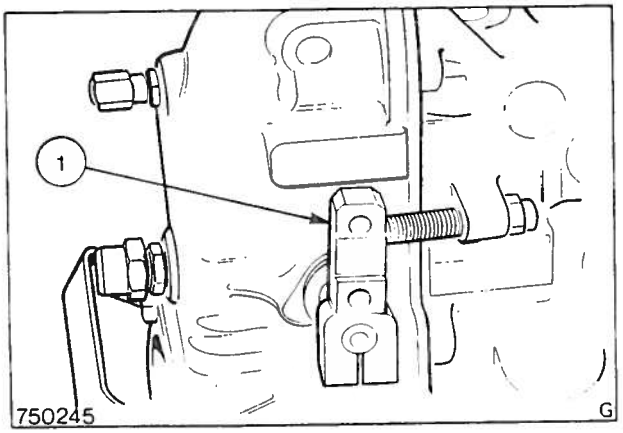


Fig. 62 The control lever against the maximum speed stop
1. Control lever

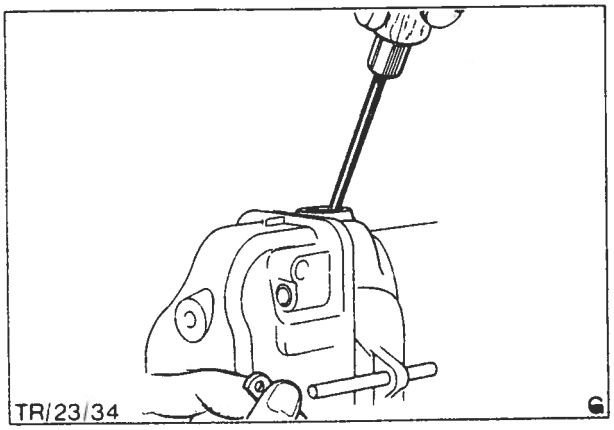


Fig. 63 Adjusting the screw on the swivelling lever

Increase the speed until the governor completes regulation and check whether the control rod can still move a further 0,3 to 1 mm. If this further control travel is not obtained, shims will have to be removed between the bearing and trunnion contained in the thrust sleeve (see overhaul procedure). This will prevent additional pressure being exerted on the tensioning lever in the break-away condition.

Fit the control lever adjusting and holding device, Fig. 61, and align with the control lever shaft. Place the driving pin of the adjusting device on the left-hand side of the control lever (STOP side), or fit in the hole in the control lever. Ensure the control lever can still be moved to and fro without interruption.

Bring the control lever to the vertical position, and set the scale of the device to 45°, Fig. 61. Then bring the control lever to the maximum position, Fig. 62, bearing in mind that the angle given is intended only as a guide. Check whether the control rod travel is 20 to 21 mm. Set the maximum speed stop in this position and secure provisionally with a locknut.

Adjusting and Testing

1. Basic setting of governor main spring, without supplementary idling spring fitted.

   Press the control lever against the maximum speed stop, Fig. 62, and drive the governor at the upper rated speed. The control rod should travel as specification. If this is not the case, the upper screw plug on the governor housing must be removed, and the adjusting screw on the swivelling lever adjusted through the opening with a screwdriver, Fig. 63. When making this adjustment, set the control lever to STOP and shut off the pump. Turning the adjusting screw to the right will give increased control rod travel.

   Afterwards check the control rod travel again. If the value is still not obtained precisely, the maximum speed stop must be slightly adjusted.

2. Testing the control rod travel at maximum rated speed, without supplementary idling spring fitted.

   Control rod travel above maximum rated speed is tested as follows:

   Hold the control lever against the maximum speed stop, Fig. 62. Check the control rod travel is correct (see Specifications). In all cases the control rod travel must be obtained. If this is not so, the control lever

1. The pre-stroke i.e. the commencement of delivery of the individual elements is adjusted by changing the rollers of the roller tappets. Tappet rollers range from 15,00 mm to 15,60 mm (0,624 in to 0,636 in) in diameter.
2. To change the quantity delivered by a plunger element, loosen the clamping screw of the control rod clamp and then move the control rod clamp along the control rod. Securely tighten the clamping screw after each adjustment.

Preparation and Initial Mechanical Test for Adjusting the Governor (Bosch Test Equipment)

Clamp the pump with the governor on to the test bench. Connect the pressure pipes, bend them off to the right, close to the pipe connector, so that they will not be in the way later, when adjusting the rocker adjustment screw. Check whether there is sufficient lubricating oil in the camshaft chamber, fill to the casting web which can be seen through the end cover aperture.

Screw back the maximum speed stop on the governor housing as far as it will go. Screw out the supplementary idling or bumper spring.

Unscrew the four retaining bolts securing the end cover and screw out the spring capsule of the torque control spring, Fig. 59.

NOTE: When testing the governor the sequence of test operations must be followed to ensure the governor is adjusted and tested correctly.

Test whether the control lever can be moved to and fro without interruption when light pressure is applied to it and whether the control rod follows immediately with it. When the control lever is in the outer STOP position, the control rod must also be in the STOP position, i.e. it must be impossible to press it back any further.

Attach the control rod adjusting device and set the scale to '0' with the control lever in the STOP position, then set the shut-off screw so that the control rod is 0,3 to 1,0 mm before the STOP position.

Set the control lever to FULL. Release the full-load stop, Fig. 60, and adjust at a speed slightly below maximum rated speed until 1 to 2 mm more control travel is obtained. Then secure the stop screw with a locknut.

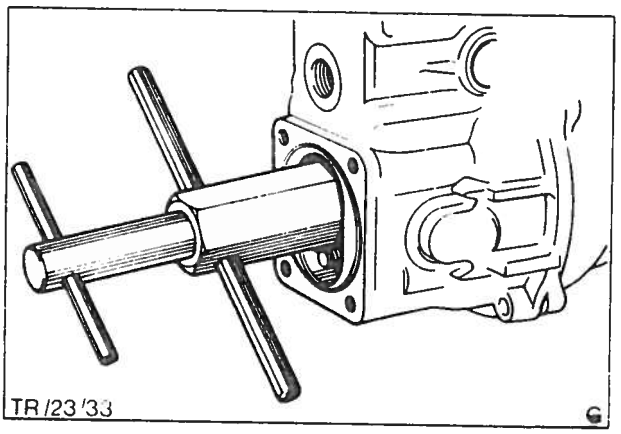


Fig. 59 Adjusting the spring capsule

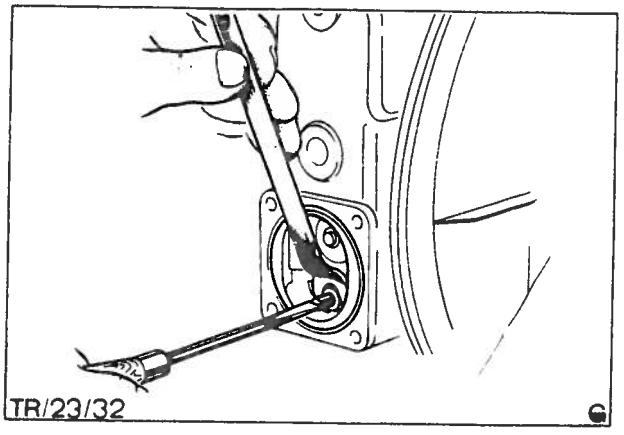


Fig. 60 Adjusting the full load stop

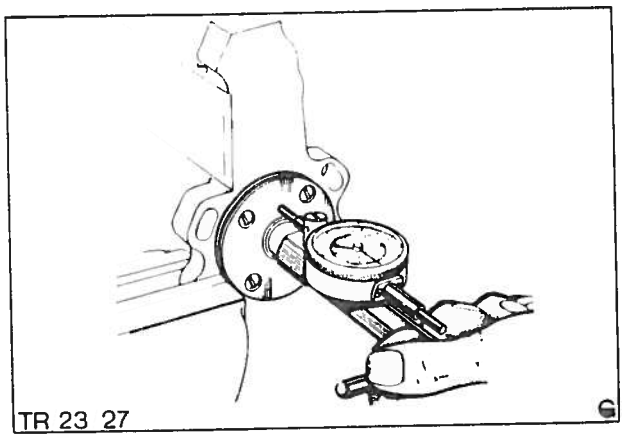


Fig. 56 Measuring the camshaft end-float

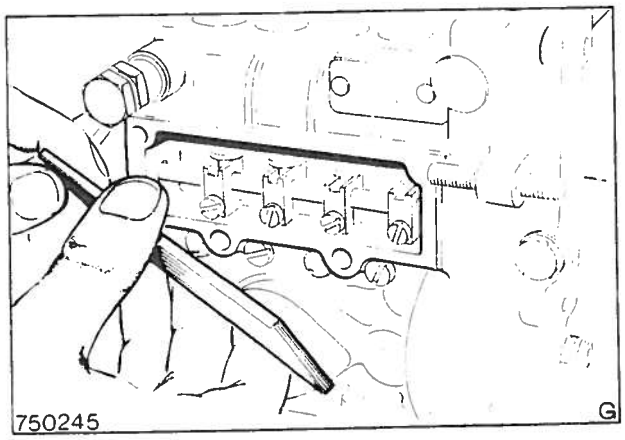


Fig. 57 Refitting the side cover

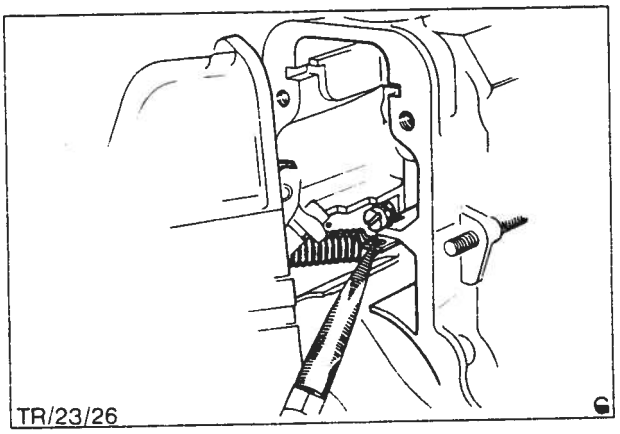


Fig. 58 Reconnecting the starting spring

12. Turn the pump the right way up. Insert the control rod from the governor side. With each element, allow the pin in the lever of the control sleeve to engage in the groove of the clamping piece and guide the control rod through the bore in the clamping pieces. When all the clamping pieces have been attached, mount the locating washers on the control rod. Take care that the guide lever on the control rod end also engages in the guide pin in the governor housing. By means of the tightening screw, firmly secure each of the clamping pieces in the middle of the corresponding two lines marked on the control rod. Check that the control rod still moves easily and that the control sleeves have a slight vertical clearance. Check that the clamping pieces do not come into contact with the upper spring seats or the plunger springs and that the pin of the control lever in the groove of the clamping member does not come out of engagement in the extreme 'STOP' or 'FULL' position of the control rod.
13. Screw the end cap onto the control rod guide sleeve. Fit the injection pump side cover, Fig. 57.
14. Position a Woodruff Key on the taper of the camshaft, push the flyweight assembly on to the taper and place the lock washer in position. Fit the nut and tighten to the specified torque.
15. Fit a gasket to the governor housing and position the governor close against the housing. Hook the starting spring to a lug on the housing and insert the shackle in the control rod and secure with the leaf spring, (Fig. 58). Mount the governor cover on to the housing and secure with the cheese head screws and lockwashers.
16. Position a new gasket and refit the fuel lift pump. Secure with the nuts and lock washers.
17. Refit the overflow valve.

TESTING & ADJUSTING THE INJECTION PUMP

Phasing and Calibrating the Fuel Injection Pump

Included here are the Phasing and Calibrating procedures for the Bosch pump using a Bosch Test Stand. For other Test Stands consult the Test Stand manufacturer. Two important adjustments are as follows:

3. Refit the valve springs, delivery valves and gaskets to the valve holders. Fit a gasket and screw the complete units into the pump housing. The delivery valve holder should be tightened to a torque of 48,8 Nm (36 lbf ft or 5 kgf m) several times, slackened after each tightening, and finally tightened to a torque of 39,3 Nm (29 lbf ft or 4 kgf m). Fit the delivery valve locking jaws.

4. Insert the control sleeve from the front into the tappet guides and push upwards over the shank of the pump barrel.

5. Place the respective upper spring seats on the plunger springs and push them upwards into the tappet guides so that the small lugs on the spring seats engage behind the recesses in the housing.

6. Turn the pump upside down and turn the control sleeve so that its lever points forward. Place the lower spring support (Fig. 53) on the pump plunger, immerse the plunger in test oil, and refit the plunger to the barrel.

7. The vane of the pump plunger must be inserted into the control sleeve, Fig. 54 so that the marking on the vane points forwards in the direction of the control sleeve lever. Carefully press on the plunger to ensure that the plunger vane engages properly in the control sleeve.

8. Fit the tappets to the tappet guides so that the longitudinal grooves point forwards. Push the tappets to top dead centre and fit the tappet holder pins.

9. Screw in the tappet locating screws. Check that the control sleeve is free to rotate within the limits of the lever movement and that the control sleeve has a small vertical clearance.

10. Refit the camshaft together with the bearing end plate and fit the retaining bolts, Fig. 55. Measure the camshaft end-float using a dial gauge, Fig. 56. This should be within the limits 0,03 to 0,13 mm (0,001 to 0,005 in). If the end-float exceeds these specifications, the camshaft must be removed and shims inserted as required between the spacer ring and ball bearing inner race.

11. Remove the tappet holder pins. Refit the bottom gasket and cover. Secure with the countersunk screws.

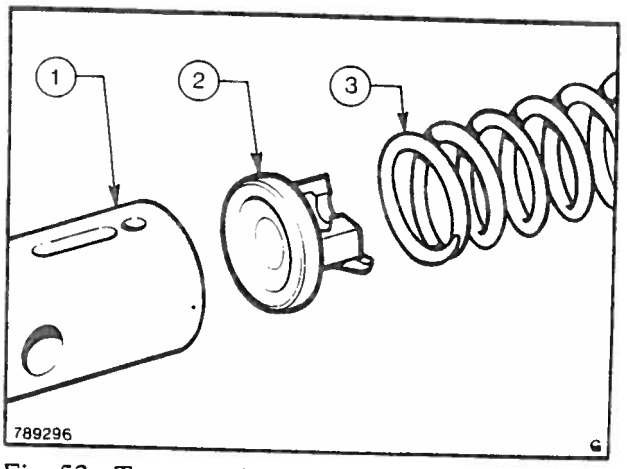


Fig. 53 Tappet guide, support and spring
1. Tappet guide. 2. Lower spring support
3. Spring

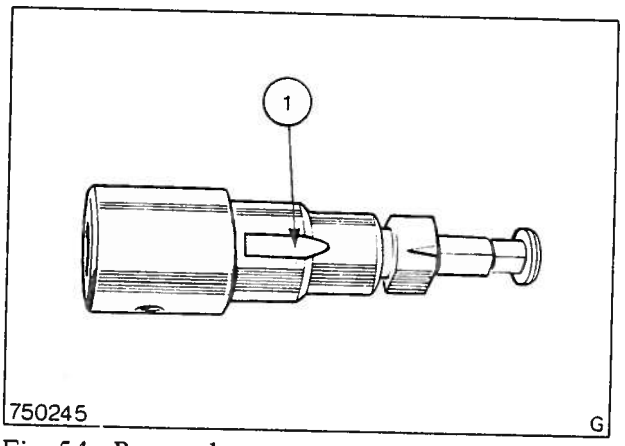


Fig. 54 Pump plunger
1. Plunger Vane

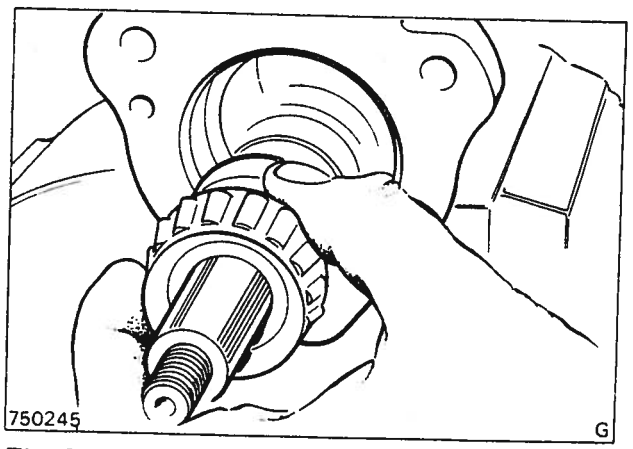


Fig. 55 Refitting the camshaft

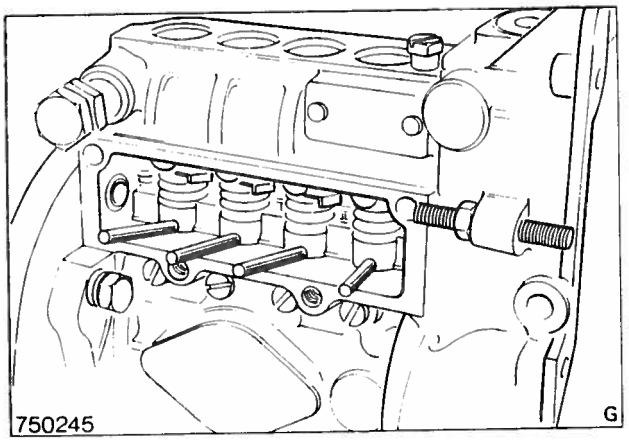


Fig. 50 Tappet holders with pins in position

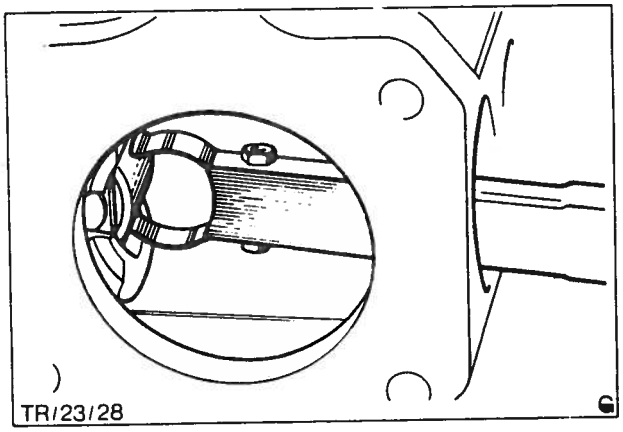


Fig. 51 Removing tappet with forceps

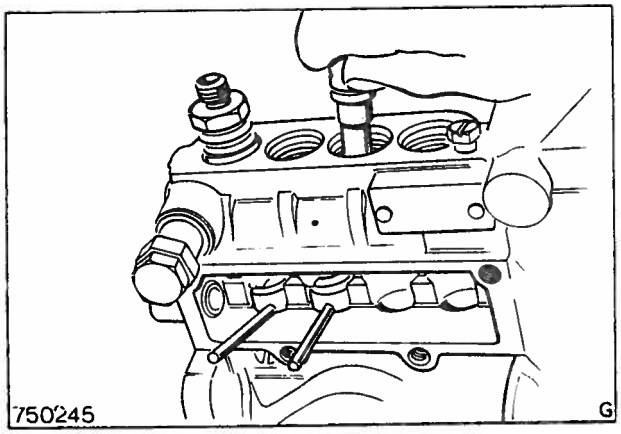


Fig. 52 Removing the pump barrel

6. Unscrew the nut on the flywheel assembly, holding the coupling at the other end of the camshaft. Remove the securing washer and withdraw the flyweight assembly. Remove the woodruff key from the camshaft taper.
7. Remove the delivery valve holder clamps, Fig. 49. Unscrew the delivery valve holders with a socket wrench and remove the valve holders ands prings.

NOTE: All components from one pump element should be kept together and replaced in their original positions.

8. Remove the delivery valves and gaskets.
9. Loosen the control rod clamping and withdraw the control rod towards the governor end, removing the clamping pieces at the same time.
10. Rotate the camshaft and, in the top dead centre position of each roller tappet, insert a tappet holder pin in the hole provided, Fig. 50.
11. Remove the four bolts securing the camshaft bearing and plate at the pump drive end. Lightly tap the camshaft at the governor end to free the shaft and the bearing end plate, remove the camshaft and bearings.
12. Slacken the tappet locating screws and, using the tappet forceps, Tool No. L1687953010, force each tappet upwards and remove the tappet holder pins. Remove each of the tappets and keep them with their respective delivery valve assemblies, Fig. 51.
13. Remove the pump plunger and the bottom spring supports.
14. Remove the plunger spring and upper spring seat by carefully guiding the spring seat down the tappet guide.
15. Remove the control sleeve and carefully remove the pump barrel by pushing upwards. Fig. 52.

ASSEMBLY

1. All components, including new parts, should be thoroughly washed, and immersed in test oil prior to assembly.
2. Refit the pump barrel into the housing so that the vertical groove for the locating pin is correctly positioned. Check that the barrel does not stick by lifting it slightly from below and allowing it to drop freely on to its seating.

Automatic Advance Unit

The automatic advance unit is mounted on the front of the pump camshaft and is driven by the drive gear, retention to the camshaft is by woodruff key and locking nut.

As engine speed increases the centrifugal force causes weights inside the unit to move outwards, the coupling flange and the camshaft advance in relation to the driving flange, thereby the commencement of delivery in each injection pump element will be advanced accordingly.

The automatic advance unit housing contains the variable sleeve. The variable disc with the hub is fixed to this variable sleeve. The variable disc has four guide bolts to locate the springs which are situated on the flyweight pins between the springs and the spring stops. Each flyweight has a moveable roller at the top. The springs force the moveable rollers on the flyweights against the tracks of the variable discs. With increasing engine speed, the flyweights move outwards as a result of centrifugal force and press against the tracks with their rollers. This action overcomes the force of the springs and rotates the variable sleeve with the hub.

The automatic advance unit is filled with oil, the oil level should be checked every 1,000 miles or every 40 hours.

PUMP CONDITION

A guide to the condition of the injection pump can be obtained from the engine performance – refer to 'Fault Diagnosis' on page 5r. If the injection pump is considered to be at fault it should be removed from the engine and tested before being dismantled – refer to 'Preliminary Checking' on page 10r.

REMOVAL FROM ENGINE – Refer to page 10r

DISMANTLING

1. Remove the fuel lift pump and drain the oil from the camshaft chamber.
2. Using the advance hub puller Tool No. KDEP 2944, remove the hub, Fig. 47.
3. Remove the side cover plate, unscrew the overflow valve at the rear of the pump.
4. Remove the bottom cover and retain the gasket.
5. Remove the retaining screws and lockwasher and slightly pull off the governor cover. Uncouple the shackle from the control rod and the starting spring from the lug in the housing, Fig. 48. Remove cover.

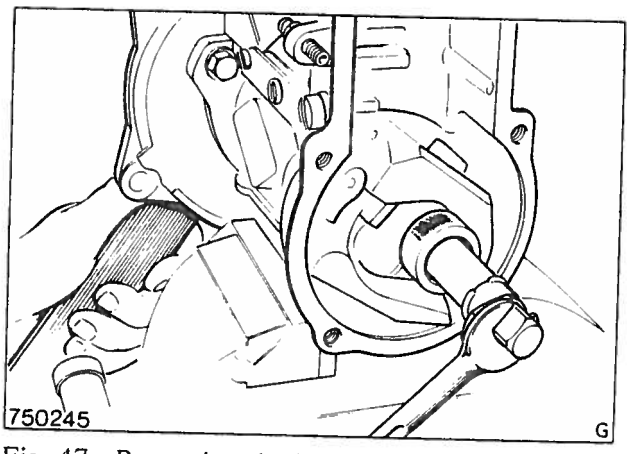


Fig. 47 Removing the hub
1. Advance Hub Puller Tool No. KDEP2944

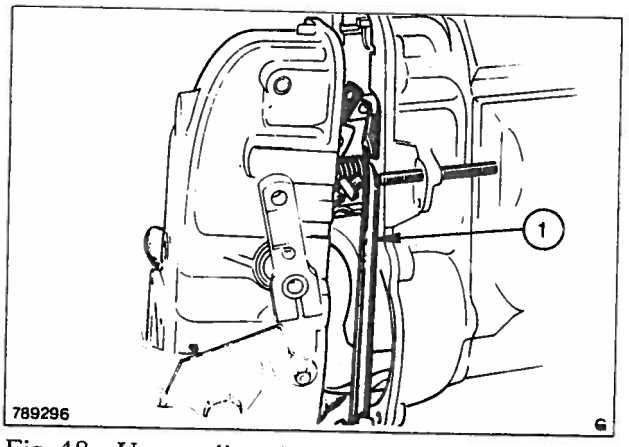


Fig. 48 Uncoupling the shackle from the control rod
1. Screwdriver

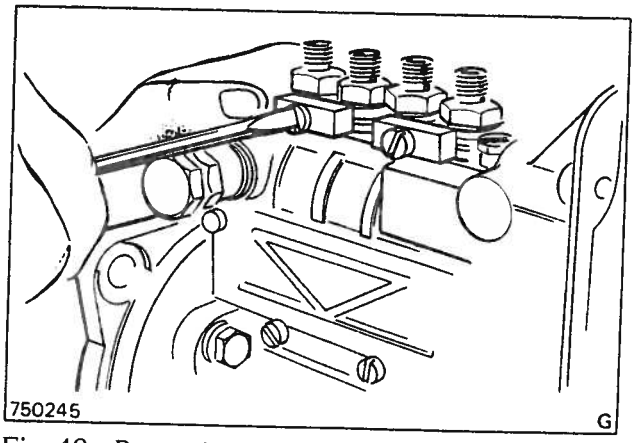


Fig. 49 Removing the delivery valve holder clamps

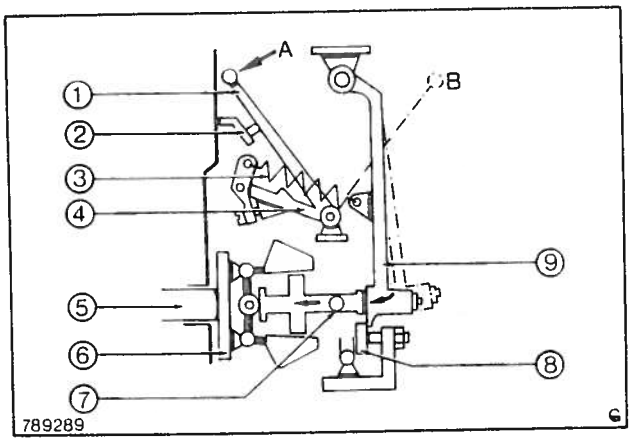


Fig. 45 MOVEMENT 1
A = START B = STOP
1. Control Lever
2. Max. Speed Stop
3. Governor Main Spring
4. Swivelling Lever with Rocker
5. Injection Pump Camshaft
6. Carrier
7. Link with Thrust Sleeve
8. Full Load Stop
9. Tensioning Lever

With the control lever moved to START, the swivelling lever tensions the governor main spring. The tensioning lever is pulled against the full-load stop. The link connecting with the thrust-sleeve bearing and the thrust sleeve follow this movement. The control rod is in the full-load position.

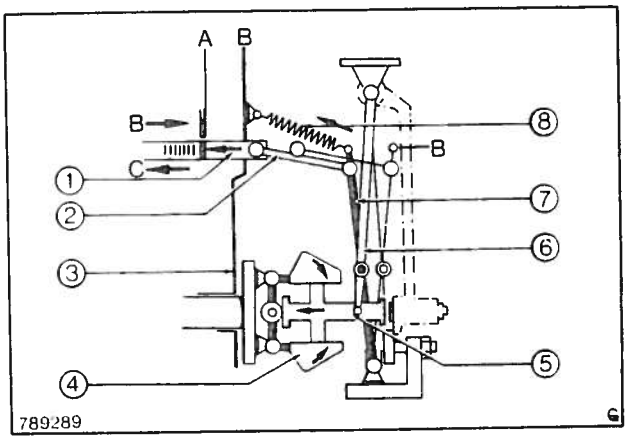


Fig. 45 MOVEMENT 2
A = START B = STOP C = FULL LOAD
1. Control Rod
2. Link Member
3. Injection Pump
4. Flyweight
5. Link with Thrust Sleeve
6. Guide Lever
7. Fulcrum Lever
8. Starting Spring

The swivelling lever projections have released the guide lever, causing the starting spring to pull the fulcrum lever and thus the control rod to the excess-fuel delivery position (START). The link connecting with the thrust-sleeve bearing and the thrust sleeve move to the left and the flyweights inwards.

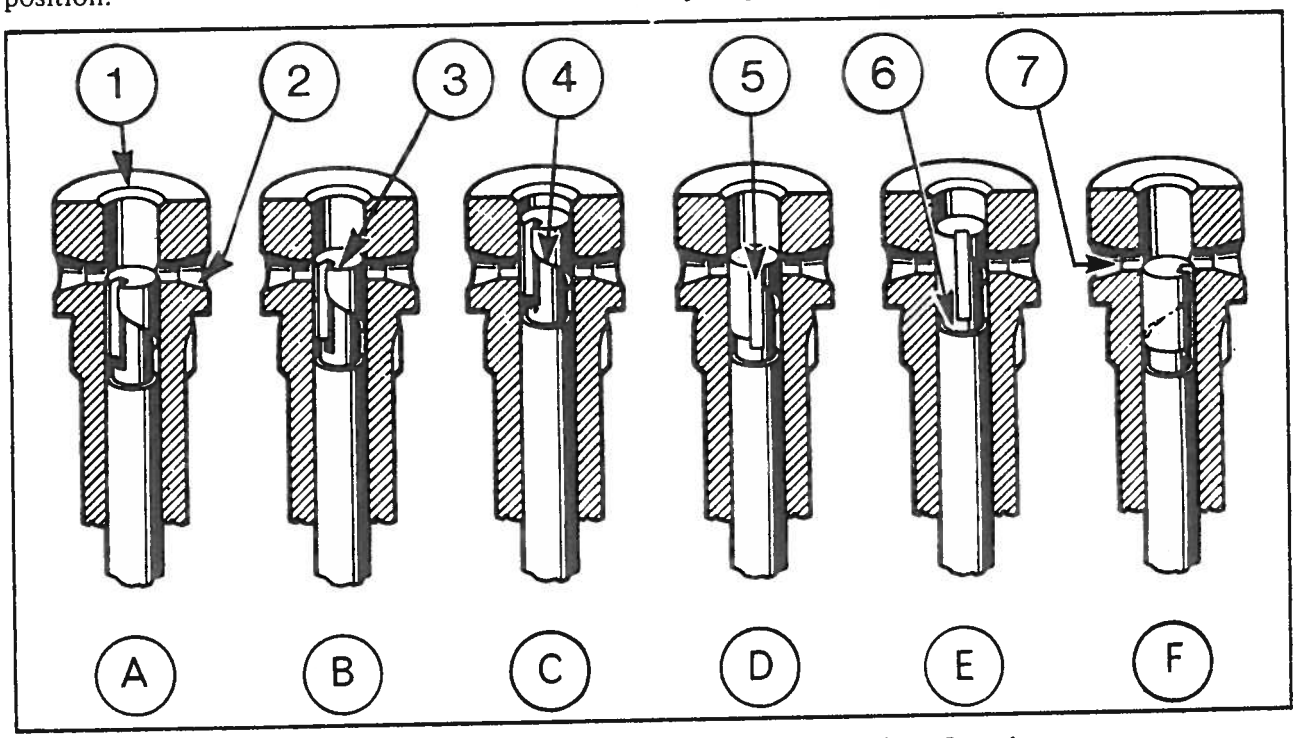


Fig. 46 PUMPING ELEMENT OPERATING CYCLE
A – Bottom Dead Centre
B – Start of Flow – Maximum Quantity
C – End of Flow
D – Start of Flow
E – End of Flow – Part Feed Intermediate Quantity
F – No Flow

1. Barrel
2. Control Port
3. Plunger
4. Control Edge
5. Longitudinal Groove
6. Annular Groove
7. Inlet Port

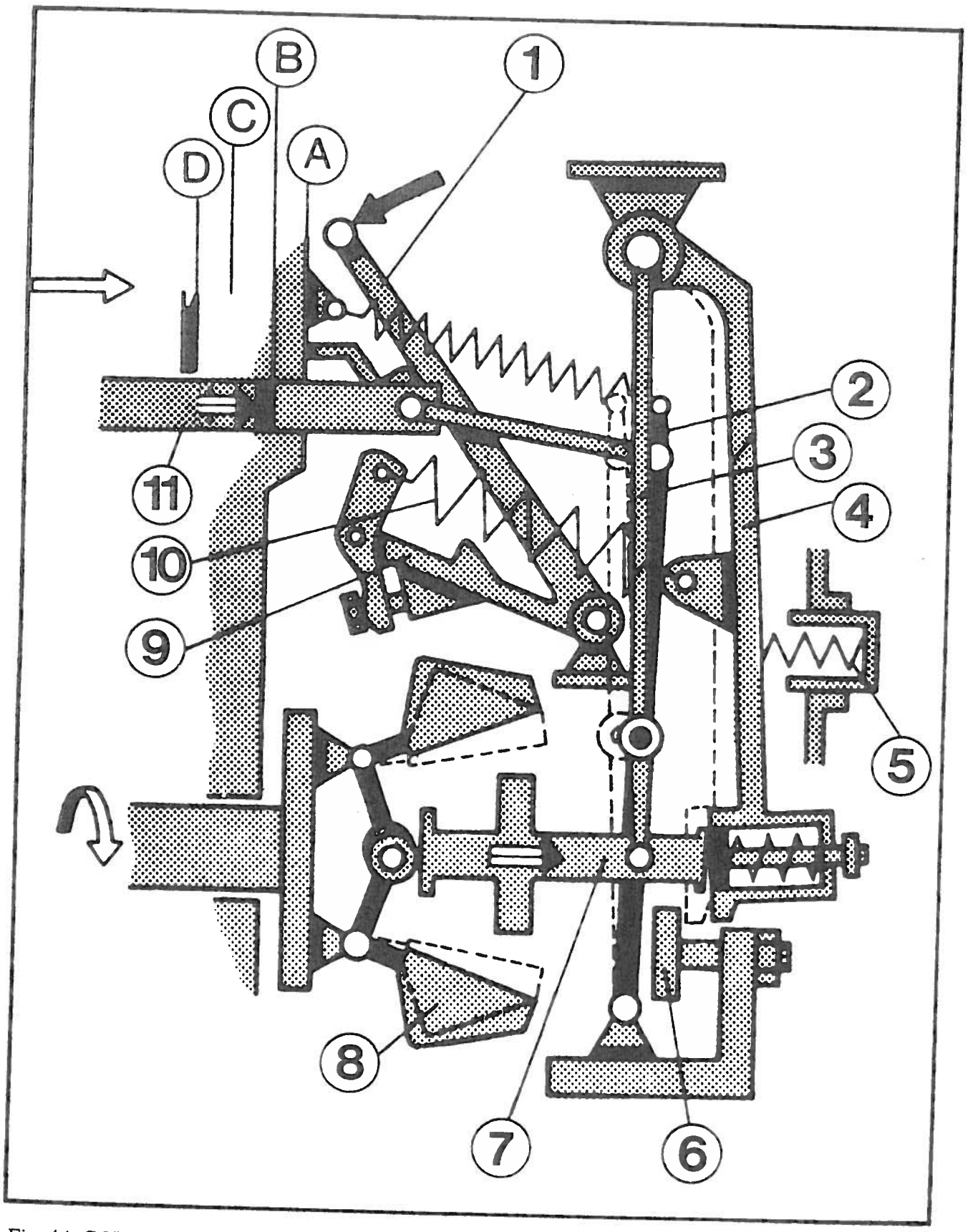


Fig. 44 GOVERNOR – Cut-off, from full load to no load

1. Throttle lever (accelerator pedal)
2. Governor lever
3, Guide lever
4. Idle speed lever
5. Secondary idling spring
6. Full load stop (flow rate)
7. Adjusting bolt with guide bush
8. Flyweights
9. Pivoting lever with swivel link
10. Control spring
11. Governor shaft

A Stop
B Idling
C Full load
D Start

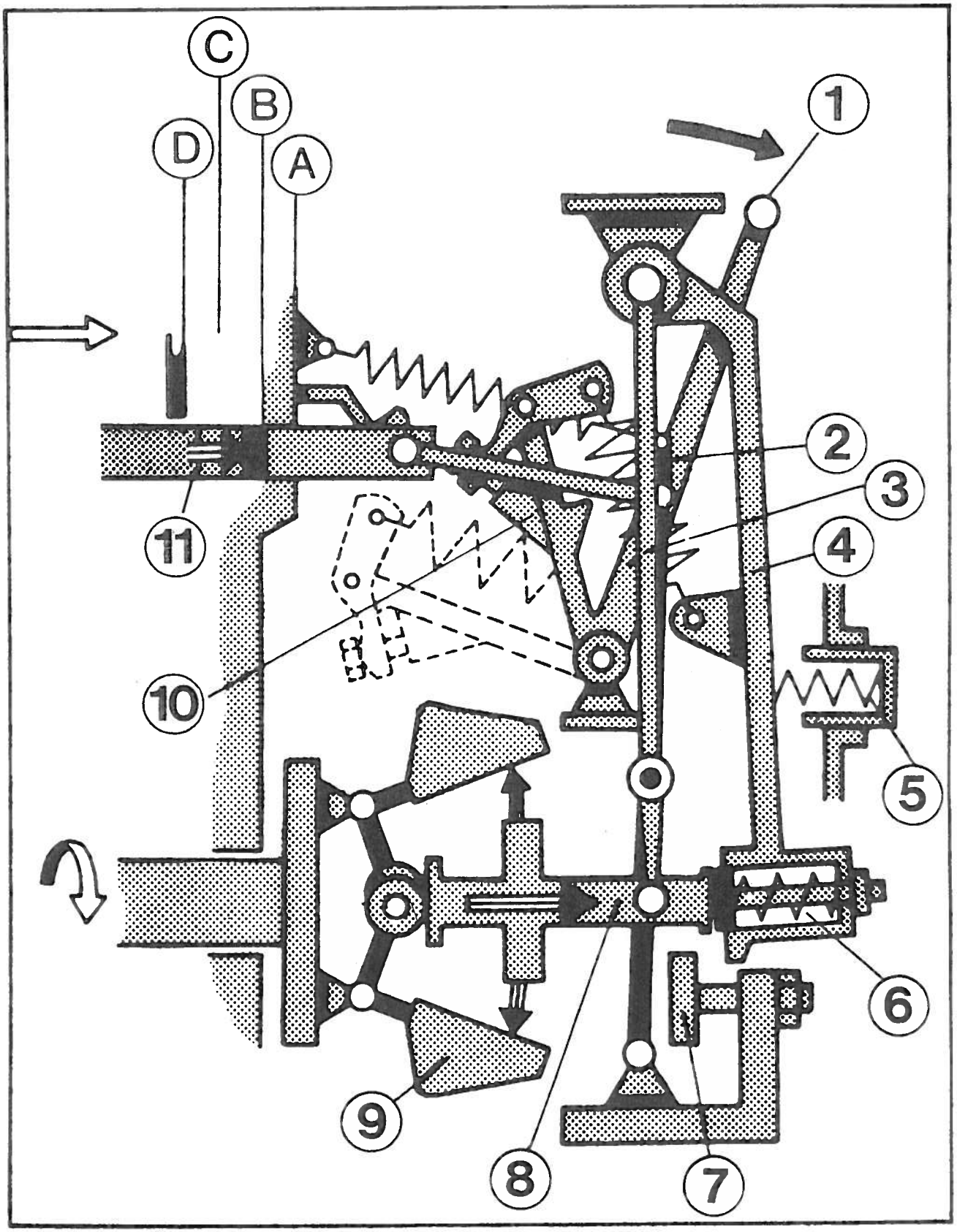


Fig. 43 GOVERNOR – Idling

1. Throttle lever (accelerator pedal)
2. Governor lever
3. Guide lever
4. Idle speed lever
5. Secondary idling spring
6. Droop
7. Full load stop (flow rate)
8. Adjusting bolt with guide bush
9. Fly weights
10. Pivoting lever with swivel link
11. Governor shaft

A Stop
B Idling
C Full load
D Start

THE BOSCH INJECTION PUMP

DESCRIPTION

The Bosch 'M' injection pump (see Fig. 42) is a self-contained unit with a centrifugal governor located at the rear end of the pump and an automatic advance unit located at the front end of the pump.

The camshaft runs in two bearings, one in the rear face of the cambox housing and the other in the governor housing.

The injection pump is of the single-acting plunger type with a separate element for each engine cylinder. Each pumping element consists of a plunger and barrel. The plunger is very accurately fitted to the barrel, having a clearance of approximately 0,0025 mm (0,0001 in) in order to provide a perfect seal under very high pressure without special sealing rings. Because of this, the plungers and barrels must be replaced in complete assemblies only.

The pump plunger is actuated in the delivery stroke by a cam, and in the filling stroke by the governor return spring. The quantity of fuel injected is regulated by a helical control edge at the top of the plunger and a port in the barrel.

At the lower end of the plunger is an arm which engages with the clamping pieces located on the control rod. This control rod is link connected to the governor. When the control rod moves, the lever on the control sleeve is carried along and transmits the movement to the pump plunger. Any movement of the governor is thus transmitted to each plunger simultaneously, causing them to turn in their barrels to control the fuel delivery by changing the position of the longitudinal groove and helical control edge and control port.

Above each element is a delivery valve, held in position by a spring. The delivery valves, springs and valve support are retained by connectors, which are sealed by nylon washers.

The fuel delivery is controlled by adjustable screws fitted at the governor housing rear, which via a fulcrum lever limits the control rod movement. An excess fuel device for starting purposes is incorporated in the governor, Fig. 45.

OPERATION

Fuel Delivery

The operation and construction of the pumping elements is identical and each plunger is operated by a separate cam on the camshaft. A pumping element is shown in the various stages of its operating cycle in Fig. 46.

When the plunger is at B.D.C., the barrel chamber fills up with fuel in the inlet port. When the plunger moves upwards, the upper edge of the plunger closes the inlet port. The plunger then forces the fuel in the barrel through a delivery valve to the injector. Fuel flow ceases as soon as the helical control edge uncovers the control port. When the port is uncovered by the control edge, the pressure on the fuel in the barrel is released. The fuel then flows through the longitudinal groove and the port back into the pressure chamber of the injection pump.

To stop the engine, the plunger is rotated so that when it moves upwards, the fuel escapes from the barrel chamber via the longitudinal groove, control edge and port.

Control rack travel is transmitted to the plungers by clamping pieces with a groove in the top that are located on the control rod. A lever with a riveted pin protrudes from the control sleeve of each element, the pin being engaged in the groove of the clamping piece.

The bottom end of the pump plunger contacts the roller tappet directly, commencement of delivery is adjusted by fitting rollers of different diameters.

Lubrication

The pump is pressure lubricated by the engine oil via oilways in the front cover, return of this oil is through the front cover to the sump. Before operating a pump ensure the cambox has been filled to the correct level with engine oil.

During engine oil change, the injection pump must also be drained and refilled with the correct grade and quantity of engine oil.

Variable Speed Governor

As the engine speed increases, the flyweights move outwards as soon as centrifugal force exceeds the force of the springs. As the engine speed decreases, centrifugal force diminishes until the forces exerted by the governor springs finally exceed it and the flywieghts swing inwards again. The movements of the flyweights are communicated to the control via a thrust sleeve link connecting with the thrust sleeve bearing and lever system. The rod is moved in the direction of STOP as the engine speed increases, i.e. speed is limited because the injection pump delivers less fuel. When engine speed decreases, the control rod is moved in the direction of FULL LOAD, i.e. the injection pump steps up the fuel delivery rate and engine speed increases, Figs. 43 and 44.

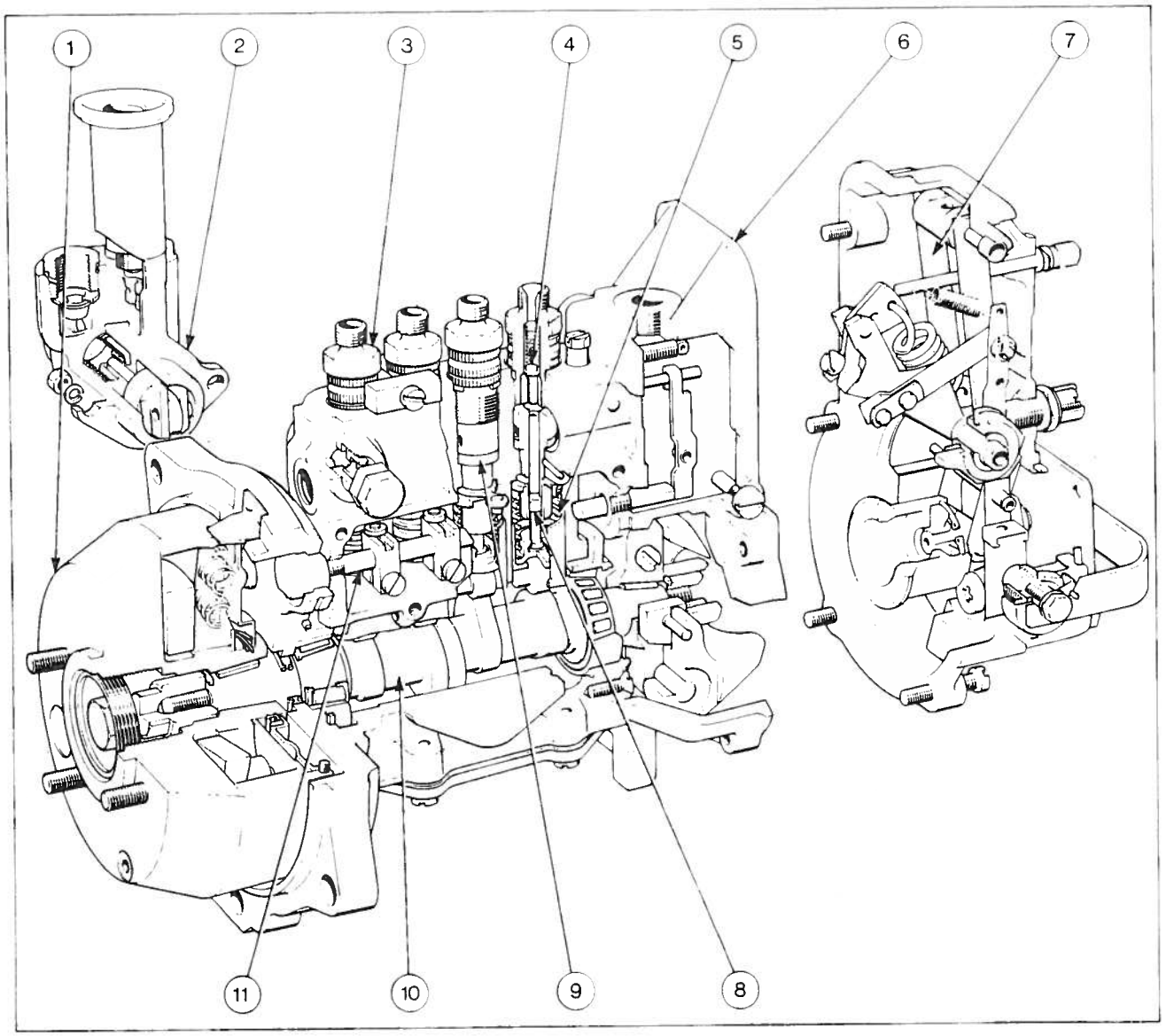


Fig. 42 BOSCH 'M' INJECTION PUMP

1. Automatic advance hub
2. Fuel lift pump
3. Delivery valve holder
4. Delivery valve
5. Plunger return spring
6. Pump body
7. Governor assy.
8. Plunger
9. Barrel
10. Camshaft
11. Control rod

CAV IN-LINE INJECTION PUMP SPECIFICATIONS

Pump Part No. Ford/CAV	Vol. for 200 Shots (cc) with BDN12SD12 Nozzles	Calib. Speed rpm	Idling rpm	Gov. Spring Colour Code	Full-load Speed rpm	No-load Speed rpm	Control Rod Starts to Move	No Delivery	Interleaf Spring Colour Code	Buffer Spring Colour Code
Automotive										
715F-9A543-AHA P5178/1B "Minimec"	7,4-7,6† 8,0-8,2††	1000	720-770	2x17swg GREEN	3600	4100-4120	1810-1830	2060-2140	27swg RED	WHITE
715F-9A543-AHD P5178/4B "Minimec"	7,4-7,6† 8,0-8,2††	1000	850-900	2x17swg GREEN	3600	4100-4120	1810-1830	2060-2140	27swg RED	WHITE
715F-9A543-BCA P5154 "Micromec"	8,0-8,2	1000	600-650	2x17swg GREY/ GREEN	3600	4040-4060	1810-1830	2060-2140	—	—
715F-9A543-AEA P5153 "Micromec"	8,0-8,2	1000	600-650	2x17swg GREY/ GREEN	3600	4040-4060	1810-1830	2060-2140	—	—
715F-9A543-BDA P5179 "Micromec"	7,4-7,6† 8,0-8,2††	1000	650	2x17swg GREEN	3600	4100-4120	1810-1830	2060-2140	27swg RED	WHITE
715F-9A543-BDB P5179/1 "Micromec"	7,4-7,6† 8,0-8,2††	1000	650	2x17swg GREEN	3600	4100-4120	1810-1830	2060-2140	27swg RED	WHITE
General Purpose										
725F-9A543-GAA P5194 "Minimec"	7,6-7,8† 8,2-8,4††	1000	600-650	2x18swg YELLOW	3600	3880-3900	1850-1900	2040-2050	27swg RED	WHITE
725F-9A543-GAC P5194/2 "Minimec"	7,6-7,8† 8,2-8,4††	1000	600-650	2x18swg YELLOW	3600	3880-3900	1850-1900	2040-2050	27swg RED	WHITE
725F-9A543-HAA P5195 "Minimec"	7,2-7,4	1000	600-650	2x18swg YELLOW	3600	3880-3900	1855-1865	2045-2090	—	—
725F-9A543-HAC	7,2-7,4† 7,8-8,0††	1000	600-650	2x18swg YELLOW	3600	3880-3900	1850-1900	2040-2050	27swg RED	WHITE
Class 'A'										
725F-9A543-EAA P5189/A "Minimec"	8,0-8,2† 8,5-8,7††	1600	1000	2x18swg YELLOW	3000	3135±5	1820-1860	1940-1960	—	—
725F-9 A543-EAB P5189/1A "Minimec"	8,0-8,2† 8,5-8,7††	1600	1000/ 1050	2x18swg YELLOW	3600/ 3000	3760±5/ 3135±5	1820-1860	1940-1950	—	—
725F-9A543-FAA P5190 "Minimec"	7,7-7,9† 8,2-8,4††	1600	1050	2x18swg YELLOW	3000	3135±5	1820-1860	1940-1960	—	—
725F-9A543-FAB P5190/1A "Minimec"	7,7-7,9† 8,2-8,4††	1600	1050	2x18swg YELLOW	3000	3135±5	1820-1860	1940-1950	—	—

† Hartridge 1100 †† Hartridge 650

Governor spring identification

– Primary	GREEN paint on eye
– Interleaf	RED
– Secondary	GREEN paint band on eye
Rack Buffer Spring	WHITE
Maximum speed – full load	3600 rpm
– no load	4050 rmp – Full Rate
	4010 rpm – De-Rate
Idling speed	680 to 750 rpm

Tightening Torques

Delivery valve holder	44,8 Nm (33 lbf ft or 4,6 kgf m)
Auto-advance unit nut	54,2 Nm (40 lbf ft or 5,5 kgf m)
Pulley to auto-advance unit nut	14,9 to 20,3 Nm (11 to 15 lbf ft or 1,5 to 2,1 kgf m)
Governor cover (small screws)	5,42 to 8,13 Nm (4 to 6 lbf ft or 0,6 to 0,8 kgf m)
Governor cover (large screws)	16,3 to 20,3 Nm (12 to 15 lbf ft or 1,7 to 2,1 kgf m)
Injector high pressure pipe connections	17,7 to 20,3 Nm (13 to 15 lbf ft or 1,8 to 2,1 kgf m)
Lubricant	As for engine
Capacity	250 cc

Test Equipment Specification

Type	Variable speed
Master injector nozzle	CAV BDN 12SD12
Nozzle opening pressure	145 atmospheres
Back leakage time for a pressure drop from 150 to 100 atmospheres	10 secs minimum
High pressure pipes	6 mm O.D. x 2 mm I.D. x 760 mm (30in) long

Test Oil

Castrol Ltd	H111/60
Esso Petroleum Co Ltd	T.S.D. 815
Shell-Mex & BP Ltd	Shell Fusus Oil "C" Shell DT 11
Oil temperature	27 to 38°C (80 to 100°F)

Auto-advance unit

Auto-advance unit end float	0,03 to 0,13 mm (0,00118 to 0,00512 in)
Angular movement	5° minimum

Test Oil

Castrol Ltd	H111/60
Esso Petroleum Co Ltd	T.S.D. 815
Shell Mex & BP Ltd	Shell Fusus Oil 'C' Shell DT 11
Oil temperature	27 to 38°C (80 to 100°F)
Auto advance unit end float	0,03 to 0,13 mm (0,00118 to 0,00512 in)
Angular Movement	5° minimum

Fuel Injectors

Type	Pintle type
Injector nozzle number	BDN OSD 6596
Holder	BKB 37S 5327
Nozzle opening pressure	175 atm
Needle Lift	0,7 mm (0,0276 in)

CAV MINIMEC INJECTION PUMP (2401E and 2402E)

Type	'Minimec' multi-element operated by enclosed camshaft
Rotation	Clockwise from drive end
Governor type	Mechanical
Cold starting device	Bv excess fuel control
Pump timing (auto advance)	12° BTDC (11° BTDC on 4 cyl glow plug head engines and later 6 cyl engines).
Plunger bore, stroke and helix angle	7,00 mm dia x 7 mm x 50°
Fuel delivery	Refer to chart on page 23
Camshaft end-float	0,05 to 0,13 mm (0,002 to 0,005 in)
Camshaft end-float shims	0,10 to 0,20 mm (0,004 to 0,008 in) thick
Thrust bearing face and the face of the pump housing dimension	19,90 to 20,60 mm (0,783 to 0,811 in)
Thrust bearing edge and spacing ring dimension	5,90 to 6,20 mm (0,23 to 0,24 in)
Phasing tolerance	±1° Pump
Timing tolerance	±½° Pump

Phasing Spacers

Grade – 8	4.55 to 4,6 mm (0,179 to 0,181 in)
– 9A	4,65 to 4,7 mm (0,183 to 0,185 in)
– 10	4,75 to 4,8 mm (0,187 to 0,189 in)
– 11	4,85 to 4,9 mm (0,191 to 0,193 in)
– 12	4,95 to 5,0 mm (0,195 to 0,197 in)
– 13	5,05 to 5,1 mm (0,199 to 0,201 in)
– 14	5,15 to 5,2 mm (0,203 to 0,205 in)
Stroke to close inlet port	2,4 to 2,6 mm (0,095 to 0,102 in)
Plunger head clearance	1,0 mm (0,04 in) nominal
Plunger arm to spring seat clearance	0,05 to 0,2 mm (0,002 to 0,008 in)

Spring Seat Spacers

Grade – 025	0,40 to 0,45 mm (0,016 to 0,018 in)
– 015	0,50 to 0,55 mm (0,020 to 0,002 in)
– 15	0,60 to 0,75 mm (0,024 to 0,026 in)
– 25	0,70 to 0,75 mm (0,028 to 0,030 in)
– 35	0,80 go 0,85 mm (0,031 to 0,033 in)
– 45	0,90 to 0,95 mm (0,035 to 0,037 in)
– 55	1,00 to 1,05 mm (0,039 to 0,041 in)

SPECIFICATIONS

CAV MICROMEC INJECTION PUMP (2401E AND 2402E)

Type	'Micromec' multi-element operated by an enclosed camshaft
Rotation	Clockwise from drive end
Governor type	Mechanical
Cold starting device	By excess fuel control
Pump timing (Auto advance)	12° BTDC (11° BTDC on 4 cyl glow plug head engines and later 6 cyl engines)
Plunger bore, stroke and helix angle	7,0 mm dia x 7 mm x 50°
Fuel delivery	Refer to Chart on page 23
Auto advance unit end float	0,03 to 0,13 mm (0,00118 to 0,00512 in)
Angular movement	5° minimum
Camshaft end-float	0,05 to 0,13 mm (0,002 to 0,005 in)
Camshaft end float shims	0,01 to 0,20 mm (0,004 to 0,008 in) thick
Phasing tolerance	± 1° Pump
Timing tolerance	± ½° Pump

Phasing Spacers

Grade – 22	5,55 to 5,60 mm (0,219 to 0,221 in)
– 23	5,45 to 5,50 mm (0,215 to 0,217 in)
– 24	5.35 to 5,40 mm (0,211 to 0,213 in)
– 25	5,25 to 5,3 mm (0,207 to 0,209 in)
– 26	5,15 to 5,2 mm (0,203 to 0,205 in)
– 27	5,05 to 5,1 mm (0,199 to 0,201 in)
Stroke to close inlet port	2,4 to 2,6 mm (0,095 to 0,102 in)
Plunger head clearance	1,0 mm (0,04 in) nominal
Plunger arm to spring seat clearance	0,05 to 0,2 mm (0,002 to 0,008 in)

Spring Seat

Grade – 20	4,00 to 4,05 mm (0,158 to 0,160 in)
– 21	4,10 to 4,15 mm (0,162 to 0,164 in)
– 22	4,20 to 4,25 mm (0,166 to 0,168 in)
– 23	4,30 to 4,35 mm (0,170 to 0,172 in)
– 24	4,40 to 4,45 mm (0,174 to 0,176 in)
– 25	4,50 to 4,55 mm (0,178 to 0,180 in)
– 26	4,60 to 4,65 mm (0,182 to 0,184 in)
– 27	4,70 to 4,75 mm (0,186 to 0,188 in)
– 28	4,80 to 4,85 mm (0,190 to 0,192 in)
– 29	4,90 to 4,95 mm (0,194 to 0,196 in)
– 30	5,00 to 5,05 mm (0,198 to 0,200 in)

Fuel Injection Pump Tightening Torque

Delivery valve holder	44,8 Nm (33 lbf ft or 4,6 kgf m)
Auto advance unit nut	62,3 Nm (46 lbf ft or 6,4 kgf m)
Pulley to auto-advance unit nut	14,9 to 20,3 Nm (11 to 15 lbf ft or 1,5 to 2,1 kgf m)
Lubricant	As for engine
Capacity	0,284 litre (0,5 pint)
Injector high pressure pipe connections	17,7 Nm (13 to 15 lbf ft or 1,8 to 2,1 kgf m)

Test Equipment Specification

Type	Variable speed
Master injector nozzle	CAV BDN 12SD12
Nozzle opening pressure	175 ± 2,5 atmospheres
Back leakage time for pressure to drop from 150 to 100 atmospheres	10 secs minimum
High pressure pipes	6 mm O.D. x 2 mm I.D. x 760 mm (30 in) long

pump, Fig. 39. Continue pumping until a stream of fuel, free of air bubbles, issues from the filter.

NOTE: If the eccentric on the injection pump camshaft is on maximum lift, the fuel lift pump priming lever will be inoperative. If this occurs, rotate the engine until the priming lever can be operated.

3. Tighten the bleed screw on the filter.
4. Loosen the bleed screw on the injection pump body two or three turns (located on the top of the pump body for 'Micromec' pumps, Fig. 40, and on the pump body side for the 'Minimec' pump, Fig. 41) and operate the priming pump as before.

NOTE: Under no circumstances should the injection pump plungers be levered up and down to prime the injector pipes or test the injectors, as the plunger arms may be seriously damaged.

5. When fuel, free from air bubbles, issues from the bleed screw, tighten the screw.
6. Wipe all surplus fuel oil from the exterior of the filter and injection pump. Start the engine and check for fuel leaks.

INJECTION PUMP STORAGE

If, after overhaul, an injection pump is being stored for a period exceeding 30 days, it should be filled with substitute oil and all connections sealed with the special plugs and caps.

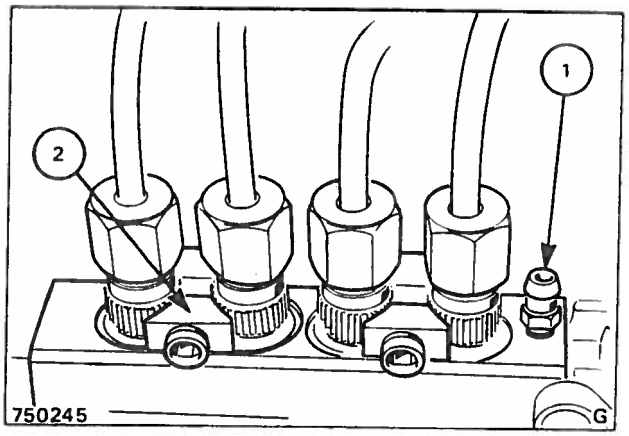


Fig. 40 Location of Micromec injection pump bleed screw
1. Bleed Screw (Micromec)
2. Valve Holder Retainers

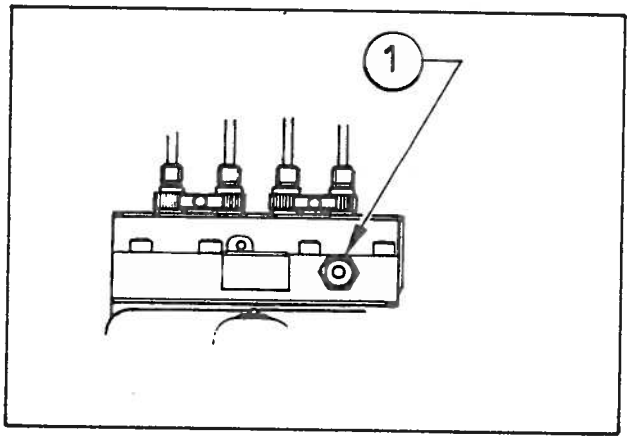


Fig. 41 Location of Minimec injection pump bleed screw
1. Bleed Screw

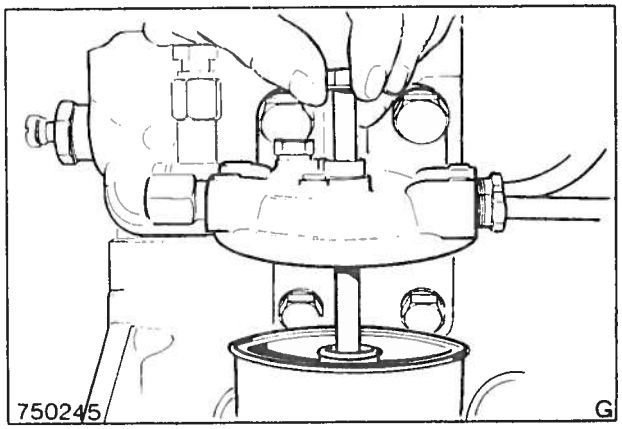


Fig. 37 Removing the fuel filter element

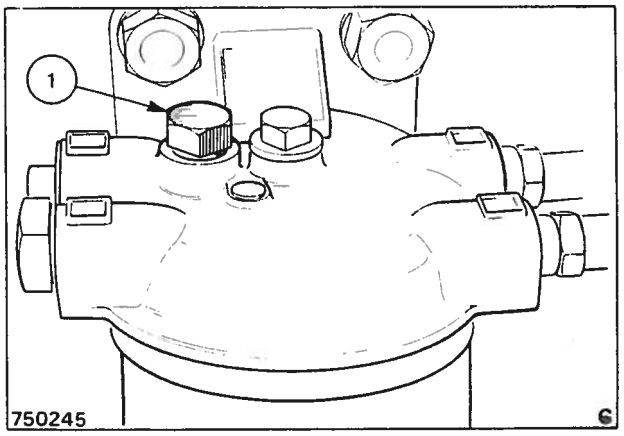


Fig. 38 Location of Filter Bleed Screw
1. Bleed Screw

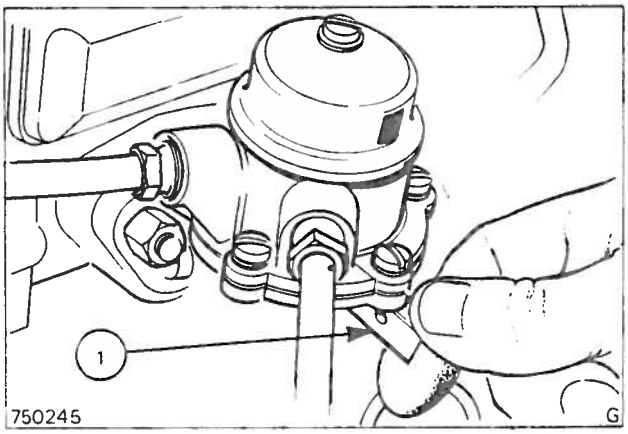


Fig. 39 Operating the Fuel Pump Priming Lever
1. Priming Lever

When filling the fuel tank, the fuel must not be poured from or have been stored in a dirty container.

Even when operating under the most favourable conditions a certain amount of dirt may be present in the fuel oil and, to prevent this reaching the injection pump and injectors, filters are provided in the fuel system.

Fuel is drawn from the tank by the fuel lift pump, and then passes through a renewable single or double element type filter.

To Replace the Fuel Filter Element/s

1. Remove the centre bolt/s from the filter/s and detach the filter bowl assembly/ies (Fig. 37).
2. Check the condition of the rubber sealing rings. Renew if necessary.

To Install

1. Position a new filter element and secure with centre bolt.
2. Bleed the fuel system as described in the appropriate section.

AIR CLEANER MAINTENANCE

In normal operating conditions the air paper element should be cleaned and checked and if necessary replaced.

To Clean or Renew the Paper Element

1. Remove the top cover from the air cleaner and take out the paper element.
2. Clean the element by directing a compressed air nozzle up and down the pleats on the inside of the element. Maintain a reasonable distance between the nozzle and the element.
3. Refit the element to the air cleaner body, replace cover and secure with bolts.

BLEEDING THE FUEL SYSTEM

If any part of the fuel system is disconnected or air has entered the system, it will be necessary to remove all air from the fuel and to prime the injection pump by bleeding as follows:–

1. Ensure that all fuel pipe connections are tight and there is sufficient fuel in the tank.
2. Loosen the bleed screw on top of the filter two or three turns, Fig. 38, and operate the priming lever on the fuel lift

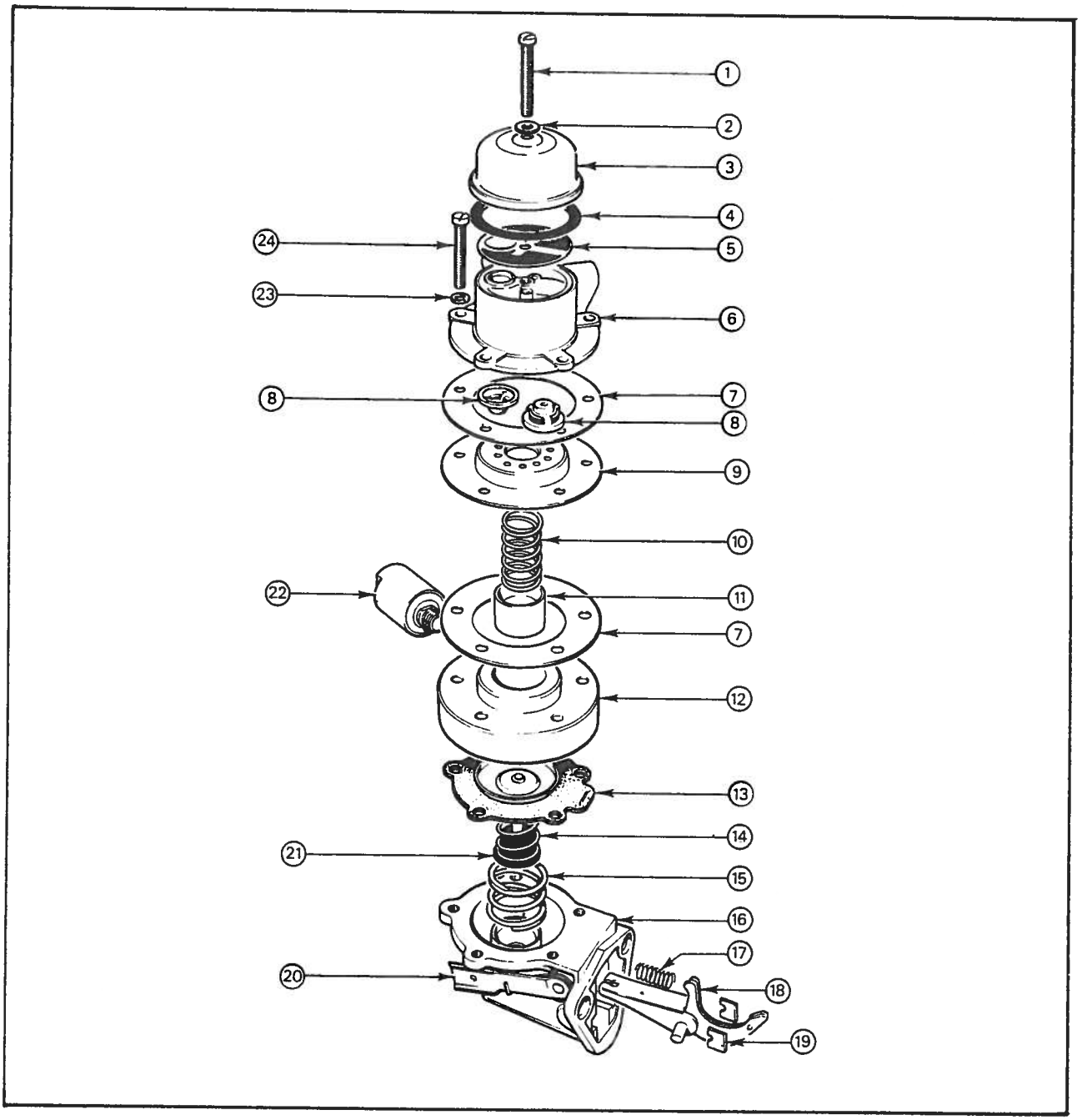


Fig. 36 CAV FUEL LIFT PUMP – HEAVY DUTY

1. Screw
2. Sealing Washer
3. Filter Bowl
4. Sealing Ring
5. Filter Gauze
6. Upper Pump Body
7. Gasket
8. Valve
9. Plate
10. Spring
11. Sleeve
12. Sandwich Plate
13. Diaphragm Assembly
14. Diaphragm Inner Spring
15. Diaphragm Outer Spring
16. Lower Pump Body
17. Rocker Lever Spring
18. Rocker Lever
19. Retainer
20. Priming Lever Assembly
21. Seal
22. Valve Connection
23. Washer
24. Screw

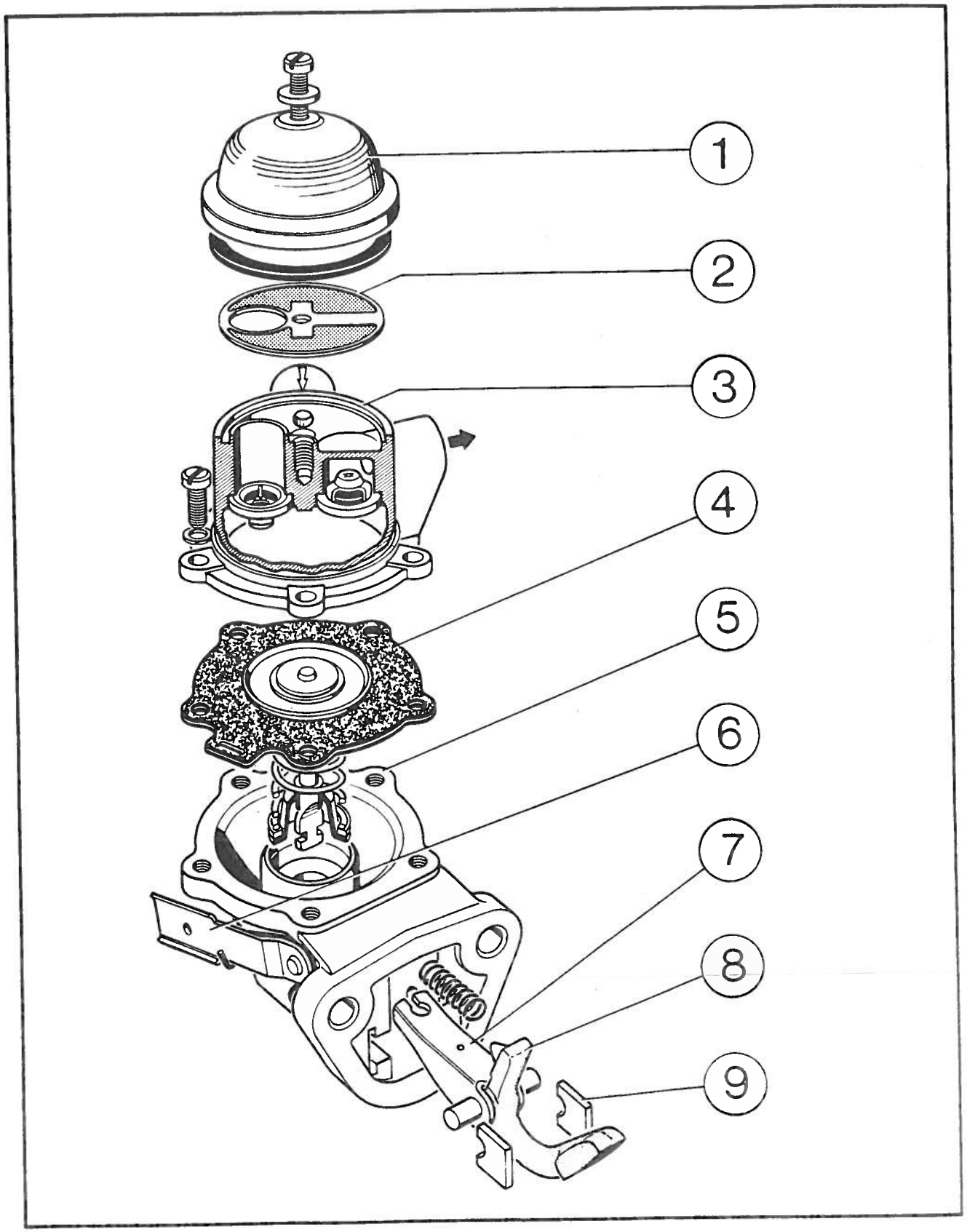


Fig. 35 CAV FUEL LIFT PUMP – STANDARD

1. Filter Bowl
2. Filter Gauze
3. Upper Pump Body
4. Diaphragm Assembly
5. Lower Pump Body
6. Priming Lever Assembly
7. Link
8. Rocker Lever
9. Retainer

OVERHAULING THE FUEL LIFT PUMP

The fuel lift pump is mounted on the injection pump and is driven by a cam on the injection pump camshaft. The pump also includes a hand priming lever to enable the fuel system to be bled.

On rotation of the injection pump camshaft, the eccentric on the cam pivots the fuel pump rocker lever 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 through the pipe line into the diaphragm chamber.

Further movement of the camshaft eccentric allows the rocker lever 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/s to the injection pump.

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 lever idles on the camshaft eccentric without operating the link.

To Dismantle the Fuel Lift Pump

1. Unscrew the centre retaining screw and remove the filter bowl, Fig. 35.
2. Remove the gasket and screen.
3. Mark the positions of the two halves of the pump adjacent to the small tag on the pump diaphragm and remove the five retaining screws. If necessary punch back the staking and remove the two halves from the outer body.

NOTE: With cold start fuel lift pumps, eccentric piece should also be scribed for reassembling procedure.

4. Push the diaphragm down against the return spring pressure and disengage the pull rod from the operating link.
5. Remove the retainers and withdraw the priming lever.

   If after dismantling, it is found necessary to replace the complete assembly, ensure that the correct pump is fitted. Pump (Part No. 715F-9350-AAB), identified by the number '90073' which is stamped on the underside of the diaphragm flange, is for use with MICROMEC injection pumps, whilst pump (Part No. 715F-9350-ABC) with the identification number '9013' is for use with MINIMEC injection pumps.

To Reassemble the Fuel Lift Pump

1. Replace the inlet and outlet valves, ensuring that they are in their correct positions. The inlet 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.
2. Assemble the rocker arm to the housing, ensuring correct relationship to the priming lever and secure with the retainers.
3. Check that the diaphragm and pull rod seal are in good condition, fit the spring/s and assemble the diaphragm to the inner body, with the tag on the diaphragm next to the mark on the body. Engage the link with the pull rod.
4. Locate the upper and lower pump bodies together (if a cold start pump, refer to Fig. 36 for correct location of parts).
5. Insert the five screws until finger tight, operate the rocker arm a few times to centralise the diaphragm and tighten the screws, holding the rocker lever fully down.
6. Fit the gauze screen and cover.

To Replace the Fuel Lift Pump

1. Ensure that the pump mounting faces are clean, fit a new gasket and secure the pump with the two locknuts and washers.
2. Reconnect the fuel inlet and outlet pipes (also the cold start pipe where applicable).
3. Bleed the fuel system as described in the appropriate section

FUEL FILTER MAINTENANCE

It must be emphasised that fuel oil must be kept clean at all times. Contamination by dirt and/or water will result in premature wear and possible failure of the finely machined components in the injection pump and injectors.

Fuel Injection Pump Removal From the Test Equipment

1. Replace the two inspection cover retainers, turning each one through 90° to locate in the slots in the camshaft housing and to bring the notch in each retainer to the top.
2. Insert the locating screws and ensure that they locate in the notches in the retainers before fully tightening.
3. Place a new inspection cover plate gasket in the recess in the housing and assemble the plate, securing with the two bolts screwed into the retainers, Fig. 34.
4. Disconnect the injector and fuel supply pipes. Fit a plug to the inlet connection and caps to the delivery valve holders to exclude dirt.
5. Fit the delivery valve holder retainers and tighten the Allen head screws, Fig. 8.
6. Unscrew the bolts and/or release the clamps securing the injection pump to the test equipment brackets and remove the injection pump.
7. Remove the injection pump drive adaptor. The idling and maximum (no load) speed adjustment must be made on the engine, the governor setting in the test procedure being to check the governor operation only.

REPLACING THE INJECTION PUMP

1. Fill the fuel injection pump with the specified quantity of engine oil. Refit the pump in position on the front cover and secure the retaining bolts.
2. Replace the drive gear and plate and install the retaining nuts finger tight.
3. Time the injection pump as specified, ensure that the crankshaft timing marks are aligned and that the camshaft gear locking pin is installed and refit the timing belt. Re-engage the timing belt tensioner spring and tighten the pivot bolt and the locking nut and bolt.

NOTE: The injection pump hub can be turned slightly within the limits of the drive gear elongated stud holes to give a fine adjustment.

On 4 cylinder engines with cylinder head glow plugs, carry out operations 1 and 2 then proceed as detailed in the following nine paragraphs:

Position the injection pump timing gear so that the studs are at the left hand end of the slots – see Fig. 40 in the 'Engine' section.

Lightly tighten the gear securing nuts, then turn injection pump gear until timing peg can be inserted as shown in Fig. 41 in the 'Engine' section. A suitable peg can be easily manufactured to the dimensions given.

Turn engine until No. 1 piston is at TDC on compression stroke and crankshaft timing marks align and insert camshaft gear timing peg, Tool No. 21–016.

Refit the timing belt and adjust the tensioner.

Remove the camshaft gear locating pin and the injection pump timing peg.

Using a valve spring compressor, depress No. 1 inlet valve spring and remove the two cotters and the valve spring retainer. Release compressor and detach valve spring. Remove circlip and oil seal from valve to allow valve to drop on to the piston crown.

Attach a clock gauge to the cylinder head to measure inlet valve lift and zero the gauge when valve is at its highest point (TDC on No. 1 piston).

Turn crankshaft slowly backwards until the clock gauge indicates minus 0,99 ± 0,05 mm (0,039 ± 0,002 in); this is exactly 11° BTDC on No. 1 piston.

Slacken the injection pump timing gear nuts and turn the pump hub, while keeping the gear stationary, until the pump timing peg can be inserted. Tighten pump gear nuts and check that camshaft is still at 11° BTDC. Remove pump timing peg and carry out operation 5.

4. Tighten the injection pump drive gear retaining bolt nuts and remove the camshaft gear timing pin.
5. Refit the timing belt cover, water pump pulley, fan belt and fan, refit the fuel pipes, bleed the system and check for leaks.

an average fuel delivery of 3 cc for 200 shots from all elements, with a maximum variation of 0,8 cc between elements.

Fuel Cut-Off

With the pump running at 300 rpm in the idling position operate the stop control lever.

Fuel delivery from all elements must cease just before the control rod reaches its limits of travel. The control rod should return immediately and delivery commence, when the stop control is returned to the run position.

Check that at 2500 rpm, all elements cease to deliver fuel when the control rod is 1 mm from the end of its travel.

NOTE: For pumps marked with an asterisk on page 23, this check should be made at 2000 rpm.

If the master injectors fitted to the calibrating machine have feeling pins, hold these pins on the needle valve spindle when checking for no fuel delivery. Any fuel delivery will cause the needle valve to lift and this can be felt through the feeling pin.

Governor Operation

The operation of the mechanical governor can only be checked on a calibrating machine equipped with a variable speed drive.

1. Remove the inspection cover and retainer plates if fitted, Fig. 32.
2. Set the governor control lever to the maximum speed position and slowly increase the calibrating machine speed. Note the speed at which the injection pump control rod starts to move. Refer to page 23. Adjust the maximum speed stop screw if incorrect, Fig. 33. Screw the maximum speed stop screw in to reduce the speed and out to increase.
3. Increase the calibrating machine speed still further and note the speed at which fuel delivery ceases. Refer to page 23.

   If a higher speed than this is obtained before the fuel delivery ceases, stiffness in the governor or control rod mechanism is indicated.
4. Repeat operation 2 with the speed decreasing. Excess variation in the speed will indicate stiffness in the governor or control rod mechanism. If the governor operation is satisfactory, tighten the maximum speed stop locknut.

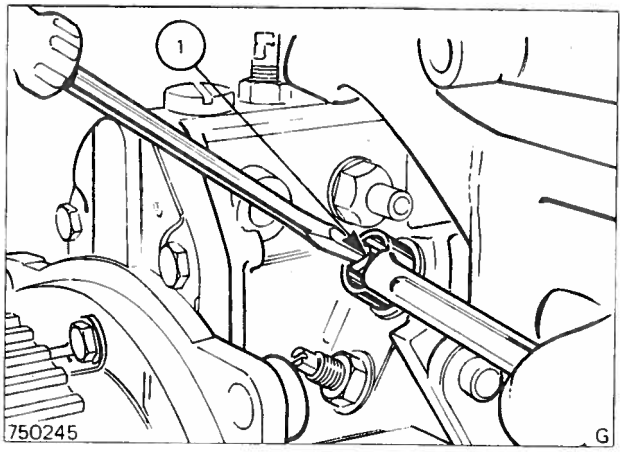


Fig. 33 Adjusting the maximum speed screw
1. Maximum Speed Screw

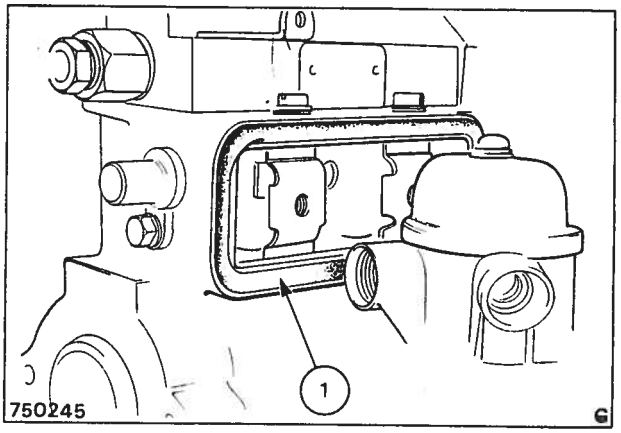


Fig. 34 Renewing the inspection cover gasket
1. Inspection Cover Gasket

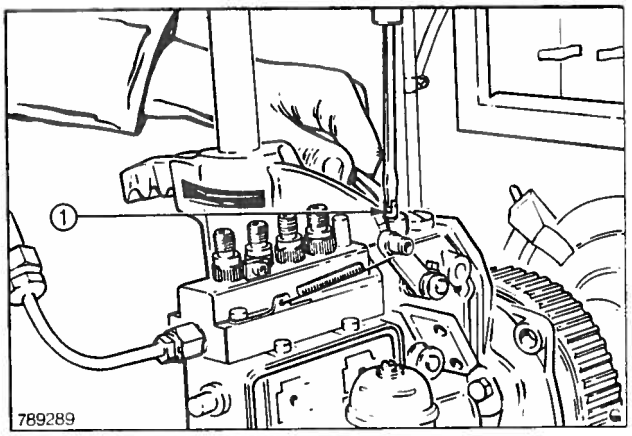


Fig. 30 Adjusting the maximum fuel stop screw
1. Maximum Fuel Stop Screw

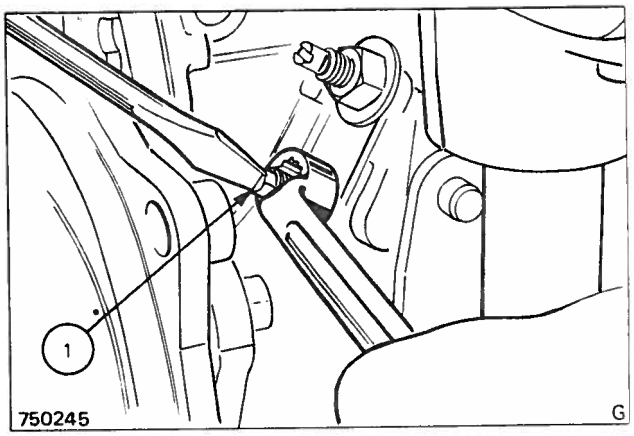


Fig. 31 Adjusting the idling stop screw
1. Idling Stop Screw

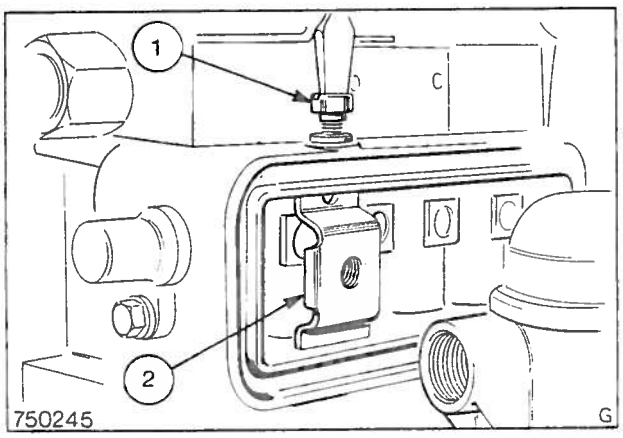


Fig. 32 Removing the inspection cover and retainer plates
1. Bridge Locating Screw
2. Inspection Cover Retaining Bridge

To ensure accurate pump calibration it is essential that the master injectors are maintained as an accurately balanced set, and checked regularly for this condition.

Calibrate the injection pump as follows:

1. Connect the test equipment injector pipes to the master injectors and the injection pump delivery valve holders.
2. Run the calibrating machine at 1000 rpm, with the governor control lever set in the maximum speed position, for at least ten minutes, to allow the injection pump and fuel to warm up.
3. Set No. 4 control fork on the control rod so that the forward edge is 0,25 to 0,75 mm (0,010 to 0,030 in) from the end of the square section.
4. Adjust the maximum fuel stop screw, Fig. 30, so that the No. 4 element gives the specified fuel delivery (see Specifications) for 200 shots at 1000 rpm, with the governor control lever set in the maximum speed position.

   It will be necessary to hold the calibrating machine trip lever down, when a slight 'click' will be heard as the injectors start delivering into the test tubes. The lever should not be released until a second 'click' is heard, otherwise only 100 shots will be collected. Each machine has its own operating instructions, but generally the trip mechanism will cut off at 100 shots automatically unless the trip lever is operated a second time.
5. Seal the maximum fuel stop screw after tightening the locknut.
6. Adjust the position of the remaining control forks on the control rod so that the overall spread does not exceed 0,2 cc for 200 shots at 1000 rpm.

   Move the forks towards the governor to increase, and away from the governor to decrease, the fuel delivery.

Excess Fuel Delivery

At 100 rpm, when the excess fuel device is operated and the control lever is set to the maximum speed position, fuel delivery from all elements should be 16 to 21 cc for 200 shots.

Idling

Run the injection pump at 300 rpm with the governor control lever in the idling position. Adjust the idling stop screw, Fig. 31, to obtain

10. Turn off the fuel, remove the plunger head clearance gauge and the camshaft end-float gauge and fit the delivery valve, spring and volume reducer to No. 1 element. Tighten the holder to a torque of 40,7 to 47,5 Nm (30 to 35 lbf ft or 4,2 to 4,8 kgf m).

Phasing the Remaining Elements

1. Remove the delivery valve, spring and volume reducer from next element in the firing order sequence, i.e. No. 5. Tighten the delivery valve holder to 40,7 to 47,5 Nm (30 to 35 lbf ft or 4,2 to 4,8 kgf m) torque and fit the spill pipe.

NOTE: If pressure phasing is used it is not necessary to remove the delivery valve, spring or volume reducer.

2. Turn the fuel on and rotate the camshaft slowly clockwise as before, until the point of inlet closure is reached. The phasing ring should now have revolved through and be reading 90°. A limit of ±1° is permitted.
3. If the phasing is outside this limit, it will be necessary to change the phasing spacer of this element. Do not change the phasing spacer now but note the error and check the phasing of the remaining elements, in firing order sequence, without altering the phasing ring setting. In this way the phasing of all elements can be corrected at the same time.
4. Check phasing of No. 1 element again, to ensure that the original setting has not been disturbed and the timing marks coincide.

Changing the Phasing Spacers

1. Remove the pump body, taking care not to drop the plungers from the barrels.
2. Lift out the tappets one at a time.
3. Remove the phasing spacers, Fig. 12, after extracting the clip with circlip pliers. There are five thicknesses of spacer available in steps of 0,1 mm (0,004 in), which affect the phasing in each case by approximately ½°, (see Specifications).

   Fit a thinner spacer to increase the phase angle, and vice versa. By careful selection of the spacers any variation in the phase angle can be eliminated.

   Check the plunger arm clearance when phasing spacers are changed.
4. After changing phasing spacers, ensure that there is 0,05 to 0,25 mm (0,002 to 0,010 in) clearance between the plunger head and the underside of the delivery valve guide when the plunger is at the top of its stroke.

   This can easily be checked with the plunger head clearance gauge and camshaft end-float gauge after removing the delivery valve, spring and volume reducer while re-checking the phasing. With the dial gauge set to zero the plunger head clearance can be checked by lifting the plunger from the top of its stroke.

Pressure Phasing

The principle of pressure phasing is similar to the method already described but the fuel is supplied to the pump gallery at a pressure sufficient to lift the delivery valve from its seating. It is therefore not necessary to remove the delivery valve, spring or volume reducer prior to phasing. However, as the fuel is supplied to the pump under pressure, it is necessary to connect all the elements, other than the one actually being phased, to the appropriate master injectors to stop fuel flowing from the delivery valve holder connections.

Electronic Phasing

On some phasing and calibrating equipment electronic phasing is available. With this method the injection pump is completely assembled and the phasing is checked while the pump is operating. Pressure impulses from the pump operate contacts sending electrical impulses to a stroboscopic timing light. The timing marks, however, must be set, using a spill pipe.

Calibration

Calibration is an adjustment to ensure that each element of the pump delivers the same amount of fuel at any position of the control rod. Fuel delivered by each element over a definite number of injections is collected and measured in graduated test tubes.

When checking deliveries, use the same set of glass tubes throughout, and give a constant drain period of 30 seconds when emptying on each occasion. Also allow fuel to settle in the test tubes for 15 seconds after delivery has ceased before taking the readings, which must be read from the bottom of the meniscus. Always take an average of three readings using the same test tube, after first disregarding an initial set of readings. This will provide constant conditions and ensure greater accuracy.

90°. Phasing is adjusted by varying the thickness of the phasing spacers incorporated in the camshaft roller tappets. Remember that the pumping elements of the injection pump operate in engine firing order sequence, i.e. 1, 2, 4, 3 (4 cyl.) and 1, 5, 3, 6, 2, 4 (6 cyl.).

Point of Inlet Port Closure

Injection commences as soon as the plunger top covers the inlet port and the phase angle for each element relative to No. 1, is set by adjusting this point. Injection pump timing is set by finding the point of inlet port closure for No. 1 element.

The point of inlet port closure for any element can be found accurately by the following method:– With the pump plunger at the bottom of its stroke, fuel can flow through both ports and out through the spill pipe attached to the delivery valve holder (Fig. 27).

When the camshaft is rotated, the plunger rises until it eventually covers the inlet port, as shown in the right-hand view, cutting off the fuel supply and terminating the flow from the spill pipe.

If the camshaft is rotated very slowly, the precise point at which the fuel ceases to flow from the spill pipe, and thus the point of inlet closure can be ascertained.

The stroke that the plunger moves through from the bottom of its stroke to the point of inlet closure should be between 2.4 to 2.6 mm (0.094 to 0.102 in). This stroke should be checked for No. 1 element to ensure correct injection characteristics and may be measured by using a camshaft end-float gauge mounted on the plunger head clearance gauge, Fig. 28. A spindle passing through the plunger head clearance gauge locates on top of the pumping element plunger, the dial gauge being located at its upper end. A flat machined on the spindle permits fuel oil to spill past the spindle to enable the point of inlet port closure to be determined in a similar manner to that described above.

Phasing No. 1 Element

1. Unscrew the delivery valve holder using the special socket (Fig. 29) on No. 1 element and remove the valve, spring and volume reducer. Fit a plunger head clearance gauge and tighten to a torque of 40,7 to 47,5 Nm (30 to 35 lbf ft or 4,2 to 4,8 kgf m). Locate the spindle in the tool and fit the camshaft end-float gauge so that the barrel rests on the spindle upper end. Do not over-tighten the thumb screw or plunger movement will be restricted.
2. Ensure that the driving belt on the calibrating machine is fitted to the 200 rpm pulleys. With a variable speed machine, ensure that it is set to the phase position.
3. Set the arms at the lower end of the plungers fully to the right, by securing the governor control lever in the maximum speed position.
4. Slowly rotate the pump camshaft in a clockwise direction from the drive end until No. 1 plunger is at the bottom of its stroke. Depending on the machine, provision may be made for a 'tommy bar' in the coupling, or, alternatively, hand turning of the motor pulley may be necessary.
5. Zero the dial gauge onto the spindle upper end and turn on the fuel supply tap. Fuel will flow freely past the flat on the spindle.
6. Further rotation of the pump camshaft in a clockwise direction from the drive end will cause No. 1 plunger to rise. Fuel will continue to flow freely until such time as the plunger covers the inlet port. Stop rotating the camshaft as soon as the fuel flow ceases.
7. The reading on the dial gauge is the stroke to close the inlet port. This should be between 2,4 to 2,6 mm (0,094 to 0,102 in). If the stroke is incorrect, fit a thinner phasing spacer to increase the stroke and a thicker phasing spacer to decrease the stroke. After changing a phasing spacer, check the plunger arm clearance.

NOTE: If the pump elements have not been changed, the phasing spacers for the other elements should also be changed by a corresponding amount to compensate for any change to No. 1 element phasing spacer.

8. At the point of inlet closure, set the graduated phasing ring to 0°.
   It is then advisable to repeat the above procedure to check that the phasing ring has been set accurately.

NOTE: During phasing the point of inlet closure must always be ascertained when the plunger is rising.

9. Check that for No. 1 element the timing mark on the hub is within ±½° of the point of inlet port closure.

Preliminary Checking

Remove the delivery valves and guides, keeping them in paired assemblies, and replace them with a standard set kept as masters.

To remove the delivery valves, first remove the delivery valve holder retainers. Unscrew the holders, using the special socket and extract, the volume reducers, springs and delivery valves. Remove each valve guide by inserting the valve guide remover into the guide, with the pumping element plunger at the bottom of its stroke, and then turning the pump camshaft to push the guide out of its location. Fit the master delivery valves and connect the injection pump to the master injectors and run at 600 rpm for 10 minutes to stabilise delivery.

The efficiency of each element may now be checked. Run the pump at 1000 rpm and collect 200 shots, noting the readings in each test tube.

Allow the fuel to settle in the test tubes for 15 seconds after delivery has ceased, and take all readings from the bottom of the meniscus. Drain the test tubes for 30 seconds before using them for the next delivery.

Run the pump at 200 rpm and collect a further 200 shots, again note the readings in each test tube. If the difference between the readings at 600 and 200 rpm in any test tube exceeds 3 cc. then this indicates that the element is worn and should be replaced if the injection pump is to be brought back to new condition.

Remove the master set of delivery valves and replace the original ones. Turn on the fuel supply to check for delivery valve seat leakage before reconnecting the injector pipes. Run the pump at 600 rpm and collect 200 shots noting reading in each test tube. If the readings in any test tube are higher than before, a worn delivery valve piston is indicated. If any reading is lower than before it indicates that the delivery valve seat is worn.

A note should be made of faulty or worn components found during this test so that new parts can be fitted during overhaul. Any variations in phasing should also be noted and corrected during reassembly.

Phasing

Phasing is an adjustment whereby each successive element of the pump is timed to commence injection at the correct angle relative to the proceeding one. In a four cylinder pump this is

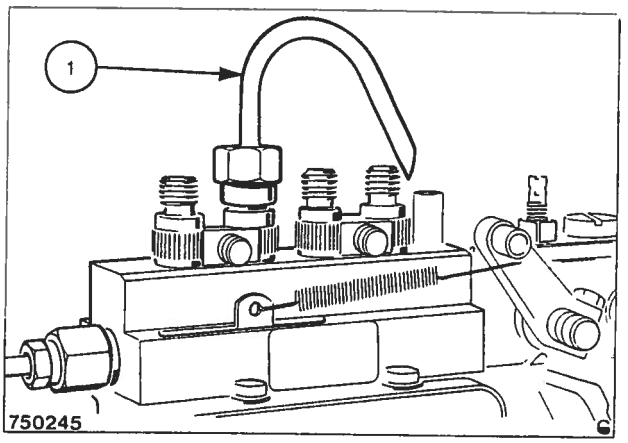


Fig. 27 Spill pipe attached to the delivery valve holder
1. Spill Pipe Tool No. CT.9023

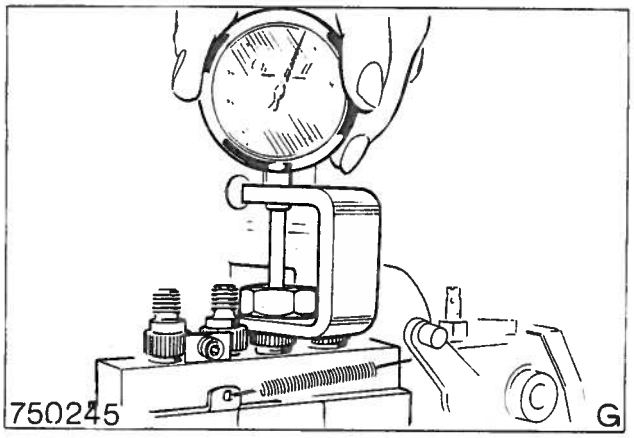


Fig. 28 Measuring the plunger stroke

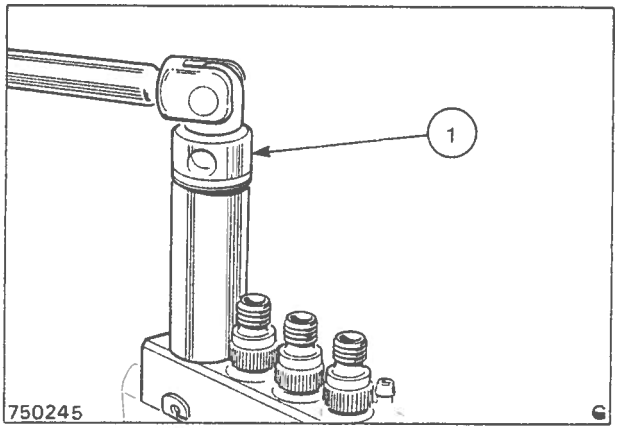


Fig. 29 Unscrewing the delivery valve holder
1. Tool No. 23-500