

# INDUSTRIAL PRODUCTS SERVICE MANUAL

## FOR 2700 RANGE ENGINES

2701E — 4 cyl. — Diesel	2711E — 4 cyl. — Diesel
2703E — 6 cyl. — Diesel	2712E — 4 cyl. — Diesel
2704E — 6 cyl. — Diesel	2713E — 6 cyl. — Diesel
2701C — 4 cyl. — Diesel	2714E — 6 cyl. — Diesel
2703C — 6 cyl. — Diesel	2715E — 6 cyl. — Diesel
2704E — 6 cyl. — Diesel	2704ET — 6 cyl. — Diesel Turbo Charged
	2704ET — 6 cyl. — Diesel Turbo Plus

This Manual is intended as a mechanics guide to the method of servicing the Ford 2700 Range of Diesel and Diesel Turbo Charged Engines.

It contains complete instructions for all service, repair and overhaul operations, and lists the special tools necessary for each operation.

For convenience the contents are divided into eight basic sections.

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Section 1.	Engine components and overhaul procedure
Section 2.	Lubrication System and Cooling System
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# SECTION 1

## ENGINE COMPONENTS AND OVERHAUL PROCEDURE

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## GENERAL DESCRIPTION

The 2700 Range of Ford Industrial Engines comprises the following models:—

2701E	4 cyl.	3.964 l.	(242 cu.in.)	Diesel
2703E	6 cyl.	5.416 l.	(330 cu.in.)	Diesel
2704E	6 cyl.	5.945 l.	(360 cu.in.)	Diesel
2704ET	6 cyl.	5.945 l.	(360 cu.in.)	Diesel Turbocharged
2701C	4 cyl.	4.150 l.	(254 cu.in.)	Diesel
2711E	4 cyl.	4.150 l.	(254 cu.in.)	Diesel
2712E	4 cyl.	4.150 l.	(254 cu.in.)	Diesel
2703C	6 cyl.	5.950 l.	(363 cu.in.)	Diesel
2713E	6 cyl.	5.950 l.	(363 cu.in.)	Diesel
2704C	6 cyl.	6.220 l.	(380 cu.in.)	Diesel
2714E	6 cyl.	6.220 l.	(380 cu.in.)	Diesel
2715E	6 cyl.	6.220 l.	(380 cu.in.)	Diesel

Refer to the relevant Engine Specifications for the bore, stroke and other details.

The terms 'Left' and 'Right' are applicable when engine is viewed from the rear.

The Diesel versions are of the direct injection type and operate on the four stroke cycle.

Overhead valves are mounted vertically in replaceable guides in the cast iron cylinder head and are operated by rockers, push rods and tappets from a camshaft located in the right-hand side of the cylinder block.

The camshaft is driven at half engine speed by a gear meshing directly with the crankshaft gear, steel backed bearing bushes are fitted to all six cylinder engines prior to April 1971. Engine No. S790085 camshaft bearings were only fitted to the four cylinder engines when the main bearing bores had been increased to 0.381 mm. (0.015 in.) o/s and/or Heavy Duty P.T.O. had been fitted. From April 1971, Engine No. S790085, all four cylinder engines are fitted with camshaft bearings.

The four cylinder engine has four bushes and the six cylinder engine has six. The front bush is of the bronze type while the remainder are white metal.

A skew gear, machined integral with the camshaft drives the oil pump. An eccentric for the fuel lift pump is also incorporated on the camshaft.

Camshaft thrust is taken by a thrust plate bolted inside the timing case to the cylinder block front face. This thrust plate is located between thrust washers adjacent to a detachable collar on the camshaft and the camshaft gear.

The forged crankshaft runs in five large diameter main bearings in four cylinder engines and seven in the sixes. These bearings and also the connecting rod big end bearings have detachable steel backed aluminium tin bearing liners. Crankshaft end-float is controlled by thrust washers fitted at each side of the centre main bearing. Main bearing bolts are 15.88 mm. (5/8 in.) diameter and are of the self-locking type. On six cylinder engines a damper is incorporated in the pulley assembly to damp out torsional oscillations in the crankshaft.

The connecting rods are H section forgings with the big end caps retained by self-locking bolts on all models with the exception of 2703E/C models, bolts and self locking nuts are fitted to these models. Two tension pins are fitted to each bearing cap for positive location on all models. The small end has a steel backed bronze bush.

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Aluminium alloy solid skirt pistons with the combustion chamber machined in the piston crowns are used. The combustion chamber has a toroidal tip to promote efficient combustion. Each piston has three compression and one oil control ring above the piston pin. The upper compression ring is barrel faced, the second is internally stepped on the top face and the lower externally stepped on the lower face. These last two rings must be fitted the correct way round and are marked to facilitate assembly. The oil control ring is of the slotted channel type scraper with a coiled expander on the inside. Refer to individual model specifications for material finish. The piston pins are fully floating and are retained in position by circlips installed in grooves at each end of the piston pin bore.

The cylinder bores of 2701E, 2703E, 2704E and 2704ET Models have dry type liners which protrude to reduce the dead air space between the cylinder head and gasket. All other models are of the "Parent Bore" type i.e. the piston being in contact with the cylinder block. The cylinder block is cast iron and does not incorporate a tappet chamber, push rod tubes and drain holes being machined in the block.

The sumps are aluminium castings and are located by dowels on six cylinder engines to ensure positive alignment of the rear face.

The 2703E and 2704E engines were fitted with either the SIMMS "Minimec" or C.A.V. D.P.A. injection pump and all other engines are fitted with either the SIMMS "Minimec" injection pump or the Bosch injection pump.

There is provision for various combinations of power take off from the front and rear of the timing gear cover, as well as from the crankshaft front end.

#### SECTIONED ENGINE—PARTS IDENTIFICATION

Note:—The item numbers in the following columns refer to the corresponding numbers in the Sectioned Engine illustration on the opposite page.

1. Push Rod	22. Stop Control Lever
2. Rocker Cover	23. Injection Pump
3. Fuel Leak off Pipe	24. Drive Gear
4. Rocker Arm	25. Pulley and Damper Assy.
5. Valve Clearance Adjusting Screw	26. Cylinder Block
6. Crankcase Ventilation Breather Valve	27. Crankshaft
7. Intake Manifold	28. Oil Filter
8. Rocker Shaft	29. Oil Pump
9. Valve Cap	30. Oil Pan
10. Oil Filler Cap	31. Connecting Rod
11. Valve Spring Retainer	32. Fuel Pump Actuating Lever
12. Valve Spring	33. Hand Priming Lever
13. Valve Guide	34. Fuel Lift Pump
14. Valve	35. Camshaft
15. Thermostat	36. Flywheel
16. Fan	37. Flywheel Ring Gear
17. Front Lifting Eye	38. Piston
18. Cylinder Head	39. Fuel Filter
19. Fan Belt	40. Injector
20. Water Pump	41. Rear Lifting Eye
21. Delivery Valve Holder	

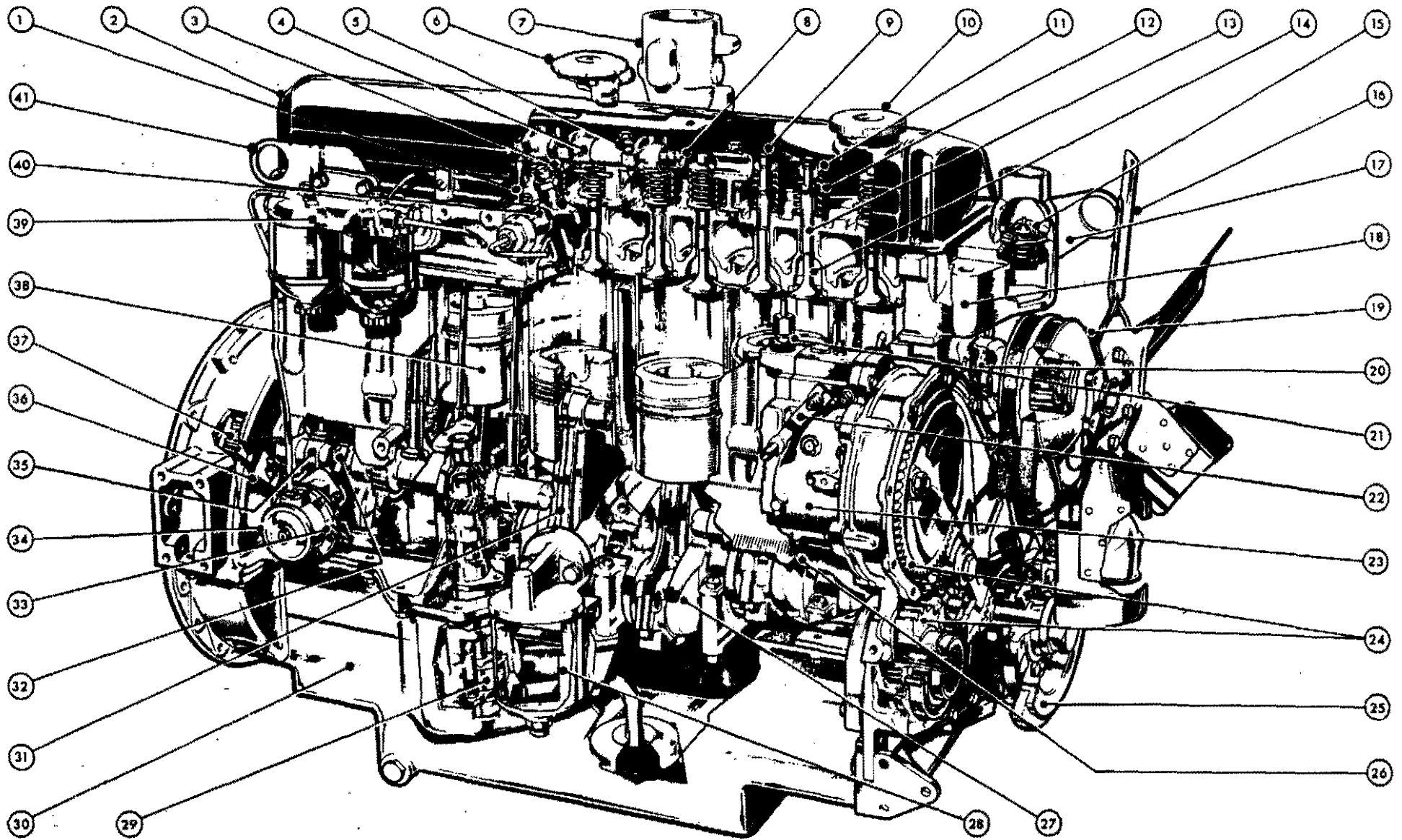


Fig. 1 - SECTIONAL VIEW OF 6 CYL. ENGINE

A list identifying the parts numbered is on the opposite page

# ENGINE COMPONENTS

## INLET AND EXHAUST MANIFOLDS (Normally Aspirated Engines)

The inlet and exhaust manifolds are separate and are retained on the left-hand side of the cylinder head by studs, with brass nuts, and bolts, all fitted with plain washers. The studs are located in the upper holes and retain both manifolds. Bolts are used in the lower holes only (See Fig. 2).

Inlet manifolds are aluminium castings providing an unrestricted passage to the inlet ports.

The exhaust manifolds are cast iron with separate ports for each cylinder and incorporate a flange for attaching the exhaust pipe. A pair of inlet/exhaust manifold gaskets are fitted.

## Inlet and Exhaust Manifolds – (Turbocharged Industrial Engines) Fig. 2.

Retention of the manifold to the cylinder head is the same as for normally aspirated engines and a pair of gaskets are fitted.

The inlet manifold is an aluminium casting incorporating two separate passages, one directing air from the air cleaner to the turbocharger and the other from the turbocharger to the inlet ports. The two inner pairs of inlet ports are joined together.

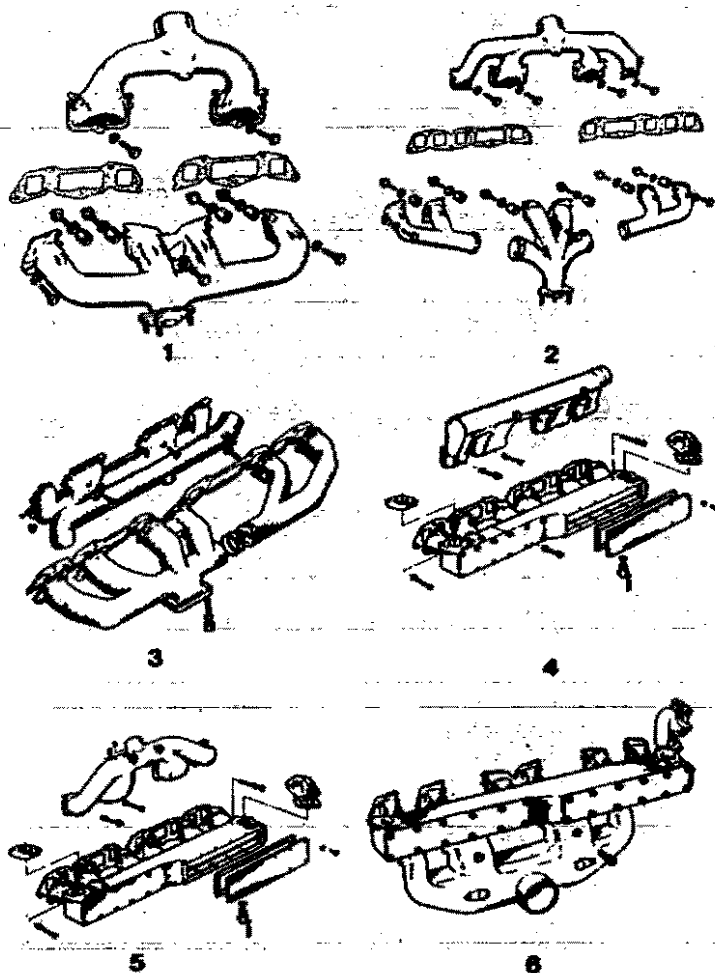


Fig. 2 A selection of manifolds used with 2700 Range Engines.

- |                                    |                                     |
|------------------------------------|-------------------------------------|
| 1. 4 cyl Normally Aspirated Engine | 2. 6 cyl. Normally Aspirated Engine |
| 3. Industrial Turbocharged Engine  | 4. Standard Marine Engine           |
| 5. Intercooled Marine Engine       | 6. Turbo Plus Marine Engine         |

**Inlet and Exhaust Manifolds — (Turbocharged Marine and Intercooled Engines) Fig. 2.**

The inlet manifold is an aluminium casting, providing an unrestricted passage to the inlet ports. The inner pair of inlet ports are joined together. The water cooled exhaust manifold is cast iron and has removable covers to the water jacket, the rear end incorporates the mounting flange for the turbo-charger. Coolant connections are flange mounted on the top face of the water jacket housing, a drain cock is fitted on the lower face.

The manifolds are fitted with gaskets.

Where it is necessary to replace the exhaust manifold on 2704ET Marine engines, ensure only the latest type (Part No. 693F-9429-JAA), with drain cock (Part No. 723F-8115-JAA) is fitted.

**ROCKER COVER**

The rocker cover is normally a steel pressing retained by screws around the flanged edge.

A breather tube and baffle are incorporated in the rocker cover and an oil filler cap is also fitted at the front of the steel cover.

**CYLINDER HEAD — Normally Aspirated Engines**

The cylinder head is made of cast iron and incorporates replaceable valve guides and exhaust valve seat inserts. A composition type cylinder head gasket, with aluminium coated steel reinforcement around the cylinder bores is used, the head is retained by 9.525 mm. (3/8 in.) diameter bolts x 105.82 mm. (4 9/16 in.) long. These bolts have a letter X on the head for identification purposes. **BOLTS MARKED 100, AS USED ON 590E/592E ENGINES MUST NOT BE USED.**

From 1st May 1976, all turbocharged engines have been fitted with new type cylinder head bolts having integral washers. These new bolts are not interchangeable with the earlier types and can only be used on engines to which they were fitted as original equipment or on earlier cylinder heads modified as detailed in paragraph 24 on Page 17.

Note: Turbo Plus engines have two special cylinder head bolts for mounting the air charge cooler.

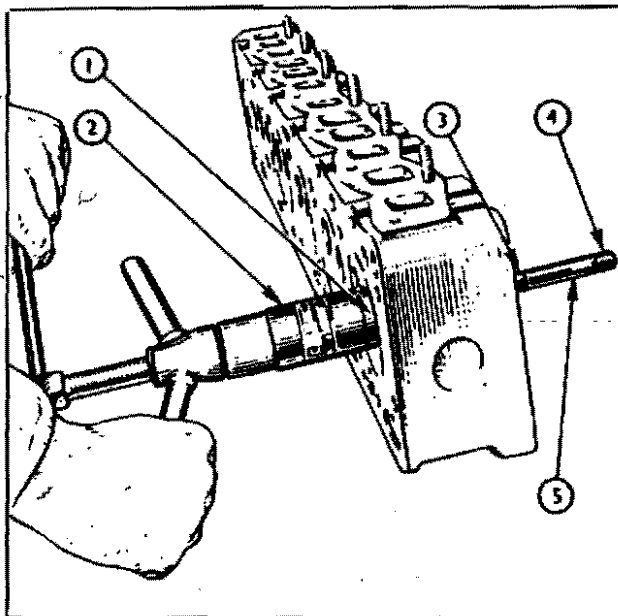


Fig. 3 — Valve Guide Removal

- 1 Conical Seat Detail "a"
- 2 Guide Remover and Replacer Tool No. CT.6073
- 3 Valve Guide
- 4 Nut Detail "d"
- 5 Spacer Detail "b"

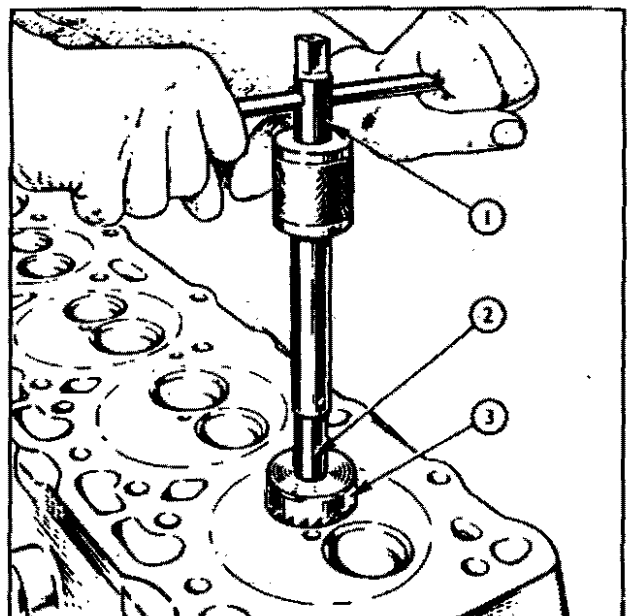


Fig. 4 — Recutting Valve Seats

- 1 Handle Tool No. 316X
- 2 Pilot Tool No. 316-12
- 3 Inlet Valve Seat Cutter Tool No. 317TT.30

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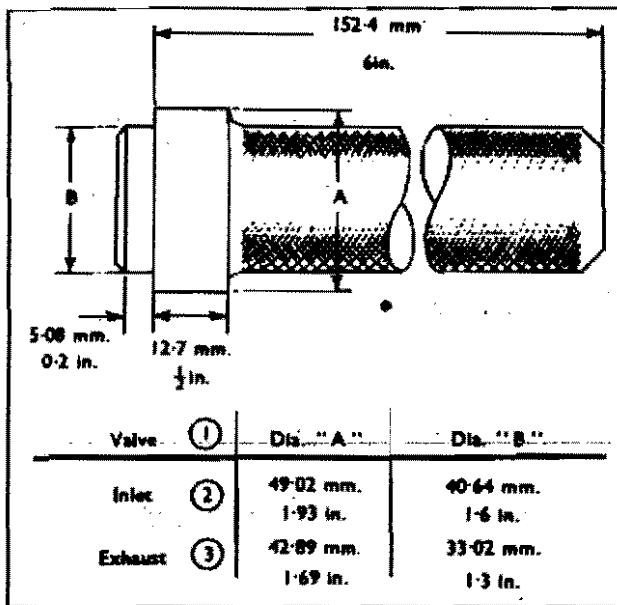


Fig. 5. — Valve Insert Replacer

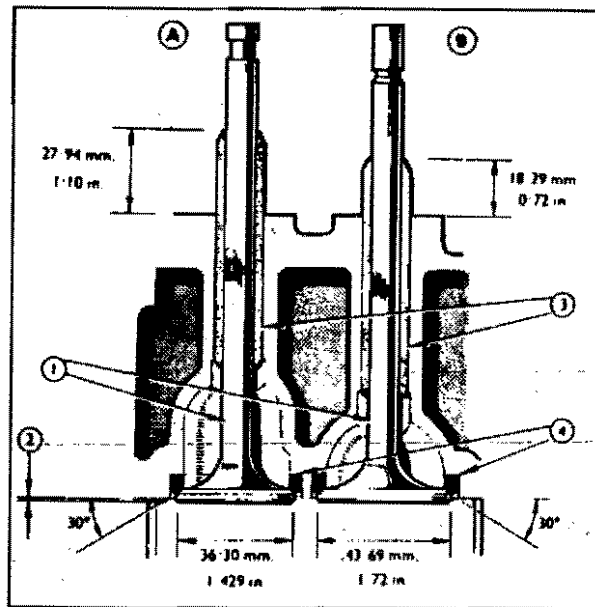


Fig. 6. — Valve Seats

- 1 Valves A Exhaust and B Inlet
- 2 Valve Protrusion 0.864 mm. (0.034 in.) Max.
- 3 Valve Guides
- 4 Valve Seat Inserts

Inlet and exhaust valve guides are identical and when excessively worn may be removed and new guides fitted using valve guide remover and replacer Tool No. CT.6073 and adaptors Tool No. CT. 6073-1A exhaust and CT. 6073-3 inlet. Screw the pull rod detail "e" into the tool centre screw and locate the conical seat detail "a" over the pull rod. Pass the pull rod through the valve guide, so that the conical seat locates in the valve seat, locate spacer detail "b" on the pull-rod and retain with the nut detail "d" (see Fig. 3). Remove the valve guide by turning the wing nut clockwise. Unscrew the nut and remove the spacer and valve guide. Pass the pull rod through the valve guide bore, again from the seat side, locate a new guide on the pull rod, tapered end away from the head, with replacer/adaptor Tool No. CT.6073-1A detail "n" (exhaust) or CT.6073-3 (inlet) over the tapered end. Screw the nut onto the pull rod and fit the guide by turning the wing nut. The respective replacer adaptors ensure that the guides are fitted to the correct depth and protrusion (see Fig. 6).

After fitting new valve guides the valve seats must be recut to ensure that the seat is concentric with the valve stem bore. Recut the seats with cutters Tool No. 317-TT-26 (exhaust) and 317-TT-30 (inlet) fitted to pilot Tool No. 316-12 in handle Tool No. 316X (Fig. 4). Where necessary seats may be narrowed with cutters Tool No. FMC.317-27 (exhaust) and FMC 317-29 (inlet). The valve seats should also be recut when they show signs of pitting or burning.

Replacement valve seat inserts are available and should be fitted where necessary. Where inserts have not been fitted previously it will be necessary to machine a recess in the cylinder head for the appropriate valve seat insert. If, for any reason, an existing insert has become loose or damaged, oversize inserts can be fitted. Use only the inserts specified for turbocharged engines for all engine ranges if it is necessary to replace the inserts.

The sizes for machining the recesses for standard and oversize valve seat inserts are tabulated in the section "General Specifications" at the end of this Chapter.

Valve seat inserts may be removed by inserting a suitable chisel under the insert and striking smartly when the insert will be forced out of its location. Care should be taken in this operation to avoid damage to the combustion chamber.

To fit a new insert, select the correct size and enter the insert with the chamfered edge away from the combustion chamber and press into place using insert replacer tools made to the dimensions shown in Fig. 5. After fitting the inserts, the seats must be cut with the appropriate cutter tools to the dimensions in Fig. 6 to give a maximum valve protrusion above the cylinder head face of 0.86 mm. (0.034 in.).



## CYLINDER HEAD (Turbo Charged Engines)

The cylinder head is different in that it has valve seat inserts on the inlet and exhaust valves, also a "Scallop" machined between the two valves.

## VALVES AND SPRINGS

The valves, which have 30° seats, are mounted vertically in the cylinder head, the inlet valve head diameter being larger than the exhausts. Their respective diameters are 45.24 mm. (1.78 in.) and 38.89 mm. (1.53 in.) and both valves have stems which are phosphate coated to improve durability. The relative positions of the valves are inlets Nos. 2, 3, 6 and 7 (4-cylinder) and 2, 4, 5, 8, 9 and 11 (6-cylinder) and exhausts Nos. 1, 4, 5 and 8 (4-cylinder), and 1, 3, 6, 7, 10 and 12 (6-cylinder).

Identical valve springs are fitted to both valves and are close-coiled at one end. When fitting these springs ensure that the close coiled end is located in the pressed steel seat located around the valve guide. The inlet valve spring is retained by a hardened steel retainer and split tapered collets, while the exhaust has a hardened steel retainer with parallel collets, as the exhaust valve is of the rotator type. With this type of valve a small cap is fitted over the valve stem to locate in the retainer on top of the collets. Rocker arm pressure is then transmitted directly to the retainer and valve spring and, as there is a small clearance between the cap and the valve stem, the valve is free to rotate when open.

NOTE: Some exhaust valves on automotive engines do not have rotator caps and have the tapered collets.

Rotator cap clearance is 0.025 to 0.127 mm. (0.001 to 0.005 in.) and it is very important that this is maintained at all times. Insufficient clearance will prevent the valve rotating when open which will eventually result in the valves and valve seats burning. If the clearance is excessive, the valve will hammer on the collets and lead to excessive wear and possible valve failure.

The use of rotator caps has been discontinued for current production engines. If it is necessary to replace exhaust valve/s fitted with rotator caps, only the latest level of exhaust valve/s must be fitted, e.g. without rotator caps. The valves can be replaced in complete sets or individually. When the latest valve/s is fitted, the valve gap is to be set to 0.381 mm (0.015 in).

The inlet valve level has also been amended, current engines are now fitted with the same valve as used in the turbocharged engine. These valves can be identified by the letter 'T' stamped on the valve head.

Valve stem caps are fitted to the inlet valve to reduce wear on the rocker arm pads and valve stems. Each valve stem is fitted with an umbrella type seal below the valve spring retainer.

The valves may be re-ground if the face is unduly pitted or distorted providing the edge thickness is not reduced to 0.79 mm. (0.008 in.) or less. Hand lapping may be used but should be kept to a minimum or the angles may be altered and the seat width become too wide. A seat width of 1.59 mm. (0.063 in.) to 2.38 mm. (0.016 in.) is acceptable.

## ROCKER SHAFT ASSEMBLY

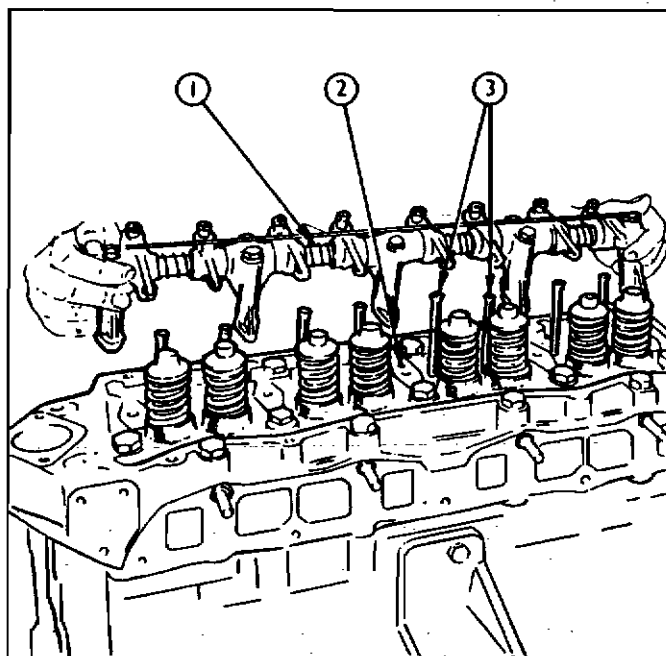
The rocker arms, which are handed and fitted with self locking screws, are located on the rocker shaft between supports, each pair of rockers being spaced by a compression spring. The rocker shaft supports are retained on the cylinder head by bolts fitted with spring washers. (Fig. 7).

A two piece hollow rocker shaft is used on 6-cylinder engines, one piece on 4 cylinder engines, and is located in the correct position by bolts through the intermediate supports either side of the central support. The extreme ends of the rocker shafts are sealed with expansion plugs and as these do not retain the end supports it is advisable to attach a piece of cord between them, when removing the rocker shaft assembly, to prevent accidental disassembly.

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Fig. 7 Rocker Shaft Removal

- 1 Push Rods
- 2 Oil Feed Hole
- 3 Rocker Shaft



Self locking screws are fitted to the rocker arms and on initial assembly the installation torque, with the thread lubricated, must be 9.5 to 20.3 Nm (0.97 to 2.07 kgf m or 7 to 15 lbf ft) when the ball end is 9.53 mm (0.375 in) below the rocker shaft bore centre line. When turning these screws or when adjusting valve clearances a socket or ring spanner must be used.

## CYLINDER BLOCK

The cylinder block is cast iron and is cast integral with the upper half of the crankcase. The cylinder bores have dry liners fitted to the turbocharged engines, also the normally aspirated engines built prior to November 1969. A full length water jacket is provided on all engines. Casting and machining pads cast on the top edge of the cylinder block on the right hand side are used for numbering the engine. The engine number is stamped on the front pad and the numbers stamped on the rear pad indicate the engine capacity.

On normally aspirated engines built prior to November 1969, the cylinder liners are pressed in to give a protrusion of 0.51 to 0.64 mm. (0.020 to 0.025 in.). Although occasionally in service it is permissible for the liners to drop to a maximum of 1.5 mm. (0.060 in.) below the block surface.

Cylinder blocks are now available for the 3964 c.c. (242 cu in) and 5950 c.c. (363 cu in) engines without liners, and are completely interchangeable with the lined assemblies. When using these assemblies ensure that the correct pistons and cylinder head gasket are used.

Reboring of these later level cylinder blocks may be carried out to suit the currently available oversize pistons.

To remove and replace the cylinder liners on normally aspirated engines Tool No. C.6136-8 should be used (see Fig. 8). Attach the protection strips to the cylinder block face, invert the cylinder block and stand on the bed of a suitable press. Locate the remover in the bottom of the liner (use large diameter spigot for larger bored engines and a small diameter spigot for the smaller bored engines) and press the liner out. To fit a new liner, stand the cylinder block with the sump face on the press bed and apply a 76 mm. (3 in.) band of Loctite to the Block bore. Locate the replacer ring over the end of the liner having the internal chamfer, insert the remover into the replacer ring and press and liner home. The replacer ring automatically sets the protrusion. After installation, bore and hone to give the correct piston fit.

To remove and replace the cylinder liners on the turbocharged engines Tool EPCO Flexi-Force cylinder liner press FF 138 should be used.

**CYLINDER BLOCK (continued)****To Remove**

1. Screw the four support legs in the cylinder pressure plate, place the ram pressure plate onto the opposite end of the legs and retain with flat washers and nuts. Mount the assembly onto the cylinder block and fit the locating bolt (See Fig. 9).
2. Insert the long pull-rod through the cylinder bore and assemble the remover plate, flat washer and nut to the end of the pull-rod.
3. Position the ram assembly, ram uppermost, over the pull-rod and onto the pressure plate, fit a flat washer and nut to the pull-rod. Ensure that the remover plate is correctly located in the lower end of the liner.
4. Connect the hydraulic pump hose to the ram assembly. Tighten the pressure release screw then operate the pump. When the ram reaches the end of its stroke, loosen the pressure release screw, adjust the pull-rod by tightening the nut down onto the ram. Tighten the pressure release screw and operate the pump. Successive operation of the ram and adjustment of the pull-rod length will withdraw the liner.

**To Replace**

Before installing the liners, remove all foreign matter from the cylinder block bores by lightly brushing with a wire brush.

Remove all traces of dust and oil from the bores by using a suitable degreasing agent, e.g. trico or petrol.

1. Apply a 76 mm. (3 in.) band of "Loctite" retaining compound No. 75 (EM4G64) to the top of the cylinder block bore using a clean, oil and grease free brush. Completely clean and degrease the cylinder liners. Coat the outside diameter with Locquic T (SM4G-4647-A) ensuring that the whole surface is covered, and allow the primer to dry. With the internal chamfer upwards, enter the liner into the bore, square the liner to the bore by using a hide mallet.
2. Using the pull-rod coupler, join the two pull-rods together, assemble the cross-beam, flat washer and nut to the lower end of the pull-rod. Insert the pull-rod into the liner so that the cross beam locates on the sump face of the cylinder block (Figs. 10 and 11).
3. Slide the replacer plate over the pull-rod and locate the machined groove onto the liner. Place the ram assembly, ram uppermost over the pull-rod and onto the replacer plate, fit a flat washer and nut to the pull-rod and tighten the nut onto the ram.
4. Connect the hydraulic pump hose to the ram, tighten the pump pressure release screw and operate the pump. When the ram has reached the end of its stroke, loosen the pressure release screw and adjust the pull-rod by tightening the nut down onto the ram. Tighten the pump release screw and operate the pump. Repeated operation of the ram and adjustment of the pull-rod will replace the liner.

The replacer plate is machined to set the correct liner protrusion.

5. Bore the liner within 0.127 mm. (0.005 in.) undersize, then hone to obtain the correct piston fit. This honing operation is applicable to the centrifugally cast iron liner only. **CROMARD LINERS ARE PREFINISHED.**

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## CYLINDER BLOCK—Continued

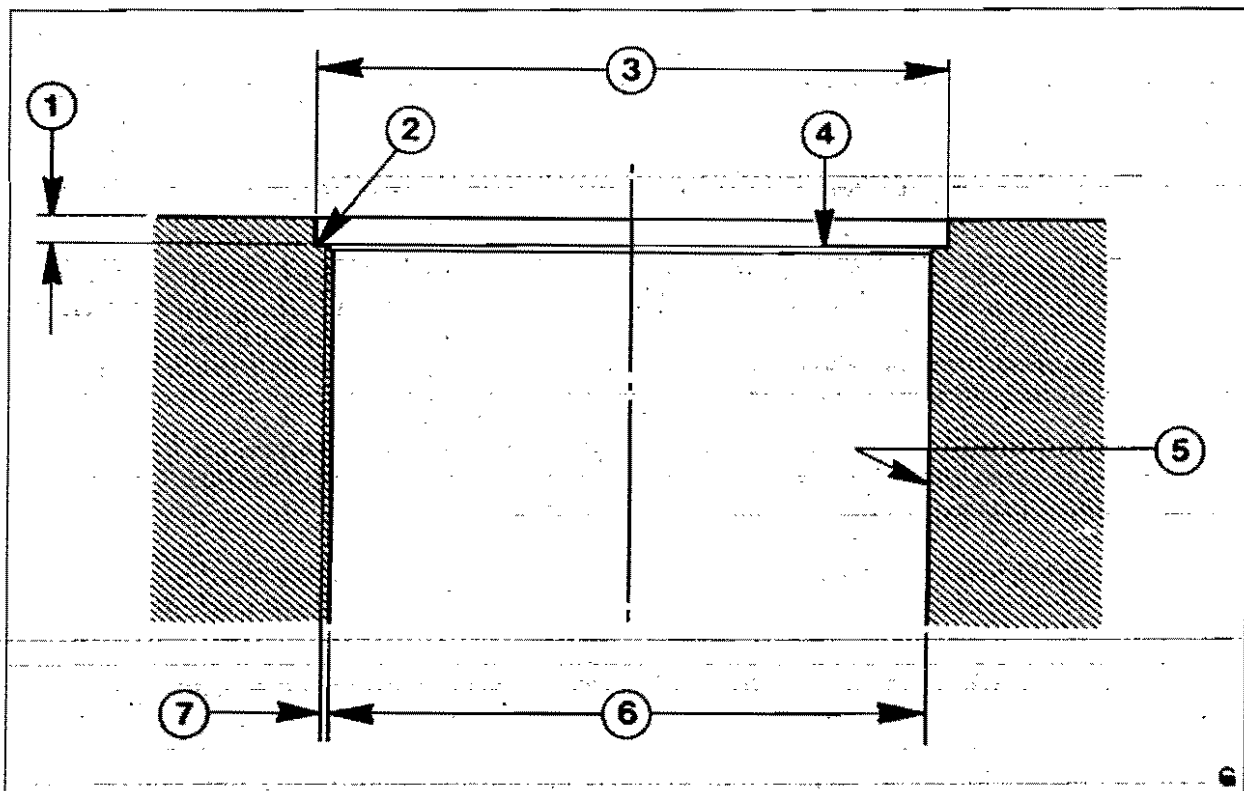
### REPLACEMENT OF CROMARD CYLINDER LINERS WITH CAST IRON LINERS (TURBO-CHARGED ENGINES)

Engines built between August 1969 and December 1972, fitted with Cromard liners may be reworked to the latest design level by machining the existing cylinder block and fitting lipped cast iron liners, new pistons and rings, connecting rods and big end bearing liners.

NOTE: Engines built after engine number S844447, will not require the later type connecting rods, as these are fitted in production.

### PROCEDURE FOR MACHINING THE EXISTING CYLINDER BLOCK

1. Remove the engine from the equipment or vehicle.
2. Strip the engine down to the basic block level.
3. Remove the Cromard cylinder liners.
4. Machine all the block bores to accept the cast iron cylinder liners (part number 733F-6055-GAB) in accordance with the dimensions shown below.



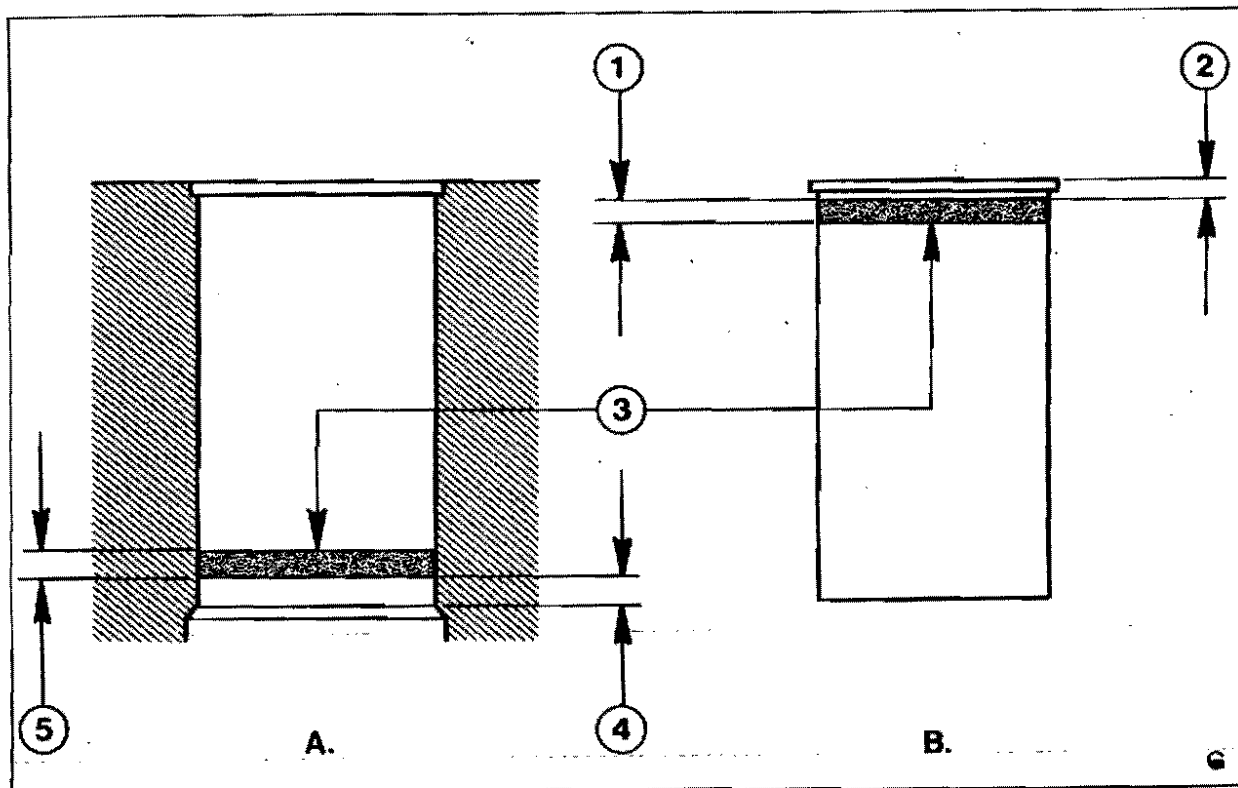
1. 4.7625 to 4.8641 mm (0.1875 to 0.1915 in.)
2. 0.5080 mm (0.02 in.) radius maximum
3. 113.1443 to 113.2713 mm (4.4545 to 4.4595 in.) diameter, to be concentric with the main bore within 0.0127 mm (0.005 in.) total indicator reading.
4. This face to be square with the cylinder block bore within 0.0254 mm (0.001 in.) total indicator reading.
5. Hone this surface to 22 to 40 centre line average (surface finish) — see Ford Specification ES-2704E-6015-A.
6. 108.5977 to 108.6231 mm (4.2755 to 4.2765 in.) diameter
7. 0.0580 to 0.6350 mm (0.020 to 0.025 in.), chamfer at 45°.

## CYLINDER BLOCK—Continued

**IMPORTANT:** The squareness and the counterbore seat to cylinder block bore must be maintained.

**NOTE:** Parallel cast iron cylinder liners (part number 2704E-6055-B) must not be fitted to the 'Cromard' cylinder blocks because of the presence of the counterbore.

5. Remove all foreign matter and traces of oil from the cylinder block bores and remove the protective coating from the cast iron cylinder liners using 'Ardox Cleaner'.
6. Apply sparingly a 13 mm (0.5 in.) wide band of sealer (part number A70SX-19554-AA) approximately 13 mm (0.5 in) from the base of each bore. Approximately 6 mm (0.5 in) below the cylinder line lip apply sparingly a 13 mm (0.5 in.) wide band of sealer (part number A70SX-19554-AA) to the outside diameter of each liner as shown below.



**A. Cylinder Block Bore**

1. 13 mm (0.5 in.)
2. 6 mm (0.25 in.)
3. Band of Sealer

**B. Cylinder Liner**

4. 13 mm (0.5 in.)
5. 13 mm (0.5 in.)

7. Push the liners into the cylinder block by hand as far as they will go. Using the cylinder liner press, position the ram and the correct adaptor on the top end of the liner and connect the pull rod to the cross beam which locates across the sump face. Press the liner home steadily, using extreme care to ensure the liner lip is not overloaded as seating occurs.

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## CYLINDER BLOCK—Continued

8. Ensure that the liner is pressed home squarely and that the liner recess in the cylinder block remains clean, enabling the liner lip to seat correctly. Remove any sealer that may have accumulated on the lower edge of the liner.
9. Repeat operations 6 to 8 for the remaining five cylinder liners.
10. Measure the pre-finished bores of the liners and select the grades of pistons required (part numbers 733F-6012-GAA/GBA).

**Note:** Piston to cylinder liner clearance is 0.15 to 0.17 mm (0.0058 to 0.0068 in.)

11. Reassemble the engine, fitting connecting rods with oil squirt holes (part number 723F-6200-AAA) and corresponding bearings (see Parts Required) if the engine was built before engine number S844447.

**Important:** When fitting the cylinder head only cylinder head gasket (part number 683F-6051-GA) must be used.

### PARTS REQUIRED:

Description	Part Number	Finis Code	Quantity Required
Cylinder liner	733F-6055-GAB	1544253	6
Piston, Pin, Rings, Retainer Assemblies (Grade 2)	733F-6102-GAA	1540318	As Required
(Grade 4)	733F-6102-GBA	1540319	As Required
Connecting Rod Assembly	723F-6200-AAA	1537591	6 (if before S844447)
Big End Bearing Liner – Upper – Standard	723F-6211-GA/1A	1537592	As Required
0.254mm (0.010 in.) Undersize	723F-6211-GB/1A	1537556	As Required
0.508mm (0.020 in.) Undersize	723F-6211-GC/1A	1537557	As Required
0.762mm (0.030 in.) Undersize	723F-6211-GD/1A	1537558	As Required
1.016mm (0.040 in.) Undersize	723F-6211-GE/1A	1537559	As Required
Big End Bearing Liner – Lower – Standard	2709E-6211-AA	1428375	As Required
0.254mm (0.010 in.) Undersize	2709E-6211-AB	1428376	As Required
0.508mm (0.020 in.) Undersize	2709E-6211-AC	1428377	As Required
0.762mm (0.030 in.) Undersize	2709E-6211-AD	1428378	As Required
1.016mm (0.040 in.) Undersize	2709E-6211-AE	1428379	As Required
Kit – Engine Overhaul Gasket	2704E-6008-C	1428986	1
Sealer	A70SX-19554-AA	1474588	As Required

It is not practical to carry out liner replacement with the cylinder block in situ, as distortion is likely to result.

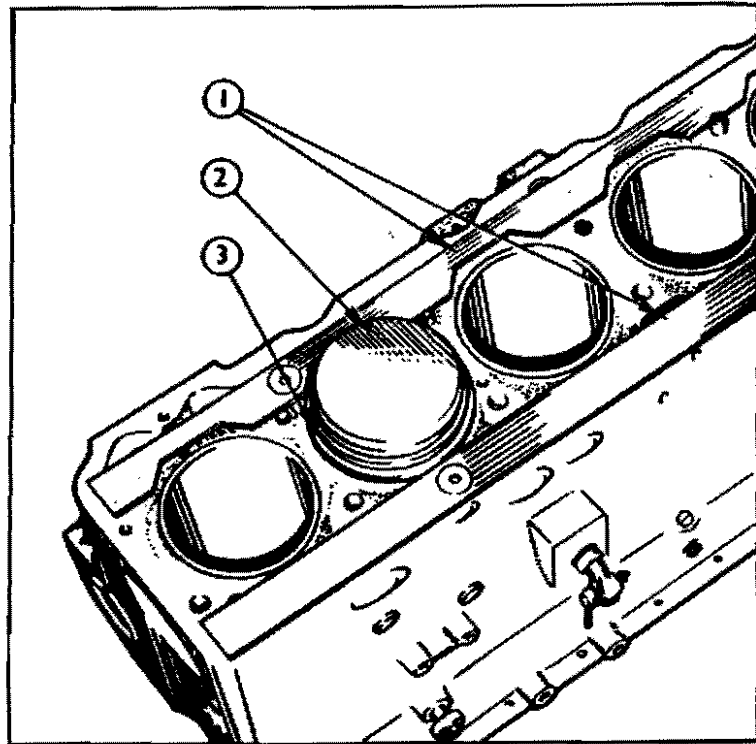
**NOTE:** For identification the letter 'T' is stamped on the rear cylinder block pad to indicate for use on Turbocharged engines.

Internally, the crankcase incorporates five main bearings (4-cylinder) and seven main bearings (6-cylinder). The main bearing caps are retained by self locking bolts 15.88 mm, (5/8 in.) diameter fitted without washers. When dismantling the main bearing caps, ensure that the intermediate cap positions are marked as these caps are identical. Also ensure that the immediate and centre caps are fitted the correct way round, these caps are marked REAR to facilitate assembly.

Semi-finished main bearing caps are available and may be used to replace caps which have become worn or damaged.

Fig. 8 Cylinder Liner

- 1 Protection Strips
- 2 Cylinder Liner Remover
- 3 Replacer Ring



### CYLINDER BLOCK (continued)

When fitting one or more replacement main bearing caps in service all the caps must be assembled to the block, the main bearing bolts tightened to 163 to 176 Nm (16.59 to 17.97 kgf m or 120 to 130 lbf ft) torque and the main bearing bores line bored 0.38 mm (0.015 in) oversize. The finished dimension for the oversize bore is 80.81 to 80.82 mm (3.1815 to 3.1823 in) diameter. If the centre main bearing cap requires replacing it must be centralised on the cylinder block prior to machining (see Fig. 8). Machine recesses 99.01 to 99.30 mm (3.900 to 3.910 in) diameter on each side of the cap and if necessary reduce the bearing width by 0.508 mm (0.020 in) undersize. An equal amount of material should be machined off each side of the bearing to give a distance of 40.36 to 40.42 mm (1.589 to 1.591 in) between the thrust faces. The finished thrust faces must be square to the main bearing bore within 0.051 mm (0.002 in) total indicator reading and concentric within 0.152 mm (0.006 in) total indicator reading. If necessary, file back the thrust washer locating slots in the cap so that they are a little deeper than the thrust washer recesses (Fig. 12). Do not increase the width of the slots. Thrust washer recesses machined to the above dimensions, will require 0.245 mm (0.010 in) oversized thickness thrust washers, if the crankshaft journal width is standard; 0.38 mm (0.015 in) and 0.51 mm (0.020 in) oversizes are also available.

If a front bearing cap is being replaced remove the locating dowels and assemble the new cap to the cylinder block so that the front face is flush with the cylinder block front face. Tighten the main bearing bolts to the correct torque and, using the dowel holes in the cap as guides, drill two holes 9.53 mm. (3/8 in.) diameter through the cap into the cylinder block to the depth of the existing holes.

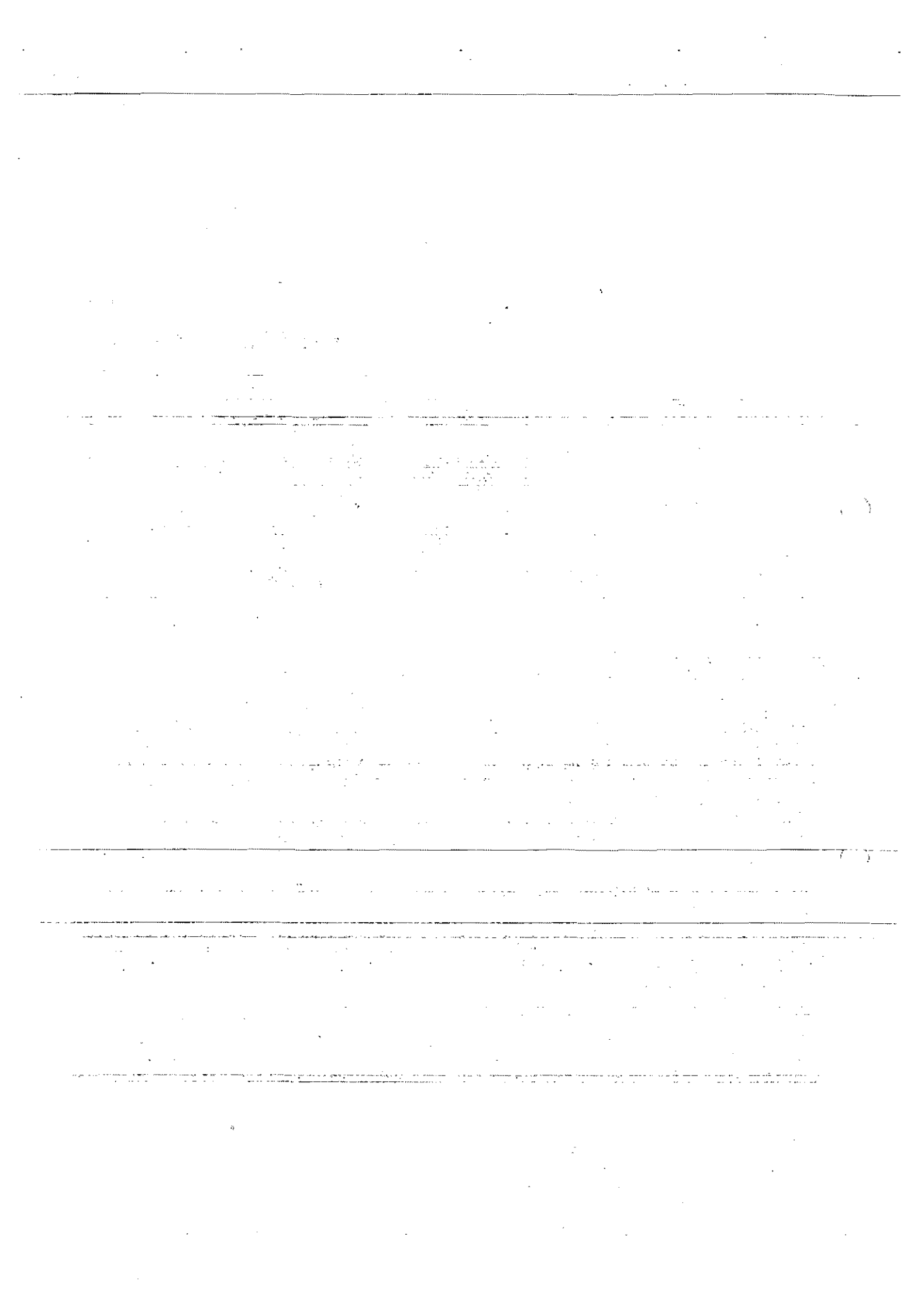
On removing the caps after machining fit oversize dowels to the cylinder block.

The parent bores for the camshaft bearings, where fitted, in the right-hand side of the crankcase may be standard or 0.508 mm. (0.020 in.) oversize.

Tappet bores and push rod tubes are drilled in the cylinder block along the right-hand side. Oil drain channels are also drilled to obviate the need for a separate tappet chamber and cover.

(Continued on page 7)

Engine Overhaul 6B





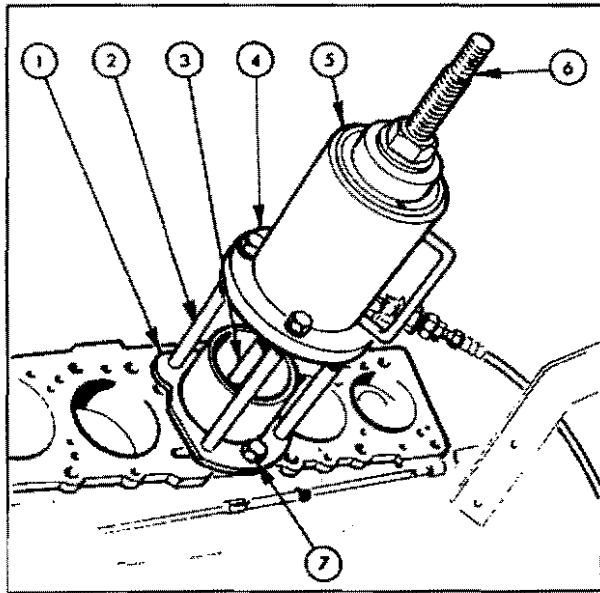


Fig. 9 - Cylinder Liner Removal

- 1 Cylinder Pressure Plate
- 2 Support Legs
- 3 Pull Rod
- 4 Ram Pressure Plate
- 5 Ram Assembly
- 6 Pull Rod
- 7 Locating Bolt

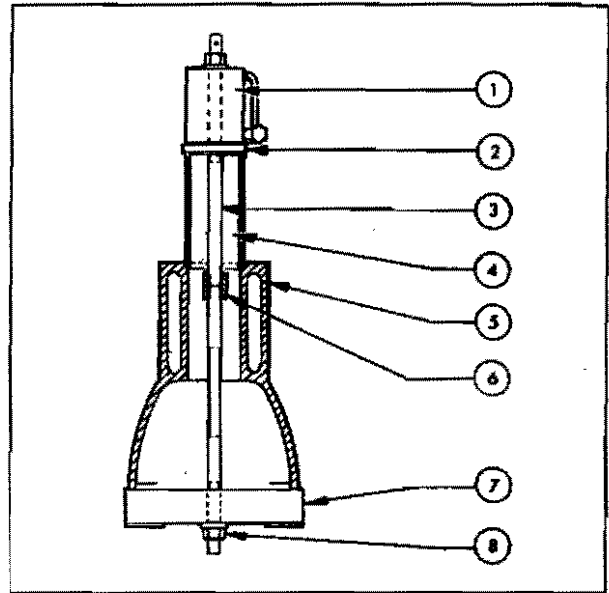


Fig. 10

- 1 Ram
- 2 Replacer Plate
- 3 Pull Rod
- 4 Liner
- 5 Cylinder Block
- 6 Pull Rod Couple
- 7 Cross Beam
- 8 Nut and Washer

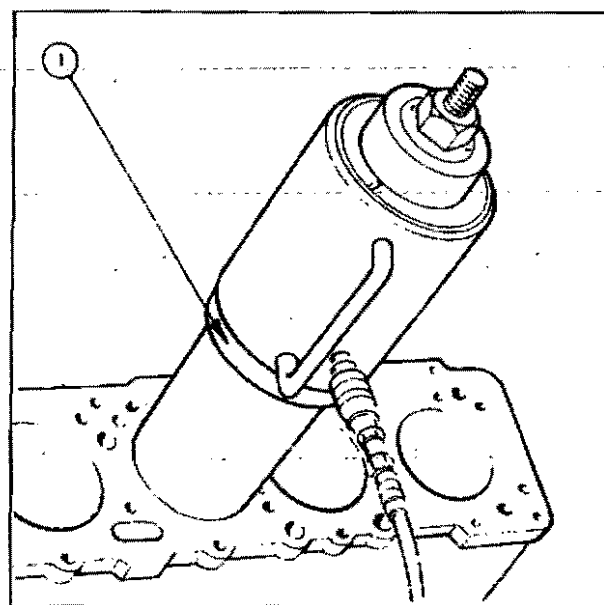


Fig. 11

- 1 Replacer Plate

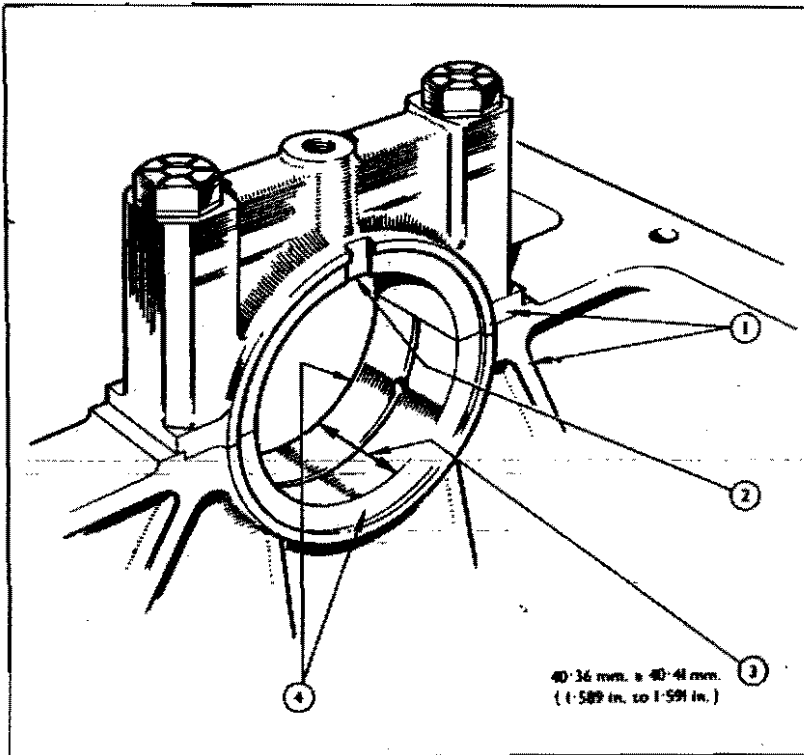


Fig. 12 Centre Main Bearing Cap

- 1 Align Cap and Block
- 2 File Back These Slots
- 3 Dimension
- 4 Machined-Recess for Thrust Washer

## CAMSHAFT AND GEAR

The cast camshaft is situated in the right hand side of the cylinder block and runs in 4 bearings (4 cylinder) or 6 bearings (6 cylinder). The bearings are steel backed, the front one being faced with copper lead the remainder white metal. Prior to Engine No. S790085, the camshaft in the majority of 4 cylinder engines ran directly in the cylinder block. When a heavy duty power take off is specified for a 4 cylinder engine, camshaft bearing bushes must be fitted.

Bushes available in service are pre-sized and require no machining after fitting. Bushes which are 0.508 mm. (0.020 in.) oversize on the outside diameter are also available. When one bush requires replacement it is advisable to replace all bushes as camshaft alignment may be affected if only one bush is changed.

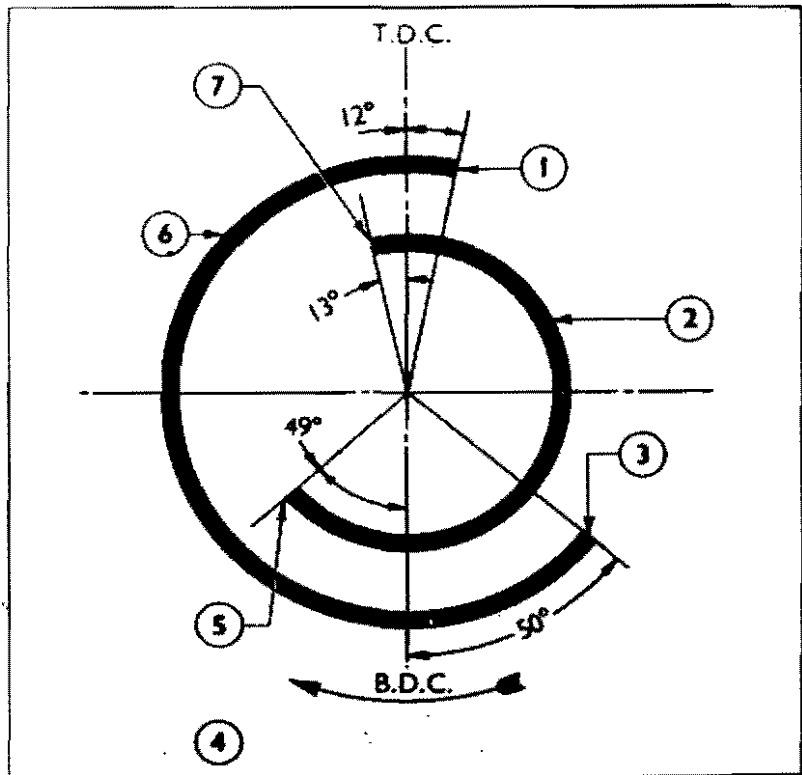
The bushes can be removed and replaced using camshaft bearing remover and replacer Tool No. CT.6119A and adaptors Tool No. C.6119-2. Camshaft bearing remover and replacer Tool No. CT.6119 can be modified to make Tool No. CT.6119A by machining the internal diameter to 59.44 to 59.94 mm. (2.34 to 2.36 in.) and 38.1 mm. (1½ in.) deep. Alternatively the tool can be returned to the manufacturers for modification. Assemble the bushes with the split on the right-hand side and the two notches to the rear and vertical to ensure alignment of oil holes. After fitting the front bush bend the tang up to locate in the hole in the cylinder block front face. If bushes are fitted to a four cylinder engine or a new camshaft is to be used in a cylinder block already fitted with bearing bushes, ensure that the phosphate coating is lapped-off all the camshaft bearing journals.

The cams on the camshaft are offset rearwards from the tappet centre lines and are also tapered. This causes the tappets and push rods to rotate, thus improving durability and eliminating the possibility of uneven wear. The nominal valve-timing diagram is shown in Fig. 13. A fuel lift pump eccentric is incorporated between the two rear cams and an integral oil pump drive gear is provided between the rear two cylinders instead of an additional bearing journal.

The camshaft is retained by a thrust plate bolted through the timing gear housing to the cylinder block front face. Thrust washers are located on the camshaft on either side of the thrust plate by a spacer and are clamped in position between the timing gear and a separate collar adjacent to the front journal. These thrust washers are steel faced with bronze and must be fitted with the bronze faces towards each other. Camshaft end-float is 0.051 to 0.584 mm. (0.002 to 0.023 in.).

Fig. 13 Valve Timing

- 1 Exhaust Valve Closes
- 2 Inlet
- 3 Exhaust Valve Opens
- 4 Direction of Rotation
- 5 Inlet Valve Closes
- 6 Exhaust
- 7 Inlet Valve Opens



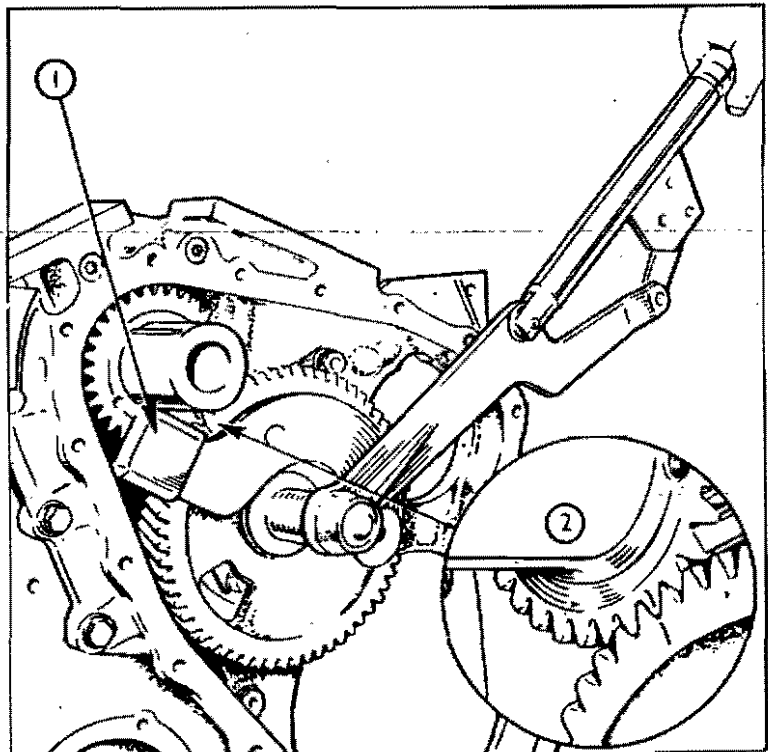
## CAMSHAFT AND GEAR (Continued)

The camshaft gear is retained by a large centre bolt. Before fitting the gear retaining bolt, ensure that the bolt hole thread in the camshaft is not damaged. Clean the camshaft and the retaining bolt threads with "Loctite Primer T" or alternatively a solvent such as carbon tetrachloride to ensure all dirt and oil is removed. Fit bolt and tighten the bolt to a torque of 203 to 210 Nm (20.74 to 21.43 kgfm or 150 to 155 lbfft). A timing mark is incorporated in the gear to facilitate correct valve timing (See Fig. 14).

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Fig. 14 Replacing Camshaft Gear

- 1 Camshaft Gear Holding Wrench, Tool No. CT.6124
- 2 Timing Marks



## 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 is located in the push rod cup end. Before fitting the push rods they should be checked for straightness.

## CRANKSHAFT AND BEARINGS

The forged steel dynamically balanced crankshaft runs in five main bearings (4-cylinder) or seven main bearings (6-cylinder) fitted with steel backed aluminium tin liners. These main bearing liners are in two halves, the upper half incorporating oil feed holes and an oil groove. The lower half liner does not incorporate oil feed holes and an oil groove is provided in the centre and rear liners only. These liners must not be fitted to the upper location. Bearing liners which have standard or 0.381 mm. (0.015 in.) oversize outside diameters are available in 0.254 mm. (0.010 in.) 0.508 mm. (0.020 in.) 0.762 mm. (0.030 in.) and 1.016 mm. (0.040 in.) undersizes.

Crankshaft thrust and endfloat are controlled by thrust washers located in recesses on either side of the centre main bearing (Fig. 15). 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 cup to prevent the washers rotating. In addition to standard size washers the following oversizes are also available 0.064 mm. (0.0025 in.) 0.127 mm. (0.005 in.) 0.191 mm. (0.0075 in.) 0.254 mm. (0.010 in.) 0.38 mm. (0.015 in.) and 0.508 mm. (0.020 in.).

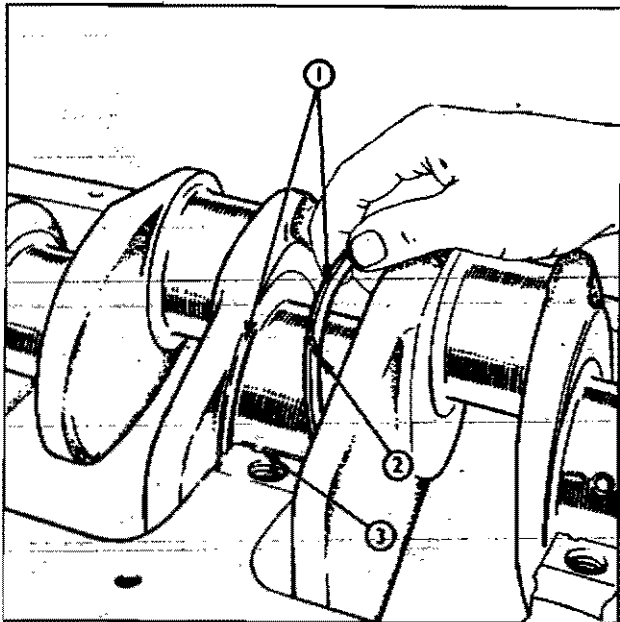


Fig. 15 Crankshaft Thrust Washers

- 1 Crankshaft Thrust Washers
- 2 Oil Groove
- 3 Liner Locating Tongue and Groove

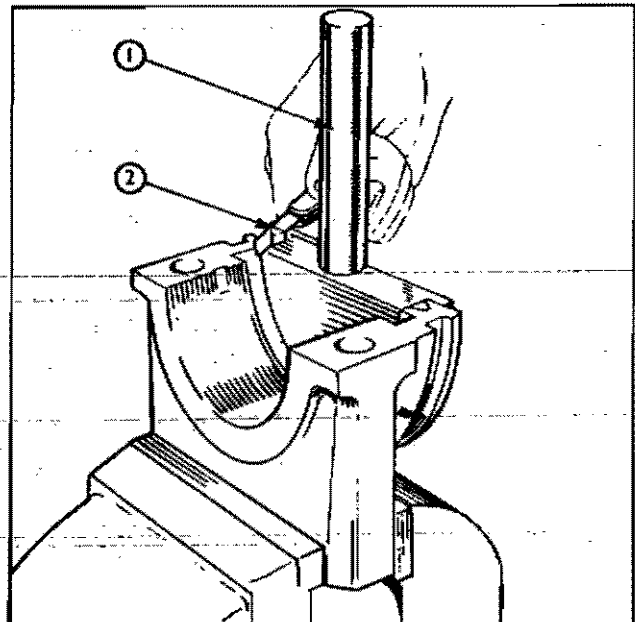


Fig. 16 Replacing Rear Oil Seal

- 1 Oil Seal Replacer Tool No. C.6134
- 2 Trim Seal 0.25 to 0.38 mm. (0.010 to 0.015 in.) above Cap Face

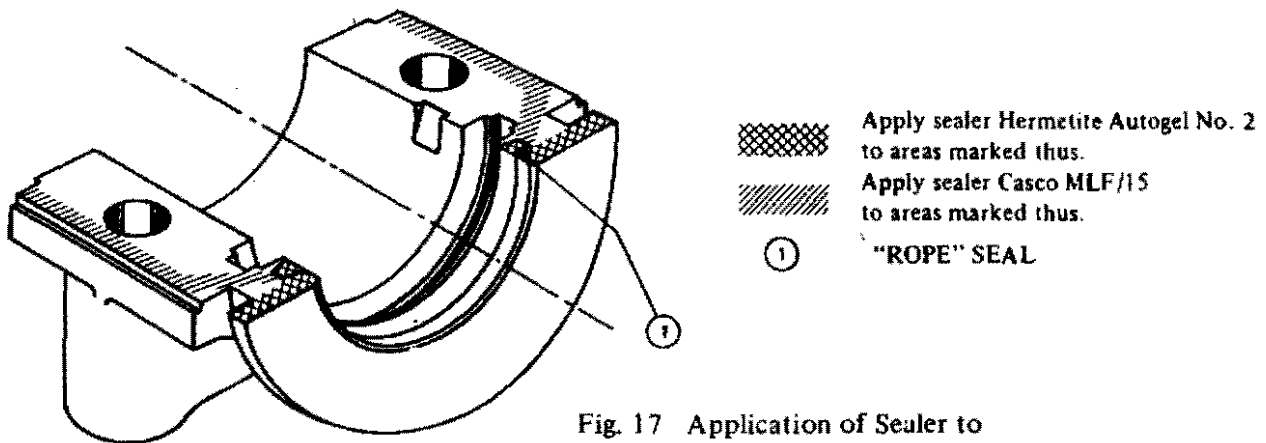


Fig. 17 Application of Sealer to Rear Main Bearing Cap

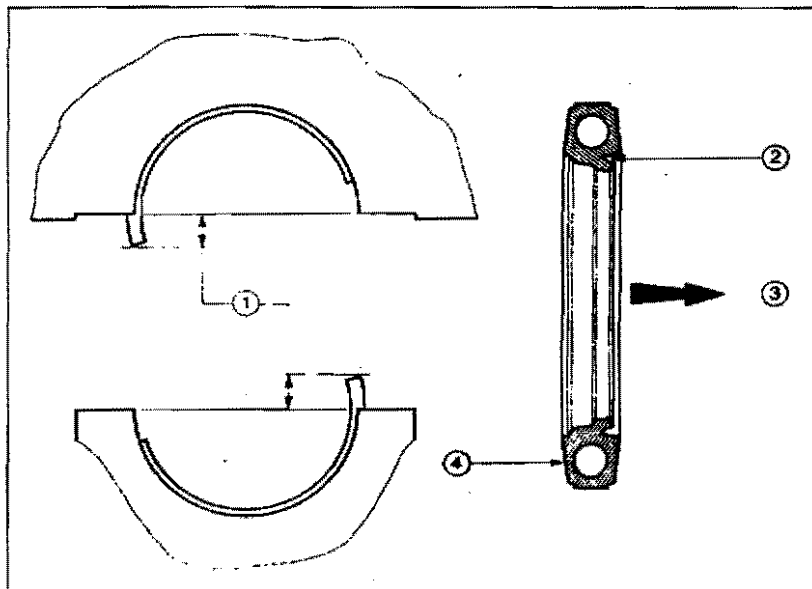


Fig. 17a - Lip-Seal

1. 10.0 mm. (0.375 in.) protrusion
2. Undercut
3. Front of engine
4. Colour marking position

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#### CRANKSHAFT AND BEARINGS (continued)

The crankshaft main bearing journals and crankpins may be ground 0.254 mm. (0.010 in.) 0.508 mm. (0.020 in.) 0.762 mm. (0.030 in.) or 1.016 mm. (0.040 in.) undersize. When grinding crankshafts the fillet radii must be maintained at 4.32 to 4.83 mm. (0.170 to 0.190 in.) and be smooth and free from visual chatter marks. Also the crankpin length must not exceed 42.52 mm. (1.674 in.), the intermediate main journal length 35.94 mm. (1.415 in.) and the rear main journal length 47.02 mm. (1.851 in.). The centre main bearing journal length can be increased by up to 1.02 mm. (0.040 in.) providing an equal amount is machined from each face and corresponding oversize thrust washers fitted. Main bearing journal and crankpin ovality should not exceed 0.00641 mm. (0.00025 in.) and taper 0.0127 mm. (0.0005 in.). Thrust face taper should not exceed 0.051 mm (0.002 in.) and the runout total indicator 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.

Note: The Turbocharged engine crankshaft is dimensionally identical to the Normally Aspirated engine, but the material specification is different and therefore they are not interchangeable.

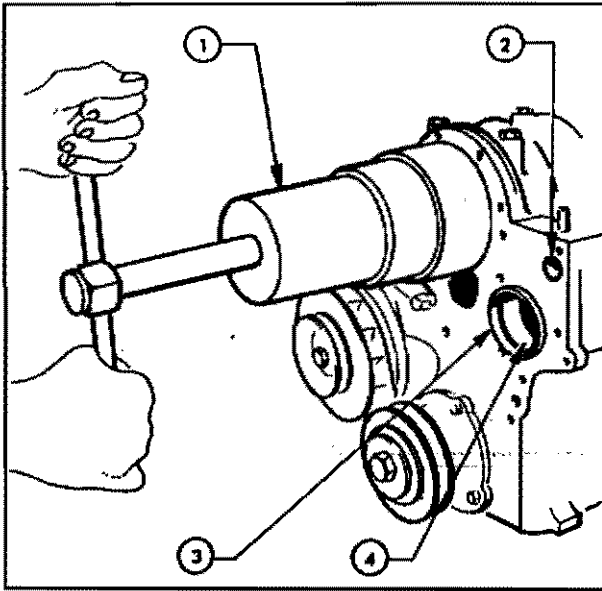


Fig. 18. Removing Crankshaft Gear

- 1 Gear Remover Tool No. CPT 6040-B
- 2 Oil Seal
- 3 Thrust Collar
- 4 Bearing Tang

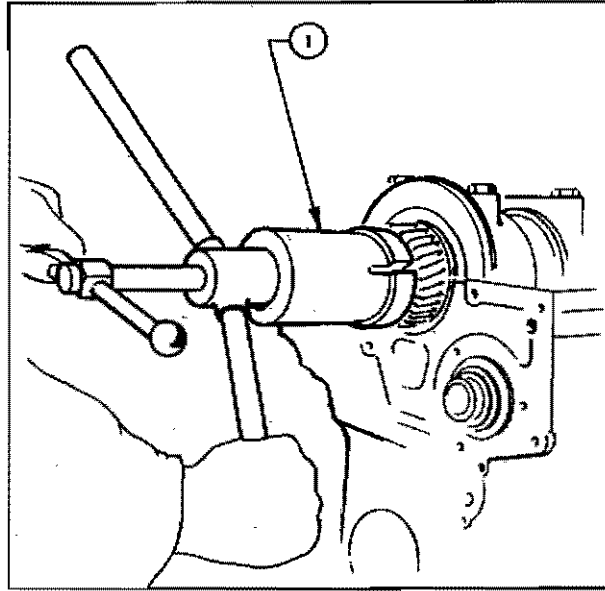


Fig. 19. Replacing Crankshaft Gear

- 1 Gear Replacer Tool No. CT 6069-A

#### CRANKSHAFT AND BEARINGS (continued)

The crankshaft rear oil seal, which prevents oil leaks from around the rear journal, consists of two woven asbestos packings impregnated with rubber and having a synthetic rubber core. The rubbing surface is coated with P.T.F.E. to ensure long life and to eliminate the possibility of the seal burning out during initial running. The upper packing is located in a housing integral with the cylinder block and the lower in a housing integral with the main bearing cap. To ensure an oil tight seal it is important that these packings are fitted with replacer Tool No. C.6134 and the ends trimmed to 0.25 to 0.38 mm. (0.01 to 0.015 in.) above the face of the rear cap. (Figs. 16 and 17).

New type oil seals have been introduced for use with the "knurled" type crankshaft. Before fitting, thoroughly clean out the old oil seal from the grooves in the cylinder block and rear main bearing cap, ensuring all traces of adhesive are removed.

Dip the seal halves into clean oil then carefully install the upper seal (cylinder block) into its groove with the under cut of the seal (Fig. 17a) toward the front of the engine.

Examine the crankshaft to ensure that the "knurling" surface is in good condition. Any machining blemishes or sharpness of knurl must be lapped with very fine emery cloth.

The seal halves must protrude approximately 10 mm. (3/8 in.) above the mating surfaces to ensure bearing cap to cylinder block alignment. Apply a sealer (Ford Specification ESEE-M46-1005A) such as Casso MLF15 to the cylinder block rear oil seal groove area. Hylomar sealer (Ford Specification A70SX-19554-BA) must also be applied to both sides of the sump rear packing seal.

Note: Allow a minimum of two hours hardening time before starting the engine.

To prevent oil leaks around the crankshaft pulley boss an oil seal is pressed into the front cover. This seal has a single spring loaded lip and must be centralised with Tool No. C.6133 when fitting the front cover, to be effective.

The crankshaft gear, which incorporates a timing mark to facilitate valve timing is pressed onto the front of the crankshaft and is located by a key. This gear can be removed with remover Tool No. CPT.6040B (Fig. 18) if the crankshaft and/or timing gear housing are first removed. With the timing housing fitted this tool cannot be used. Fit the gear with replacer Tool No. CT.6069A (see Fig. 19). This tool is a modification of Tool No. CT.6069 and existing tools should be reworked by increasing the length of the slot to at least 50.8 mm. (2 in.).

### TIMING HOUSING AND COVER

A cast iron timing gear housing is bolted to the cylinder block front face and is located by a sleeve around the camshaft bore. The three bolts retaining the camshaft thrust plate also pass through the housing and it should be noted that the two socket head screws at the bottom screw into the front main bearing cap. When replacing the housing it is important that all the bolts, including those retaining the camshaft thrust plate are tightened in the correct sequence. (Fig. 20). The timing scale is retained by the two lower external bolts on the left-hand side.

The injection pump and exhaustor or compressor are mounted on the rear face of the timing gear housing on the right-hand side of the engine. These components are driven individually by gears meshing directly with the camshaft gear.

A pressed steel cover is fitted to the front of the timing gear housing. When a forward mounted timing gear P.T.O. is required on the engine, a cast iron timing cover is fitted. Both timing covers incorporate the crankshaft front oil seal. When fitting a cover, it is important that the oil seal is centralised with centraliser Tool No. C.6133 (fig. 21).

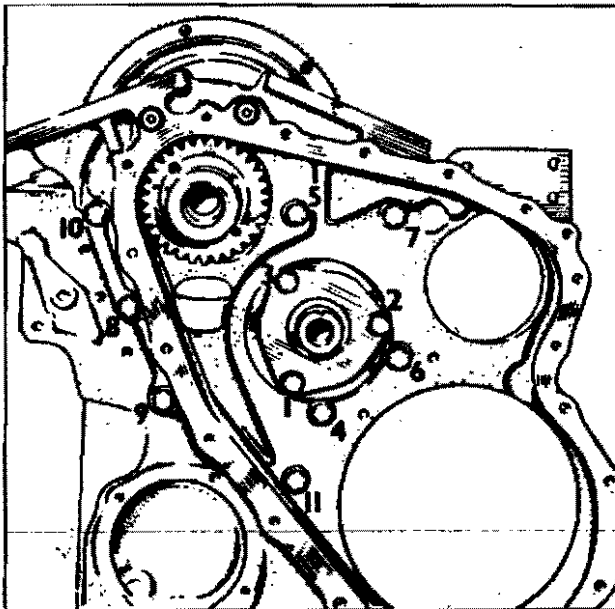


Fig. 20

Bolt Tightening Sequence for Timing Gear Housing

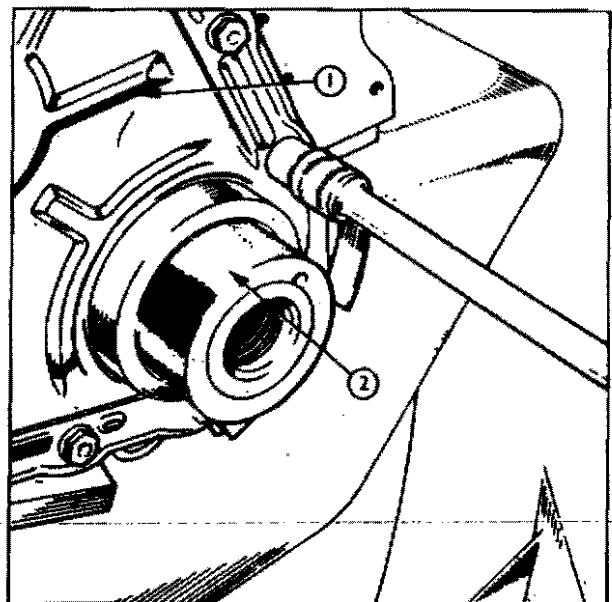


Fig. 21 Centralising Front Oil Seal

1 Timing Gear Housing Front Cover  
2 Centraliser Tool No. C.6133

### CONNECTING RODS

The connecting rods are H section steel forgings with detachable big end caps. The caps are located by hollow tension pins pressed into the connecting rod and retained by 12.7 mm ( $\frac{1}{2}$  in) diameter self-locking bolts. On 330 and 363 C.I.D. engines the big end cap is retained by 11.113 mm ( $\frac{7}{16}$  in) diameter bolts and self-locking nuts.

## CONNECTING RODS (Cont'd)

Steel backed bearing liners with aluminium tin bearing surfaces are used for the big ends, and are also available as 0.254 mm. (0.010 in.) 0.508 mm. (0.020 in.) 0.762 mm. (0.030 in.) and 1.016 mm. (0.040 in.) undersized. The crankpin diameter on the 330 and 363 C.I.D. engines is 67.2 to 67.22 mm (2.6460 to 2.6465 in.) and on the 240, 254, 360 and 380 C.I.D. engines the crankpin diameter is 70.88 to 70.89 mm (2.7905 to 2.7910 in.). The crankpin diameter for Turbocharged engines is 66.68 mm. (2.625 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.

Effective from engine No. S844447, the connecting rods fitted to the Turbo-charged engines incorporate an additional oil squirt hole (Fig. 22) to improve the lubrication of the cylinder bore. The upper bearing has also an oil hole that aligns with the squirt hole of the connecting rod.

Where it is necessary to replace a connecting rod or upper bearing ensure the correct level is fitted. The drilled and undrilled connecting rods and/or bearings must not be mixed on an engine.

New small end bushes can be fitted in service, providing suitable equipment is available to accurately machine the bore to the correct size. This bore is 34.92 to 35.028 mm. (1.3751 to 1.3754 in.) diameter and must be parallel with the big end bore within 0.0127 mm. (0.0005 in.) per 24.50 mm. (inch) and the twist in the same plane within 0.037 mm. per 25.40 mm. (0.0015 in. per inch). Assemble the bush to the connecting rod so that the oil hole is in alignment with the hole in the connecting rod and the split is to the non-thrust side, i.e. on the opposite side to the big end bearing liner locating groove.

When dismantling an engine examine the piston marking to check the connecting rods for straightness. A heavy marking on the piston skirt above the pin on one side together with a correspondingly heavy marking below the pin on the other side indicates a bent connecting rod which should be either straightened or a replacement fitted.

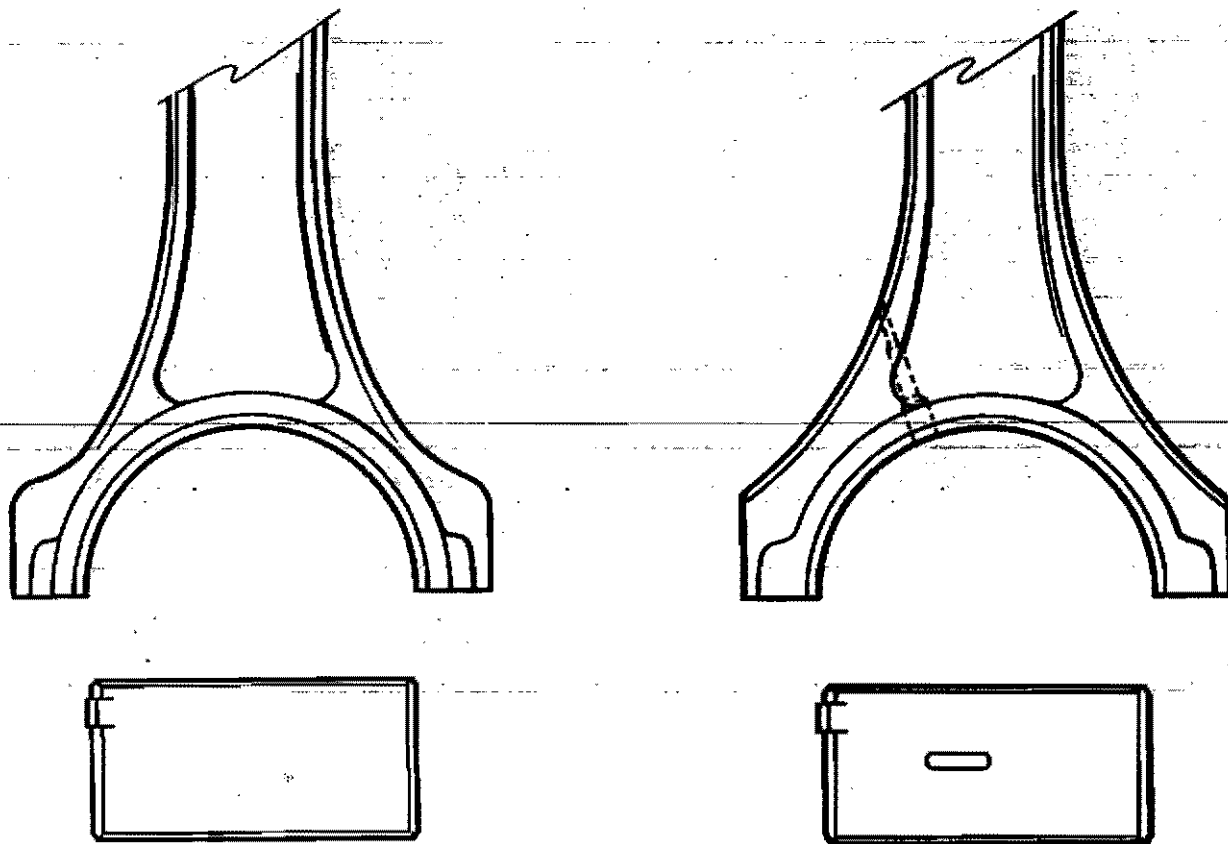


Fig. 22

Previous type of connecting rod and bearing

Current type of connecting rod and bearing



## CONNECTING RODS (Cont'd.)

When assembling a connecting rod to the piston ensure that it is fitted the correct way round. The marking "FRONT" is embossed on the web to facilitate this.

### Connecting Rod Numbering

Connecting rods are numbered when installed in the engine during manufacture, to facilitate correct reassembly should they be dismantled.

The number is stamped on the camshaft side of the big end so that a cap replaced with the numbers together must be in its original position. Never reassemble a bearing cap to another connecting rod.

It is advisable when removing connecting rods from an engine to check that the connecting rods have been numbered correctly. Where the connecting rods are unmarked they should be suitably stamped unless the connecting rods are being scrapped.

## PISTON, PISTON PINS AND RINGS

The pistons are made of aluminium alloy and are of the solid skirt type with the combustion chamber and valve recesses machined in the crown. The combustion chamber is offset to the thrust side and incorporates a toroidal tip to promote efficient combustion. An arrow head is also cast in the crown to facilitate correct assembly. When assembling the piston to the connecting rod and the piston and connecting rod assembly to the cylinder bore, ensure that this arrow head points towards the front of the engine.

Four ring grooves are machined in the piston above the piston pin bore, three for compression and a wider one for an oil control ring. (Fig. 23). Radial holes drilled in this lower groove into the inside of the piston together with holes in the lower land provide a return for oil scraped from the cylinder wall. The piston is machined oval, the minor axis being in line with the piston pin bore to compensate for thermal expansion along the piston pin axis at operating temperature. Also the skirt is barrel shaped from the top to the largest diameter at approximately 25.4 mm. (1 in.) from the bottom and then tapers back to the bottom of the skirt to ensure the correct working clearance at operating temperatures.

The pistons are weighed during manufacture and, if necessary, the weight is adjusted by removing surplus metal from inside the bottom of the skirt. On assembling the piston, pin and connecting rods the assemblies are weighed. The maximum variation of weight between all the piston and connecting rod assemblies fitted in the normally aspirated and turbocharged engines is 30 grams (1.0582 ozs.).

For the intercooled engines the maximum variation of weight between all pistons and connecting rod assemblies is 50 grams. (1.7637 ozs.).

For Turbo-Plus engines the piston crown height from the centre line of the gudgeon pin is graded in order to obtain permissible tolerances in relation to piston crown and cylinder block face. The maximum permissible height for the piston crown to protrude above the cylinder block face is 0.356 mm. (0.014 in.). The permissible minimum height of piston crown above the cylinder block face is 0.127 mm. (0.005 in.).

Pistons that are outside these specifications must be replaced. The identification plate will indicate the piston height fitted:— 'S' for standard height, 'H' for high crown.

The tubular steel piston pins are fully floating and are retained in position by circlips installed in grooves at each end of the piston pin bore. The piston bores are graded during manufacture and paint spots corresponding to the grade are placed on the pin bosses. The piston pins are selected to give the correct fit in the piston pin bore and small end bush in the connecting rod.

The piston pins vary in length and diameter according to cubic capacity of the engine for correct usage of pins, refer to Engine Specifications.

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## PISTON, PISTON PINS AND RINGS (Continued)

Four piston rings are fitted, three compression and one oil control ring. These are shaped as shown in Fig. 23. When fitting the piston rings ensure that the compression rings are correctly located in their respective grooves and that the intermediate and lower rings are fitted the correct way up. The upper compression and the oil control ring can be fitted either way up. Space the ring gaps at 90° when inserting the piston in the cylinder bore.

Oversize pistons for the normally aspirated range of engines are available ranging from 0.653 mm. (0.025 in.) to 1.397 mm. (0.055 in.). Refer to individual specifications for usage.

For turbo charged engines of pre-August 1969 production 0.635 mm. (0.025 in.) oversize pistons and rings are available.

Turbo charged engines produced after August 1969 up to Engine No. S859440 had "Cromard" liners, and unplated piston rings. Standard graded pistons only are available with the "Cromard" liners.

Turbo charged engines produced prior to August 1969, had centrifugally cast iron liners.

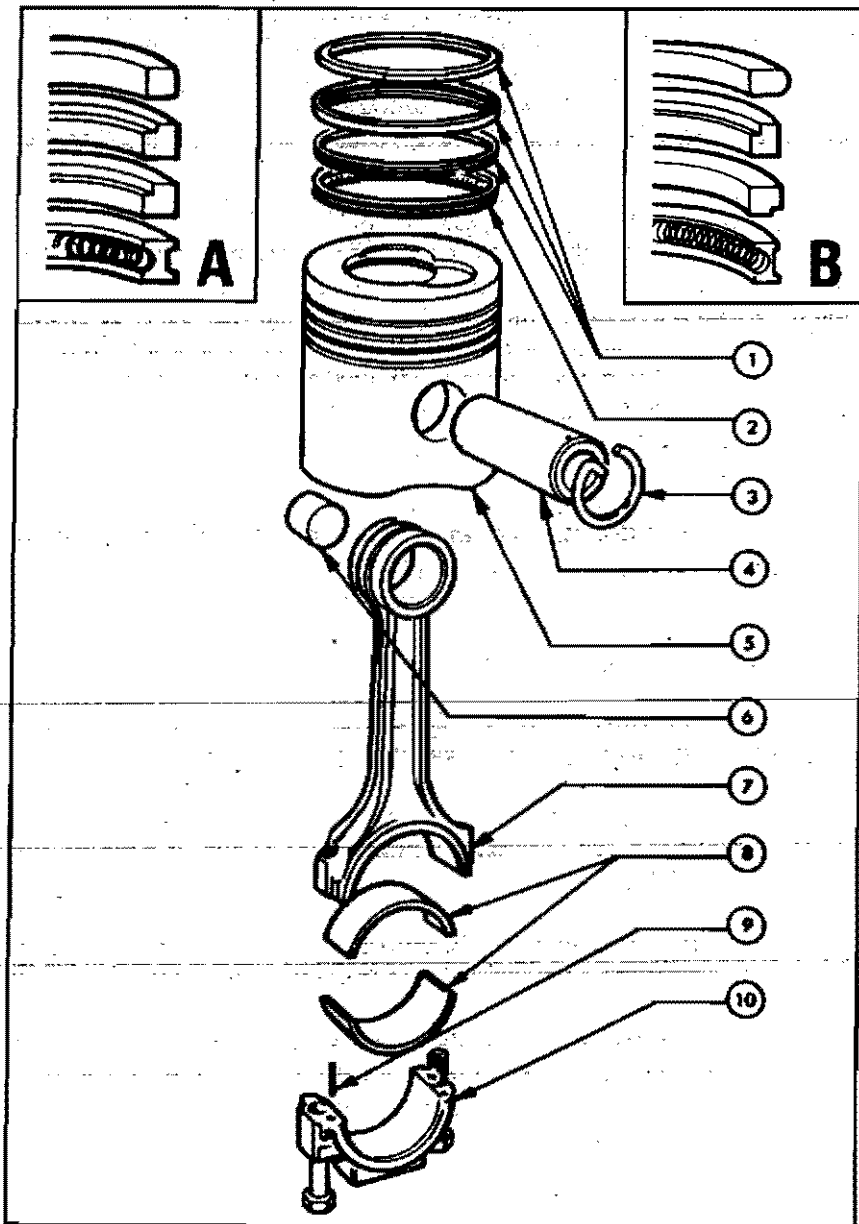
Fig. 23

### Piston and Connecting Rod Assembly

A - Parent Bore and Turbocharged engines

B - 2701E, 2703E and 2704E engines

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



### PISTON, PISTON PINS AND RINGS (continued)

From Engine No. S859441 the centrifugally cast iron liner has been fitted to Turbo-charged engines. Where cast iron liners are fitted to an engine, oversize piston and rings of 0.635 mm. (0.025 in.) are available. The piston rings are plated and must only be used with centrifugally cast iron liners.

### PISTON SELECTION

During engine manufacture the cylinder bore and pistons are graded. The piston grade letter is stamped on the piston crown and in production each cylinder bore grade letter is stamped on the push rod side of the cylinder block. These grade letters ensure that piston to bore clearance at the bottom of the piston skirt is 0.173 to 0.198 mm. (0.0068 to 0.0078 in.).

Only specific grades of pistons are serviced under the same part number, refer to appropriate specifications to ascertain grades. If the piston to bore clearance is insufficient when replacing a piston, the cylinder bore on normally aspirated engines must be honed until the correct clearance is obtained.

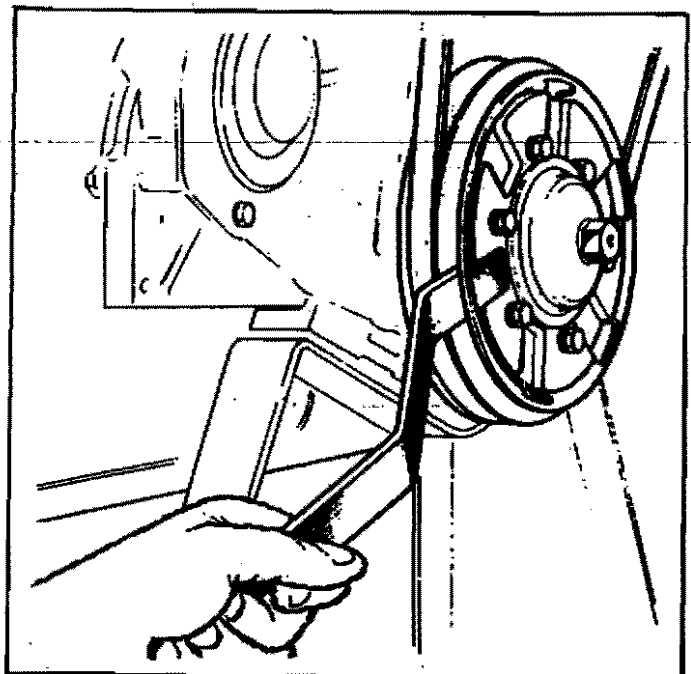
When re-boring cylinders on normally aspirated engines in service, to suit oversize pistons or standard size pistons, it is essential that each cylinder bore is machined to give the correct fit for the individual piston. The piston skirt diameter must be measured accurately at right angles to the piston pin at 21.43mm (0.95 in) from the bottom of the skirt, the maximum measurement being taken as the piston skirt is oval.

### FLYWHEEL AND RING GEAR

The cast iron dynamically balanced flywheel is attached to the crankshaft flange by six bolts, each pair of bolts being locked with a lock plate. An accurately machined recess in the front face ensures that the flywheel is located concentrically on the crankpin flange and a single dowel in line with No. 1 crankpin prevents the position of the flywheel relative to the crankshaft being moved. A timing scale, from T.D.C. to 30° before top dead centre is marked on the flywheel periphery. Two 3/8 in -16 U.N.C. tapped holes are provided on the same pitch circle as the retaining bolts to facilitate flywheel removal.

Depending on the application, the engine may be fitted with various sizes of flywheel. The standard flywheel weighs 39.463 kg (87lbs) and the heavy flywheel weighs 90.718 kg (200lbs).

Fig. 24. "Engine Turning Bar located in barring plate".



## FLYWHEEL AND RING GEAR (Cont'd)

A ring gear is attached to the front face of the flywheel by six countersunk screws. When fitting the ring gear apply plastic sealer Part No. EM-4G-52 to the screw threads prior to assembly as a safeguard against slackening in service.

The clutch pilot spigot bearing is located in a bore machined in the centre of the flywheel and may have a large or small bore depending on the type of gearbox fitted.

## CRANKSHAFT PULLEY

The crankshaft pulley is located on the front end of the crankshaft and is retained by a large centre bolt. The pulley assembly consists of a flanged hub with a fabricated pulley located behind the flange and positioned by an integral key. A dished plate, which has six equidistant slots in the rim, is sandwiched between the pulley and the hub flange. Similar slots in the hub flange enable the engine to be turned over by inserting a bar 25.4 mm. (1 in.) wide by 6.35 mm. (¼ in.) thick and approximately 38.10 cm. (15 in.) long (see Fig. 24). If desired a 38.10 mm. (1½ in.) crank can be set in the bar 76.2 mm. (3 in.) from one end to provide clearance for the water pump pulley hub.

## SUMP

The aluminium alloy sump is cast integral with the lower half of the flywheel housing, and incorporates a dipstick housing. An oil filler and crankcase ventilation tube is pressed into the left hand side of the sump.

When replacing the oil filler cap, it is extremely important to ensure that the correct type of cap is fitted – Prior to late 1972 a non ventilated cap for industrial breathing, and a ventilated cap for automotive breathing. After late 1972 use a non ventilated cap for all models.

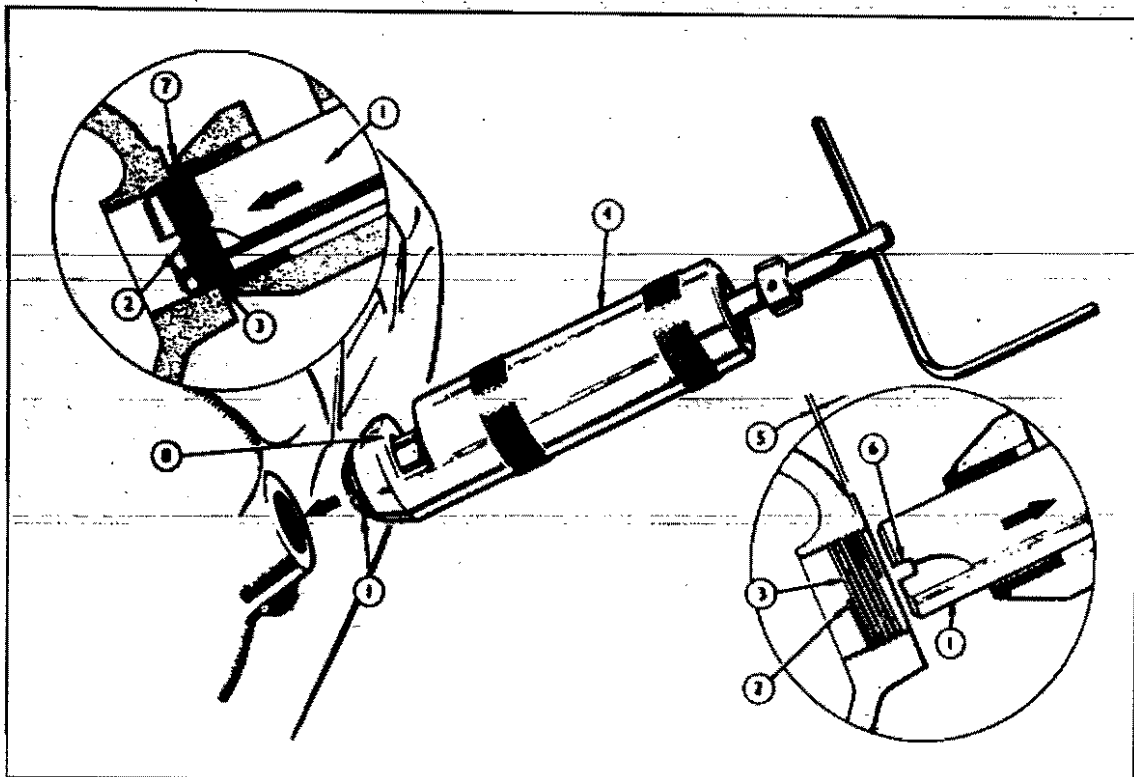


Fig. 25 Fitting New Insert To Oil Pan Drain Plug

SUMP (Continued)

The sump drain plug boss is fitted with a thread insert which normally should not require replacement in service. However, in the course of time, an insert may become dislodged and be removed with the drain plug. Should this occur a new  $\frac{3}{4}$ in – 24 N.S. insert, Part No. E24-CE-5 must be fitted. These inserts can be fitted by using a special prewind tool (see Fig. 25) in the following manner:—

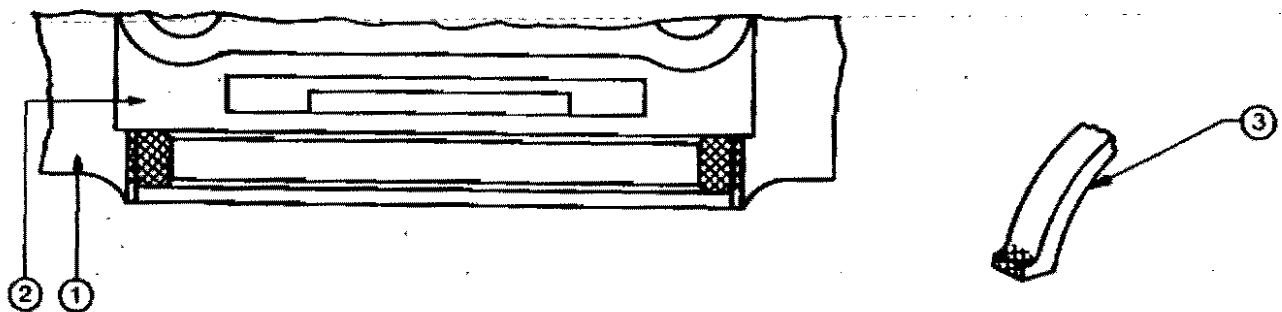
1. Withdraw the handle from the tool body until the mandrel is clear of the chamber.
2. Locate the insert in the chamber with tang towards the nozzle.
3. Push the handle into the tool body to engage the slot in the mandrel with the tang.
4. Rotate the handle clockwise and gently push the handle into the body until the insert engages with the nozzle. Continue winding until the first coil of the insert is nearly through the nozzle.
5. Locate the tool squarely over the drain plug hole and wind the insert out of the nozzle into the sump, without applying any end pressure, until the insert is 0.25 to 1.02 mm. (0.010 to 0.040 in.) below the boss face.
6. Break the tang off by gripping with a pair of long nosed pliers and using push-pull movement.

On six cylinder engines the sump is located by two hollow dowel pins pressed into the cylinder block sump face to ensure accurate alignment of the flywheel housing faces on the cylinder block and sump.

When fitting a new sump to one of these engines, the dowel holes in the sump flange will have to be reamed after assembling the sump to the cylinder block. Remove the dowels and fit the new sump so that the sump flywheel housing face is flush to 0.152 mm. (0.006 in.) below the cylinder block rear face. Tighten the bolts in pairs starting at the rear. Using the dowel holes in the cylinder block as guides, ream the sump flange dowel holes to 9.531 mm (3/8 in.) diameter. Ream from the cylinder block side only to ensure accurate alignment. Fit the dowel pins to the cylinder block, it is not necessary to remove the sump as they should be fitted from the top and then driven through into the sump. Do not fit the dowels to the sump first as they will damage the reamed hole in the aluminium.

The sump gaskets are a rubber asbestos composition and a sealing compound is applied to each end during manufacture, no other sealing compound being necessary in service. Synthetic rubber seals are fitted around the front and rear main bearing caps to complete the sump sealing. The ends of the sump gaskets being located over the ends of the rear seal and under the front seal. When fitting the oil pan rear seal apply a thin coating of Sealer EM-4G-58 or equivalent on the ends of the seal and seal ends locations of the block (Fig. 26) ensure the ends of this seal are fitted correctly.

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Apply sealer Hermetite Autogel No. 2 to Cylinder Block and Oil Pan Seal Ends where shown thus.

Fitting Oil Pan Rear Seal

- Cylinder Block
- Bearing Cap
- Oil Pan Seal

Fig. 26

# TO DISMANTLE THE ENGINE

(Normally Aspirated and Turbo charged)

1. Remove the starter motor, fan, water pump, belt/s, alternator/generator, manifolds, clutch and clutch housing (where fitted). Fit the engine mounting Tool No. CT.6138 to the left hand side of the cylinder block. Fit the lifting tackle to the lifting eyes, take up the engine weight and mount the engine to the universal stand.
2. Remove other engine ancillaries. Disconnect and remove the injector pipes, remove the injection pump, exhauster/compressor fuel filter, fuel lift pump, thermostat housing, thermostat. Fit the appropriate plugs and caps to the fuel injection equipment. Drain the engine oil and remove the engine oil filter.
3. Remove the rocker cover and then withdraw the injectors.
4. Remove the rocker shaft assembly. Tie cord around the end supports to prevent the rockers becoming disassembled during removal.
5. Dismantle the rocker shaft assembly. Release the cord and remove the supports, rockers and springs in sequence to facilitate reassembly. Unscrew two bolts locating the rocker shaft to remove remaining components.
6. Extract the push rods, keeping them in their correct order.
7. Remove the cylinder head. Unscrew the cylinder head bolts evenly. Lift off the cylinder head and gasket.

NOTE:—The cylinder head must not be laid on its face if the injectors are still fitted or the nozzle will become damaged.

8. Dismantle the cylinder head as follows:—
  - (a) Remove the valve stem and rotator caps, keeping them in order.
  - (b) Compress the valve springs, using valve spring compressor Tool No. 6118A and adaptor Tool No. CT.6118-3, and extract the split collets.
  - (c) Release the valve spring compressor and remove the spring retainer, valve spring, oil seal and spring seat.
  - (d) After removing all valve springs turn the cylinder head onto its side and remove all the valves keeping them in their correct order.
9. Invert the engine and remove the sump.

10. Remove the oil pump. Disconnect the suction pipe bracket, unscrew two bolts and withdraw the oil pump.
11. Withdraw the piston and connecting rod assemblies. Unscrew the big end self-locking nuts or bolts a few turns and tap them to release the connecting rods from the caps. Then completely remove the bolts and detach the big end caps. Push the pistons out of the cylinder bores and withdraw the assemblies. It may be necessary to carefully scrape the carbon formation away from the cylinder bore top land to facilitate removal. Replace big end caps on to the connecting rods the correct way round and replace the nuts or bolts.
12. Dismantle the piston and connecting rod assemblies. First remove the piston rings and then extract the piston pin circlips. Push the piston pins out of each piston, if necessary, warm the pistons first to facilitate removal.
13. Remove the crankshaft pulley by unscrewing the centre bolt.
14. Remove the timing gear housing front cover.

## TO DISMANTLE THE ENGINE (continued)

15. Remove the camshaft gear. Unscrew the centre bolt holding the gear with holding wrench, Tool No. CT.6124 and then remove the camshaft gear. If necessary, gear puller Tool No. C.9081 can be used to remove the gear.
16. Extract the camshaft key and remove the front thrust washer.
17. Remove the camshaft thrust plate. Unscrew the three bolts and remove the plate.
18. Remove the timing gear housing. Unscrew the bolts, including the two socket head bolts into the front main bearing cap. The timing scale is also retained by the two lower bolts on the left-hand side.
19. Remove the flywheel. Bend back the locking tabs and unscrew the six bolts. Screw two 3/8 in – 16 U.N.C. bolts into the two tapped holes and jack the flywheel off the crankshaft flange by tightening these bolts evenly.
20. Remove the crankshaft complete with gear. Unscrew the main bearing bolts and remove each bearing cap in turn. Remove the thrust washers located on either side of the centre main bearing. Lift the crankshaft out.
21. Withdraw the camshaft, taking care not to damage the bearings with the cam lobes. Remove the spacer, thrust washer and collar from the front of the camshaft.
22. Extract the tappets, keeping them in order for replacement in the same positions.

## Turbo-Plus

The following additional operations will be necessary when dismantling the Turbo-Plus engines.

1. Remove the intercooler, brackets, dipstick and tube, manifolds, oil cooler pump and pipes.
2. Unscrew the oil inlet adaptor from sump bulkhead and withdraw the oil rail connecting tube. (Fig. 27).

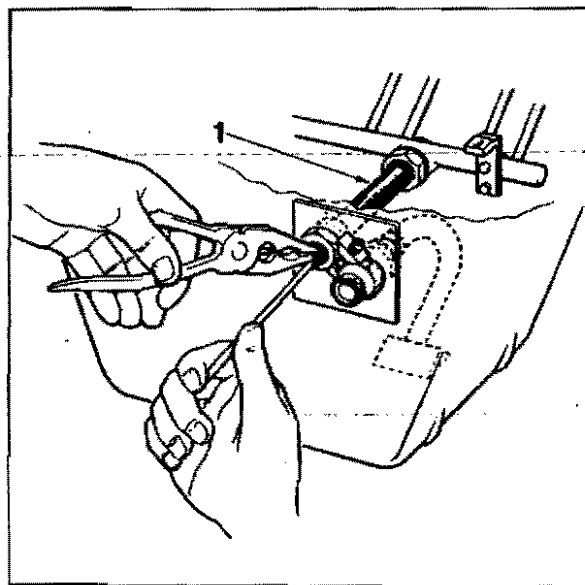


Fig. 27 Removal of Connection Tube

1 Connection Tube

## TO DISMANTLE THE ENGINE (continued)

3. Remove sump, disconnect suction pipe, unscrew the 'U' bolt nuts also the oil pipe securing nuts and remove the oil rail. (Fig. 28).
4. To inspect the oil pressure relief valve, remove the end split pin and withdraw the relief valve seat, spring and plunger. (Fig. 28).

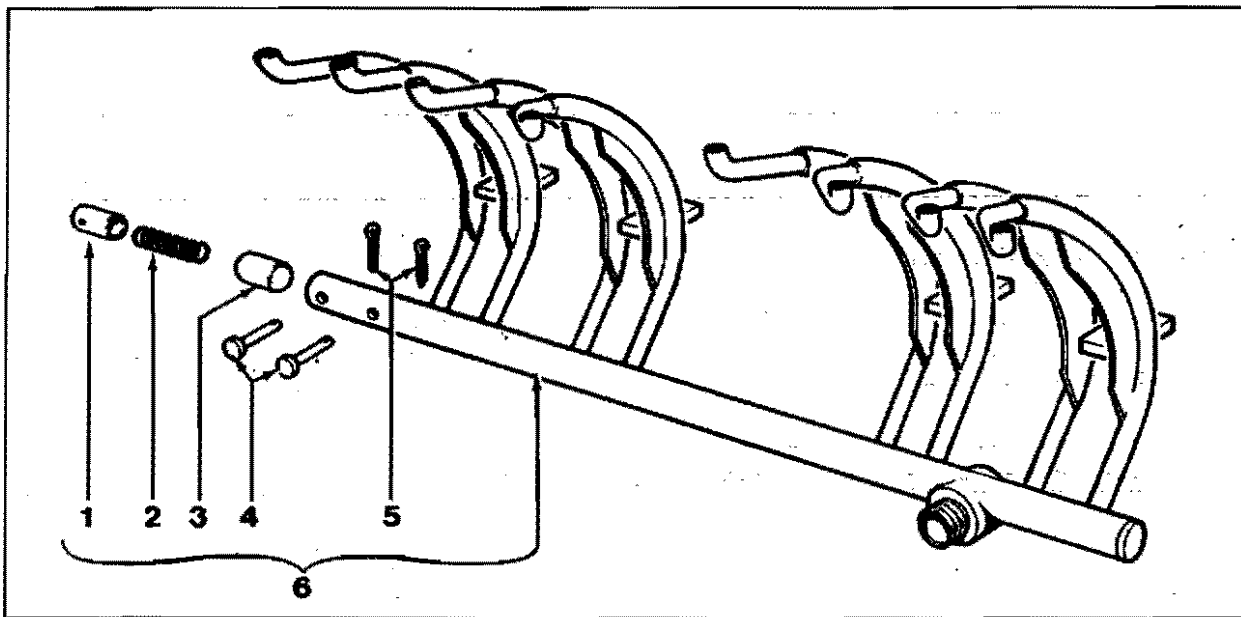


Fig. 28 Piston Oil Cooling Rail

1 Spring Collar

2 Spring

3 Plunger

4 Clevis Pins

5 Split Pins

6 Piston Cooling Rail Assy.

## To Reassemble the Oil Cooling Rail Assembly

1. Ensure the interior and exterior of the oil cooling rail is thoroughly clean before reassembling the relief valve.
2. Before refitting the oil cooling rail ensure all pistons are fully within liners, slide the oil cooling rail into position, fix firmly into position on studs, fit washers and nuts tightening nuts to a torque of 20.3 to 23 Nm (2.07 to 2.35 kgfm or 15 to 17 lbfft). Fit 'U' bolts, torque nuts to 20.3 to 23 Nm (2.07 to 2.35 kgfm or 15 to 17 lbfft).
3. Rotate engine to ensure clearance of pistons in all positions, adjust if necessary.
4. If gland oil seals are being replaced, it is important that the seal lip is towards the threaded end of the gland nut.
5. Fit the bonded seal to the rail connection, smear connection thread with "Loctite" assemble gland nut to rail and tighten.
6. To renew lip seal at the sump bulkhead, unscrew the locknut and withdraw the union connection fit lip seal toward the threaded end of the connection, fit bonded seal to the union connection, smear thread with 'Loctite', fit union connection to sump bulkhead, fit locknut and partly tighten.
7. Assemble suction pipe to bulkhead connection, tighten nut, ensuring that the oil pick-up pipe is at 90° to the sump face.



## TO DISMANTLE THE ENGINE (continued)

8. Fit the gland nut locking blocks and screw, position the gland nuts to accept the locking blocks and tighten the screw. Tighten the gland locking nuts. Finally adjust the position of the oil pick up pipe. (Fig. 27).
9. Refit sump as described in Engine Reassembly.
10. Insert a thin tube through the inlet connection to the oil rail pipe to act as guide, then fit the connecting pipe to the oil rail, ensuring the pipe is seated between each lip seal. (See fig. 27)
11. Fit new bonded seal to the inlet connection, fit adaptor connection

## TO REASSEMBLE THE ENGINE

Before reassembling the engine, the cylinder block and all components should be thoroughly cleaned, paying particular attention 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 as the bolt may bottom on the resulting plug before the bolt head pressurises the mating part.

The currently produced 2710 range of engines are being fitted with stainless steel core plugs. These new core plugs, which are already standard equipment on the 2704ET range of engines, offer greater protection against corrosion and subsequent coolant leakage than the previously fitted mild steel core plugs.

Two different sizes are fitted to all production engines and oversize versions of each are available.

The new type of stainless steel core plugs should be fitted to an engine as and when required. Should a hole become deformed, it can be enlarged to take an oversize plug. The cylinder block hole sizes are:—

	Standard	Oversize
Small Holes	1,624 to 1,627 in. dia. (41,250 to 41,326 mm. dia.)	1,639 to 1,642 in. dia. (41,631 to 41,707 mm. dia.)
Large Holes	2,190 to 2,193 in. dia. (55,626 to 55,702 mm. dia.)	2,210 to 2,213 in. dia. (56,134 to 56,210 mm. dia.)

Note: The cylinder head contains one small plug only to fit the small size hole specified above.

## Parts Required

Description	Part No.	Finis Code	Total Quantity	
			4 cyl.	6 cyl.
S/Steel core plug (small) Standard Oversize	130029-ES	1448568	2	4
	E.457013-S	6048529		
S/Steel core plug (large) Standard Oversize	E.457012-S	6048528	3	3
	E.457011-S	6048527		

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

If necessary, recondition the engine by overhauling the cylinder head, fitting new valve guides and/or valve seat inserts where required, rebore the cylinders or fit new liners, fit new camshaft bushes and grind the crankshaft undersize as described in the section on "Engine Components".

Service cylinder blocks are now available for 2701E (3,964 cc.; 242 cu. in.) and 2704E (5,950 cc.; 363 cu. in.) engines, which are manufactured for use without liners, and which are completely interchangeable with the lined assemblies.

When rebuilding either of the subject engines (i.e. those originally built prior to November 1969), the pistons as specified for these engines, together with the cylinder head gasket, must be used. Do NOT use pistons and cylinder heads from engines with parent bore built after this date. Reboring of the service blocks may be carried out to suit the currently available pistons.

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## TO REASSEMBLE THE ENGINE (continued)

### PARTS REQUIRED:

Part No.	Description	Finis Code	Usage
683F-6010-AAB	Cyl. block assy.	1460397	2701E
703F-6010-BA	Cyl. block assy.	1447611	2704E
2701E-6102-C	Kit, piston pin/ring, STD	1436363	
2701E-6102-D	Kit, piston pin/ring, o/s (0.635 mm.; 0.025 in.)	1436364	
683F-6051-AAA	Cyl. head gasket	1447269	2701E
683F-6051-HA	Cyl. head gasket	1444136	2704E

Check all oilways and galleries to ensure that they are clear. When replacing the taper plugs, ensure that they are thoroughly clean and apply a thin line of EM-4G-52 plastic sealer to the screw threads to prevent any possibility of oil leaks or loosening in service.

In the following reassembly sequence it is assumed that all normal instructions regarding cleanliness and lubrication are observed and that all gaskets, oil seals and lockwashers and plates are renewed.

1. Fit the tappets. If still serviceable, insert the tappets into the bores from which they were removed.
2. Slide the camshaft into position after locating the collar, thrust washer, with the grooved face outwards, and spacer on the camshaft end. Ensure that all tappets are clear and take care not to damage the bearings or the edges of the cams and journals. Rotate the camshaft to ensure that it revolves freely in its bearings after fitting. Where it is necessary to renew the camshaft on 2711E/2712E engines incorporating the use of H.D. PTO, use only the latest type (Part No. 693F-6250-AAB). This camshaft can be identified by its part number which is located between the first and second cam lobes.
3. Fit a new crankshaft rear oil seal after extracting the old seal. Coat the seal groove in the bearing cap with aircraft type sealer – High Speed Hermetite or equivalent immediately before fitting seal, using replacer Tool No. C.6134 trim ends of the seal so that they protrude 0.25 to 0.38 mm. (0.010 to 0.015 in.) above the joint face of the cap, support the seal with the replacer tool while trimming the ends, ensuring that there are no frayed threads after trimming (see Fig. 16). Apply Sealer CASCO MLF/15 or equivalent to mating surface of rear main bearing cap from outer edge of “rope” seal diagonally outwards to the undercut groove (see Fig. 17). Apply non-setting Sealer HERMETITE AUTOGEL No. 2 or equivalent across the abutment ends of the “rope” seal and outwards along the rear edge of the bearing face and replace the cap.
4. Clean and fit the main bearing liners to their appropriate cylinder block and cap locations. Wipe the liner locations clean and fit the liners so that the locating tongues engage in the locating grooves. The liners with oil holes fit in the cylinder block and those without in the caps.
5. Install the crankshaft in the cylinder block after lubricating the main bearing liners. Locate the crankshaft thrust washers on either side of the centre main bearing with the oil grooves facing the crankshaft flange. Fit the main bearing caps in their correct positions in accordance with the mating marks and the REAR mark at the back. Lubricate the threads on the main bearing bolts and insert into the caps. Lever the crankshaft backwards and forwards to centralise the centre main bearing cap and then tighten the bolts evenly to 156 to 163 Nm (15.89 to 16.58 kgf m or 115 to 120 lbf ft) torque. Check the crankshaft rotation after tightening each cap.

## TO REASSEMBLE THE ENGINE (continued)

## CRANKSHAFT BEARING CAP BOLTS — TURBO-PLUS ENGINES ONLY

THE CAP BOLTS SHOULD BE TIGHTENED TO THE CORRECT TORQUE, UNSCREWED A QUARTER OF A TURN THEN RETIGHTENED TO THE CORRECT TORQUE.

6. Check the crankshaft end-float. Move the crankshaft forwards to take up the end-float in one direction and insert feeler blades between the crankshaft and the front thrust washer, to check that the end-float is between 0.051 to 0.254 mm. (0.002 and 0.010 in.). If necessary, fit oversize thrust washers to rectify excessive end-float (see Fig. 15).
7. Refit the flywheel. Ensure that the mounting face and crankshaft flange are clean and free from burrs. Locate the flywheel squarely upon the dowel and flange and press it into place. Do not hammer the flywheel into place. Fit the retaining bolts and locking plates, with one plate covering the dowel. Tighten the bolts evenly to 108 to 122 Nm (11.06 to 12.43 kgf m or 80 to 90 lbf ft).
8. Check the flywheel run-out at a radius of 13.97 cm. (5½ in), using a gauge, Tool No. P.4008, this should not exceed 0.178 mm. (0.007 in.) total indicator reading.

If the flywheel run-out is within limits, bend up the locking plate tabs to secure the retaining bolts. If incorrect remove the flywheel and re-check the mounting face and crankshaft flange.

9. Fit the timing gear housing and camshaft thrust plate. Do not forget to locate the timing scale on the two lower left-hand bolts. Tighten the bolts to 34 to 40.7 Nm (3.46 to 4.15 kgf m or 25 to 30 lbf ft) torque in the sequence shown in Fig. 20.
10. Locate the remaining thrust washer on the camshaft and fit the key. Ensure that the grooved face of the thrust washer is adjacent to the thrust plate.
11. Fit the camshaft gear. Align the camshaft and crankshaft gear timing marks (see Fig. 14) and press the camshaft gear home. Do not hammer the gear into place. Retain the gear with the centre bolt.  
(If the gear was originally retained by a bolt, plain and internally toothed lockwasher these MUST be replaced by the latest level bolt.) Tighten the bolt to a torque of 203 to 210 Nm (20.74 to 21.43kgf m or 150 to 155 lbf ft) holding the gear with wrench Tool No. CT.6124 (See Fig. 14).
12. Check the camshaft end-float using a gauge, Tool No. P.4008, by pulling and pushing the camshaft and gear in and out. End-float should be 0.051 to 0.533 mm. (0.002 to 0.021 in.) and if incorrect, rectify by fitting new thrust washers and/or thrust plate.
13. Before replacing the front cover on the 2710 and 2704ET engine ranges, check the area around the oil seal for hairline cracks, as these could be the source of oil leaks. If cracks are present, replace the cover as any attempt to repair the cover (i.e. welding) could almost certainly cause distortion, with subsequent oil leaks.

Fit the timing gear housing front cover. Remove and replace the oil seal using remover/replacer Tool No. C.6132. Ensure that the seal is fitted with the lip towards the inside of the cover. Fit the cover on the timing gear housing, centralising the oil seal about the crankshaft by using centraliser Tool No. C.6133 (Fig. 21). Fit the throttle linkage and stop control bracket both in the positions from which they were removed.

14. Fit the crankshaft pulley. Align the keyway with the crankshaft key and push the pulley onto the shaft, screw the centre bolt in to draw the assembly fully home. Tighten the centre bolt to 325 Nm (33.2 kgf m or 240 lbf ft) torque.
15. If the old pistons are being re-used, decarbonize the crowns and ring grooves. If new pistons are required proceed as follows:  
Visually examine the cylinder bores for glazing, scuffing, or metallic deposits. If these are evident, determine the cause and rectify. Measure the diameter 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 93.90 mm. (3.70 in.) below the top face of the cylinder block.
  - c. At 200 mm. (7.90 in.) below the top face of the cylinder block.

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TO REASSEMBLE THE ENGINE (continued)

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.

Measure the piston pin diameter at 90° to the piston pin axis, and at 24.13 mm. (0.95 in.) up from its lower edge (immediately below piston pin bore). 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.

From Engine No. S.877724, 2704ET (180 BHP) Intercooled engines have been fitted with 15.7:1 CR pistons in order to improve combustion characteristics on starting and light load running, and thus reduce the tendency to produce white smoke.

Where it is desired to fit the high compression pistons to engines prior to the above Engine Number, the parts required are:

Part No.	Finis Code	Description
693F-6102-GAC (Grade 3)	1523643	Piston, pin and ring assy.
693F-6102-GBC (Grade 1)	1523644	
693F-6102-GCC (Grade 5)	1523642	

16. Before installing new rings on a piston, check the following. Each ring should be checked in the bore in which it is to be used, to ascertain that the specified ring gap is obtained according to the table. The cylinder bore must be marked accordingly on completion of this operation. To carry out this check, push the piston ring down into the bore to the lower unworn portion of the bore, using the head of the piston to ensure the ring is square with the cylinder wall. Check the gap between the ends of the ring with a feeler gauge, referring to Specifications for the appropriate ring gap.
- Check also for wear in the ring lands by using a new ring and a feeler gauge, and comparing dimensions with the Specifications.

TO REASSEMBLE THE ENGINE (continued)

17. Check the piston ring to groove clearances, which should be as follows:—

	Model Range						
	2701E 3.964 l. 242 C.I.	2703E 5.146 l. 330 C.I.	2704E 5.950 l. 363 C.I.	2701C 2711E 2712E 4.150 l. 254 C.I.	2703C 2713E 5.950 l. 363 C.I.	2704C 2714E 2715E 6.220 l. 380 C.I.	2704ET Turbo & Turbo Plus 5.950 l. 363 C.I.
Upper Compression — 0.058 to 0.096 mm. (0.0023 to 0.0038 in.) 0.063 to 0.102 mm. (0.0025 to 0.0040 in.)	X	X	X	X	X	X	X
Intermediate — 0.043 to 0.081 mm. (0.0017 to 0.0032 in.) 0.069 to 0.107 mm. (0.0027 to 0.0042 in.)	X	X	X	X	X	X	X
Lower — 0.043 to 0.094 mm. (0.0017 to 0.0037 in.) 0.043 to 0.081 mm. (0.0017 to 0.0032 in.) 0.069 to 0.107 mm. (0.0027 to 0.0042 in.)	X	X	X	X	X	X	X
Oil Control — 0.064 to 0.102 mm. (0.0025 to 0.004 in.)	X	X	X	X	X	X	X

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18. Assemble the pistons to the corresponding connecting rods. If necessary, warm the piston, locate the connecting rod small end inside the piston so that the arrow head, notch or oval depression on the piston crown and the FRONT mark on the connecting rod are facing the same way, and then insert the piston pin into the pin bores and connecting rod small end. Fit circlips at each end to retain in position.

NOTE: Pistons with any of the three types of marking stated, are interchangeable.

19. Fit the piston rings in the correct order. Ensure that the intermediate and lower compression rings are fitted the correct way up.

## TO REASSEMBLE THE ENGINE (continued)

20. Clean and fit the connecting rod big end bearing liners to their appropriate connecting rod and cap locations. Wipe the liner locations clean and fit the liners so that the locating tongues engage in the locating grooves.
21. Fit the piston and connecting rod assemblies into the appropriate cylinder bores. Tip the engine on end while completing this operation, as it is necessary to work on the top and bottom of the cylinder block. Space the piston ring gaps at 90° and compress the rings, using a ring squeezer, Tool No. 38U3. Push each piston into its cylinder bore.

**NOTE:** The arrow, notch or oval depression on the crown of each piston must point towards the front of the engine.

Turn the crankshaft as necessary to fit the connecting rod big ends to the crank pins. Fit new locking plates to the connecting rod bolts. Locate the big end caps on the connecting rod dowels, and enter the bolts into the connecting rod. Tap the big end caps right home and tighten the connecting rod bolts to a torque of 115 to 122 Nm (11.76 to 12.45 kgf m or 85 to 90 lbf ft). On engines where self-locking nuts are used, the nuts should be tightened to 74.6 to 81.4 Nm (7.6 to 8.3 kgf m or 55 to 60 lbf ft) torque.

Check the engine rotation after tightening each big end.

Graded connecting rods have been introduced to control the 'Bump' clearance between the piston crown face and cylinder head face to ensure that the piston protrusion above the cylinder block face is within the limits of 0.152 and 0.381 mm. (0.006 to 0.015 in.).

The connecting rods are in four grades, each grade being 0.076 mm. (0.003 in.) longer than the previous grade in nominal centre distance.

The cylinder blocks are stamped with the appropriate bore height grade adjacent to the bore.

For example:

- A – Standard distance dimensions between nominal centres
- B – Plus 0.076 mm. (0.003 in.) distance dimensions between nominal centres
- C – Plus 0.152 mm. (0.006 in.) distance dimensions between nominal centres
- D – Plus 0.229 mm. (0.009 in.) distance dimensions between nominal centres.

### Service Action

When overhaul work is being carried out on an engine, it is important to check that the correct connecting rod(s) is fitted to obtain the protrusion of the piston above the cylinder block face.

Fit the piston and connecting rod assembly to the crankshaft and rotate the crankshaft until the piston is at T.D.C. Measure the protrusion of the piston by placing a straight edge across the piston crown and with a feeler gauge check the distance between the cylinder block face and straight edge.

## TO REASSEMBLE THE ENGINE (continued)

## Connecting Rod Grade:

Part No.	Grade	Finis Code	Description	
733F-6200-AAA	A	6007061	Connecting rod-std	} 2711/12E 2714/15E
733F-6200-ABA	B	6007062	Connecting rod-0.076 mm. (0.003 in.)	
733F-6200-ACA	C	6007063	Connecting rod-0.152 mm. (0.006 in.)	
733F-6200-ADC	D	6007064	Connecting rod-0.229 mm. (0.009 in.)	
733F-6200-BAA	A	1542947	Connecting rod-std	} 2713E
733F-6200-BBA	B	1542948	Connecting rod-0.076 mm. (0.003 in.)	
733F-6200-BCA	C	1542949	Connecting rod-0.152 mm. (0.006 in.)	
733F-6200-BDA	D	1542950	Connecting rod-0.229 mm. (0.009 in.)	
733F-6200-GAA	A	1542955	Connecting rod-std	} 2704ET
733F-6200-GBA	B	1542956	Connecting rod-0.076 mm. (0.003 in.)	
733F-6200-GCA	C	1542957	Connecting rod-0.152 mm. (0.006 in.)	
733F-6200-GDA	D	1542958	Connecting rod-0.229 mm. (0.009 in.)	

22. Fit the oil pump. Check that the pump turns freely before inserting it into the cylinder block. Tighten the two bolts and secure the suction pipe to the appropriate main bearing cap. Tighten and lock the suction pipe union if it has been disturbed.
23. Refit the sump. Locate the rear oil seal in the groove in the rear main bearing cap, ensure that the area under the seal feet is completely free of sealing compound. Locate the sump gasket in position and apply a suitable sealing compound in the space left the front ends of the gaskets in the front oil seal groove around the front main bearing cap. Fit the front oil seal in this groove, taking care not to trap the timing gear housing gasket.
24. Decarbonise the cylinder head. Remove all the carbon from the cylinder head face, valves and ports. Re-cut the valve seats and grind the valves if necessary and then lightly lap in to produce a continuous narrow seating. Excessive lapping will result in a seating which is too wide and pocketed valves.

The later type cylinder head bolts with integral washers cannot be used on turbocharged engines produced before May 1st 1976 without modification to the cylinder head. However, the necessary modification can be carried out during routine servicing of the cylinder head as follows:

'Spot face' each cylinder head bolt boss to remove any marks left by the previous cylinder head bolts using special tool No. B.A.20. The construction of this tool is such that it is only possible to remove a maximum of 0.25 mm. (0.010 in.) from the boss. A minimum tool cutting speed of 1400 rpm is essential.

Clean out each cylinder head bolt tapped hole in the cylinder block with compressed air, then re-tap it using a ½ in. U.N.C. 3A plug tap. Ensure that each hole has full thread depth of 25 mm. (1.0 in.) measured from the block face, by screwing in a new cylinder head bolt by hand. Clean each hole again using compressed air.

Discard the original cylinder head bolts and use the later type, smearing the threads and underside of the integral washer with clean engine oil when fitting.

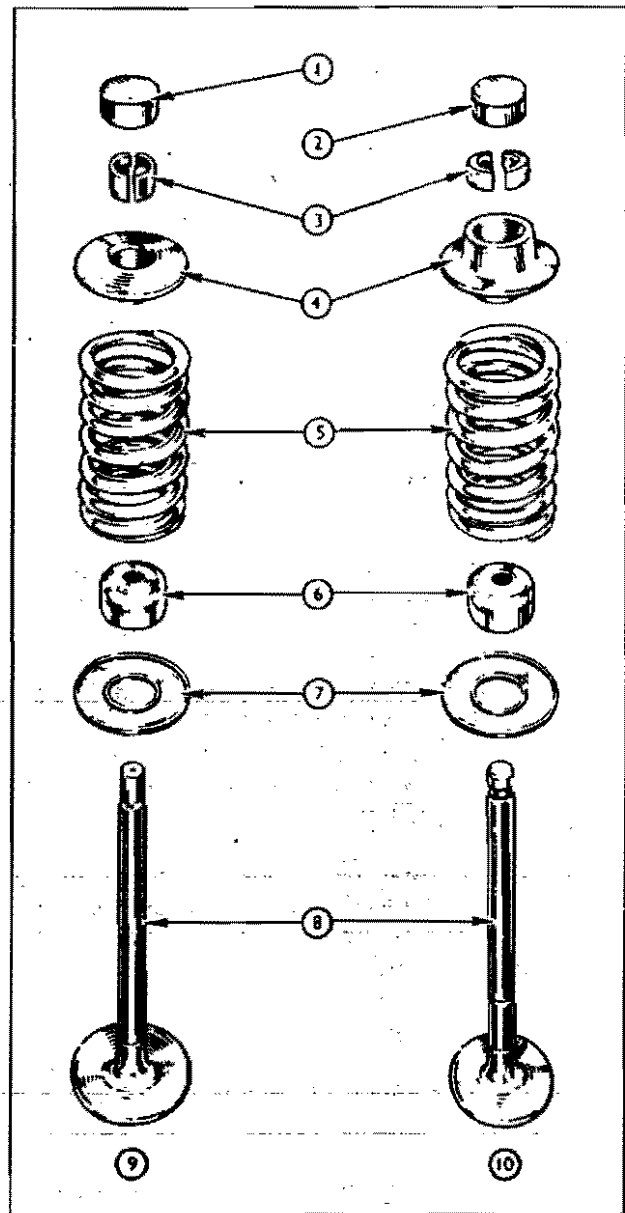
## Parts Required

Description	Part No.	Finis Code	Quantity
Cylinder Head Bolt	763F-6065-GAA	6049281	25 per engine
Spot Face Tool No. BA 20			

TO REASSEMBLE THE ENGINE (continued)

Fig. 29 Inlet and Exhaust Valves

- 1 Valve Stem Cap
- 2 Rotator Cap
- 3 Split Collets
- 4 Spring Retainer
- 5 Valve Spring
- 6 Oil Seal
- 7 Spring Seat
- 8 Valve
- 9 Inlet Valve
- 10 Exhaust Valve



25. Reassemble the valves and springs as follows:—

- a. Lubricate each valve stem, insert it into the appropriate valve guide and position the head against the seat. Fit the valve spring seats around the valve guides and the umbrella type oil seals to the valve stems with the open ends to the head (See Fig. 29).
- b. Turn the cylinder head onto its face and place the valve springs and retainers over the valve stems and oil seals locating the springs in the spring seats (See Fig. 30).



## TO REASSEMBLE THE ENGINE (continued)

- c. Compress the valve springs using valve spring compressor Tool No. 6118 and adaptor screw Tool No. CT.6118-3, located in a rocker support bolt hole. Place the split collets in the valve stem collet grooves and engage the collet and spring retainers by slowly releasing the valve spring compressor.
- d. Assemble the rotator caps to the exhaust valve stems and check the clearance between the end of the valve stem and the inside face of the cap using Tool No. P.4008. Zero the gauge on the cap and then lift the plunger and reverse the cap, ensure that the plunger when released does not locate in machining dimple. The reading obtained will be the clearance, which should be 0.0254 to 0.127 mm. (0.001 to 0.005 in.). If the clearance is incorrect, check the collets for uneven wear and then lap the valve stem or fit a new cap to increase the clearance and lap the base of the cap or fit a new valve to reduce the clearance.
- e. Fit the inlet valve stem caps.

Note: If exhaust valves to the latest level are being fitted, it will not be necessary to fit the rotator caps. It is permissible for one latest level exhaust valve to be fitted in service to an engine without the rotator cap. The valve clearance will be as shown in the Specifications.

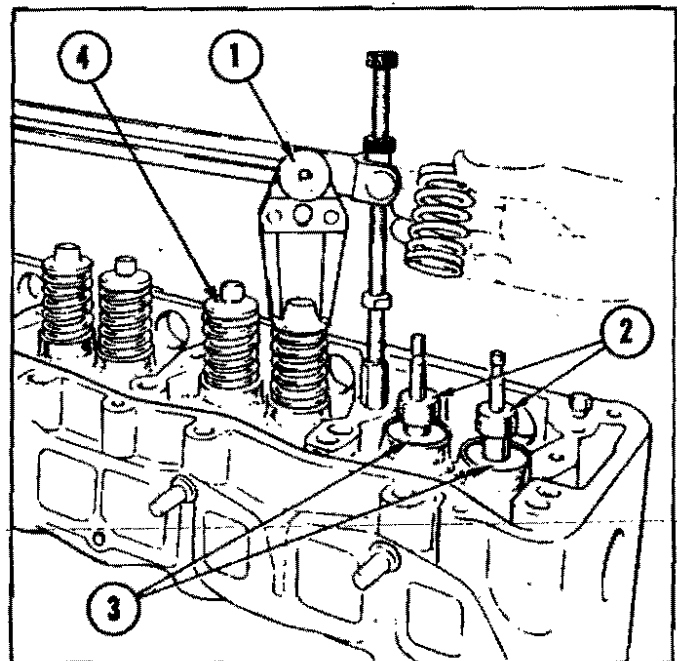


Fig. 30 Valve Replacement

- 1 Valve Spring Compressor Tool
- 2 Oil Seals
- 3 Spring Seats
- 4 Spring Retainer

26. Fit the cylinder head. Locate the cylinder head gasket on the locating dowel and studs, Tool No. C.6135-4 screwed into the four corner cylinder head bolt holes. Fit the cylinder head and install the bolts before removing the two locating studs. Tighten the head bolts down evenly in the sequence shown in Figs. 31 and 32. Finally, tighten the bolts down to the correct torque shown in the 'Specifications' on Page 24. (Note: Turbo Plus engines have two special extension cylinder head bolts for intercooler mounting.)

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## TO REASSEMBLE THE ENGINE (continued)

Commencing with August 1976 production all 2704ET, 2714E, 2715E engines have been fitted with a new cylinder head gasket, which is positively located by thimble dowels adjacent to No.'s 1 and 6 cylinder bores thus improving cylinder bore gas sealing.

With the introduction of the new gasket, some machining has been necessary to both the cylinder block and the cylinder head, in order to incorporate the thimble dowels. When fitting the new gasket to these later engines, the Churchill Cylinder Head Locating Studs will NOT be required. The new gasket can be fitted to earlier engines (when the Churchill Tool will still be required), but it is NOT RECOMMENDED that the thimble dowels be fitted, as this could cause structural weakening of both the cylinder block and cylinder head.

The part number of the new gasket is: 763F-6051-GBB

From 1st May 1976, new cylinder head bolts which incorporate an integral washer have been fitted to all turbocharged engines. When fully tightened the torque loading of these new bolts should be as shown in 'Specifications' on Page 24.

The torque loading of the bolts should be checked at the following intervals:

1. Pre-Delivery Inspection (PDI)
2. After first 15 hours
3. After first 400 hours
4. After every subsequent 400 hours

irrespective of whether it is a new engine installation, or if the cylinder head has been removed for any reason.

DO NOT fit the new type cylinder head bolts to engines other than those to which they were fitted as original equipment unless the cylinder head has been modified as detailed in paragraph 24 on Page 17.

Earlier type bolts must not be mixed with the new type bolts.

Where conditions of "bowing" or "warping" are encountered, the cylinder head and/or cylinder block must be replaced.

Machining (skimming) of the cylinder head and/or cylinder block faces is NOT RECOMMENDED as it can result in 'fouling' between valves and pistons.

Current Production cylinder head assemblies fitted to 2710E engines are now fitted with the turbo-charged engine valve inserts.

If it is desired to fit the valve inserts to earlier engines, the parts required are:

Part No.	Finis Code	Description
743F-6050-AAA	6008539	Head (cylinder) assy.
743F-6050-BAB	6008540	Head (cylinder) assy.
2704E-6057-A	1430247	Insert (valve seat) inlet—std.
2704E-6057-B	1430248	Insert (valve seat) inlet—0.254 mm. (0.010 in.) o/s o/dia.
2704E-6057-C	1430249	Insert (valve seat) exhaust std.
2704E-6057-D	1430250	Insert (valve seat) exhaust 0.254 mm. (0.010 in.) o/s o/dia.
353000-S	3416689	Plug—cylinder head—rear

TO REASSEMBLE THE ENGINE (continued)

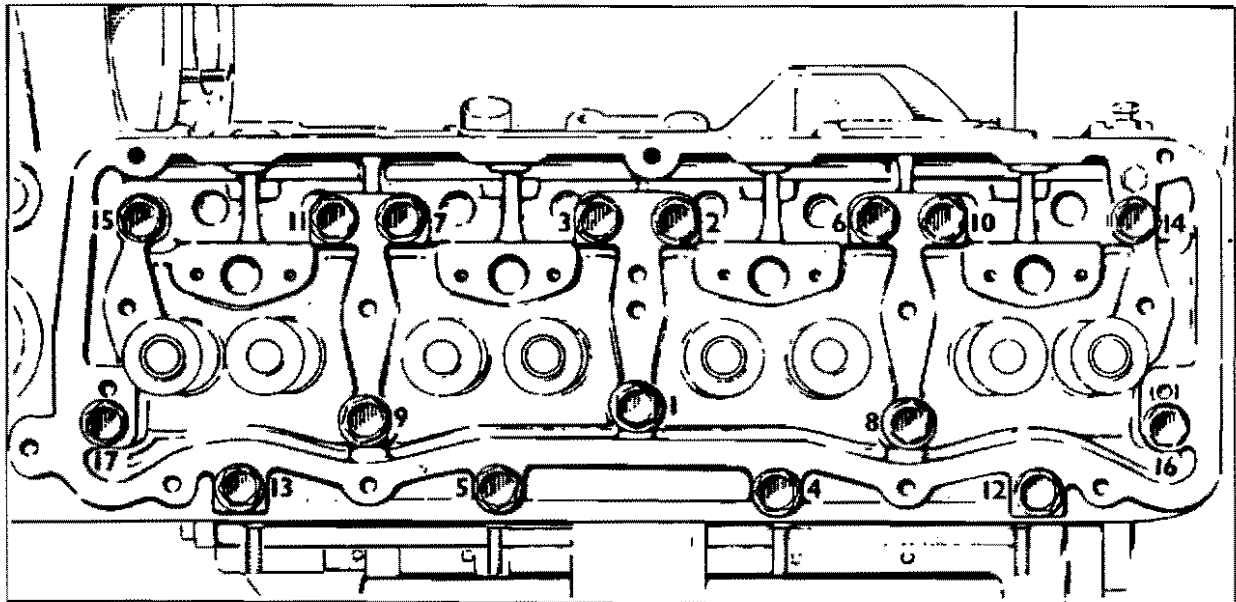


Fig. 31 Cylinder Head Bolt Tightening Sequence (4 cylinder)

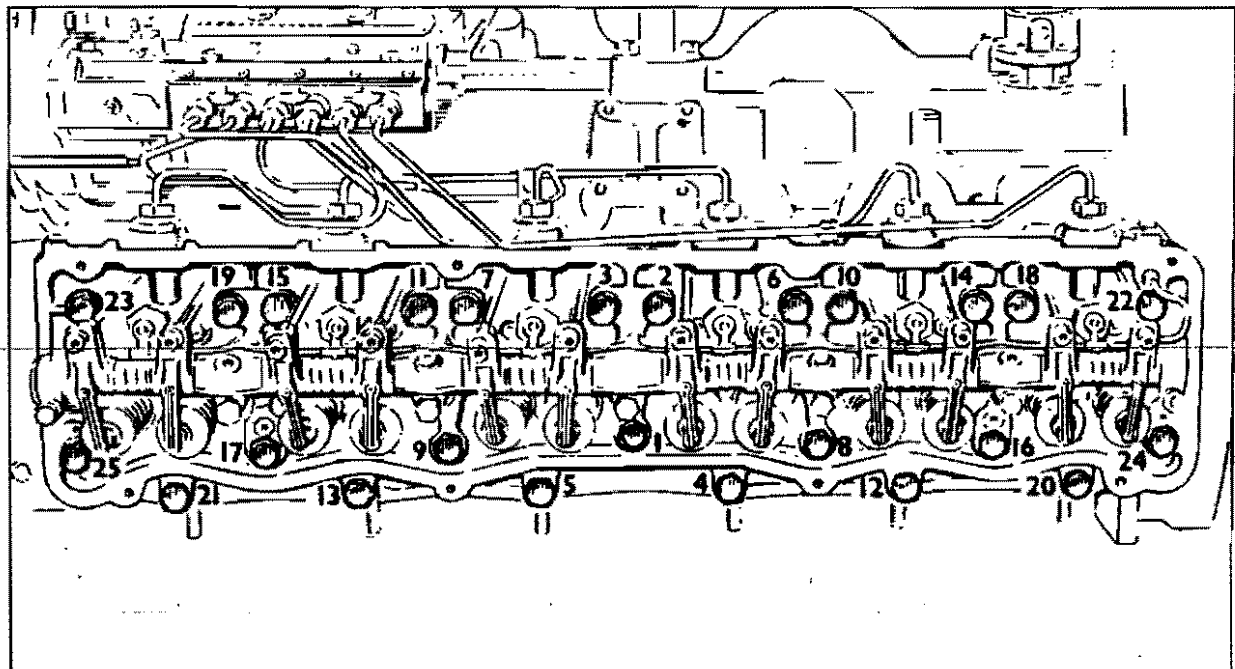


Fig. 32 Cylinder Head Bolt Tightening Sequence (6 cylinder)

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## TO REASSEMBLE THE ENGINE (continued)

27. Insert the push rods, ball end first, into their respective bores where they will automatically engage with the tappets.
28. Reassemble the rocker shaft. Note that the rocker arms are "handed" and if the original parts are being refitted they should be assembled in the locations from which they were originally removed.

### Four cylinder

Assemble the centre support first, followed by the rockers and springs for No. two and three cylinders. Fit the intermediate supports on either side of these and return by screwing the locating bolts into the rocker shaft. Assemble the remaining rockers and supports to each end and retain in position with a cord tied between the end supports.

### Six cylinder

The six cylinder rocker shaft is in two parts, assemble an intermediate support first and retain in position by screwing a locating bolt into the rocker shaft. Locate the rockers and supports in position on each shaft and insert the inner end of each shaft into the centre support. Tie a cord between the end supports to retain the assembly.

29. Fit the rocker shaft assembly to the cylinder head, ensuring that the cupped ends of the push rods correctly engage with the adjusting screws. Tighten the rocker shaft retaining bolts, which are fitted with spring washers, evenly to a torque of 23 to 30 Nm (2.49 to 3.04 kgf m or 17 to 22 lbf ft).
30. Adjust the valve clearances (Fig. 33). The clearances must be set initially to give a gap of:—

	Normally Aspirated	Turbocharged
Inlet	0.406 mm (0.016 in)	0.483 mm (0.019 in)
Exhaust (with rotator cap)	0.305 mm (0.012 in)	
Exhaust (without rotator cap)	0.305 mm (0.012 in)	0.483 mm (0.019 in)

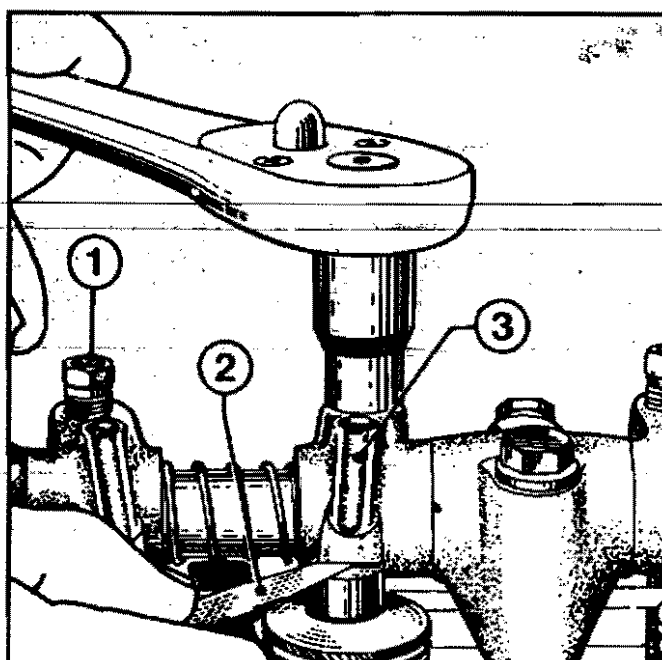


Fig. 33 Valve Clearance Adjustment

- 1 Adjusting Screw
- 2 Feeler Blade
- 3 Rocker Arm

**TO REASSEMBLE THE ENGINE (continued)**

Turn the crankshaft until the valves given in the first column are fully open, when the valves shown in the second column may be checked and adjusted as required:

**Four cylinder—**

Valves Open	Valves to Adjust
1 and 6	3 In. and 8 Ex.
2 and 4	5 Ex. and 7 In.
3 and 8	4 Ex. and 6 In.
5 and 7	2 In. and 4 Ex.

**Six cylinder—**

1 and 4	9 In. and 12 Ex.
8 and 10	3 Ex. and 5 In.
2 and 6	7 In. and 11 Ex.
9 and 12	1 Ex. and 4 In.
3 and 5	8 In. and 10 Ex.
7 and 11	2 Ex. and 6 in.

To adjust a valve clearance, insert a feeler blade between the rocker pad and the valve end. Turn the adjusting screw with a ring spanner or socket until the correct clearance has been obtained.

**NOTE.**—The clearance should again be checked and readjusted if necessary, when the engine is at its normal operating temperature (see General Specifications).

31. Refit the engine ancillaries. Fit the left-hand front engine mounting bracket, thermostat, thermostat housing, water pump, fan, fuel lift pump, oil filter (ensure that the tab in the gasket is away from the canister), exhauster/compressor and fuel injection pump. For Static Spill Timing refer to the appropriate Fuel System section and also to the plate attached to the fuel injection pump. Do not tighten the injectors until the injector pipes have been connected.
32. Fit the rocker cover.
33. Remove the engine from the universal stand, using the appropriate lifting eyes and tackle.
34. Refit remaining engine ancillaries. Fit the alternator or generator, water pump belt, starter motor, manifolds, clutch and clutch housing. Adjust the belt tension to give a total free movement of 13mm (0.5 in) measured in the centre of the largest span between pulleys.

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## SPECIFICATIONS

### 2700 RANGE ENGINES

Engine Model No.	2701E	2703E	2704E
Type	Vertical 4-cyl. Diesel	Vertical 6-cyl. Diesel	Vertical 6-cyl. Diesel
Overhead Valve, Direct Injection			
Bore	105 mm. (4.125 in.)	100 mm. (3.937 in.)	105 mm. (4.125 in.)
Stroke	115 mm. (4.524 in.)	115 mm. (4.524 in.)	115 mm. (4.524 in.)
Capacity	3.964 l. (241 cu.in.)	5.146 l. (330.5 cu.in.)	5.945 l. (362.8 cu.in.)
Industrial Speed Range	1250 – 2500 r.p.m.		
Continuous P.S. Maximum	DIN 6270 –		
	Cont. 'A' 63 at 2500 r.p.m.	85.5 at 2500 r.p.m.	96.5 at 2500 r.p.m.
	Cont. 'B' 70 at 2500 r.p.m.	98.5 at 2500 r.p.m.	107.5 at 2500 r.p.m.
Max. B.H.P.	BS 649		
	B.S. Overload 71 at 2500 r.p.m.	99.5 at 2500 r.p.m.	108.5 at 2500 r.p.m.
	B.S. Rating 64 at 2500 r.p.m.	89.5 at 2500 r.p.m.	98 at 2500 r.p.m.
Max. Torque (M. Kg.)	DIN 6270 –		
	Cont. 'A' 21 at 1700 r.p.m.	28.55 at 1700 r.p.m.	31.3 at 1500 r.p.m.
	Cont. 'B' 23.29 at 1700 r.p.m.	31.7 at 1700 r.p.m.	34.8 at 1500 r.p.m.
Max Torque (lb.ft.)	BS 649		
	B.S. Overload 170 at 1700 r.p.m.	229.5 at 1700 r.p.m.	253.5 at 1500 r.p.m.
	B.S. Rating 153 at 1700 r.p.m.	206 at 1700 r.p.m.	228 at 1500 r.p.m.
Compression Ratio	16.5 : 1	16.5 : 1	16.5 : 1
Firing Order	1, 2, 4, 3	1, 5, 3, 6, 2, 4	1, 5, 3, 6, 2, 4

## 2704ET ENGINES

Engine Model No.	2704ET Ind. & Marine	2704 ET Intercooled	2704ET Turbo-Plus
Number of Cyl.	6	6	6
Bore	105 mm. (4.125 in.)	105 mm. (4.125 in.)	105 mm. (4.125 in.)
Stroke	115 mm. (4.524 in.)	115 mm. (4.524 in.)	115 mm. (4.524 in.)
Capacity	5.950 l. (363 cu.in.)	5.950 l. (363 cu.in.)	5.950 l. (363 cu.in.)
Speed Range		1250 – 2500 r.p.m.	
Continuous P.S. Maximum	152 at 2400 r.p.m.	182 at 2450 r.p.m.	
Max. B.H.P.	150 at 2400 r.p.m.	180 at 2450 r.p.m.	250 at 2450 r.p.m.
Max. Torque (M.Kg.)	46.5 at 2000 r.p.m.	57.3 at 1600 r.p.m.	
Max. Torque (lb.ft.)	337 at 2000 r.p.m.	413 at 1600 r.p.m.	540 at 2450 r.p.m.
Compression Ratio	15.7 : 1	14.5 : 1	13.7 : 1 (Racing) 14.7 : 1 (Cruising)
Firing Order		1, 5, 3, 6, 2, 4	

## 2710 RANGE ENGINES

Engine Model No.	2711E	2712E	2713E	2714E	2715E
Type	Vertical Diesel with Overhead Valves and Direct Injection				
No. of Cyls.	4	4	6	6	6
Bore	107 mm. (4.22 in.)	107 mm. (4.22 in.)	105 mm. (4.12 in.)	107 mm. (4.22 in.)	107 mm. (4.22 in.)
Stroke	115 mm. (4.52 in.)	115 mm. (4.52 in.)	115 mm. (4.52 in.)	115 mm. (4.52 in.)	115 mm. (4.52 in.)
Capacity	4.150 l. (254cu.in.)	4.150 l. (254cu.in.)	5.950 l. (363cu.in.)	6.220 l. (380cu.in.)	6.220 l. (380cu.in.)
Industrial Speed Range	1250 – 2500 r.p.m.				
Continuous P.S. Maximum	1250 – 2500 r.p.m.				
Din 6270 – Cont. 'A'	59 at 2500 r.p.m.	66 at 2500 r.p.m.	85.5 at 2500 r.p.m.	93 at 2500 r.p.m.	102.5 at 2500 r.p.m.
– Cont. 'B'	65 at 2500 r.p.m.	74.2 at 2500 r.p.m.	94.5 at 2500 r.p.m.	105 at 2500 r.p.m.	114.5 at 2500 r.p.m.
Max. B.H.P. BS649					
B.S. Overload	71 at 2500 r.p.m.	80 at 2500 r.p.m.	100 at 2500 r.p.m.	108.5 at 2500 r.p.m.	120 at 2500 r.p.m.
B.S. Rating	64 at 2500 r.p.m.	72 at 2500 r.p.m.	90 at 2500 r.p.m.	97.5 at 2500 r.p.m.	108 at 2500 r.p.m.
Max. Torque (M.Kg.)					
Din 6270 – Cont. 'A'	21.5 at 1600 r.p.m.	25 at 1600 r.p.m.	27.9 at 1600 r.p.m.	32 at 1600 r.p.m.	34 at 1600 r.p.m.
– Cont. 'B'	23.7 at 1600 r.p.m.	26.1 at 1600 r.p.m.	30.9 at 1600 r.p.m.	35.5 at 1600 r.p.m.	37.8 at 1600 r.p.m.
Max. Torque B.S. 649 (lbs.ft.)					
B.S. Overload	178 at 1600 r.p.m.	194 at 1600 r.p.m.	230 at 1600 r.p.m.	265 at 1600 r.p.m.	280 at 1600 r.p.m.
B.S. Rating	160 at 1600 r.p.m.	175 at 1600 r.p.m.	207 at 1600 r.p.m.	237 at 1600 r.p.m.	252 at 1600 r.p.m.
Compression Ratio	16.0:1 (Comp Ratio was 15.5:1 for 2701/3/4C Engines)				
Firing Order	1,2,4,3	1,2,4,3	1,5,3,6,2,4	1,5,3,6,2,4	1,5,3,6,2,4

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Note: The 2701C, 2703C and 2704C engines were the forerunners of the 2711E, 2713E and 2714E engines and had a compression ratio of 15.5:1.

## CAMSHAFT – ALL MODELS

Material (Standard)	Special Ford cast iron alloy
(Heavy duty P.T.O.)	Special Ford cast iron alloy
Drive	Gear
Gear Clearance Fit on Spigot	0,025 mm (0,001 in)
Maximum Cam Lift	7,747 mm (0,303 in)
Bearing Type—4 cylinder	Direct in block or steel backed bushes, front copper and remainder white metal
—6 cylinder	Steel backed bushes, front copper lead remainder white metal
No. of Bearings—4 cylinder	4
—6 cylinder	6
Oversize bearing available	0,508 mm (0,020 in) o/s on O.D. std. I.D.
Journal Diameter	54,59 to 54,69 mm (2,1845 to 2,185 in)
Bearing Clearance—	
Front, 6 cylinder	0,038 to 0,063 mm (0,0015 to 0,0025 in)
Rear and Intermediate, 6 cylinder	0,025 to 0,051 mm (0,001 to 0,002 in)
4 cylinder	0,051 to 0,089 mm (0,002 to 0,0035 in)
Backlash—Crankshaft to Camshaft Gears	0,025 to 0,323 mm (0,001 to 0,0127 in)
End-float of Camshaft	0,051 to 0,584 mm (0,002 to 0,023 in)
No. of Teeth on Camshaft Gear	62

## ORIGINAL ENGINE BUILD DATA PLATE – NORMALLY ASPIRATED ENGINES ONLY

This plate is attached to the flywheel housing and will indicate for each particular engine, the nominal dimensions in millimeters of:—

- (a) The diameter of the crankshaft main bearing journals.
- (b) The diameter of the crankshaft main bearing bore in the cylinder block.
- (c) The diameter of the crankshaft crankpin journals.

These plates will be coloured light blue, orange, green or black according to the crankshaft/cylinder block dimensions.

## CONNECTING RODS AND BIG END BEARINGS – ALL MODELS

Type	'H' section steel forgings
Length—Centre to centre (See also pages 16r & 17)	203,149 to 203,251 mm (7,998 to 8,002 in)
Small End Bore (with bush)	34,930 to 34,937 mm (1,3751 to 1,3754 in)
Small End Bush	Steel backed bronze
Big End Bore—5,416 l. (330 cu.in.)	
and 5,950 l. (363 cu.in.) Engines	67,2 to 67,22 mm (2,6460 to 2,6465 in)
— All other engines.	70,88 to 70,89 mm (2,7905 to 2,7910 in)
Big End Bearings	Steel back, aluminium/tin
Undersize of Liner—66,68 mm (2,625 in) diameter	0,254 mm (0,010 in), 0,508 mm (0,020 in),
and 63,50 mm (2,500 in) diameter crankpins	0,762 mm (0,030 in), 1,016 mm (0,040 in)
Undersize of Liner—66,42 mm (2,615 in) diameter	0,508 mm (0,020 in), 0,762 mm (0,030 in),
and 63,25 mm (2,490 in) diameter crankpins	1,016 mm (0,040 in)
Liner Width	33,79 to 34,04 mm (1,33 to 1,34 in)
Liner Thickness (standard)—5,416 l. (330 cu.in.)	1,816 to 1,822 mm (0,0715 to 0,7175 in)
and 5,950 l. (363 cu.in.) engines	
—All other engines.	2,07 to 2,08 mm (0,08150 to 0,08175 in)
Clearance on Crankpin *	0,051 to 0,096 mm (0,002 to 0,0038 in)
End-float on Crankpin	0,076 to 0,229 mm (0,003 to 0,009 in)
Clearance between Small End and Piston Pin	0,0025 to 0,0178 mm (0,0001 to 0,0007 in)



## CRANKSHAFT AND MAIN BEARINGS

Material	Steel forging
Main Journal Diameter—All engines	76,205 to 76,230 mm (3,0002 to 3,0012 in)
some naturally aspirated engines only	75,951 to 75,976 mm (2,9902 to 2,9912 in)
Main Journal Length (front)	32,89 to 33,15 mm (1,295 to 1,305 in)
Main Journal Length (intermediate)	35,43 to 35,69 mm (1,395 to 1,405 in)
Main Journal Length (centre)	45,69 to 45,75 mm (1,799 to 1,801 in)
Main Journal Length (rear)	46,507 to 46,67 mm (1,831 to 1,841 in)
Main Journal and Crankpin Fillet Radii	4,32 to 4,83 mm (0,17 to 0,19 in)
Main Bearings	Steel back, aluminium/tin
Main Bearing Liner Thickness (standard)	2,07 to 2,08 mm (0,08150 to 0,08175 in)
Undersizes—76,200 mm (3,000 in) diameter journals	0,254 mm (0,010 in) 0,508 mm (0,020 in)
Undersizes—75,950 mm (2,990 in) diameter journals	0,762 mm (0,030 in) 1,016 mm (0,040 in)
Main Bearing Clearance	0,508 mm (0,020 in), 0,762 mm (0,030 in), 1,016 mm (0,040 in).
Length of Main Bearing Liners	0,051 to 0,104 mm (0,002 to 0,0041 in)
Front and Intermediate	26,42 to 26,67 mm (1,04 to 1,05 in)
Centre and Rear	35,94 to 36,2 mm (1,415 to 1,425 in)
Thrust Washer Thickness (standard)	2,31 to 2,36 mm (0,091 to 0,093 in)
Oversizes	0,0635 mm (0,0025 in) 0,127 mm (0,005 in)
	0,190 mm (0,0075 in) 0,254 mm (0,010 in)
	0,381 mm (0,015 in) 0,508 mm (0,020 in)
Crankshaft End-float	0,051 to 0,254 mm (0,0020 to 0,010 in)
Wear limit	0,33 mm (0,013 in)
Crankpin Journal Diameter — 5,416 l. (330 cu.in.) & 5,950 l. (363 cu.in.) engines	63,496 to 63,5127 mm (2,4997 to 2,5005 in)
All other engines	66,657 to 66,675 mm (2,6242 to 2,6250 in)
Some naturally aspirated engines only	63,213 to 63,258 mm (2,4887 to 2,4905 in)
	63,492 to 63,513 mm (2,4997 to 2,5005 in)
	66,400 to 66,421 mm (2,6142 to 2,6150 in)
	66,655 to 66,675 mm (2,6242 to 2,6250 in)
Crankpin Journal Length	42,2 to 42,3 mm (1,660 to 1,664 in)
Crankpin Journal Clearance	0,051 to 0,096 mm (0,002 to 0,0038 in)
No. of Teeth on Crankshaft Gear	31

## CYLINDER BLOCK

Type	Monobloc casting integral with top half of crankcase
Material	Ford cast alloy iron
Water Jackets	Full Length
Cylinder Liners	Dry Type
Material	Centrifugally cast iron
Standard Cylinder Bore Diameter	Graded at the grade point 94 mm (3,7 in) from top of the liner.
Grade — 1	99,993 to 100,006 mm (3,9368 to 3,9373 in)
— 2	100,006 to 100,019 mm (3,9373 to 3,9378 in)
— 3	100,019 to 100,031 mm (3,9378 to 3,9383 in)
— 4	100,031 to 100,044 mm (3,9383 to 3,9388 in)
— 1	104,770 to 104,783 mm (4,1248 to 4,1253 in)
— 2	104,783 to 104,795 mm (4,1253 to 4,1258 in)
— 3	104,795 to 104,808 mm (4,1258 to 4,1265 in)
— 4	104,808 to 104,820 mm (4,1263 to 4,1268 in)
Bore for Cylinder Liners	109,091 to 109,599 mm (4,2815 to 4,2835 in)
	5,416 l. (330 cu.in.)
	3,964 l. (240 cu.in.)
	5,945 l. (360 cu.in.) normally aspirated engines only
	Turbocharged engines with cast iron liners
	108,742 to 108,793 mm (4,2812 to 4,2832 in)

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## CYLINDER BLOCK (Cont'd.)

Initial Liner Protrusion	$\left\{ \begin{array}{l} 3.964 \text{ l. (240 C.I.D.)} \\ 5.416 \text{ l. (330 C.I.D.)} \\ 5.945 \text{ l. (360 C.I.D.)} \\ \text{Engines only} \end{array} \right\}$	0.508 to 0.635 mm. (0.020 to 0.025 in.)
Bore for Piston	$\left\{ \begin{array}{l} 5.950 \text{ l. (363 C.I.D.)} \\ \text{Engines Only} \\ \\ 4.150 \text{ l. (254 C.I.D.)} \\ 6.220 \text{ l. (380 C.I.D.)} \\ \text{Engines Only} \end{array} \right\}$	$\left\{ \begin{array}{l} 104.770 \text{ to } 104.775 \text{ mm. (4.1248 to 4.1253 in.)} \\ 104.775 \text{ to } 104.795 \text{ mm. (4.1253 to 4.1258 in.)} \\ 104.795 \text{ to } 104.810 \text{ mm. (4.1258 to 4.1263 in.)} \\ 104.810 \text{ to } 104.820 \text{ mm. (4.1263 to 4.1268 in.)} \\ \\ 107.188 \text{ to } 107.200 \text{ mm. (4.2200 to 4.2205 in.)} \\ 107.200 \text{ to } 107.213 \text{ mm. (4.2205 to 4.2210 in.)} \\ 107.213 \text{ to } 107.226 \text{ mm. (4.2210 to 4.2215 in.)} \\ 107.226 \text{ to } 107.238 \text{ mm. (4.2215 to 4.2220 in.)} \end{array} \right\}$

## CYLINDER HEAD

Type	Cast iron with vertical valves. Separate inlet and exhaust ports
Valve Guides	Standard
Length of Valve Guide	76.2 mm. (3.00 in.)
Valve Guide—Internal Diameter	9.525 to 9.550 mm. (0.3751 to 0.3761 in.)
—Outside Diameter	15.893 to 15.905 mm. (0.6257 to 0.6262 in.)
Valve Guide Protrusions—inlet	18.29 mm. (0.72 in.)
Valve Seat Insert	Standard exhaust only
Valve Seat Insert Recess Diameter (standard)	
—inlet	49.458 to 49.483 mm. (1.947 to 1.948 in.)
—exhaust	43.155 to 43.18 mm. (1.699 to 1.700 in.)
Valve Seat Insert Recess Depth (standard)—inlet	7.395 to 7.523 mm. (0.291 to 0.296 in.)
—exhaust	7.573 to 7.849 mm. (0.298 to 0.309 in.)
Oversize Inserts available—inlet	0.254 mm. (0.010 in.) O/S dia. O/S depth
—exhaust	0.254 mm. (0.010 in.) O/S dia., std. depth
	0.254 mm. (0.010 in.) O/S dia. O/S depth
	0.508 mm. (0.020 in.) O/S dia. O/S depth
Valve Seat Angle	30° to 30° 30'

## FLYWHEEL

Run-out Clutch Face (T.I.R. max.)	0.178 mm. (0.007 in.) at a radius of 13.97 cm. (5½ in.)
No. of Teeth on Ring Gear	128
Flywheel Retention	Dowel and Bolts
Flywheel Ring Gear Retention	Screws

**PISTONS**

<b>Type</b>		Solid skirt with combustion chamber in crown
<b>Material</b>	Normally aspirated also used on earlier Turbocharged engine. Turbocharged Intercooled Turbocharged Marine Turbocharged Ind. Turbo Plus	Aluminium alloy, tin plated
		Aluminium alloy — graphite coated
<b>Number of Rings</b>	All Models	Three compression, one oil control
<b>Width of Ring Grooves</b>		
—Upper Compression	Normally Aspirated Turbocharged (Wedge type ring)	2.43 to 2.46 mm. (0.0958 to 0.0968 in.)
—Intermediate		2.44 to 2.47 mm. (0.0962 to 0.0972 in.)
—Lower compression	Normally Aspirated Turbocharged	2.42 to 2.44 mm. (0.0952 to 0.0962 in.)
—Oil Control		2.44 to 2.47 mm. (0.0962 to 0.0972 in.)
<b>Piston Clearance in Cylinder Bore</b>	All Models	4.80 to 4.83 mm. (0.189 to 0.190 in.)
	5.146 l. (330 C.I.D.) 3.964 l. (240 C.I.D.) 5.945 l. (360 C.I.D.) ENGINES ONLY	0.1727 to 0.1981 mm. (0.0068 to 0.0078 in.)
	4.150 l. (254 C.I.D.) 5.950 l. (363 C.I.D.) 6.220 l. (380 C.I.D.) ENGINES ONLY	0.147 to 0.172 mm. (0.0058 to 0.0068 in.)
<b>Effective Piston Dia.</b>	All Models	Graded at bottom of skirt
Grade -1	5,416 l. (330 C.I.D.) ENGINE ONLY	99.811 to 99.82 mm. (3.9295 to 3.9300 in.)
-2		99.82 to 99.833 mm. (3.9300 to 3.9305 in.)
-3*		99.833 to 99.845 mm. (3.9305 to 3.9310 in.)
-4*		99.845 to 99.858 mm. (3.9310 to 3.9315 in.)
-1	3,964 l. (240 C.I.D.) and 5,945 l. (360 C.I.D.) ENGINES ONLY	104.58 to 104.60 mm. (4.1175 to 4.1180 in.)
-2		104.60 to 104.61 mm. (4.1180 to 4.1185 in.)
-3*		104.61 to 104.62 mm. (4.1185 to 4.1190 in.)
-4*		104.62 to 104.63 mm. (4.1190 to 4.1195 in.)
* (Grades 3 and 4 supplied in Service)		
-1	5,950 l. (363 C.I.D.)	104.7699 to 104.7826 mm. (4.1248 to 4.1253 in.)
-2	ENGINES ONLY	104.7826 to 104.7953 mm. (4.1253 to 4.1258 in.)
-3*		104.7953 to 104.8080 mm. (4.1258 to 4.1263 in.)
-4*		104.8080 to 104.8207 mm. (4.1263 to 4.1268 in.)
-1	4,150 l. (254 C.I.D.)	107.03 to 107.04 mm. (4.2137 to 4.2142 in.)
-2		107.04 to 107.05 mm. (4.2142 to 4.2147 in.)
-3*	6,220 l. (380 C.I.D.)	107.05 to 107.06 mm. (4.2147 to 4.2152 in.)
-4*		107.06 to 107.07 mm. (4.2152 to 4.2157 in.)
* (Grades 3 and 4 supplied in Service)		

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**PISTONS (continued)**

-2	} 5.945 l. (363 C.I.D.) Industrial and Marine Turbocharged Engine With Cast Iron Liners	{ 104.623 to 104.635 mm. (4.1190 to 4.1195 in.) 104.648 to 104.661 mm. (4.1200 to 4.1205 in.)
-4		

(Grades 2 and 4 Supplied in Service)

-1*	} 5.945 l. (363 C.I.D.) Industrial Turbocharged Engines With 'Cromard' Liners	{ 104.58 to 104.60 mm. (4.1175 to 4.1180 in.) 104.60 to 104.61 mm. (4.1180 to 4.1185 in.) 104.61 to 104.62 mm. (4.1185 to 4.1190 in.) 104.62 to 104.63 mm. (4.1190 to 4.1195 in.) 104.63 to 104.64 mm. (4.1195 to 4.1200 in.) 104.64 to 104.65 mm. (4.1200 to 4.1205 in.)
-2		
-3*		
-4		
-5*		
-6		

\* (Grades 1, 3 and 5 Supplied in Service)

**Piston Pin Bore Diameter**

Grade - Red	} All normally Aspirated Engines Marine and Industrial Turbocharged Engine	Graded { 34.919 to 34.922 mm. (1.3747 to 1.3748 in.) 34.922 to 34.925 mm. (1.3748 to 1.3749 in.) 34.925 to 34.928 mm. (1.3749 to 1.3750 in.) 37.098 to 37.101 mm. (1.4372 to 1.4373 in.) 37.101 to 37.104 mm. (1.4373 to 1.4374 in.) 37.104 to 37.107 mm. (1.4374 to 1.4375 in.)
- Yellow		
- Blue		
- Black		
- Green		
- White		

Oversize Pistons	Normally Aspirated Engines	{ 0.381 mm. (0.015 in.) 0.889 mm. (0.035 in.) 1.397 mm. (0.055 in.) 1.016 mm. (0.040 in.) 5416 cc. (330 C.I.D. only.)
	Turbocharged engines With Cast Iron Liners	{ 0.635 mm. (0.025 in.)

**Clearance between  
Block Face and Piston  
Crown at T.D.C.**

Normally aspirated and Turbocharged Eng. Turbo-Plus Engines	{ Piston between 0.152 mm. (0.006 in.) below and 0.406 mm. (0.016 in.) above block face. Piston between 0.102 mm. (0.004 in.) and 0.406 mm. (0.016 in.) above block face.
--	--

**PISTON PIN**

Type Outside Diameter	All Models	{ Fully Floating 34.929 to 34.937 mm. (1.3751 to 1.3754 in.)
Length	{ 5.416 l. (330 C.I.D.) Engine only	{ 85.44 to 85.75 mm. (3.364 to 3.376 in.)
	{ All Other Models	{ 89.685 to 90.072 mm. (3.531 to 3.546 in.)
Fit in Piston at 21°C (70°F) Method of Retention	All Models	{ 0.00 to 0.0051 mm. (0 to 0.0002 in.) End Circlips

**PISTON RINGS**

Upper Compression Ring	Normally Aspirated Engines Turbocharged Engines With Cast Iron liners Turbocharged Engines With 'Cromard' liners Marine Intercooled	} Cast iron, chrome plated, barrel face } Keystone section, cast iron, chrome plated barrel face. } Keystone section, cast iron, barrel face			
			Intermediate Compression Ring	Normally Aspirated Engines Turbocharged Engines With Cast Iron liners Turbocharged Engines With 'Cromard' liners	} Cast iron, chrome plated, internally stepped on top face } Cast iron, chrome plated, internally stepped on top face } Cast iron, internally stepped on top face
Oil Control Ring	Normally Aspirated Engine also Turbocharged Engines With Cast Iron liners Turbocharged Engs. With 'Cromard' liners	} Cast iron, chrome plated, slotted channel with helical expander } Cast iron, slotted channel with helical expander			

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**PISTON RING GAP (With Cast Iron or Cromard Liners)**

Upper Compression	0.406 to 0.787 mm (0.016 to 0.031 in)
Intermediate and Lower Compression	0.305 to 0.737 mm (0.012 to 0.029 in)
Oil Control	0.305 to 0.737 mm (0.012 to 0.029 in)

## RING TO GROOVE CLEARANCE

-Compression Ring	Normally Aspirated Eng. Turbocharged and Marine Intercooled Eng.	0.058 to 0.096 mm. (0.0023 to 0.0038 in.)
		0.063 to 0.102 mm. (0.0025 to 0.0040 in.)
-Intermediate	3.964 l. (242 C.I.D.)	2.362 to 2.375 mm. (0.930 to 0.935 in.)
	5.416 l. (330 C.I.D.)	
	5.945 l. (363 C.I.D.)	
	4.150 l. (254 C.I.D.)	0.067 to 0.107 mm. (0.0027 to 0.0042 in.)
	5.950 l. (363 C.I.D.)	
	6.220 l. (380 C.I.D.)	
-Lower Compression	Turbocharged Engines	2.362 to 2.375 mm. (0.930 to 0.935 in.)
	Marine Intercooled	
	3.964 l. (242 C.I.D.)	0.043 to 0.094 mm. (0.0017 to 0.0037 in.)
	5.416 l. (330 C.I.D.)	
	5.945 l. (363 C.I.D.)	
	Oil Control Rings	4.150 l. (254 C.I.D.)
5.950 l. (363 C.I.D.)		
6.220 l. (380 C.I.D.)		
	Turbocharged Eng.	2.362 to 2.375 mm. (0.930 to 0.935 in.)
	Marine Intercooled	0.069 to 0.107 mm. (0.0027 to 0.0040 in.)
	All models	0.063 to 0.102 mm. (0.0025 to 0.0040 in.)

## PUSH RODS AND TAPPETS - ALL MODELS

Length of Push Rods	301.3 to 302.8 mm. (11.88 to 11.92 in.)
Diameter of Push Rods	7.997 to 8.257 mm. (0.315 to 0.325 in.)
Diameter of Tappet Stem	14.456 to 15.443 mm. (0.6080 to 0.6085 in.)
Overall Length of Tappet	61.388 to 61.898 mm. (2.417 to 2.437 in.)
Tappet to Block Clearance	0.012 to 0.050 mm. (0.001 to 0.002 in.)

## ROCKER SHAFT AND ROCKERS

Rocker Shaft Diameter-6 cylinder	18.876 to 18.902 mm. (0.743 to 0.744 in.)
-4 cylinder	18.902 to 18.927 mm. (0.744 to 0.745 in.)
No. of Rocker Shaft Springs-6 cylinder	6
-4 cylinder	4
Compressed Length and Load of Spring	26.92 mm. at 1.81 to 2.3 kg.m. (1.06 in. at 4 to 5 lb.ft.)
Clearance between Rocker Arm and Shaft	0.025 to 0.076 mm. (0.001 to 0.003 in.)

## VALVES - ALL MODELS

Valve Head Diameter-inlet	44.96 to 45.21 mm. (1.770 to 1.780 in.)
-exhaust	38.938 to 39.19 mm. (1.533 to 1.543 in.)
Angle of Valve Head	29° 15' to 29° 30'
Stem to Guide Clearance-inlet	0.025 to 0.084 mm. (0.0011 to 0.0033 in.)
-exhaust	0.046 to 0.102 mm. (0.0018 to 0.004 in.)
Valve Stem Diameter-inlet	9.774 to 9.779 mm. (0.3730 to 0.3740 in.)
-exhaust	9.449 to 10.061 mm. (0.3723 to 0.3733 in.)

## VALVE SPRINGS — ALL MODELS

No. of Coils on Valve Spring	7.5 total, 5.5 Active
Free Length of Valve Spring	5.87 cm (2.31 in)
Load Valve open	73.94 kg (163 lb)
— Valve closed	29.48 kg (65 lb)

## VALVE TIMING AND CLEARANCES — ALL MODELS

Nominal Valve Timing at 0.457 mm (0.018 in)  
clearance

Inlet opens	13° before T.D.C.
Inlet closes	48° 49' 12" after B.D.C.
Exhaust opens	49° 49' 12" before B.D.C.
Exhaust closes	12° after T.D.C.

## Valve Clearance

## Normally Aspirated Engines

	hot	cold
—inlet	0.381 mm (0.015 in)	0.406 mm (0.016 in)
—exhaust (with rotator caps)	0.305 mm (0.012 in)	0.305 mm (0.012 in)
—exhaust (less rotator caps)	0.381 mm (0.015 in)	0.305 mm (0.012 in)

## Turbocharged Engines

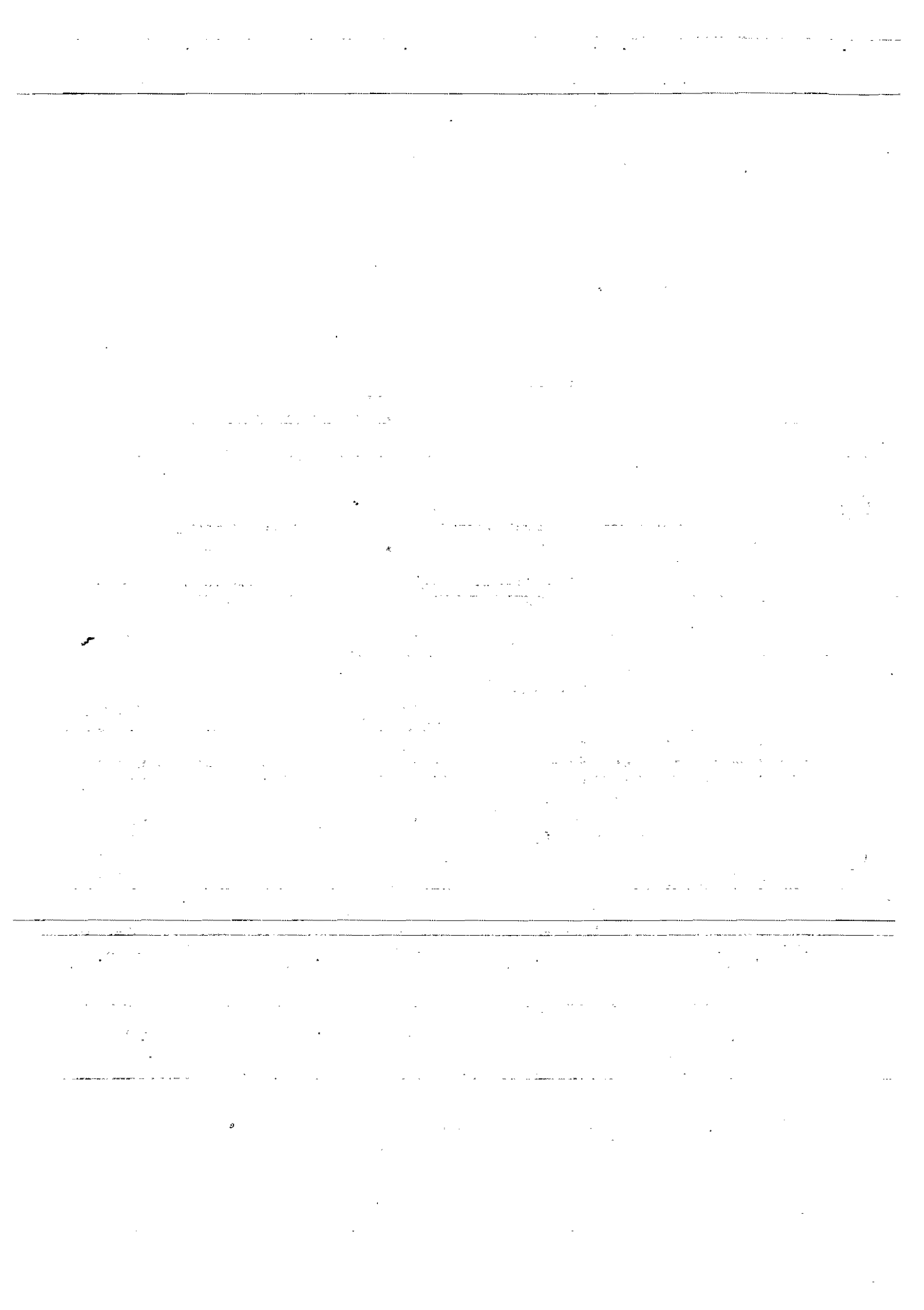
—inlet	0.457 mm (0.018 in)	0.483 mm (0.019 in)
—exhaust	0.457 mm (0.018 in)	0.483 mm (0.019 in)

Rotator Cap Clearance (cold) 0.025 to 0.127 mm (0.001 to 0.005 in)

## TIGHTENING TORQUES — ALL MODELS

	Nm	kgf m	lbf ft
Main Bearing Cap Bolts	156 to 163	15.89 to 16.58	115 to 120
Connecting Rod Nuts (where fitted)	74.5 to 81.4	7.6 to 8.29	55 to 60
Connecting Rod Bolts (where fitted)	115 to 122	11.75 to 12.44	85 to 90
Cylinder Head Bolts (early type)	149 to 156	15.21 to 15.91	110 to 115
Cylinder Head Bolts (later type with integral washers)	176 to 183	17.95 to 18.66	130 to 135
Flywheel to Crankshaft Flange Bolts	108 to 122	11.06 to 12.44	80 to 90
Gear to Camshaft Bolt	203 to 210	20.7 to 21.4	150 to 155
Oil Pan Drain Plug	47.5 to 54.2	4.84 to 5.53	35 to 40
Rocker Shaft Bracket Bolts	23 to 30	2.35 to 3.04	17 to 22
Front Housing to Cylinder Block (including Camshaft Thrust Plate)	34 to 40.7	3.45 to 4.15	25 to 30
Front Cover to Front Housing	8.1 to 10.8	0.83 to 1.11	6 to 8
Oil Pan to Cylinder Block	30 to 32.5	3.04 to 3.32	22 to 24
Crankshaft Centre Bolt	325	33.20	240
Exhaust Manifold Retaining Bolts	23 to 30	2.35 to 3.04	17 to 22
Inlet Manifold Retaining Bolts	23 to 30	2.35 to 3.04	17 to 22
Engine Mounting Bolts	40.7 to 47.5	4.15 to 4.84	30 to 35
Oil Pick-up Pipe Support Bolts	4.07 to 5.42	0.42 to 0.55	3 to 4
Valve Rocker Cover Bolts	16.3 to 24.4	1.66 to 2.4	12 to 18
Fuel Lift Pump Mounting Bolts	16.3 to 20.3	1.66 to 2.07	12 to 15
Water Pump Mounting Bolts	16.3 to 20.3	1.66 to 2.07	12 to 15
Water Outlet Housing Mounting Bolts	16.3 to 20.3	1.66 to 2.07	12 to 15

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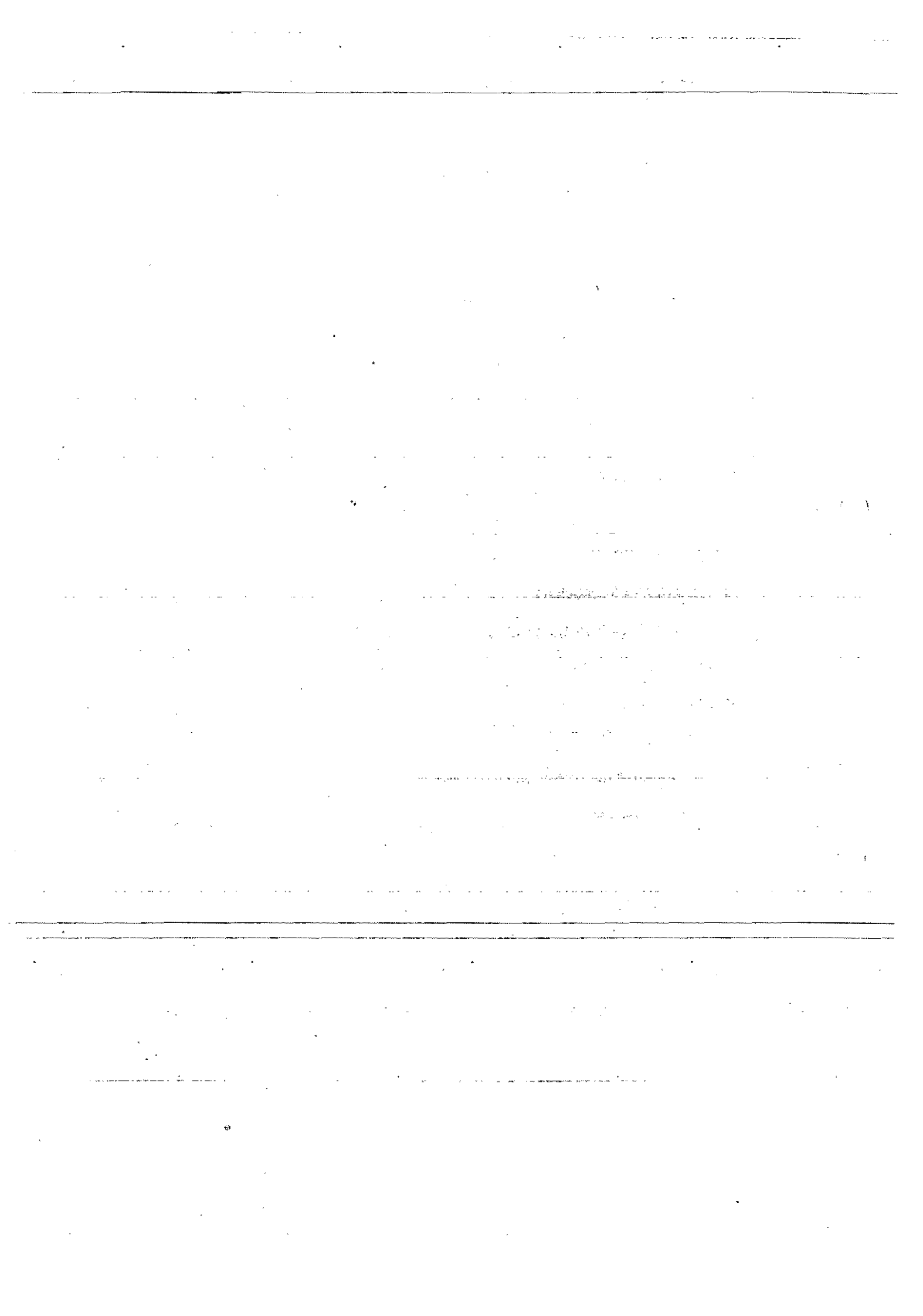
# SECTION 2

## LUBRICATION SYSTEM AND COOLING SYSTEM

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## LUBRICATION SYSTEM

### GENERAL DESCRIPTION

The engine lubrication system is of the forced feed type, the oil being circulated by an oil pump mounted in the crankcase on the right-hand side of the engine and driven by a skew gear on the engine camshaft.

Oil from the engine sump is drawn into the oil pump through a gauze screen and inlet pipe. The oil pressure is controlled by a plunger type relief valve incorporated in the oil pump, which when open, bleeds oil back to the sump. A scroll on the oil pump shaft provides an oil feed to the drive gear. Two holes in the gear shoulder feed oil from the scroll, via an annular groove in the shaft, to the gear teeth. This oil feed is supplemented on the underside of the gear by oil leaking between the gear and pump body and by a jet of oil from a groove in the mounting spigot on the pump body.

Oil, from the pump, flows under pressure through an oil gallery on the right-hand side of the engine to a full flow filter. A cross drilling through the cylinder block, from the oil filter, connects with the main oil gallery on the left-hand side of the engine. A switch for the oil pressure warning light is located in a tapping into this gallery.

From the main oil gallery, oil passes through drillings to each main bearing and on turbocharged engines via a short feed pipe to the turbocharger. Drillings in the crankshaft journals feed oil to the big end bearings.

The camshaft bearings are fed via drillings in the cylinder block from the main bearings. The timing gears being lubricated by a metered jet of oil from the front drilling.

Drillings in the camshaft centre journal control the oil feed to the rocker shaft, which is thus pressurised intermittently as the camshaft revolves.

The oil is fed through drillings in the cylinder block and head to the centre rocker shaft support, thence to the hollow rocker shaft to lubricate the valve rockers.

The rockers have oil drillings and grooves on the top edge to lubricate the rocker pad and valve stem caps. Also oil seeping down the adjusting screw thread lubricates the push rod cups.

Oil from the rockers drains through the push rod drillings and lubricates the tappets and cams as it returns to the sump through the drain holes. Drain holes are also provided in the left-hand side corners of the cylinder head.

The cylinder bores and small end bushes are lubricated by splash. The oil pump drive gear and also the compressor (when fitted) are lubricated by an un-filtered oil supply.

### LUBRICATION OF TURBOCHARGER

The oil feed to the turbocharger is from a tapping in the cylinder block, the oil serving both as a lubricant and a coolant. The oil is returned to the engine via a drain tube attached to the sump.

The oil pressure should never fall below 2.07 bar (2.1 kgf/cm<sup>2</sup> or 30 lbf/in<sup>2</sup>) under normal working conditions. At idling speeds a minimum pressure of 0.69 bar (0.7 kgf/cm<sup>2</sup> or 10 lbf/in<sup>2</sup>) must be maintained to ensure satisfactory lubrication and cooling.

The oil flow through each type of turbocharger is 964 grams/min. (31 oz./min.)

**N.B. SERIOUS DAMAGE TO THE TURBOCHARGER BEARINGS WILL RESULT FROM INADEQUATE LUBRICATION. THE FULL STOP/START PROCEDURE FOR TURBOCHARGED ENGINES IS GIVEN ON PAGE 6.**

## LUBRICATION OF TURBOCHARGER (continued)

### TURBO-PLUS ENGINE PISTON COOLING

Additional piston cooling is incorporated in the Turbo-Plus engine by an independent pump, mounted externally on the timing gear cover. The pump is driven by a gear meshed with the timing gear train.

A pick-up and return pipe, secured to the oil pan wall are connected to the oil pump by metal pipes.

Oil from the engine is drawn through the gauze screened pick-up pipe to the pump and fed to an oil cooler. Then it is returned to the engine under pressure via a connection tube to a horizontal oil gallery, bolted to the main bearing caps. The horizontal gallery has six open ended pipes extended vertically upwards, whereby the tops of the pipes actually enter the skirt area of the pistons at the bottom dead centre positions. The oil cooler makes sure that the temperature of the oil which is continuously impinging on the undersides of the pistons, is kept below 137°C (280°F). A relief valve fitted at the end of the horizontal oil gallery limits the oil pressure to 4.14 bar (4.218 kgf/cm<sup>2</sup> or 60 lbf/in<sup>2</sup>). Oil flow through the pumps is 47.7 litres (10½ galls.) per min.

### OIL PUMPS

There are two types of oil pump available for the 2700 engine range. The Standard oil pump is of the sliding vane type and the optional pump, used in conjunction with the high inclination oil pan, is a rotor type scavenge pump. Both oil pumps are driven by a skew gear on the engine camshaft, and incorporate a non-adjustable plunger type pressure relief valve in the body which limits the oil pressure to 3.1 to 3.4 bar (3.16 to 3.51 kgf/cm<sup>2</sup> or 45 to 60 lbf/in<sup>2</sup>).

Later 4-cylinder engines (November-1976 onwards) have been fitted in Production with an oil pump (Part No. 773F-6600-AAA) of "Motofides" manufacture. The pump is completely interchangeable with the "Holbourn-Eaton" pumps currently in Service.

### SLIDING VANE TYPE PUMP (Standard)

#### Operation.

The pump consists of a rotor housed eccentrically in a bore machined in the pump body. Four sliding vanes are located in grooves machined in the periphery of this rotor and are positioned by locating rings on either side of the rotor (see Fig. 2). The vanes being held against the pump body bore by centrifugal force whilst the pump is operating.

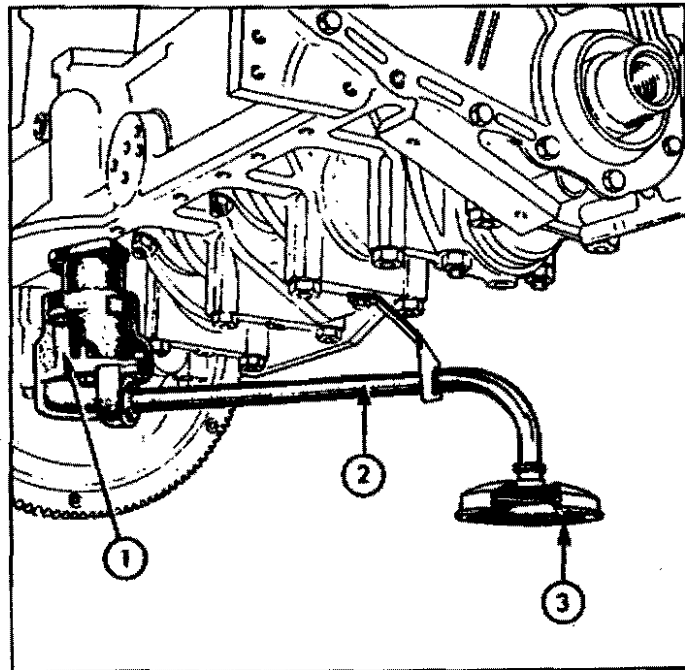
The inlet port is connected to the sump and the outlet port is connected to the oil galleries in the engine. As the rotor revolves, the vanes pass over the inlet port and oil is drawn into the space between the rotor and the pump housing. This oil is carried round between the vanes to the outlet port, where it is forced out into the engine oil galleries, as the space between the rotor and the pump bore decreases.

The action of the pump is a continuous repetition of this process. Oil flowing into the space between the rotor and the pump bore from the inlet port is carried around between the vanes and then, as the space decreases, the oil is forced out through the pump outlet port.

## SLIDING VANE TYPE PUMP (Standard) (continued)

Fig. 1.

- 1 Oil Pump
- 2 Inlet Pipe
- 3 Gauze Screen



## To Dismantle:

1. Bend back the locking plate tab and unscrew the inlet pipe union to remove the inlet pipe.
2. Remove the four bolts and lockwashers retaining the end plate and lift off the plate, which is pressurised by the relief valve spring. Keep the pump shaft vertical (rotor end upwards) to prevent the sliding vanes falling out. Withdraw the relief valve spring seal, spring and plunger from the pump body.
3. Check the oil pump for wear.

Place a straight edge across the face of the pump body and check the clearance between the face of the vanes and rotor assembly and the straight edge. This should not exceed 0.127 mm. (0.005 in.). If this clearance is excessive the face of the pump body can be carefully lapped on a flat surface.

Turn the oil pump until one of the vanes is in the centre of the cam form. Check the clearance between the rotor and the oil pump body. If this exceeds 0.127 mm. (0.005 in.) a worn body is indicated and a new oil pump assembly should be fitted.

With the rotor in the same position centralise the locating ring and check the clearance between the diametrically opposite vane and the pump body. If the clearance exceeds 0.279 mm (0.011 in) the vanes are worn and should be renewed.

Check the vane clearance in the locating groove, if this exceeds 0.127 mm. (0.005 in.), the vanes and/or rotor are worn. Substitute new vanes and recheck the clearance to see if the rotor grooves are worn. If the rotor is worn fit a new rotor and shaft assembly and gear.

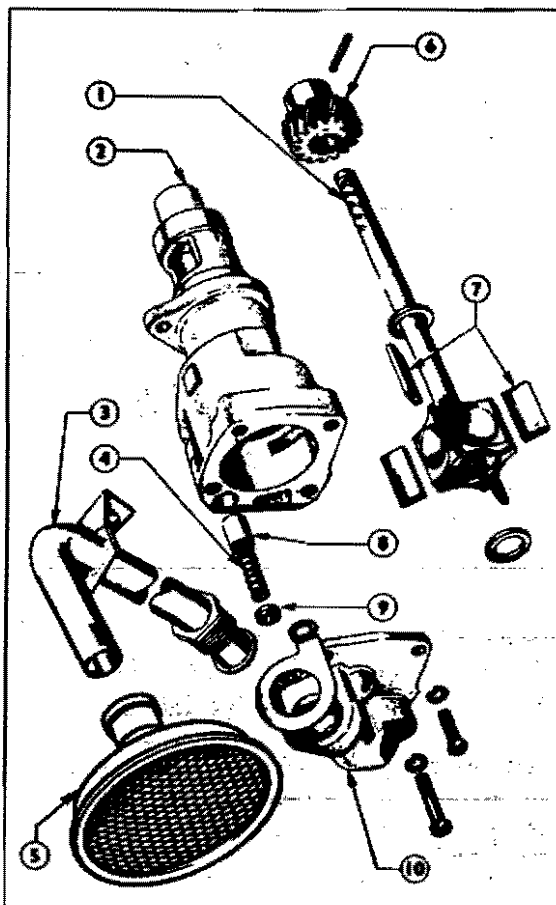
4. If it is necessary to renew the rotor and shaft assembly or the skew gear, lift out the vanes and the outer locating ring. Drive out the retaining pin securing the skew gear to the drive shaft and pull off the gear.

## SLIDING VANE TYPE PUMP (Standard) (continued)

5. Remove the drive shaft and rotor assembly together with the vane locating inner ring from the pump housing.

Fig. 2

- 1 Rotor and Shaft Assembly
- 2 Pump Body
- 3 Inlet Pipe Assembly
- 4 Spring
- 5 Skew Gear
- 6 Vanes
- 7 Oil Pressure Relief Valve Plunger
- 8 Retainer
- 9 Cover



### To Reassemble:

1. If the pump has been completely dismantled place the vane locating inner ring in the pump housing and fit the drive shaft and rotor assembly to the pump body. Press the skew gear onto the drive shaft end until there is a clearance of 0.178 to 0.305 mm. (0.007 to 0.012 in.) between the gear and the pump body with the face of the rotor flush with the cover mounting face. Support the shaft at the rotor end, on a suitable spacer to avoid damage to the rotor. Drill and ream a 3.175 mm. (3/8 in.) diameter hole diametrically through the gear hub and shaft 13.72 mm (0.540 in.) from the slotted end. Fit the gear retaining pin and peen the ends over securely to prevent it becoming loose in service.
2. Replace the vane locating outer ring and locate the sliding vanes in the rotor grooves with the curved edges outwards.
3. Insert the relief valve plunger, spring and spring seat into the pump body.

**SLIDING VANE TYPE PUMP (Standard) (continued)**

4. Fit the end plate and secure it in place with four bolts and lockwashers. Locate a new inlet pipe union locking plate on the bolt adjacent to the inlet connection and align it with this hole when tightening the bolts to 16.3 to 20.3 Nm (1.66 to 2.07 kgf m or 12 to 15 lbf ft) torque.
5. Insert inlet pipe into the connection and screw in the union. Do not tighten and lock the union until the pump is fitted to the engine to ensure accurate alignment.

**ROTOR TYPE SCAVENGE PUMP****Operation.**

The optional lubrication system uses a rotor type pump, which consists of two sets of rotors driven on the same shaft, but separated by a thick metal diaphragm which is part of the lower pump housing (see Fig. 5). Oil from the sump reservoir in the front end of the sump is drawn into the oil pump through a gauze screen and inlet pipe, and the upper set of rotors deliver the pressurised oil. The lower set of rotors scavenge oil from the rear of the sump and feed it to the front reservoir maintaining a good oil level for the pump inlet pipe at any inclination up to 30°.

To ensure that there is always sufficient oil in the reservoir, the scavenging set of rotors deliver approximately 10% more than the pressure feed set.

The oil pipe layout is shown in Fig. 3.

**To Dismantle:**

1. Remove all bolts and lockwashers retaining the pump and pipes and remove the pump from the spigot location in the block.
2. Remove the gauze screens by turning through 90° to release.
3. Bend back the locking plate tabs and unscrew the pipe unions and remove the pipes.
4. Remove the four retaining bolts and remove the end plate.
5. Check the oil pump for wear. Place a straight edge across the face of the pump body and check the clearance between the straight edge and both parts of rotor. If this exceeds 0.127 mm. (0.005 in.) the pump body can be lapped to bring the clearance within tolerance.

Inner to outer rotor clearance should be measured with a feeler gauge, see Fig. 4. If this clearance exceeds 0.153 mm. (0.006 in.) the inner and outer rotor should be renewed.

6. Remove the inner and outer scavenge rotors, and remove the woodruff key from the shaft.
7. Remove the lower pump body and the oil pressure relief plunger and spring.
8. The same checks for wear should be carried out on the delivery rotors as on the scavenge rotors. See paragraph 5. Should the inner to outer-rotor clearance exceed 0.153 mm. (0.006 in.) fit a new shaft and inner and outer rotors.
9. If it is necessary to renew the delivery rotors and shaft or skew gear, remove the outer rotor. Drive out the retaining pin securing the skew gear to the drive shaft and pull off the gear. The inner rotor and shaft can now be removed from the upper housing.

To Dismantle (continued)

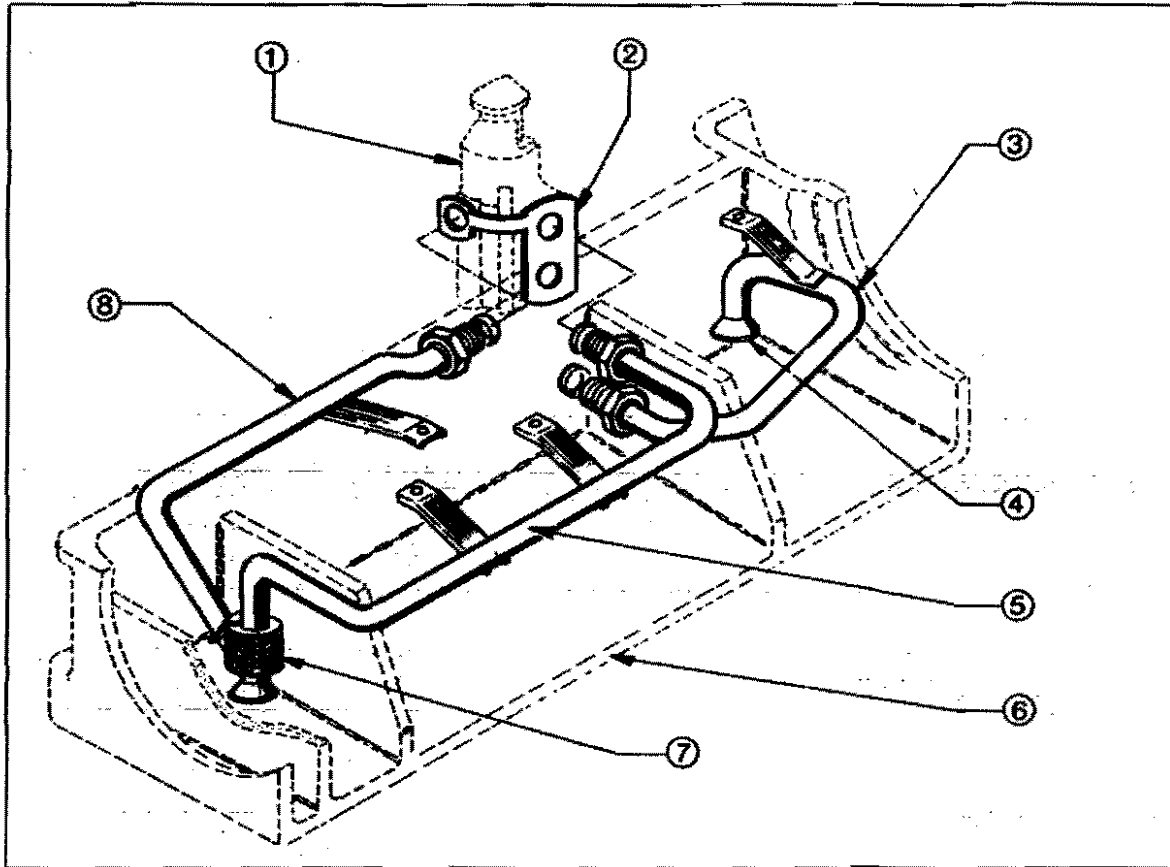


Fig. 3

1 Scavenge Pump	5 Delivery Pipe
2 Lock Plate	6 Sump (Section)
3 Scavenge Pipe	7 Diffuse Box
4 Gauze Screen	8 Oil Reservoir Feed Pipe

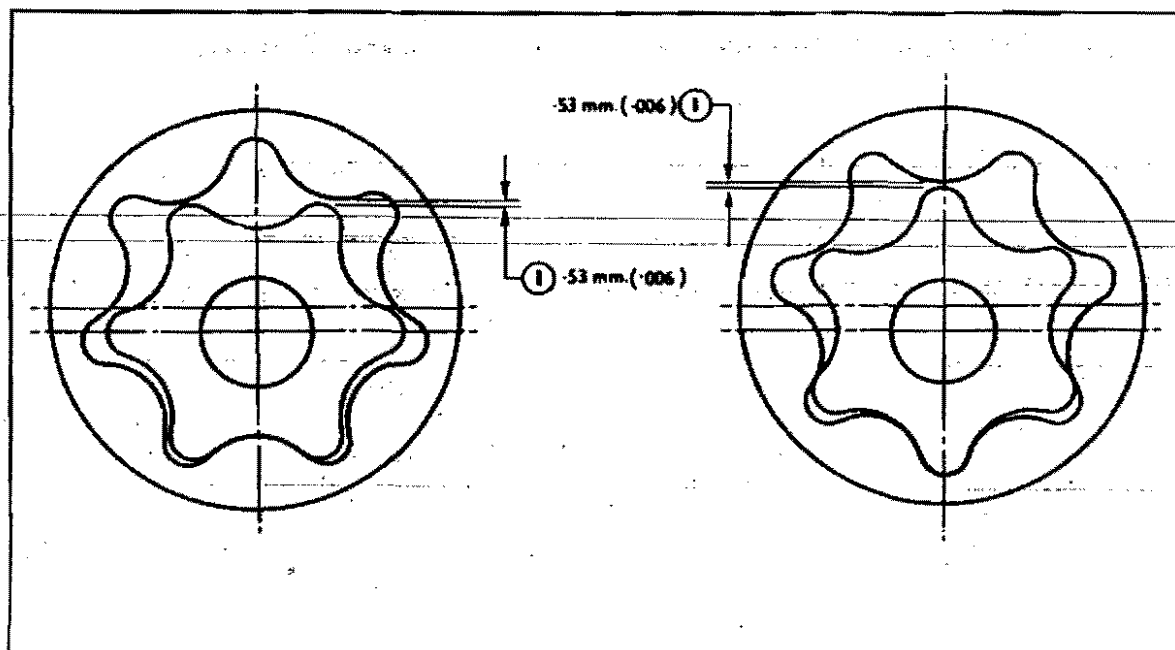


Fig. 4



## To Dismantle (continued)

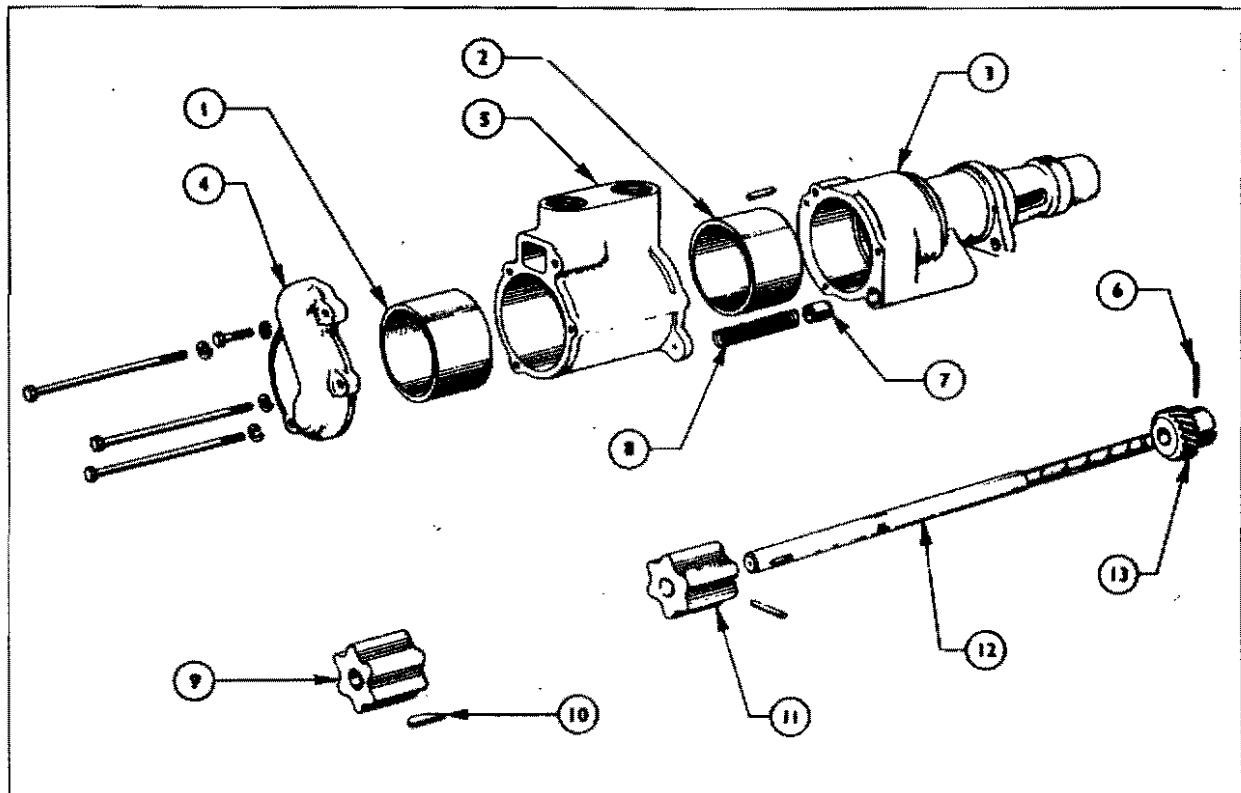


Fig. 5.

- |                                       |                           |
|---------------------------------------|---------------------------|
| 1 and 9 Scavenge Rotor Assembly       | 6 Pin                     |
| 2, 11 and 12 Shaft and Rotor Assembly | 7 Pressure Relief Plunger |
| 3 Upper Pump Housing                  | 8 Pressure Relief Spring  |
| 4 End Plate                           | 10 Woodruff Key           |
| 5 Lower Pump Housing                  | 13 Skew Gear              |

## To Reassemble:

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

Press the skew gear onto the drive shaft end until there is a clearance of 0.178 to 0.305 mm. (0.007 to 0.012 in.) between the gear and pump body.

Supporting the shaft at the rotor end, drill and ream 3.175 mm. (1/8 in.) diameter hole diametrically through the gear hub and shaft 13.72 mm. (0.540 in.) from the slotted-end.

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

2. Replace the outer rotor, chamfered end first, and insert the oil pressure relief plunger and spring in the upper pump housing.
3. Slide the lower pump housing onto the shaft and fit the woodruff key in the shaft.

To Reassemble (continued)

4. Replace inner rotor and outer rotor, chamfered end first, into the lower pump housing.
5. Fit the end plate and secure with the four bolts and lockwashers, ensuring that each is in its correct location, and then tighten to 16.3 to 20.3 Nm (1.66 to 2.07 kgf m or 12 to 15 lbf ft) torque.
6. Locate a new union locking plate and insert the pipes into their correct locations but do not tighten or lock the unions until the pump is secured to the engine and the pipes correctly aligned.
7. Secure the pipe brackets to the block, tighten the pipe unions and bend the locking plate to lock the unions.

Fit the gauze screens.

When fitting a Service cylinder assembly supplied without an oil pump on 2710 and 2704ET engines, the following checks and modifications must be carried out to the existing oil pump assembly. Failure to carry out these checks and modifications may result in an inadequate oil supply to the new engine assembly.

- A.
  1. Examine the existing oil pump. If it is of the Vane type, then a new Bi-rotor type oil pump (See Parts Required) must be fitted.
  2. If the engine is turbocharged then a new oil pump assembly must be fitted. Use pump part number 703F-6600-BA for all except high inclination sumps and 2703E-6600-C with high inclination sumps.
- B. If the existing oil pump is of the Bi-rotor type and is fitted to a normally aspirated engine then the following modifications should be carried out to the existing oil pump assembly.
  1. With the pump vertical, rotor end upwards, remove the bolts retaining the end plate and lift off the plate.
  2. Mark the outer rotor relative to the inner rotor, to ensure correct reassembly, withdraw and clean all parts.
  3. Insert the outer rotor in its original position and place a straight edge across the pump face to check the clearance between the rotor assembly and the pump face. If the clearance is in excess of 0.127 mm. (0.005 in.) the pump body may be carefully lapped on a flat surface.
  4. Check and ensure that the clearance between the inner and outer rotor lobes is below 0.228 mm. (0.009 in.) and the clearance between the outer rotor and the pump body is below 0.304 mm. (0.012 in.).

**NOTE:** The rotors are supplied as a matched pair only, so if the lobe clearance is excessive a new shaft and rotor assembly must be fitted (See Parts Required). Should the clearance between the outer rotor and the pump body be excessive a new shaft and rotor assembly or a new pump assembly must be fitted.

5. Drive out the pin securing the skew gear to the shaft; discard the gear and replace it with a new gear.

**NOTE:** The skew gear and retaining pin are not supplied with the Service Cylinder Assembly and must be ordered separately.
6. Turn the new gear through an angle of 90° and obtain a clearance of 0.18 to 0.30 mm. (0.007 to 0.012 in.) between the gear and the pump body.
7. Drill and ream a 3.175 mm. (1/8 in.) diameter hole through the gear hub and shaft, 13.72 mm. (0.540 in.) from the slotted end.
8. Fit a new retaining pin and peen the ends to secure.
9. Fit the end plate and secure it with the two bolts. Fit a new lock washer to the bolt adjacent to the inlet orifice and tighten the bolts to a torque of 152 to 197 Nm (16 to 20 kgf m or 112 to 145 lbf ft).
10. Fit the oil pump to the engine (ensure that the two "O" rings are in position if part of the old oil pump).

To Reassemble (continued)

**PARTS REQUIRED:**

Description	Part Number	Finis Code	Quantity
Oil pump assembly			
4 cylinder engines	703F-6600-AA	1447625	1
6 cylinder and turbo engines	703F-6600-BA	1447626	1
	(except with high inclination sump)		
	2703E-6600-C	1702427	1
	(with high inclination sump)		
Rotor and shaft assembly			
4 cylinder engines	703F-6608-AAA	1466956	1
6 cylinder and turbo engines	703F-6608-BAA	1466957	1
	(except with high inclination sump)	1794335	
	2703E-6608-C	1794335	1
	(with high inclination sump)		
Lockwasher	2704E-6K632-A	1433167	1
Skew Gear	2701E-6652-C	1793868	1
Retaining Pin	72472 S	1720056	1

**OIL LEVEL**

To check the oil level the engine must be standing on a level surface, withdraw the dipstick from the sump and wipe with a clean rag. Insert the dipstick fully onto the dipstick tube and again withdraw. The mark made by the oil on the lower end of the dipstick will indicate the oil level. If necessary remove the oil filler cap and add clean engine oil to bring the level to the "FULL" mark. Do not overfill as this may result in oil leaks.

On a new engine the oil in the sump should be changed after the first 50 hours and thereafter approximately every 200 hours.

The exact period at which the oil should be changed depends upon the condition of the oil in the sump. Should the oil get dirty for any reason, it should be renewed and the filter element replaced.

It is preferable to drain the oil when the engine is warm, to ensure that it drains away quickly, carrying away with it any sediment or foreign matter which may be present.

**OIL FILTER**

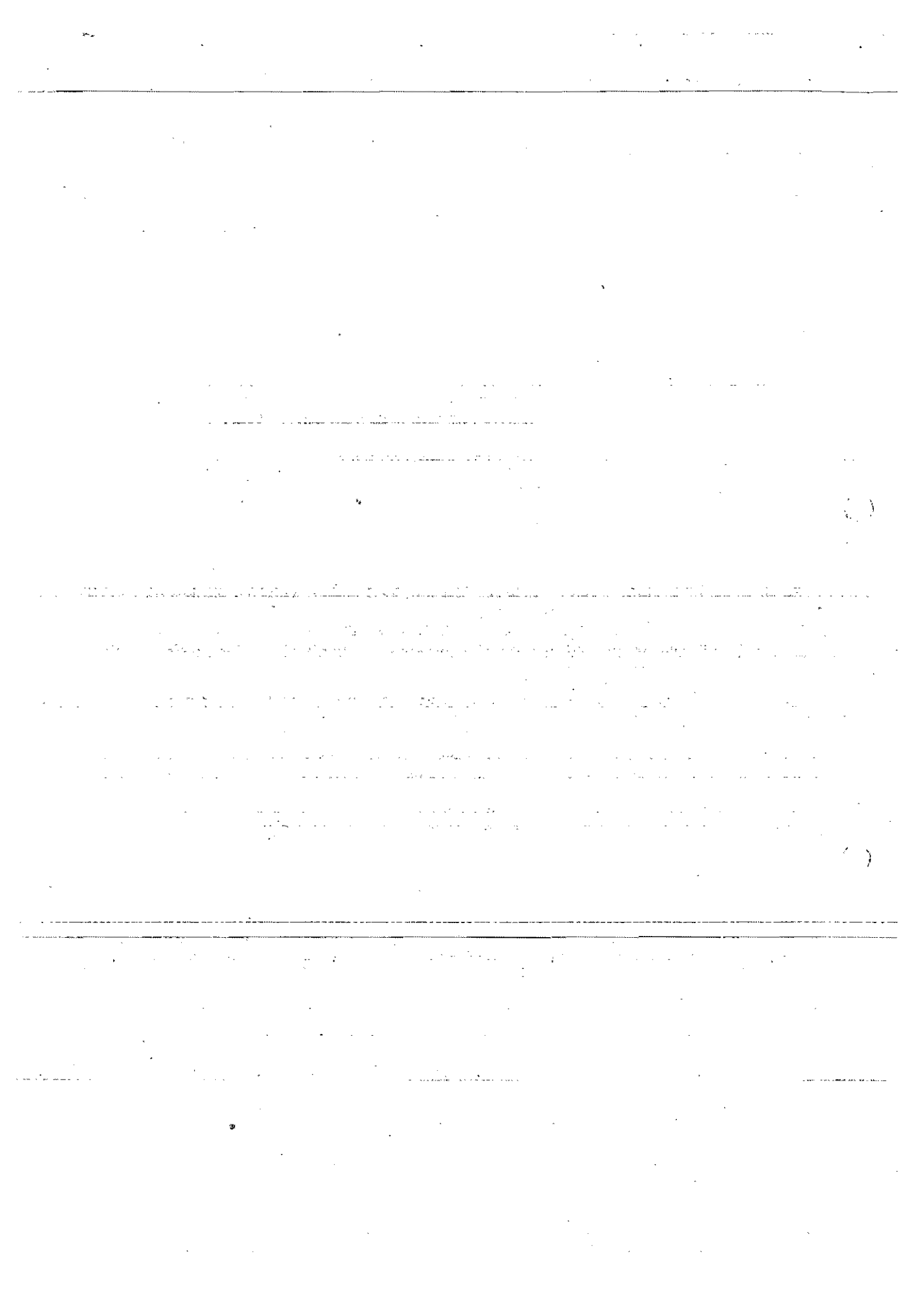
The full flow type oil filter is bolted to the right-hand side of the cylinder block. Oil from the pump enters the filter and passes through the element, from the outside to the inside, before entering the engine lubrication system oil galleries. A filter relief valve, which opens to by-pass the filter when there is an excessive pressure difference across the filter element, is incorporated in the filter mounting flange between the filter inlet and outlet.

The oil filter element should be renewed and the filter body thoroughly cleaned after every 200 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 body and element.

Remove the sealing ring from the groove in the filter body mounting flange, 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 round the groove as the rubber may stretch, thus leaving a surplus which may cause an oil leak.

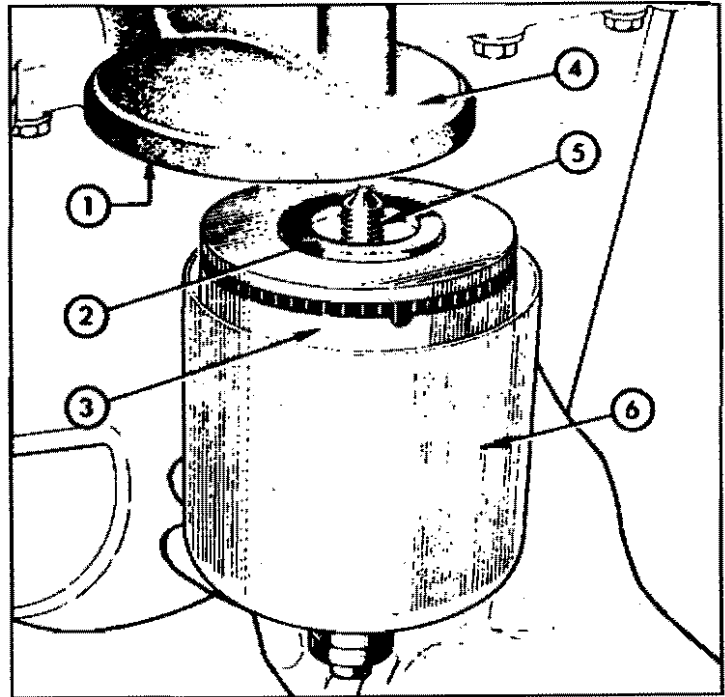
Thoroughly clean the filter body, insert a new element, and refit the filter assembly to the oil pump body.



## OIL FILTER (continued)

Fig. 6.

- 1 Rubber Gasket
- 2 Sealing Ring
- 3 Filter Element
- 4 Filter Head
- 5 Centre Bolt
- 6 Casing



The gauze filter in the oil filler cap should be cleaned every 200 hours or whenever the engine oil is changed. To clean the filter it is only necessary to remove the filler cap from the oil filler pipe and wash the assembly in petrol to remove any accumulation of dirt. Oil the gauze with clean engine oil, shaking off any surplus, and replace the cap.

If an oil bath type filler cap is fitted, this should be removed, dismantled and the oil discarded every 200 hours or whenever the engine oil is changed. The gauze should be washed in petrol and dipped in clean engine oil. Refill the cap body with clear engine oil to the level indicated by the arrow, reassemble and refit the cap to the oil filler pipe.

## TURBOCHARGED ENGINE STOP/START PROCEDURE

To avoid serious damage to the turbocharger bearing and seals, it is important to follow this procedure:—

## 1. Starting the engine

When the engine has been inoperative in excess of four weeks or when the turbocharger is newly installed, proceed as follows:

- a. Check there is sufficient oil in the engine sump, but do not top up at this stage. Disconnect the oil feed pipe at the turbocharger end and fill the housing with oil. Reconnect the pipe.
- b. Remove the square headed plug from the lubrication oil filter head and using a suitable syringe, inject a minimum of 2.3 litres (4 pints) of clean engine oil through the aperture. Refit the plug.

Note: On engines prior to S 988767 this aperture is not present and the oil must be injected through the oil pressure gauge connection.

- c. Start the engine and allow to idle for 1 minute before increasing speed.

## TURBOCHARGED ENGINE STOP/START PROCEDURE (continued)

- d. Stop the engine and check that the oil level is correct, after allowing sufficient time for the oil to return to the sump. If necessary top up with clean engine oil. If the oil level is above the full mark the surplus oil should be drained off.

**NOTE: ON ENGINES IN NORMAL USE (EXCEPT GENERATOR OR ALTERNATOR SETS), WHEN STARTING FROM COLD, THE ENGINE MUST BE RUN AT IDLE SPEED FOR ONE MINUTE TO OBTAIN ADEQUATE OIL CIRCULATION TO THE BEARINGS BEFORE APPLYING LOAD.**

### 2. Stopping the engine

Before shutting down, allow the engine to idle for one minute, to reduce "heat soak" from the turbine housing to the bearings and seals of the turbocharger by enabling the lubricant to cool same.

#### N.B. Generator and Alternator

Because certain generating and Alternator Applications make fewer starts and stops than other industrial applications, the stop/start procedure can be waived without any undue risk of reduced life.

However, the Turbocharger lubrication procedure for these applications, when inoperative for four weeks or more remains in effect.

## ENGINE VENTILATION

### Phase I Engines

#### 1. Automotive

Fresh air enters the engine through the open type breather cap fitted to the crankcase, thence to the rocker cover via the push rod drillings. Engine fumes mixed with air leave the rocker area via a breather tube connected to the air cleaner to be burnt in the engine.

#### 2. Closed Industrial

This uses the same principle as the automotive, except that a closed breather cap is fitted to the crankcase. A hose fitted to the rocker cover and extended below the engine vents the fumes. This system is specified for heavy dust conditions.

#### 3. Semi-Closed Industrial

The only variance to the closed system is an open type breather cap fitted to the crankcase. system is specified for light dust conditions.

### Phase II Engines

The engine breather system is the same as Phase I engines, with the addition of an emission control valve fitted on the rocker cover. This valve is connected to the inlet manifold by a hose thus reducing the possibility of oil "pull over" and sludge formation.

Under no circumstances should a closed breather cap be fitted with this system. For heavy dust concentrations, the heavy duty oil bath crankcase breather must be used.

## COOLING SYSTEM

### WATER PUMP

The water pump is mounted on the front face of the cylinder block, and is driven by the fan belt from the crankshaft pulley. It is of the impeller type and assists the natural thermo-syphon circulation of the water. The pump shaft and the double ball bearing are serviced as an assembly and should not be dismantled.

#### To Remove:

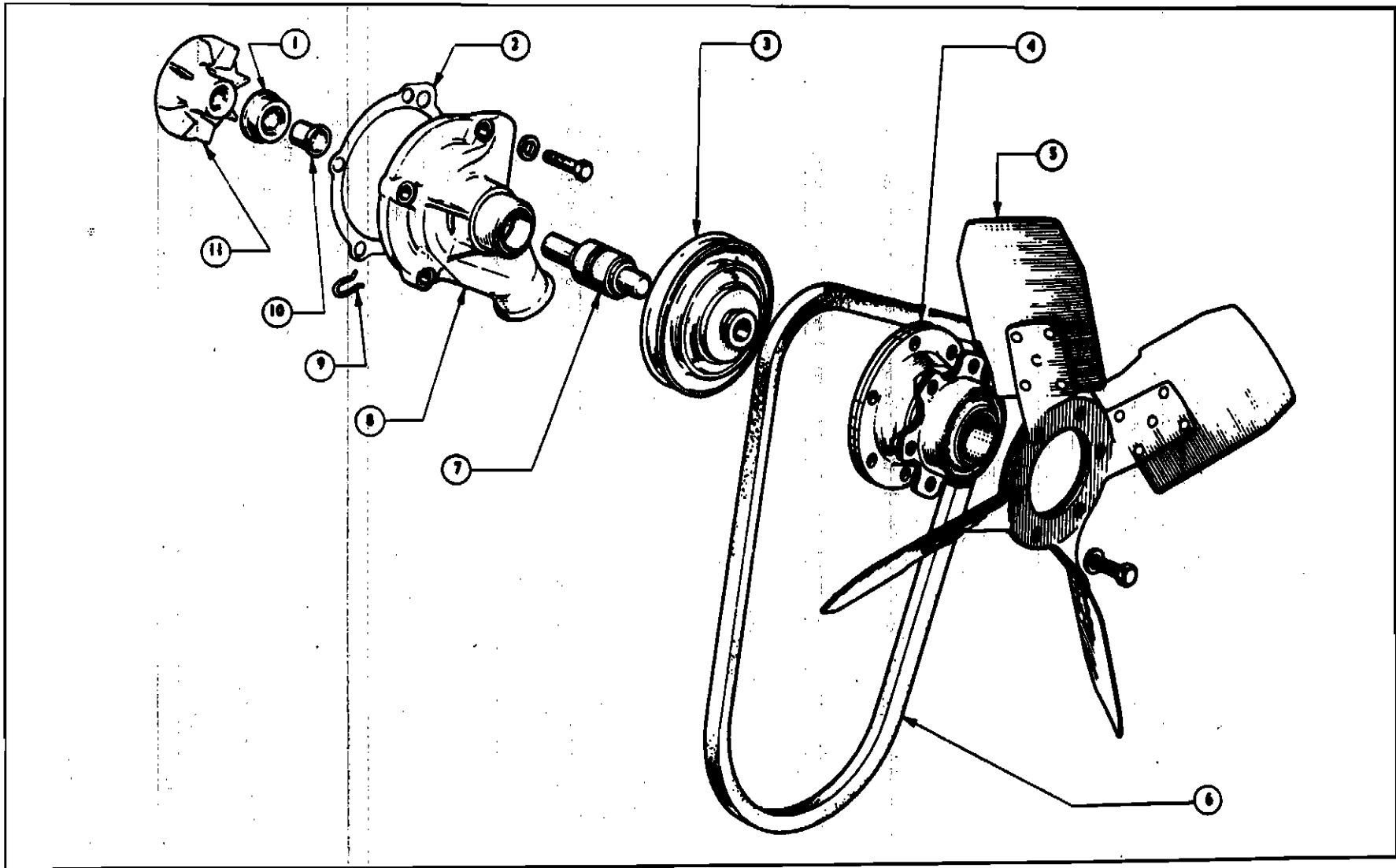
1. Drain the cooling system and remove the fan.
2. Remove the fan belt after removing the alternator or generator adjusting arm clamp bolt and slackening the alternator mounting bolt. The alternator or generator must be pivoted towards the engine.
3. Slacken the hose clamps and disconnect the lower water hose from the water pump.
4. Detach the pump and gasket, after removing the four bolts and spring washers securing the pump to the block, together with the alternator adjusting arm.

#### To Dismantle:

Throughout the following operations, a suitable press with the 370 Universal taper base and slave ring should be used, together with the water pump tool kit CPT.8009. If a press is not available, a hand press CPT.4000 may be used with the water pump kit.

1. Remove the water pump as described above.
2. Remove the pump pulley from the shaft, using the split ring (CPT.8000-2 detail "a") assembled around the boss on the front of the pulley. The centre screw adaptor (CPT.8000-3 detail "d") must also be used to push against the centre of the shaft (see Fig. 8).
3. Remove the bearing retainer clip by carefully levering it out of the slot in the housing.
4. Press the impeller, seal, slinger, shaft and bearing assembly out of the housing, using adaptors CPT.8000-2 detail "d" and CPT.8000-3 detail "b" as shown in Fig. 9. Adaptor detail "b" is hollow, and fits over the shaft and bears against the outer diameter of the bearing.
5. Press the impeller off the end of the shaft, using adaptors CPT.8000-2 detail "b" and CPT.8000-3 detail "d" as shown in Fig. 10.
6. Remove the pump seal from the shaft.
7. If required, carefully split the slinger bush with a chisel to detach it from the shaft.

**NOTE.**—A water pump repair kit is available should extensive replacement of parts be necessary on overhauling the pump. The kit consists of the shaft and bearing assembly, slinger bush, pump seal, impeller, retainer clip and gasket.



The Water Pump

Fig. 7.

- |          |                      |                              |                  |
|----------|----------------------|------------------------------|------------------|
| 1 Seal   | 4 Fan Hub            | 7 Bearing and Shaft Assembly | 10 Shaft Slinger |
| 2 Gasket | 5 Fan Blade Assembly | 8 Water Pump Housing         | 11 Impeller      |
| 3 Pulley | 6 Fan Belt           | 9 Bearing Retainer           |                  |



## To Dismantle (continued)

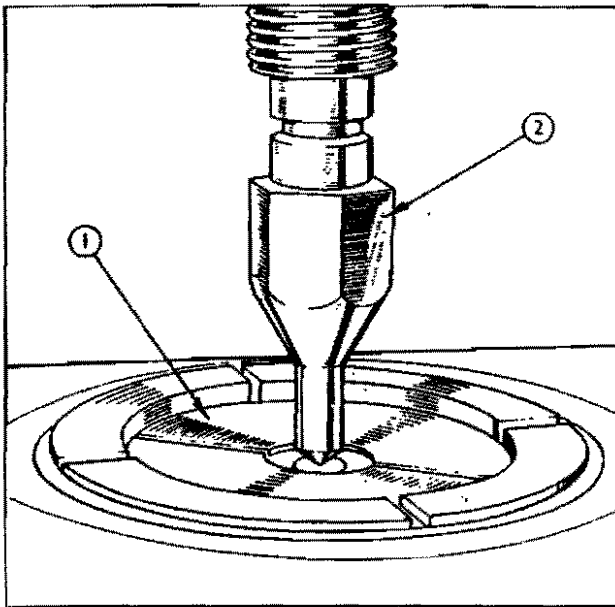


Fig. 8

- 1 Adaptor CPT.8000-2a
- 2 Adaptor CPT.8000-3d

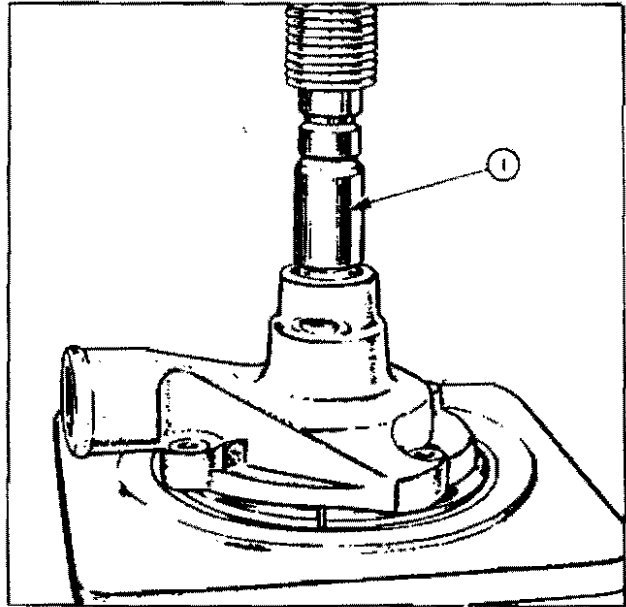


Fig. 9

- 1 Adaptor CPT.8000-3b

## To Reassemble:

1. Press the shaft and bearing assembly into the housing (short end of shaft to the front of the housing) until the groove in the shaft is in line with the groove inside the housing, using adaptors CPT.8000-2 detail "d" and CPT.8000-3 detail "b" as shown in Fig. 9.
2. Refit the bearing retainer clip in the groove of the bearing and housing.
3. Press the pump pulley on to the front end of the shaft until the end of the shaft is flush with the end of the pulley, using adaptor CPT.8000-2 detail "a".
4. If necessary, fit the new slinger bush (flanged end first) on the rear of the shaft, using adaptor CPT.8000-3 detail "a".
5. Refit the pump seal on the slinger bush with the carbon thrust face towards the impeller, using adaptor CPT.8000-3 detail "k" (see Fig. 11).
6. Press the impeller onto the shaft, using the adaptor CPT.8000-2 detail "b" until a clearance of 0.762 mm. (0.030 in.) is obtained between the impeller blades and the housing face. As the impeller is recessed into the water pump housing, it is necessary to use 'bent wire' feelers.

## To Replace the Water Pump

1. Clean the front face of the cylinder block and locate a new gasket on the water pump housing face.
2. Fit the water pump and tighten all retaining bolts except that which retains the alternator adjusting arm.

### To Replace the Water Pump (continued)

3. Locate the fan belt around the pulleys, and adjust as described in the section "Fan Belt".
4. Refit the fan.
5. Refill the cooling system and check for coolant leaks.

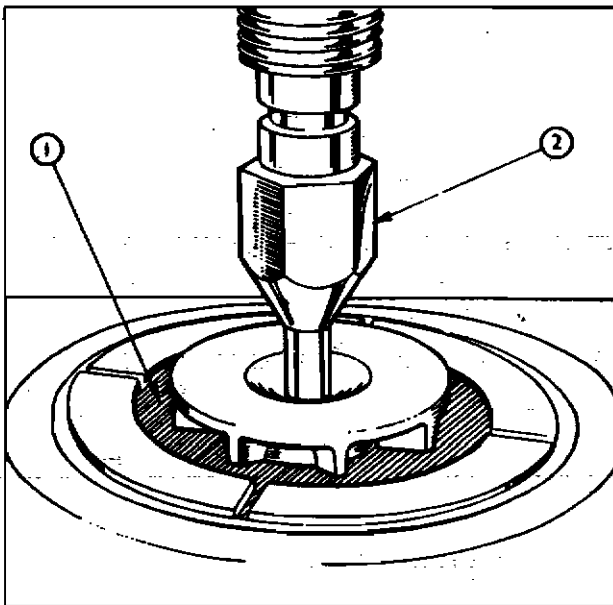


Fig. 10.

- 1 Adaptor CPT.8000-2d
- 2 Adaptor CPT.8000-3d

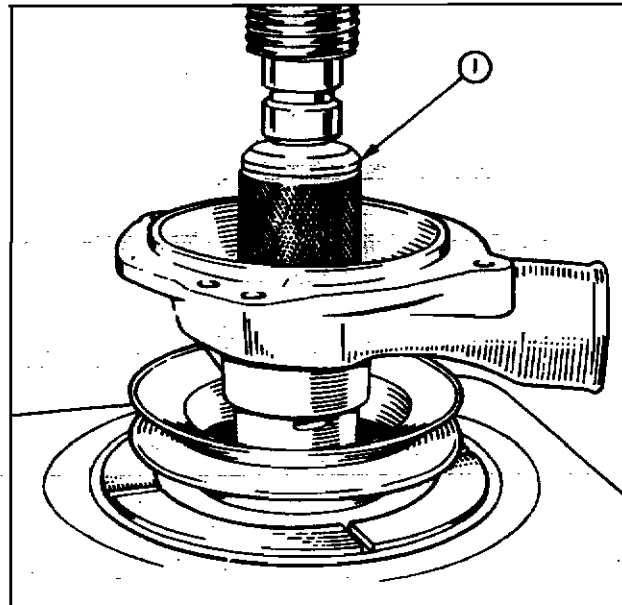


Fig. 11.

- 1 Adaptor CPT.8000-3k

### THERMOSTAT (Normally Aspirated & Turbocharged Engines)

A wax type thermostat is located beneath the water outlet on the cylinder head or, in the case of the Turbo-plus engine in the external pipework.

### TWIN THERMOSTATS

Some 6 cyl. engines are fitted with twin thermostats, fitted in a housing bolted to the water outlet on the cylinder head.

When the coolant is cold, the thermostat is in the closed position and the by-pass restricts the circulation to the block and cylinder head. When the thermostat is fully open, the full circulation through the block, cylinder head and radiator takes place.

Use of a wax type thermostat ensures that its operation, although fully sensitive to temperature changes, remains unaffected by pressure developed within the cooling system.

### To Remove the Thermostat: (Normally Aspirated and Turbocharged Engines)

1. Drain the cooling system as previously described and disconnect the hose from the water outlet.
2. Remove the water outlet connection after unscrewing the two bolts securing the water outlet to the cylinder head, lift off the gasket and extract the thermostat from the recess in the cylinder head.

Where twin thermostats are fitted, remove them from the special housing; if they are of different operating temperatures, note their relative positions in the housing.

**Testing the Thermostat:**

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

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

The thermostat should commence to open and be fully opened at the temperatures shown in the specifications at the end of this section.

All 2704ET Industrial engines are now fitted with a 71°C (160°F) thermostat (Part No. 715F-8575-AAA) in order to assist coolant flow.

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

**To Replace:**

1. Locate the thermostat in the recess at the front of the cylinder head, fit a new gasket and replace the water outlet connection, securing with two bolts and spring washers.

Where twin thermostats are used, replace them in the special housing.

**NOTE:** Where twin thermostats of different operating temperature are fitted, they must be replaced in their original positions — the lower temperature by-pass thermostat nearest to the manifold. Later housings have an additional rib, making the two thermostats non-interchangeable.

2. Reconnect the top hose, refill the cooling system and check for water leaks.

A corrosion inhibitor is now available for use with plain water as an alternative to anti-freeze or where the anti-freeze concentration is below the specified limit.

The inhibitor will protect water pumps, core plugs, thermostat housings and radiators against corrosion when used at the correct concentration.

**NOTE: THE INHIBITOR IS NOT AN ANTI-FREEZE.**

Add the corrosion inhibitor concentrate to the vehicle coolant in the ration of 2½% by volume, i.e., 1 part inhibitor to 39 parts water. This proportion has the anti-corrosion properties of a 50% concentration of Motorcraft Anti-freeze-Plus.

**Weak Anti-Freeze Concentration**

The inhibitor may be added to the vehicle coolant to supplement the anti-freeze corrosion resisting properties as follows:—

- a) Test the anti-freeze concentration using a suitable hydrometer
  - A reading of 1080 represents a 50% anti-freeze concentration
  - A reading of 1040 represents a 25% anti-freeze concentration
  - A reading of 1000 represents plain water.

If the hydrometer reading is 1080 or above, no inhibitor need be added. If the hydrometer reading is 1040 add half the quantity required for plain water.

The addition of the inhibitor will not increase the frost protecting properties of the coolant.

- b) Calculate the amount of inhibitor required for plain water as described in 1.

**Note:** Adding the inhibitor will not alter the hydrometer reading, therefore, a note should be made on the vehicle records and a label attached to the cooling system filler cap recording the date and amount of inhibitor added. The cooling system should be topped up with water/inhibitor mixture consisting of 1 part inhibitor to 39 parts of water.

The effective life of the inhibitor is similar to that of Motorcraft Anti-freeze-Plus (2 years), therefore the cooling system should be drained and refilled with a plain water/inhibitor mixture after this period of time.

**Parts Required**

Description	Part No.	Finis Code	Quantity
Corrosion Inhibitor	A77SX 9100 AA	5003912	0.25 litre
Corrosion Inhibitor	A77SX 9100 BA	5003913	1.00 litre

## FAN

The fan is secured to the water pump hub on the crankshaft by four bolts and spring washers, and 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 and cause them to run out of true.

## FAN BELT

V-belts are used to drive the alternator or generator and water pump from the crankshaft pulley, the fan being mounted on the water pump. Dual fan belts are fitted as standard on turbocharged engines.

Correct fan belt adjustment is important, otherwise the belt itself may be damaged or undue strain placed upon the alternator and water pump bearings.

There is provision for fan belt adjustment by moving the alternator or generator on its mounting, and it is important that this adjustment be released when a new fan belt is to be fitted, otherwise any attempt to strain a new belt over the sides of the pulley, using a lever, can easily cause damage to the belt or pulleys.

### To Adjust the Fan Belt Tension:

The correct tension of the fan belt is such that when the belt is alternately pushed and pulled at a point midway between the alternator or generator and water pump pulleys, a total movement of 13mm (0.5 in) is obtained without using undue pressure.

1. Slacken the alternator or generator adjustment locking screw and the mounting bolt.
2. Move the alternator or generator towards or away from the engine as necessary until the correct belt tension is obtained, testing the tension midway between the alternator and water pump pulleys.
3. Lock the adjustment locking screw and tighten the alternator or generator mounting bolt.

# SPECIFICATIONS

## LUBRICATION SYSTEM

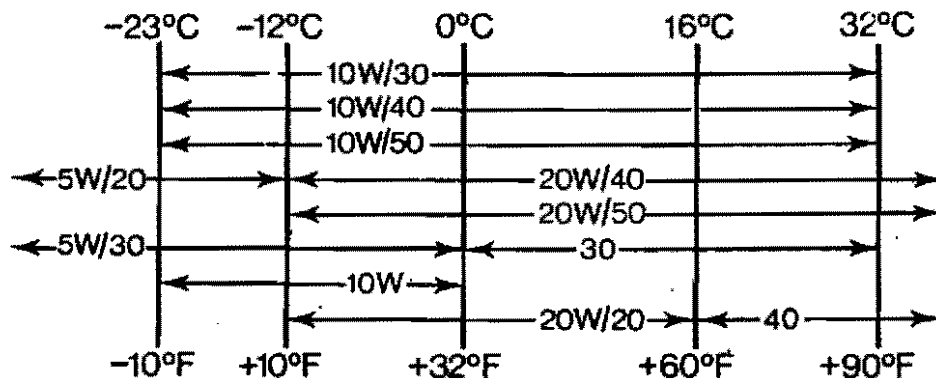
	2701E/ 2701C	2711/12E	2703E/ 2703C/ 2713E	2704E/ 2704C/ 2714E	2704ET	Turbo Plus
Sump Capacity (inc. filter) Front, Rear or Shallow Well	9.1 Litres (16 Pints)	9.1 Litres (16 Pints)	13.7 Litres (24 Pints)	13.7 Litres (24 Pints)	13.7 Litres (24 Pints)	23.4 Litres (41 Pints)  Including External Oil Pump
High Inclination	13.7 Litres (24 Pints)	12.2 Litres (21½ Pints)	20 Litres (35 Pints)	20 Litres (35 Pints)	20 Litres (35 Pints)	
High inclination with loose deep well	11.38 Litres (20 Pints)	—	—	—	—	—
Oil Filter		External Full Flow Type With Replaceable Element				
Oil Filter Capacity	0.85 Litres (1.5 Pints)	0.85 Litres (1.5 Pints)	1.14 Litres (2 Pints)	1.14 Litres (2 Pints)	1.14 Litres (2 Pints)	1.14 Litres (2 Pints)
Oil Temperature	74°–116°C (165°– 240°F)	74°–116°C (165°– 240°F)	74°–116°C (165°– 240°F)	74°–116°C (165°– 240°F)	74°–116°C (165°– 240°F)	86°C (187°F)
Oil Drain Points	PLUG AT BASE OF SUMP (TWO PLUGS ON THE HIGH INCLINATION SUMP)					

\* N.B. Imperial pints quoted

## GRADE OF LUBRICANT 2710 RANGE

The oil must meet Ford Specification SPM-2C-9104A and must be of a suitable viscosity as shown on the chart below to suit the ambient temperature range.

Series III oils to Ford Specification SM-2C-1017A may also be used (Except in Stop/Start conditions).



Turbocharged 2704ET engines (except turbo-plus)

Warning: Only Series III oils or oil that meets Ford Specification SM-2C-1017A or ESE-M2C-87A/88A may be used.

Ford manufacture an oil to the above specification. The following oils are also suitable

Amoco 300  
B.P. Energol DS3  
Castrol Deusol CRD  
Duckham Deenol 3  
Essolube D3

Fina Solco S3  
Mobil Delvac 1300  
Regent Ursa  
Shell Rimula

Above 32° C (90° F)  
32°-0° C (90°-32° F)  
Below 0° C (32° F)

Grade SAE 30  
Grade SAE 10 or 20  
Grade SAE 10

Turbo-plus Engines

The recommended lubricant for all conditions likely to be encountered in service is Shell Rimula CT 20/20W Series III.

Pressure Feed Bearings  
Metered Feed  
Timing Gear Lubrication

Main, Camshaft and Connecting Rod big ends  
O.H.V. Gear  
Controlled Spray

## OIL PUMP STANDARD

Type

Sliding Vane

Drive Gear Backlash

0.051 to 0.338 mm. (0.002 to 0.0133 in.)

Capacity — 4 cylinder

28.84 litres (6.35 imp. galls.) per min at 1000 rev/min.

— 6 cylinder

36.34 litres (8.00 imp. galls.) per min. at 1000 rev/min.

Pump Body Bore Diameter

15.066 to 15.092 mm. (0.593 to 0.594 in.)

Drive Shaft Diameter

15.0281 to 15.0540 mm. (0.5915 to 0.5925 in.)

Rotor and Vane-End-float

0.127 mm. (0.005 in.)

Rotor to Cam Form Clearance

0.127 mm. (0.005 in.)

Vane to Cam Form Clearance

0.279 mm. (0.011 in.)

Vane Clearance in Rotor

0.127 mm. (0.005 in.)

## OIL PUMP SCAVENGING

Type	Rotor
Capacity – 4 cylinder Pressure Feed	27.90 litres (6.13 imp. galls.) per min. at 1000 rev./min.
Scavenger Feed	30.65 litres (6.74 imp. galls.) per min. at 1000 rev./min.
Capacity – 6 cylinder Pressure Feed	36.34 litres (8.00 imp. galls.) per min. at 1000 rev./min.
Scavenger Feed	40.04 litres (8.80 imp. galls.) per min. at 1000 rev./min.
Inner to Outer Rotor Clearance	0.153 mm. (0.006 in.)
Rotor End Face to Pump Body End Face, Clearance	0.127 mm. (0.005 in.)

## COOLING SYSTEM

Type	Thermo syphon system, thermostatically controlled, Impeller assisted				
Engine	2701E	2701C	2703E	2704E	2704ET
		2711E		2704ET	Turbo Plus
		2712E		2704C	
				2713E	
				2714E	
				2715E	
Engine Coolant Capacity	8.23 Litres	7.54 Litres	10.22 Litres	9.95 Litres	9.95 Litres
Cylinder Head and Block	(14.5 Pints)	(13.25 Pints)	(18 Pints)	(17.5 Pints)	(17.5 Pints)
Operating Temperature	79°C	85°C (175°F)	185°F	88°C (190°F)	88°C (190°F)
Fan Belt Tension	13 mm (0.5 in) total free movement				

## THERMOSTATS

Model	Starts to open	Fully open
2710 Range	75 to 80°C (167 to 176°F)	91°C (196°F)
2710 Range and 2704ET – IND	80.6 to 83.9°C (177 to 183°F)	98°C (208°F)
2704 ET MARINE	79.5 to 83.5°C (175 to 182°F)	93.5 to 96°C (200 to 205°F)

## LOW PROFILE FAN BELTS (2710 Range)

Part No.	Finis Code	Supersedes
Single Belt:		
723F-8620-AEA	1540767	703F-8620-ABA
Twin Belts:		
723F-8A615-AAA	1540764	703F-8A615-AAA
723F-8A615-ABA	1540765	703F-8A615-ABA

# SECTION 3

## FUEL SYSTEMS

N.B. Overhaul and Specification details for the Bosch Injection Pump are given in the publication "Ford 2710 Range Service Supplement – Bosch Fuel Injection Equipment". This may be requested on a Literature Ordering Form in the normal way.

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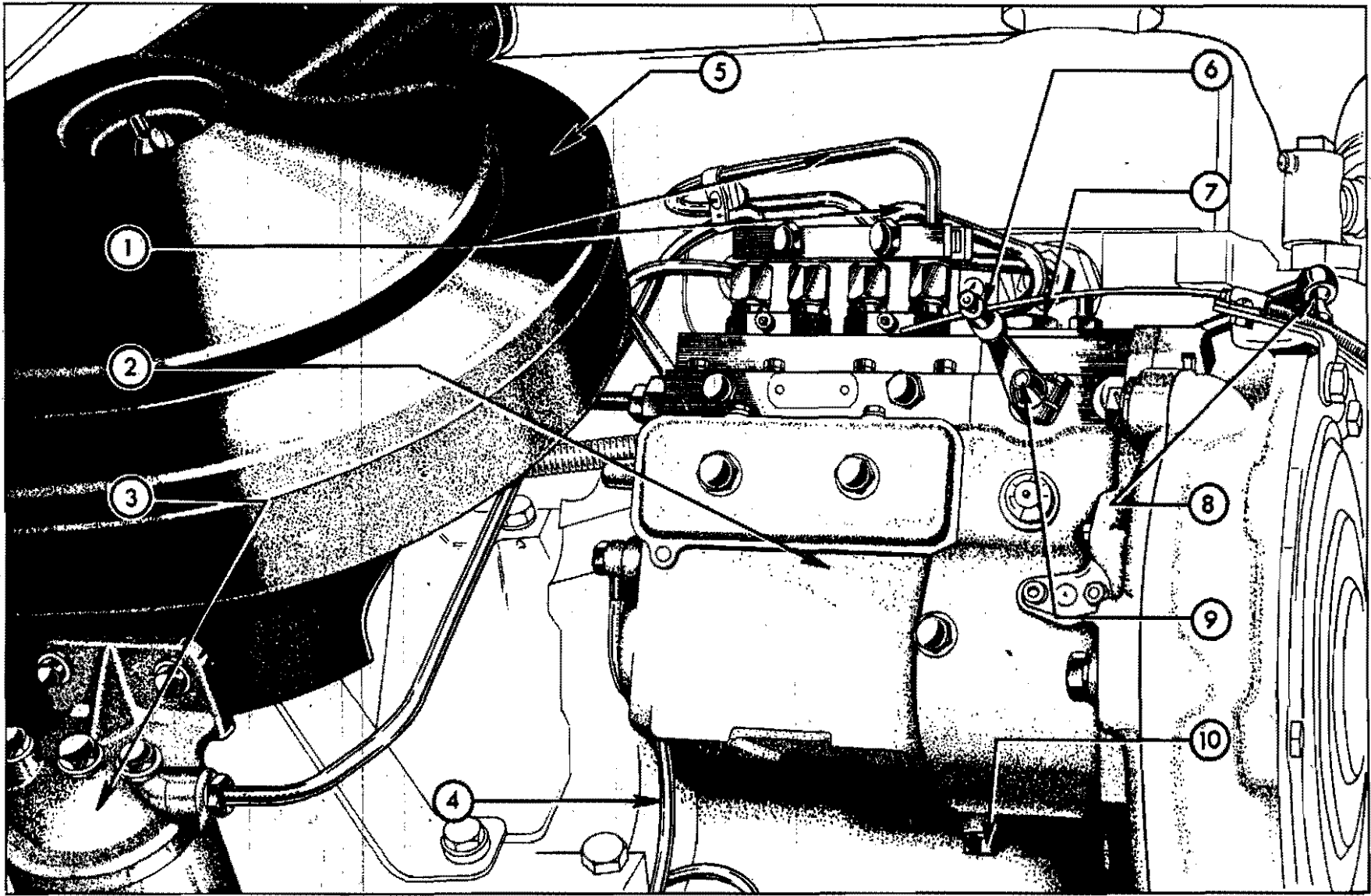


Fig. 1 "MINIMEC" FUEL PUMP IN LOCATION

- |                  |                      |                      |
|------------------|----------------------|----------------------|
| 1 Injector Pipes | 5 Air Cleaner        | 8 Throttle Linkage   |
| 2 Injector Pump  | 6 Stop Control Lever | 9 Excess Fuel Button |
| 3 Fuel Filter    | 7 Filler Plug        | 10 Drain Plug        |
| 4 Overflow Pipe  |                      |                      |



## INTRODUCTION

The fuel system of the 2700 Diesel Engine Range consists of a fuel lift pump, filter, injection pump and injectors.

The standard fuel lift pump is of the diaphragm type and incorporates a hand priming lever to enable the fuel system to be bled.

A high pressure diaphragm type pump is also available and this has a priming plunger for bleeding the fuel system. A suction valve type of high pressure lift pump is also used and this too incorporates a priming plunger.

From the fuel lift pump the fuel passes through a replaceable element-type filter to the injection pump. Fuel at high pressure is then passed in turn, to each of the four hole, long stem type 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 of one of three different types; the "Minimec" injection pump, which has a separate pumping element for each injector, the "D.P.A." distributor type injection pump, which has only one pumping element for all injectors or the Bosch injection pump which has a separate pumping element for each injector. Each pump is mechanically governed.

Where a thermostart is specified, all 2711E engines have been fitted with a thermostart non-return valve since July, 1974. These valves may be identified by a BLUE paint spot on the valve body. Fuel leakage past the non-return valve will cause fuel to drain out of the thermostart reservoir over an extended rest period (i.e. overnight). This allows air to enter the fuel system, resulting in difficult starting. When investigating difficult cold starting, the fuel non-return valve should be checked as follows:

1. Check the fuel system to confirm the presence of air in the fuel lines.
2. Remove the suspect non-return valve from the filter/banjo connections.
3. With the valve held vertical, fill with diesel fuel to the top thread. Roll the ball to break the surface tension. If leakage of fuel occurs within 5 minutes, the valve is defective and should be replaced. If leakage does not occur the valve should be refitted.
4. Fit a new valve to the filter/banjo connection if necessary. Where a fuel pressure relief valve is also fitted, this should be similarly tested, particularly if the original non-return valve is to be refitted.
5. Bleed the fuel system.
6. Start the engine and check for fuel leaks.
7. Re-check the starting performance after an extended rest period.

### PARTS REQUIRED:

Part No.	Description	Finis Code	Quantity
D71DB-9K061-AA	Valve assy.	1556858	1

### 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 carrying out the test procedure on the D.P.A. pump, 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 Specification and Repair Data.

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.**

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# THE SIMMS MINIMEC INJECTION PUMP

## DESCRIPTION

The "Minimec" injection pump (see Fig. 2) is a self-contained unit with a camshaft and governor assembly operating separate pumping elements for each cylinder of the engine.

The pump casing consists of two main parts, an alloy cambox and governor housing, and a steel pump body.

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 (which also acts as a mounting flange for the pump to the engine). Located on an extension of the camshaft at the front of the pump is the governor, which can be either of two types:-

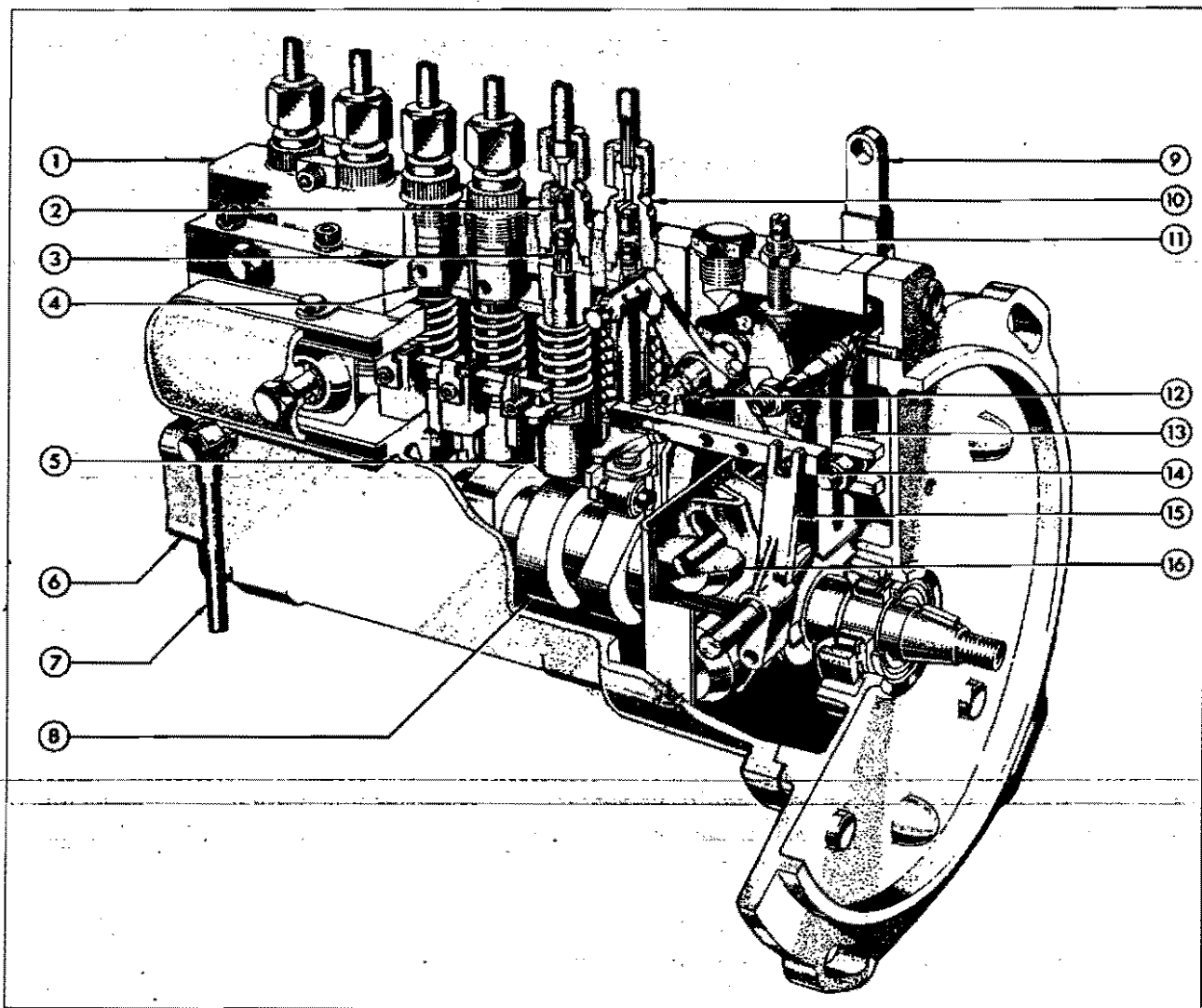


Fig. 2

- |                               |                            |                                       |
|-------------------------------|----------------------------|---------------------------------------|
| 1 Pump Body                   | 8 Camshaft                 | 13 Governor Spring                    |
| 2 Volume Reducer              | 9 Governor Control Lever   | 14 Control Rod                        |
| 3 Delivery Valve              | 10 Delivery Valve Holder   | 15 Rocking Lever                      |
| 4 Pumping Element             | 11 Maximum Fuel Stop Screw | 16 Governor Weight Assembly (GE Type) |
| 5 Roller Tappets              | 12 Excess Fuel Device      |                                       |
| 6 Cambox and Governor Housing |                            |                                       |
| 7 Overflow Pipe               |                            |                                       |

### THE GE TYPE MASS GOVERNOR

This consists of a governor weight assembly located between the flanges of a channel sectioned backplate dowelled and bolted to the camshaft. When the camshaft revolves, the flanges of the backplate cause the weight assembly to revolve also.

The governor weight assembly consists of two spindles each with a roller weight at either end. The spindles are located diametrically opposite one another in the weight carrier, and in the centre of each spindle is a roller which is free to roll on an inclined ramp formed in the weight carrier. The weight carrier itself is attached to a hub which is free to slide axially on the camshaft extension, and when the camshaft revolves, centrifugal force causes the governor weights to fly out from the camshaft. However as the spindles can only move in angled slots formed in the flanges of the weight carrier, the force of the weights moving outwards acts against the back plate causing the weight carrier to move away from the back plate against the action of the governor spring.

The governor spring is a leaf spring pivoted on a cross-shaft, and applies a load to a thrust pad and bearing, thus holding the weight assembly against the backplate. A dumbbell shaped roller bearing assembly pivots in a fork on the throttle lever cross-shaft and bears on one side against the spring, and on the other side against a ramp which on some injection pumps is formed on the inside of the governor housing, other injection pumps have a detachable ramp that is retained by three screws to the governor cover.

The forms of the ramps vary, it is therefore important to select the correct ramp when making a replacement Fig. 3.

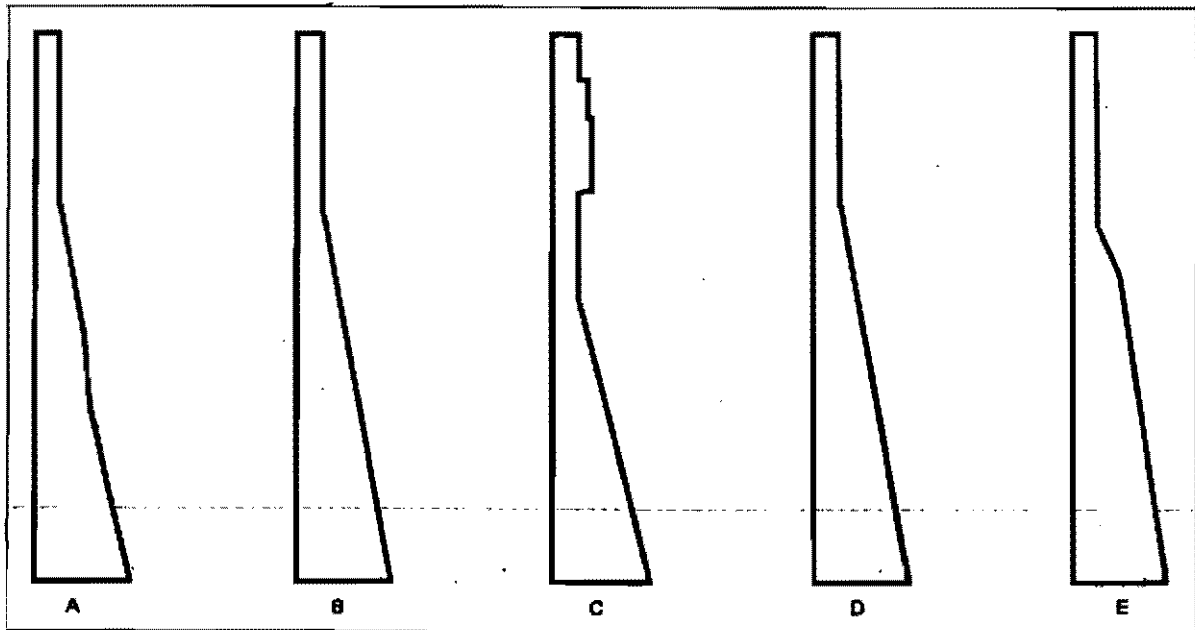


Fig. 3

MAY 1974

THE GE TYPE MASS GOVERNOR (Cont'd.)

The specified height 'X' is obtained by fitting shims between the governor cover and ramp Fig. 4. Shim thickness is 0.29 to 0.34 mm. (0.0114 to 0.0134 in.). Refer to Fig. 5 for specified ramp height. As the throttle lever is moved towards the maximum speed position, the roller bearing is moved away from the governor front face, and applies a greater force to the spring which in turn applied a greater force to the thrust pad and weight carrier assembly, against the effect of the centrifugal force of the governor weights.

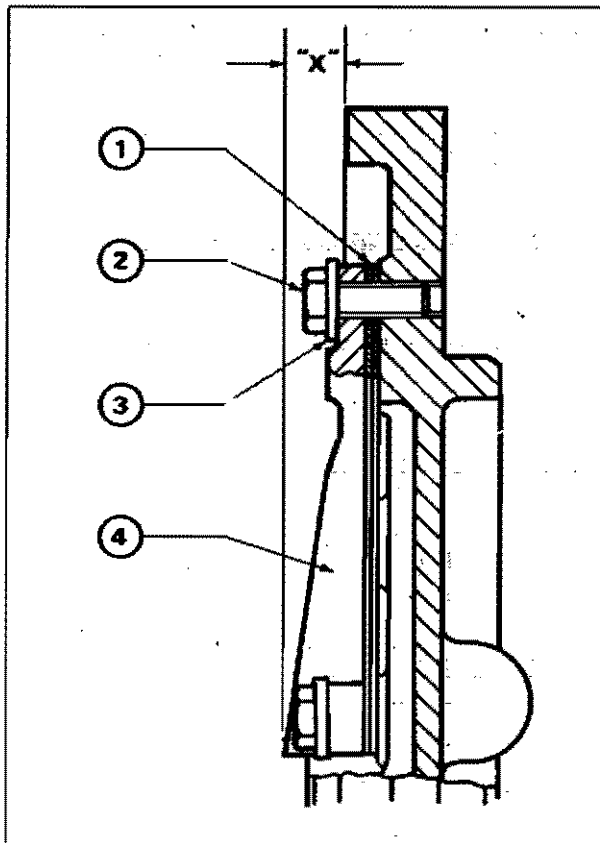


Fig. 4

- 1. Ramp Shims
- 2. Ramp Screw
- 3. Lockwasher
- 4. Ramp

Pump No.	Ramp Height (mm)	Ramp	Pump No.	Ramp Height (mm)	Ramp
P4741	—	Ramp integral part of governor cover	P5078	8.1 – 8.4	D
P4742	—		P5079	7.9 – 8.2	A
P4872	—		P5080	7.9 – 8.2	A
P4873	—		P5084	8.3 – 8.5	A
P4897	6.2 – 6.5	C	P5085	8.3 – 8.5	A
P4899	8.1 – 8.4	A	P5087	6.25 – 6.55	B
P4899/A	7.9 – 8.2	A	P5088	6.25 – 6.55	B
P5012/A	8.1 – 8.4	A	P5089	4.9 – 5.5	C
P5012/B	7.9 – 8.2	A	P5127	7.8 – 8.1	A
P5012/C	7.9 – 8.2	A	P5128	6.7 – 7.1	B
P5021	8.1 – 8.4	A	P5129	7.8 – 8.1	A
P5052	4.9 – 5.5	C	P5130	6.7 – 7.1	B
P5053	4.9 – 5.5	C	P5165	6.2 – 6.5	C
P5054	4.9 – 5.5	C	P5186	8.6 – 8.9	E
P5060	5.4 – 5.8	B	P5229	8.1 – 8.4	D

Fig. 5

## TO REPLACE (Cont'd)

7. Reconnect the injector pipes after ensuring that the olives are in good condition and seating properly.
8. Replace the pipe from the filter to the injection pump and tighten the unions.
9. Reconnect the throttle linkage.
10. Reconnect the stop control, ensuring that the stop control lever is pushed to the off position when the cable is inserted in the stop control lever orifice and the bolt tightened.
11. Reconnect the excess fuel device remote control.
12. Position the air cleaner on its bracket, and insert and tighten the butterfly headed bolt. Attach the manifold air hose and the rocker cover breather to the air cleaner.
13. Bleed the fuel system (see later in this section).
14. Adjust the idling and maximum speeds as outlined.

## TO DISMANTLE

1. Remove the timing gear. Unscrew the retaining nut, if not already removed, holding the gear with wrench Tool No.C.9078. Pull the gear off the taper, using puller Tool No.C.9081 (see Fig. 18). Extract the key.
2. Remove the oil drain plug and drain off the lubricating oil.
3. Remove the retainers (where fitted) and slacken the delivery valve holders, using the special splined socket Tool No. CT.9054.
4. Remove the screws securing the pump body to the housing evenly and lay the pump at an angle to the bench as shown in Fig. 19. Remove the pump body in an arc as shown, so that the plunger arms are disengaged from the control forks.
5. Remove the plungers, springs and lower spring seats from their barrels (Fig. 20) and lay them carefully in the dismantling tray. Tool No. CT.9005, keeping them in their correct positions.

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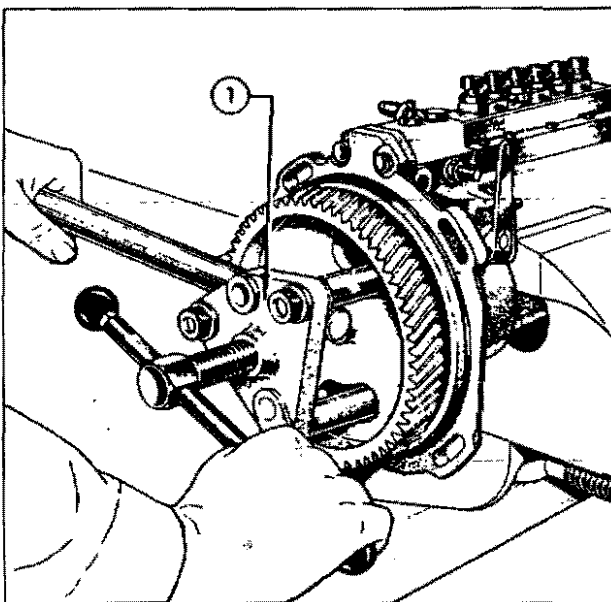


Fig. 18

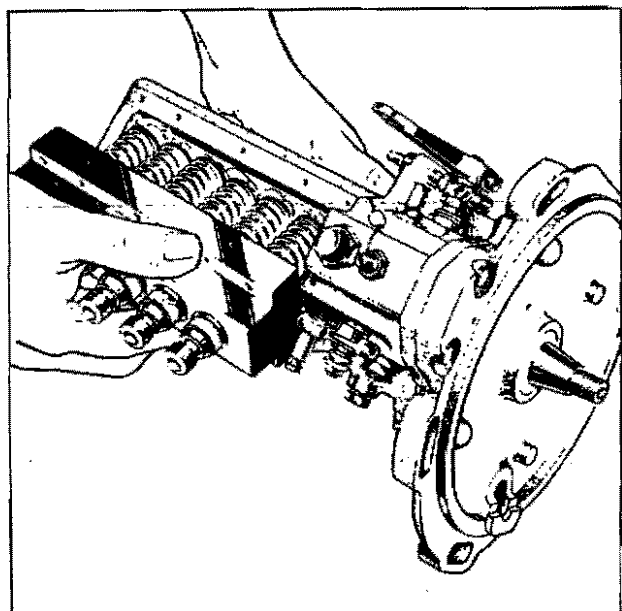


Fig. 19

1 Timing Gear Removal Tool No. C.9081

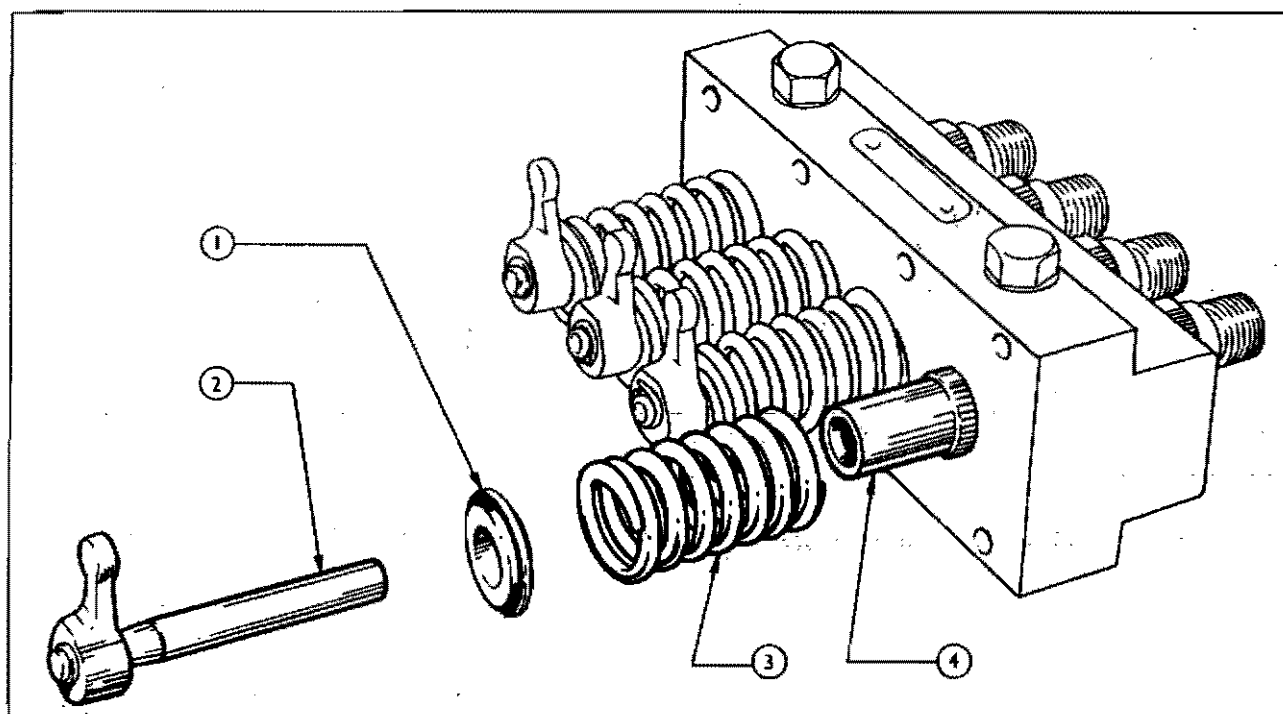


Fig. 20

1 Spring Seat  
2 Plunger

3 Spring  
4 Barrel

**TO DISMANTLE (Cont'd).**

6. Remove the delivery valve holders. Extract the volume reducers, springs and delivery valves.
7. 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 as they are mated parts.

8. Unscrew the two bolts and remove the inspection cover. Remove the screws locating the cover retainer plates and rotate the retainers through 90°, about the axes of the tapped holes, to remove them.

9. 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 (see Fig. 21).

10. Slide the steel "T" pieces from between the tappet bores.

11. It is advisable to check the camshaft endfloat at this stage so that the thickness of shim behind the camshaft bearing inner races may be adjusted, if necessary, when reassembling. Use adaptor, Tool No. CT.9017-1, in conjunction with dial gauge, Tool No. 9017, by screwing the adaptor onto the threaded end of the camshaft and measure the end-float in relation to the pump housing (see Fig. 22).

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

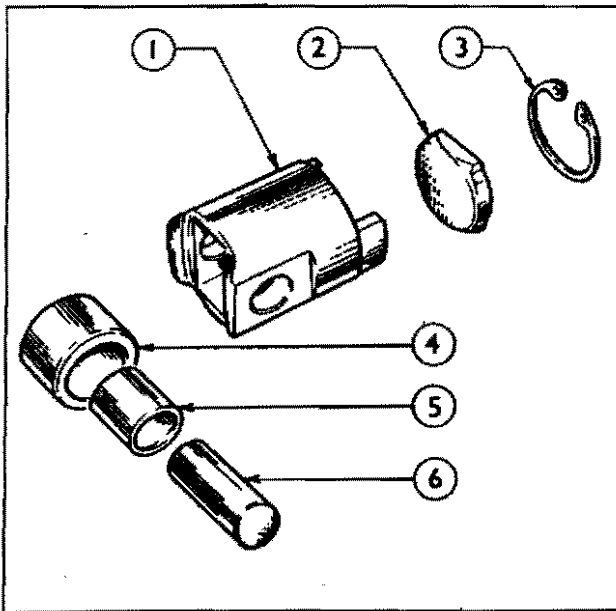


Fig. 21

- |                  |                |
|------------------|----------------|
| 1 Tappet Body    | 4 Cam Follower |
| 2 Phasing Spacer | 5 Inner Roller |
| 3 Circlip        | 6 Tappet Pin   |

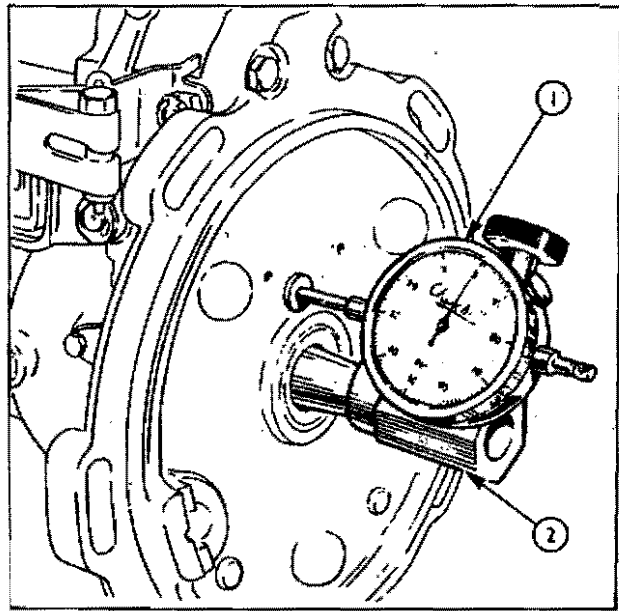


Fig. 22

- |  |
|--|
| 1 Camshaft End-Float Gauge Tool<br>No. CT.9017 |
|--|

**TO DISMANTLE (Cont'd).**

12. Remove the screws securing the mounting flange cover plate to the governor housing and ease the plate from its location.

**NOTE:**—Do not remove ramp from backplate as this is assembled to a critical dimension.

13. Remove the “dumbbell” shaped roller bearing from the throttle control lever cross-shaft fork.

14. Undo the nut on the end of the governor spring cross-shaft. Withdraw the shaft to remove the governor springs.

15. 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.

16. Remove the circlip from the right-hand end of the control lever cross-shaft then remove the washer, “O” ring and oil seal.

17. 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 the shaft is withdrawn from the governor housing.

18. Lift out the camshaft and governor mass as an assembly.

19. Remove the ball and cage assemblies from the bearing inner races on the camshaft on which they are a light push fit.

20. Remove the camshaft bearing inner races using a suitable press, universal taper plate Tool No.370, slave ring Tool No. CT.9056, and adaptors Tool No.CT.6085-1A (see Fig. 23).

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.

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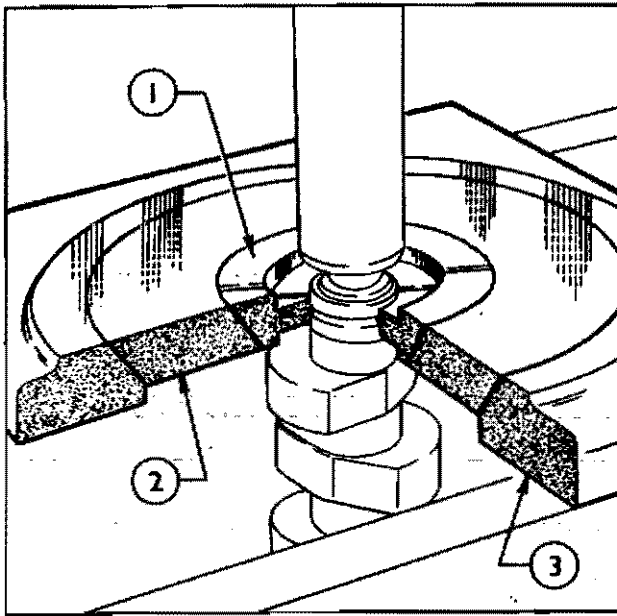


Fig. 23

- 1 Adaptors CT.6085-1A
- 2 Slave Ring CT.9056
- 3 370 Universal Taper Base

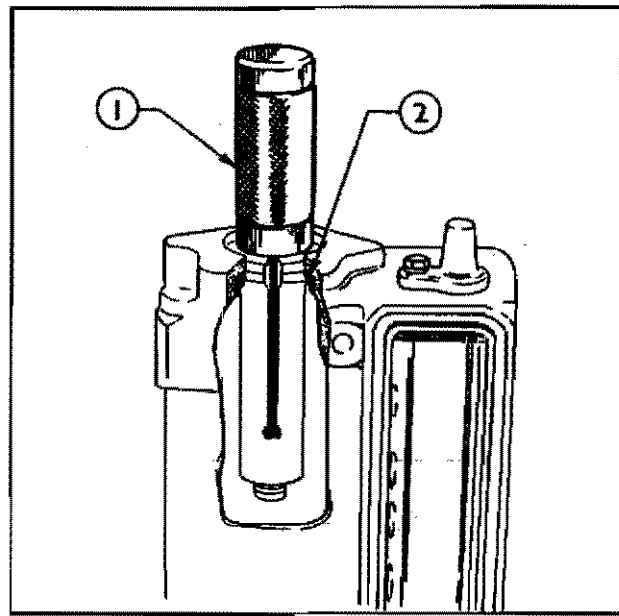


Fig. 24

- 1 Bearing Cup Remover Tool No. CT.9050
- 2 Bearing Cup

**TO DISMANTLE (Cont'd).**

21. For GE Mass Governor:—After removing the front bearing inner race, the oil slinger, governor thrust pad and bearing assembly, together with the weight carrier assembly can be removed from the camshaft. If necessary, straighten the locking tabs on the screws securing the governor backplate to the camshaft, unscrew the screws and remove the governor backplate which is dowelled to the camshaft.

22. For GX Mass Governor:—Slide off the thrust pad (3 in Fig. 13), needle bearing, sleeve (7), thrust race and needle bearing. Unbend the tabs of the two tab washers and remove the four bolts that hold the weight carrier to the camshaft. Remove the weight carrier from the camshaft.

23. Remove the rubber boot from the stop control lever sleeve 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.

24. Tap out the tension pin securing the maximum fuel stop bell crank to the spindle, unscrew the threaded bush from the governor housing and remove the return spring.

25. 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 bell crank and the stop control sleeve.

26. Slide the stop control sleeve and lever assembly into the governor housing and remove.

27. 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.

28. Lever the oil seal out of the front cover, taking care not to damage the bore.



**TO DISMANTLE (Cont'd).**

29. If the rear bearing cup is to be removed from the camshaft housing, first tap out the expansion plug, sealing this bore.

The injection pump is now completely dismantled. Wash all components in a substitute fuel 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.

30. The camshaft bearing cups can be removed by using Tool No. CT.9050 (see Fig. 24) 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 cover plate then drive the assembly thus formed forwards out of the cover plate.

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. Remember, 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 through the locating hole in the bush and extended 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 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.

On later pumps, the bush is held in position by a threaded sleeve covered by a cap nut. In certain applications, a control rod damper is fitted; this replaces the threaded sleeve.

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.

**TO REASSEMBLE**

1. Replace the camshaft bearing cups, using Tool No. CT.9051 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 outside, and use a ring spanner to tighten the nut and draw the bearing into position (see Fig. 25). When fitting the front bearing fit the oil seal at the same time ensuring that the lip is inwards.

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. C.9082 fitted to handle Tool No. 550. This tool ensures that the base of the plug protrudes 3 mm.

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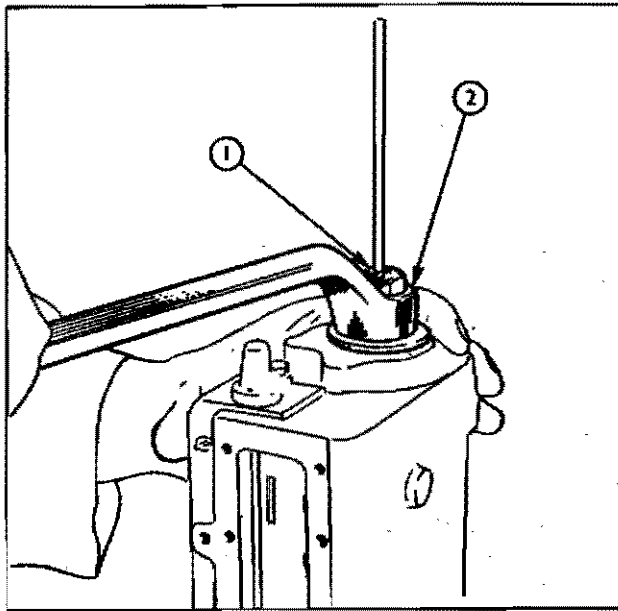


Fig. 25

- 1 Bearing Cup Replacer Tool  
No. CT.9051
- 2 Spanner

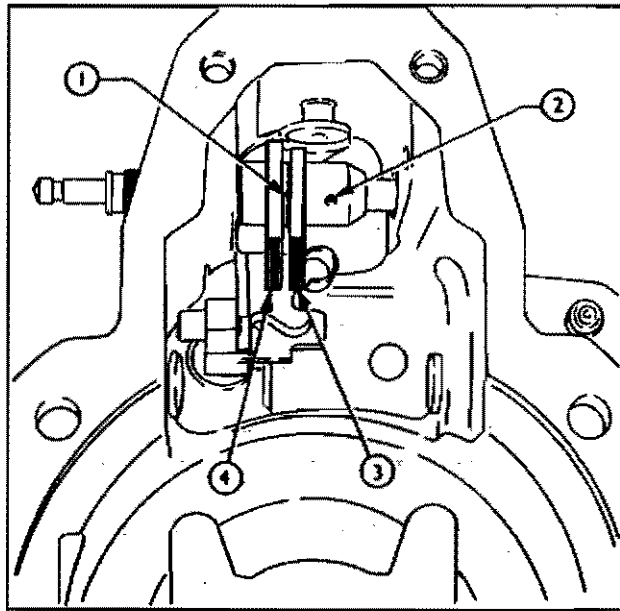


Fig. 26

- 1 Fibre Washer
- 2 Tension Pin
- 3 Maximum Fuel  
Stop Bell Crank
- 4 Stop Control  
Bell Crank

**TO REASSEMBLE (Cont'd)**

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 bell crank 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. 26).

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.

## TO REASSEMBLE (Cont'd).

8. Locate the plain washer, dished washer, another plain washer, a new "O" ring and oil seal on the control lever cross-shaft and then insert it into the governor housing, passing it through 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. Having regard to the camshaft end-float previously obtained, select shims for fitting between the camshaft and the camshaft bearing inner races to give correct end-float. The shims should be divided equally between the front and rear races.

Correct camshaft end-float is 0.51 to 0.127 mm. (0.002 to 0.005 in.) and shims are available in thickness of 0.1 to 0.2 mm. (0.004 and 0.008 in.).

12. Fit half the shims to the camshaft rear end and assemble the rear bearing inner race, using a suitable press, universal taper base Tool No. 370, slave ring Tool No. CT.9056, and adaptors Tool No. CT.6085-1A.

13. For GE Mass Governor:—Assemble the governor backplate locating it on its dowel and securing it to the camshaft with the special high tensile steel screws, using new locking plates with one fitted over the dowel. Bend up the tabs of the locking plates to retain the screws after tightening to 12.2 Nm (1.24 kgf m or 9 lbf ft) torque. Assemble the governor weight carrier assembly thrust bearing, thrust pad and oil slinger to the camshaft. Replace the front bearing inner race together with the remainder of the selected shims, using the same tools as for the rear face (see Fig. 27).

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NOTE:—For all Class 'A' governors and all GX Mass Governors the thrust pad must be assembled with the grooved shoulder toward the drive end of the camshaft.

14. For GX Mass Governor:—Assemble the weight carrier on the camshaft to locate on the dowel. Fit two new tab washers on the four bolts so that the camshaft dowel is covered by one of the tab washers. Tighten the screws to 12.2 Nm (1.24 kgf m or 9 lbf ft), then bend the tabs to lock the screws.

Assemble the needle bearing and thrust race on the camshaft so that the larger diameter face of the thrust race abuts the bearing. Slide the sleeve (15) on camshaft, then the needle bearing and the thrust pad with its identification groove in the position as shown in Fig. 13.

Fit the baffle washer and/or stop disc on camshaft.

15. Fit the bearing and cage assembly to each bearing inner race and insert the camshaft into the camshaft housing.

16. 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.

TO REASSEMBLE (Cont'd)

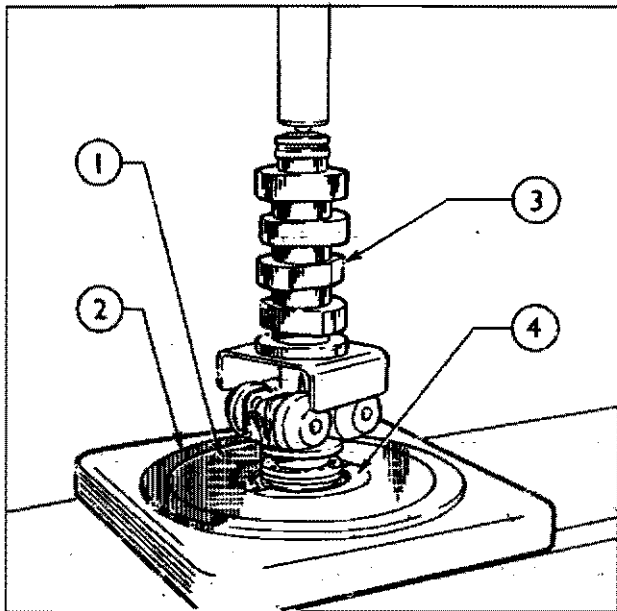


Fig. 27

- 1 Slave Ring CT.9056
- 2 370 Universal Taper Base
- 3 Camshaft
- 4 Adaptors CT.6085-1A

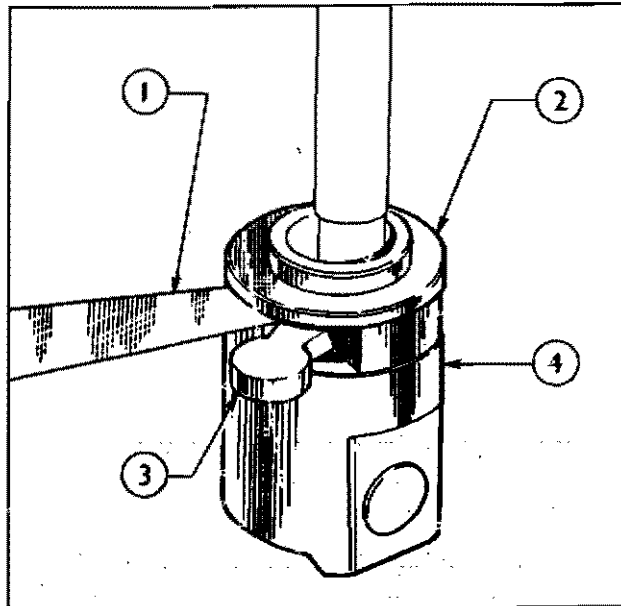


Fig. 28

- 1 Feeler Gauge
- 2 Spring Seat
- 3 Plunger Arm
- 4 Tappet Assembly

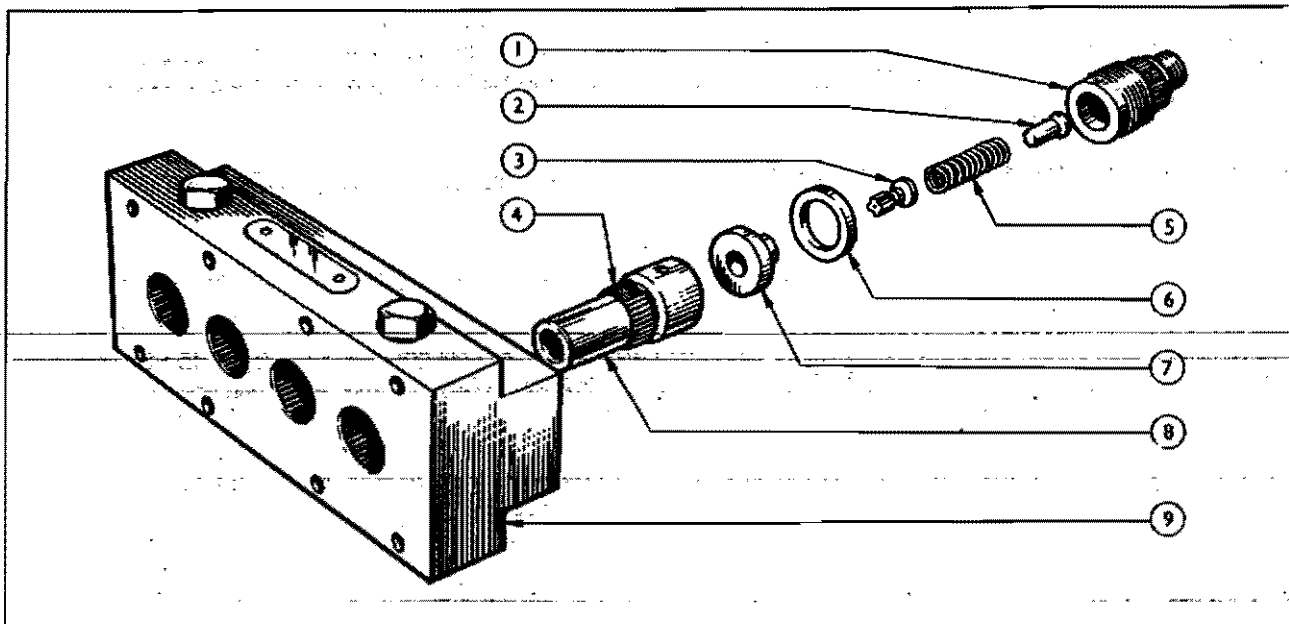


Fig. 29

- 1 Delivery Valve Holder
- 2 Volume Reducer
- 3 Delivery Valve
- 4 Master Spline
- 5 Spring
- 6 Nylon Washer
- 7 Delivery Valve Guide
- 8 Barrel
- 9 Pump Body

**TO REASSEMBLE (Cont'd).**

17. 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 provided, and replace the circlip on the shaft inside the governor housing.
18. Locate the governor spring in the housing with the curved feet of the spring bearing against the thrust pad.
19. 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 and then replace and tighten the nut on the end of the shaft.
20. Replace the mounting flange cover plate on the governor housing, using a new gasket and secure with bolts and spring washers.
21. Check the camshaft end-float (see previously). If this is not within the specified limits it will be necessary to dismantle the camshaft in order to adjust the shim thickness—hence the advisability of checking this end-float when dismantling the pump.
22. Assemble the tappets, using the original components or new phasing spacers if irregularities were noticed when checking prior to dismantling.
23. Pass the plungers through the lower spring seats and holding the seats on the tappet assemblies check that the plungers have free vertical movement of 0.05 to 0.2 mm. (0.002 to 0.008 in.) (see Fig. 28).
24. Fit the steel "T" pieces to their locations in the housing (see Fig. 30), then replace the tappet assemblies, ensuring that they are fully located and not lodged on the "T" pieces.
25. 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 (see Fig. 20). Screw in the delivery valve holders and tighten to a torque of 40.6 to 47.5 Nm (4.15 to 4.84 kgf m or 30 to 35 lbf ft).
26. 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 unit on its side with the plunger arms hanging downwards, engaging the arms with the control forks and then rotating the pump body to the correct position.
27. Secure the pump body to the housing, tightening the eight Allen screws evenly in a diagonal sequence 6.8 Nm (0.69 kgf m or 5 lbf ft) torque.
28. Phase and calibrate the pump as described in the section on Testing and Adjusting (see following section).

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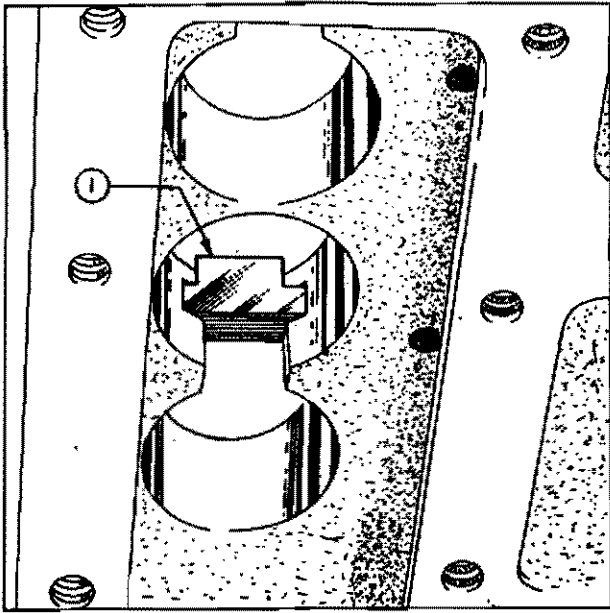


Fig. 30  
1 Tee Piece

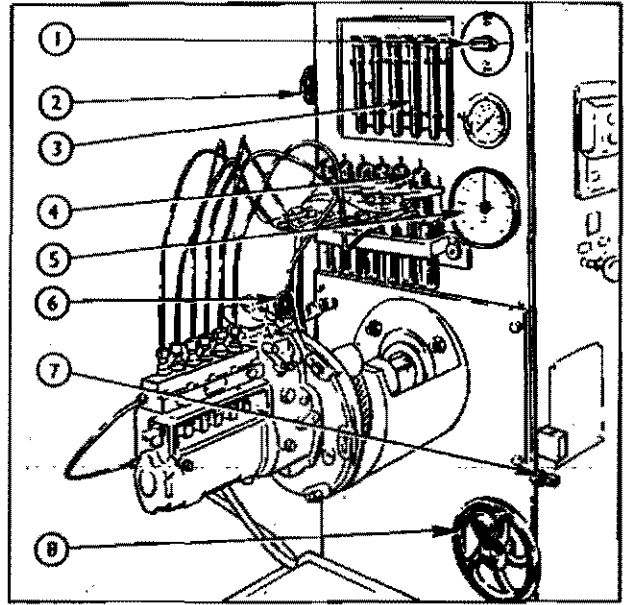


Fig. 31  
1 Reversing Switch  
2 Test Tube Reversing Handle  
3 Graduated Test Tubes  
4 Master Injectors  
5 Tachometer  
6 Fuel Tap  
7 Trip Lever  
8 Speed Control Handle

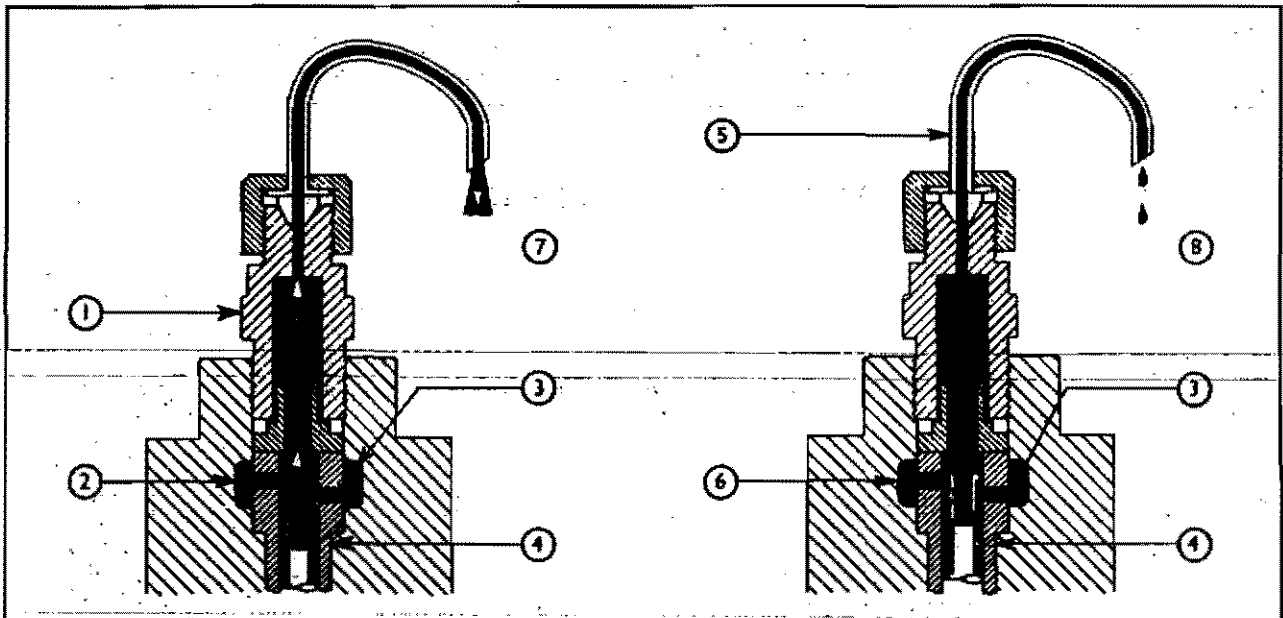


Fig. 32  
1 Delivery Valve Holder  
2 Inlet Port Open  
3 Fuel Gallery  
4 Plunger  
5 Spill Pipe Tool No. CT.9023

6 Inlet Port Closed  
7 Flow from Spill Pipe  
8 Flow from Spill Pipe ceases at point of inlet Port closure

## TESTING AND ADJUSTING THE INJECTION PUMP

The "Minimec" injection pump has a separate pumping element for each cylinder of the engine. The commencement of injection for each successive element must occur at regular intervals relative to each other, 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 also 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.

## PHASING AND CALIBRATION MACHINES

The "Minimec" injection pump has a mechanical governor, and to completely test and adjust a pump of this kind, a variable speed testing machine is necessary (see Figs. 31 and 35).

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

## TEST EQUIPMENT SPECIFICATION

Injectors BKB50SD 19b fitted with a BDN12SD12 nozzle set at 185 atmospheres opening pressure for Normally Aspirated engines and 205 atmospheres opening pressure for Turbocharged engines. Nozzle back leakage must not be less than 10 secs. for a drop from 150 to 100 atmospheres.

High pressure pipes 6 mm by 2 mm by 76.2 cm (30 in.) long. Ensure that the pipes are free from sharp bends, kinks and restricted ends.

Gravity feed with special substitute fuel oil, see Specification and Repair Data. Oil temperature 15.6 to 48.9°C. (60° to 120°F).

## MAINTENANCE

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. Where 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 a substitute test fuel in the calibrating machine as the variation of this fuel is less than that of diesel fuel so that more accurate readings can be obtained. Also the test fuel gives better protection to the master injectors.

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## MASTER INJECTORS

The master injectors must be checked regularly for balance. To carry out this test, mount an in line injection pump on the calibrating machine, connect all pipes and run the machine for at least 15 minutes to allow everything to reach normal operating temperature. It is essential that this is strictly observed when carrying out this test.

Adjust one pump element to deliver 15 c.c. for three consecutive readings, running at 600 rev./min. for 300 shots of fuel. NOTE:—All readings must be taken from the bottom of the meniscus. Connect this pump element to each master injector in turn, using the same pipe and test tube throughout this test. Running at 600 rev./min. collect 300 shots of fuel, allowing 30 seconds after delivery has ceased for the fuel to settle before taking the readings, and 30 seconds for the tube to drain when emptying.

Take the mean of three readings from each injector in turn and the variation between the highest and lowest readings should not exceed 0.3 cc. If the variation exceeds this figure a fresh set of master injectors should be fitted. Do not attempt to balance master injectors by cleaning or pressure adjustment.

## INJECTOR PIPES

After a prolonged period of use on the calibrating machine it may be found that the ends of the injector pipes have closed up slightly thus reducing the bore. This condition will affect the pump delivery and if it is found to exist, the pipes should be renewed. As an emergency measure the ends of the pipes can be cleared by using a 2 mm. diameter drill to a depth of 20 mm. ( $\frac{3}{4}$  in.) and then the pipe bore thoroughly cleaned (preferably with pressure equipment) before refitting.

## MOUNTING THE FUEL INJECTION PUMP ON THE TEST EQUIPMENT

1. Remove the timing gear retaining nut, holding the gear with wrench Tool No.C.9078. If the gear has been removed, fit the woodruff key and locate the gear on the camshaft taper. Fit the special drive adaptor supplied by the equipment manufacturer.
2. Mount the pump securely in position on the testing machine, using the brackets available from the equipment manufacturer.
3. Connect the fuel supply pipe from the test equipment to the fuel inlet on the pump body.
4. Fit cleaning pipe Tool No.CT.9001A (4 cyl.) or CT.9002A (6 cyl.) to the delivery valve holders.
5. Fill the injection pump governor housing with the correct amount of engine oil. DO NOT OVERFILL.
6. Turn on the fuel tap, slacken the two bleed screws and allow the fuel to flow from them. Tighten the bleed screws, starting with the one nearest to the fuel inlet, when all air bubbles in the fuel have disappeared.
7. Run the pump for 5 minutes to flush it through, discharging the fuel to waste.

If the pump is fitted with a control rod damper, the adjusting screw should be turned fully anti-clockwise and locked before attempting to calibrate the pump.



## 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 (where fitted). Unscrew the holders using socket Tool No. CT.9054 and extract the volume reducers, springs and delivery valves. Remove each valve guide by inserting a valve guide remover Tool No. CT.9022 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.

Connect the injection pump to the master injectors and run at 600 rev./min. for 10 minutes to stabilise delivery.

The efficiency of each element may now be checked. Run the pump at 600 rev./min. 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 rev./min. and collect a further 200 shots, again note the readings in each test tube.

If the difference between the readings at 600 and 200 rev./min. in any test tube exceeds 2.7 cc then this indicates that the element is worn and should be replaced if the injection 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 rev./min. and collect 200 shots noting readings 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.

Check the phasing as described below, noting any inaccuracies which may exist to enable the phasing to be rectified.

If the delivery valves and/or phasing spacers are changed the injection pump must be recalibrated.

If the phasing is correct and the pump delivery is within limits, check the governor operation. The injection pump is now, in practice, fit for further service.

## PHASING

Phasing is an adjustment whereby each successive element of the pump is timed to commence injection at the correct angle relative to the preceding one. In a four-cylinder pump this is 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 the engine firing order sequence, i.e. 1, 2, 4, 3 (4 cyl.), or 1, 5, 3, 6, 2, 4 (6 cyl.).

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## 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:—

In Fig. 32 the L.H. view shows 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.

When the camshaft is rotated, the plunger rises until eventually it covers the inlet port, as shown in the R.H. 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 2.9 and 3.1 mm. (0.114 and 0.122 in.). This stroke should be checked for No. 1 element to ensure correct injection characteristics and may be measured by using camshaft end-float gauge Tool No. CT.9017 mounted on plunger head clearance gauge Tool No. CT.9076A. 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 on No. 1 element and remove the valve, spring and volume reducer. Fit a plunger head clearance gauge Tool No. CT.9076A and tighten to a torque of 40.6 to 47.5 Nm (4.15 to 4.84 kgf m or 30 to 35 lbf ft). Locate the spindle in the tool and fit the camshaft end-float gauge Tool No. CT.9017 so that the barrel rests on the spindle upper end (see Fig. 33). Do not overtighten the thumb screw or plunger movement will be restricted.
2. Ensure that the driving belt on the calibrating machine is fitted to the 200 rev./min. 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 until No. 1 plunger is at the bottom of its stroke. Depending on the type of 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.

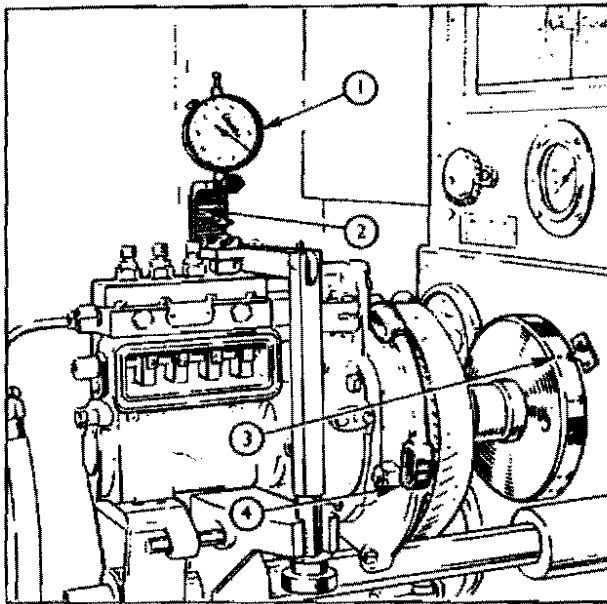


Fig. 33 1 Camshaft End-Float Gauge  
Tool No. CT.9017  
2 Plunger Head Clearance Gauge  
Tool No. CT.9076A  
3 Phasing Marks  
4 Timing Tool No. C9077

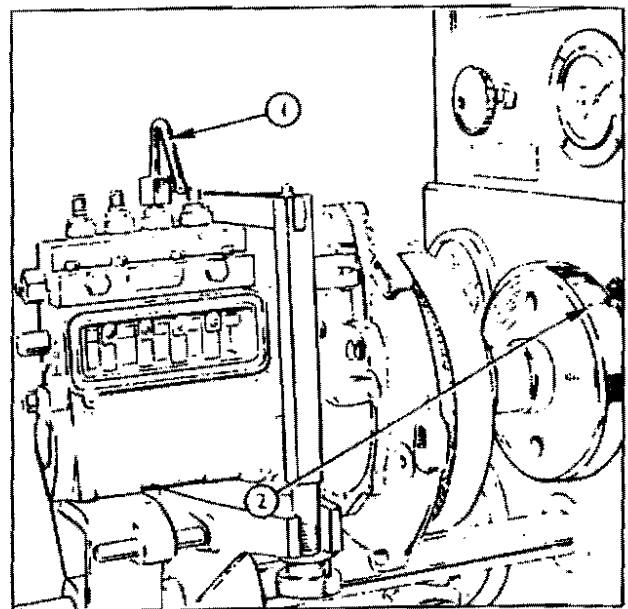


Fig. 34 1 Spill Pipe Tool No. CT.9023  
2 Phasing Marks

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 2.9 and 3.1 mm. (0.114 and 0.122 in.). If the stroke is incorrect, fit a thinner phasing spacer to increase and a thicker phasing spacer to decrease the stroke.

After checking a phasing spacer, check the plunger arm clearance, see "To Reassemble", operation 23.

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 in No. 1 element phasing spacer.

8. At the point of inlet closure, set the graduated phasing ring to 0 (see Fig. 33).

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 phasing closure must always be ascertained when the plunger is rising.

9. Insert the timing Tool No. C.9077 in the front flange of the injection pump and locate the spring loaded plunger in the timing mark on the rear face of the gear. Check that for No. 1 element the timing mark on the gear is within  $\pm 2^\circ$  of the point of inlet port closure. When a new gear is fitted it can be marked by striking the timing tool plunger with the pump set in this position.

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 51.5 to 57 Nm (5.26 to 5.81 kgf m or 38 to 42 lbf ft).

## PHASING THE REMAINING ELEMENTS

1. Remove the delivery valve, spring and volume reducer from next element in the firing order sequence, i.e. No. 2 (4 cyl.) and No. 5 (6 cyl.). Tighten the delivery valve holder to 51.5 to 57 Nm (5.26 to 5.81 kgf m or 38 to 42 lbf ft) torque and fit the spill pipe Tool No. CT.9023 (see Fig. 32).

**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 either 60° for a 6 cyl. pump, or 90° for the 4 cyl. type. A limit of plus or minus 1 degree is permitted.

3. If the phasing is outside of 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 their barrels (see "To Dismantle").

2. Lift out the tappets one at a time.

3. Remove the phasing spacers after extracting the circlip with circlip pliers Tool No. 7065—D. There are five thicknesses of spacer available in steps of 0.1 mm. (0.004 in.), which affect the phasing in each case approximately ½ degree see "Specification and Repair Data".

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 (see "To Reassemble", operation 23) when phasing spacers are changed.

After changing phasing spacers, ensure that there is 1.5 to 2 mm. (0.059 to 0.079 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 Tool No. CT.9076A and the camshaft end-float gauge Tool No. CT.9017 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 fuel is supplied to the pump gallery 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 set of test tubes, after first disregarding an initial set of readings. This will provide constant conditions and ensure greater accuracy.

To ensure accurate pump calibrations it is essential that the master injectors are maintained as an accurately balanced set, and checked regularly for this condition.

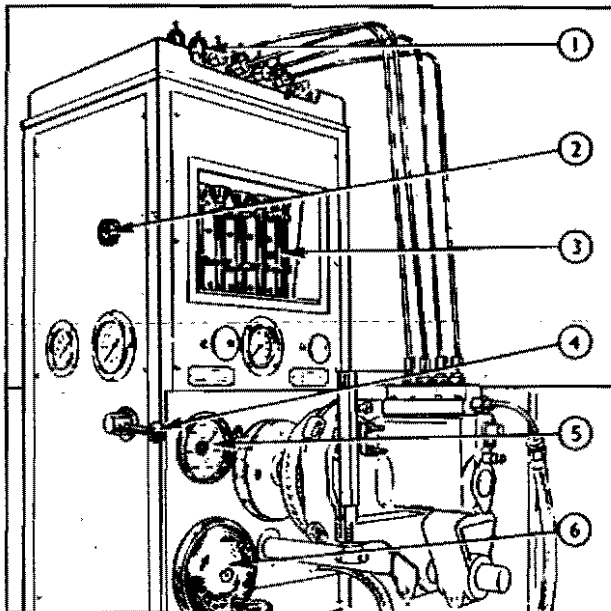


Fig. 35 1 Master Injectors  
2 Test Tube Reversing Handle  
3 Graduated Test Tubes  
4 Trip Lever  
5 Tachometer  
6 Speed Control Handle

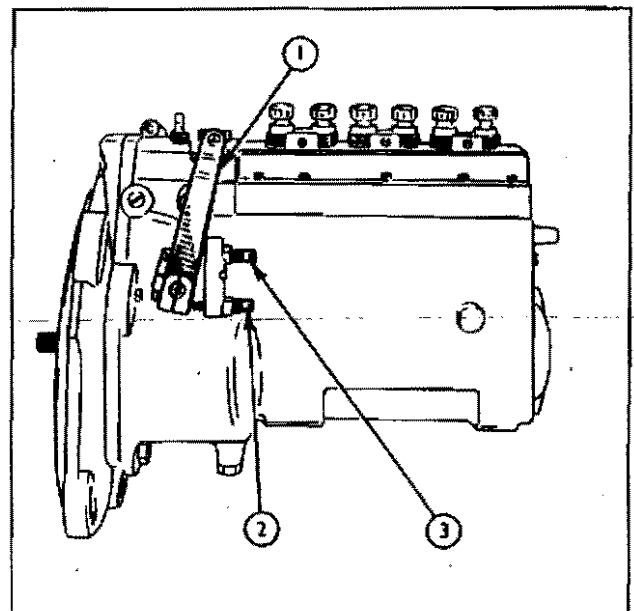


Fig. 36 1 Governor Control Lever  
2 Maximum Speed Stop Screw  
3 Idling Stop Screw

## CALIBRATION (Cont'd)

Calibrate the injection pump as follows:—

1. Connect the test equipment injector pipes to the master injectors and the injection pump delivery valve holders (see Fig. 35).
2. Run the calibrating machine at 600 rev./min. 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 (4 cyl.) or No. 6 control fork (6 cyl.) 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 so that the delivery from the adjusted element, is as shown in the table below.

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 had its own operating instructions, but generally the trip mechanism will cut off at 100 automatically unless the trip lever is operated a second time.

Pump Part Number Ford	Supplier	Volume for 200 Shots (cc with BDN12SD12) nozzles	Calibration Speed RPM	Idling RPM 3 cc + 0.8 cc
<b>Automotive</b>				
2701E-9A543-F	P4873/A	11.2 – 11.4	600	250
2703E-9A543-F	P4872/C	9.8 – 10.0	600	250
2704E-9A543-T	P4872/A	11.2 – 11.4	600	250
2704E-9A543-W	P4897/A	14.4 – 14.6	600	250
713F-9A543-GBA	P4897/1A	14.4 – 14.6	600	250
713F-9A543-GBB	P4897/A2			
703F-9A543-ABA	P5052/B	9.8 – 10.0	600	250
703F-9A543-ABB	P5052/1B			
703F-9A543-ABC	P5052/2B			
703F-9A543-BBA	P5053/B	8.7 – 8.9	600	500
703F-9A543-BBB	P5053/1B			
703F-9A543-BBC	P5053/2B			
703F-9A543-CBA	P5054/B	9.8 – 10.0	600	500
703F-9A543-CBB	P5054/1B			
703F-9A543-CBC	P5054/2B			
703F-9A543-CKB	P5089/1	9.0 – 9.2	600	500
703F-9A543-CKC	P5089/2			
703F-9A543-CKD	P5089/3			
<b>General Purpose</b>				
2701E-9A543-C	P4741/1	11.2 – 11.4	600	500
2703E-9A543-C	P4742/1	11.2 – 11.4	600	500
2704E-9A543-AC	P4742/1A	11.2 – 11.4	600	500
693F-9A543-GBA	P5060/1A	14.8 – 15.0	600	250
693F-9A543-GBB	P5060/2A			
693F-9A543-GBC	P5060/3A			
703F-9A543-AFA	P5087	9.8 – 10.0	600	250
703F-9A543-AFB	P5087/1			
703F-9A543-AFC	P5087/2			

## CALIBRATION (Cont'd)

Pump Part Number Ford	Supplier	Volume for 200 Shots (cc with BDN12SD12) nozzles	Calibration Speed RPM	Idling RPM 3 cc ± 8cc
<b>General Purpose (Cont'd)</b>				
703F-9A543-ARA	P5128	13.3 – 13.5	600	250
703F-9A543-ARB	P5128/2B			
703E-9A543-ARC	P5128/3B			
703F-9A543-BCA	P5088/A	8.7 – 8.9	600	250
703F-9A543-BCB	P5088/1A			
703F-9A543-BCC	P5088/2A			
703F-9A543-CFA	P5088	9.8 – 10.0	600	250
703F-9A543-CFB	P5088/1			
703F-9A543-CFC	P5088/2			
703F-9A543-CMA	P5130/1	11.0 – 11.2	600	250
703F-9A543-CMB	P5130/2			
703F-9A543-CMC	P5130/3			
<b>Class 'A'</b>				
2701E-9A543-G	P4899	11.2 – 11.4	600	500
2703E-9A543-G	P5012	9.8 – 10.0	600	500
2704E-9A543-AD	P5012/A	11.2 – 11.4	600	500
703F-9A543-ANA	P5127	12.8 – 13.0	600	500
703F-9A543-ANB	P5127/1			
703F-9A543-ANC	P5127/2			
713F-9A543-BAA	P5012/2	11.2 – 11.4	600	500
713F-9A543-BAB	P5012/3			
703F-9A543-CLA	P5129	11.9 – 12.1	700	500
703F-9A543-CLB	P5129/1			
703F-9A543-CLC	P5129/2			
2704E-9A543-Y	P5021/1	14.4 – 14.6	600	500
693F-9A543-GAA	P5078	16.8 – 17.0	1100	600
<b>Combine Harvester</b>				
2701E-9A543-H	P4899/A	12.0 – 12.2	800	500
693F-9A543-AAA	P5079	12.3 – 12.5	1000	525
2703E-9A543-H	P5012/B	11.2 – 11.4	800	500
693F-9A543-BAA	P5080/A	9.5 – 9.7	1000	525
2704E-9A543-AE	P5012/C	12.0 – 12.2	800	500
693F-9A543-CAA	P5080	12.3 – 12.5	1000	525
703F-9A543-AJA	P5084/1A	11.5 – 11.7	1000	600
723F-9A543-AAA	P5084/2B	12.9 – 13.1	1000	600
723F-9A543-AAB	P5084/3B			
703F-9A543-BEA	P5085/B	10.2 – 10.4	1000	600
703F-9A543-BEB	P5085/2B			
703F-9A543-BEC	P5085/3B			
703F-9A543-CJA	P5085/C	11.5 – 11.7	1000	600
703F-9A543-CJB	P5085/2C			
703F-9A543-CJC	P5085/3C			
713F-9A543-CAA	P5186	13.6 – 13.8	1200	550
713F-9A543-CAB	P5186/1			
713F-9A543-CAC	P5186/2			

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**CALIBRATION (Cont'd)**

Pump Part Number Ford	Supplier	Volume for 200 Shots (cc with BDN12SD12) nozzles	Calibration Speed RPM	Idling RPM 3 cc ± 8 cc
<b>Combine Harvester (Cont'd)</b>				
693F-9A543-GAA	P5078	16.8 – 17.0	1100	600
693F-9A543-GAB	P5078/1			
693F-9A543-GAC	P5078/2			
723F-9A543-GAA	P5229	Refer to page 33r for calibration and testing procedure.		
743F-9A543-AAA	PES4A85D210 RS 2378	11.3 – 12.5	1000	550
743F-9A543-BAA	PES6A85D210 RS 2378Z	9.2 – 10.4	1000	550
743F-9A543-CAA	PES6A85D210 RS 2379	10.6 – 11.8	1000	550
<b>Marine Turbocharged</b>				
693F-9A543-JAA	P4897/C	14.8 – 15.0	600	250
693F-9A543-JAB	P4897/1C			
693F-9A543-JAC	P4897/2C			
693F-9A543-KAA	P4897/B	17.4 – 17.6	1200	250
693F-9A543-KAB	P4897/1B			
693F-9A543-KAC	P4897/2B			
713F-9A543-AAA	P5165/1	17.7 – 17.6	1200	275

Static Spill Timing for all Engines as indicated on the plate attached to the injection pump.

- Seal the maximum fuel stop screw after tightening the locknut.
- 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 the calibration speed.

Move the forks towards the governor to decrease, and away from the governor to increase, the fuel delivery.

Excess Fuel Delivery. At 100 rev./min. when the excess fuel service is operated and the control lever is set to the maximum speed position, fuel delivery from all elements should be 21 to 25 cc for 200 shots.

**Idling**

Run the injection pump at the specified rev./min. (see Table) with the governor control lever in the idling position. Adjust the idling stop screw to obtain an average fuel delivery of 3 cc for 200 shots from all elements, with a maximum variation of 0.5 cc between elements.

Fuel Cut-off. With the pump running at the specified rev./min. in the idling position operate the stop control lever. Fuel delivery, from all elements must cease just before the control rod reaches its limit of travel. The control rod should return immediately and delivery commences, when the stop control is returned to the run position.

Check that the specified rev./min., all elements cease to deliver when the control rod is 1 mm from the end of its travel.

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 pins.



**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 fitted.
  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, this should be as in the table below. Adjust the maximum speed stop screw if incorrect. 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. This should occur at the fuel delivery cut-out speed as in the table below.
- 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. Excessive variation in the speed will indicate stiffness in the governor control rod mechanism. If the governor operation is satisfactory, tighten the maximum speed stop locknut.
  5. Where the injection pump is fitted with a control rod damper, run pump at maximum 'no load' speed.
  6. Turn the damper adjusting screw clockwise to obtain an increase of 10 rev/min, on the speed recorded in paragraph 5.
  7. Turn the adjusting screw three-quarters-of-a-turn (270°) anti- (counter) clockwise, and lock in that position with the locknut. Check the engine speed through its entire range, then stop engine.
  8. Finally replace and lock the damper unit outer cover.

Ford	Pump Part No. Supplier	Gov. Spring Colour Code	Gov. Mass	Engine No-Load Speed R.P.M.	Pump Speed R.P.M. Control Rod Starts to move	No Delivery
<b>Automotive</b>						
	2701E-9A543-F P4873/A	Green	GE	3000 – 3050	1410 – 1430	1560 – 1600
	2703E-9A543-F P4872/C	Green	GE	3000 – 3050	1410 – 1430	1560 – 1600
	2704E-9A543-T P4872/A	Green	GE	3000 – 3050	1410 – 1430	1560 – 1600
	2704E-9A543-W P4897/A	Green	GE	2550 – 2604	1210 – 1230	1330 – 1380
	713F-9A543-GBA P4897/1A					
	713F-9A543-GBB P4897/2A	Green	GE	3100 – 3125	1410 – 1430	1560 – 1600
	703F-9A543-ABA P5052/B					
	703F-9A543-ABB P5052/1B					
	703F-9A543-ABC P5052/2B	Green	GE	3100 – 3125	1410 – 1430	1560 – 1600
	703F-9A543-BBA P5053/B					
	703F-9A543-BBB P5053/1B					
	703F-9A543-BBC P5053/2B	Green	GE	3100 – 3125	1410 – 1430	1560 – 1600
	703F-9A543-CBA P5054/B					
	703F-9A543-CBB P5054/1B					
	703F-9A543-CBC P5054/2B	Green	GE	3100 – 3125	1410 – 1430	1560 – 1600
	703F-9A543-CKB P5089/1					
	703F-9A543-CKC P5089/2					
	703F-9A543-CKD P5089/3					

Ford	Pump Part No. Supplier	Gov. Spring Colour Code	Gov. Mass	Engine No-Load Speed R.P.M.	Pump Speed R.P.M. Control Rod Starts to move	No Delivery
<b>General Purpose</b>						
2701E-9A543-C	P4741/1	Yellow	GE	2700 - 2720	1250 - 1260	1380 - 1400
2703E-9A543-C	P4742/1	Yellow	GE	2700 - 2720	1250 - 1260	1380 - 1400
2704E-9A543-AC	P4742/1A					
693F-9A543-GBA	P5060/1A	Green	(4) GX	2584 - 2604	1220 - 1240	1350 - 1380
693F-9A543-GBB	P5060/2A					
693F-9A543-GBC	P5060/3A					
703F-9A543-AFA	P5087	Yellow	GE	2700 - 2720	1225 - 1275	1395 - 1415
703F-9A543-AFB	P5087/1					
703F-9A543-AFC	P5087/2					
703F-9A543-ARA	P5128	Yellow	GE	2700 - 2720	1265 - 1275	1395 - 1425
703F-9A543-ARB	P5128/2B					
703F-9A543-ARC	P5128/3B					
703F-9A543-BCA	P5088/A	Yellow	GE	2700 - 2720	1255 - 1275	1395 - 1415
703F-9A543-BCB	P5088/1A					
703F-9A543-BCC	P5088/2A					
703F-9A543-CFA	P5088	Yellow	GE	2700 - 2720	1255 - 1275	1395 - 1415
703F-9A543-CFB	P5088/1					
703F-9A543-CFC	P5088/2					
703F-9A543-CMA	P5130/1	Yellow	GE	2700 - 2720	1265 - 1275	1395 - 1425
703F-9A543-CMB	P5130/2					
703F-9A543-CMC	P5130/3					

<b>Class 'A'</b>						
2701E-9A543-G	P4899	Yellow	(4) GX	1552 - 1562 1865 - 1875	910 - 920	950 - 980
2703E-9A543-G	P5012	Yellow	(4) GX	1552 - 1562 1865 - 1875	910 - 920	950 - 980
2704E-9A543-AD	P5012/A	Yellow	(4) GX	1552 - 1562 1865 - 1875	910 - 920	950 - 980
703F-9A543-ANA	P5127	Yellow	(4) GX	1552 - 1562 1865 - 1875	890 - 900	950 - 980
703F-9A543-ANB	P5127/1					
703F-9A543-ANC	P5127/2					
713F-9A543-BAA	P5012/2	Yellow	(4) GX	1552 - 1562 1865 - 1875	910 - 920	950 - 980
713F-9A543-BAB	P5012/3					
703F-9A543-CLA	P5129	Yellow	(4) GX	1552 - 1562 1865 - 1875	890 - 900	950 - 980
703F-9A543-CLB	P5129/1					
703F-9A543-CLC	P5129/2					
2704E-9A543-Y	P5021/1	Yellow	(4) GX	1552 - 1562 1865 - 1875	910 - 920	950 - 980
693F-9A543-GAA	P5078	Green	(4) GX	2503 - 2513	1160 - 1170	1250 - 1270

Ford	Pump Part No.	Supplier	Gov. Spring Colour Code	Gov. Mass	Engine No-Load Speed R.P.M.	Pump Speed R.P.M. Control Rod Starts to move	No Delivery
<b>Combine</b>							
	2701E-9A543-H	P4899/A	Green	(4) GX	2383 – 2387	1010 – 1020	1060 – 1080
	693F-9A543-AAA	P5079	Green	(4) GX	2383 – 2387	1160 – 1170	1215 – 1245
	2703E-9A543-H	P5012/B	} Green	(4) GX	2383 – 2387	1010 – 1020	1060 – 1080
	2704E-9A543-AE	P5012/C					
	693F-9A543-BAA	P5080/A	} Green	(4) GX	2383 – 2387	1160 – 1170	1215 – 1245
	693F-9A543-CAA	P5080					
	703F-9A543-AJA	P5084/1A	} Yellow	(2) GX	2383 – 2387	1150 – 1160	1240 – 1260
	723F-9A543-AAA	P5084/2B					
	723F-9A543-AAB	P5084/3B					
	703F-9A543-BEA	P5085/B	} Yellow	(2) GX	2383 – 2387	1160 – 1170	1220 – 1250
	703F-9A543-BEB	P5085/2B					
	703F-9A543-BEC	P5085/3B					
	703F-9A543-CJA	P5085/C	} Yellow	(2) GX	2383 – 2387	1160 – 1170	1220 – 1250
	703F-9A543-CJB	P5085/2C					
	703F-9A543-CJC	P5085/3C					
	713F-9A543-CAA	P5186	} Yellow	(2) GX	2597 – 2603	1245 – 1255	1325 – 1425
	713F-9A543-CAB	P5186/1					
	713F-9A543-CAC	P5186/2					
	693F-9A543-GAA	P5078	} Green	(4) GX	2383 – 2387	1160 – 1170	1250 – 1270
	693F-9A543-GAB	P5078/1					
	693F-9A543-GAC	P5078/2					
	723F-9A543-GAA	P5229	Green	(4) GX	2420 – 2425	1140 – 1170	1240 – 1250
	743F-9A543-AAA	PES4A85D210 RS 2378	Yellow	–	2420 – 2425	1185 – 1195	
	743F-9A543-BAA	PES6A85D210 RS 2378Z	Red	–	2420 – 2425	1180 – 1190	
	743F-9A543-CAA	PES6A85D210 RS 2379	Red	–	2420 – 2425	1185 – 1195	
	693F-9A543-CAB	PES6A85C4103 RV 8880		–	2420 – 2425	1123 – 1133	

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	693F-9A543-JAA	P4897/C	} Green	GE	2550 – 2604	1210 – 1230	1330 – 1380
	693F-9A543-JAB	P4897/1C					
	693F-9A543-JAC	P4897/2C					
	693F-9A543-KAA	P4897/B	} Green	GE	2600 – 2659	1240 – 1260	1410 – 1450
	693F-9A543-KAB	P4897/1B					
	693F-9A543-KAC	P4897/2B					
	713F-9A543-AAA	P5165/1	Green	GE	2650 – 2700	1240 – 1260	1410 – 1450

## 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 hexagon headed 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.
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.
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.
8. Refit the timing gear retaining nut and lock-washer and tighten to 6.4 kg.m. (46 lb.ft.) torque. Hold the gear with wrench Tool No.C9078 while tightening the nut.

## IDLING AND MAXIMUM SPEED ADJUSTMENTS

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.

Fit the injection pump to the engine, as described previously and adjust the idling and maximum speeds, with the engine and gearbox at normal operating temperature. Use a tachometer to ensure an accurate setting, this can be driven by the tachometer drive slots in the oil pump gear, using a suitable adaptor, after first removing the plug from the cylinder block or by disconnecting the drive-shaft and engaging direct drive in the gearbox and checking the speed at the gearbox flange.

1. Ensure that the ignition switch is in the 'ON' position but do not start the engine.
2. Move the fuel injection pump throttle lever to the maximum fuel delivery position and hold.
3. Press the excess fuel button in until a distinct 'click' is heard.
4. Release the throttle lever allowing it to return to the idle position.
5. Move the fuel injection pump stop control lever to the 'no fuel' delivery position. The excess fuel button should now throw out.
6. If the button does not throw out, then ease back the gaiter on the excess fuel shaft and apply a few drops of clean engine oil to the shaft. Work the shaft in and out until it is free; the throttle should be held in the idle position.
7. Test for button 'throw out' again as formerly described. If sticking occurs the shaft may be bent; if so, it must be renewed.

## IDLING SPEED

Set the idling speed at the specified rev./min. by adjusting the idling speed stop screw on the governor housing back plate (see Fig. 36). Blip the throttle to ensure a consistent return to this setting.

NOTE:—A completely cold engine, with the correct idling adjustment, may stall but will run satisfactorily after approximately 30 seconds warm-up. Do not increase the idling speed to compensate for this stalling condition when the engine is cold.

## MAXIMUM SPEED

With the engine running at normal operating temperature, in neutral, operate the throttle control to hold the governor control lever against the maximum speed stop. Adjust the stop screw (see Fig. 36) to give a no-load speed as in the table above. Tighten the locknut and seal the adjusting screw.

## INJECTION PUMP STORAGE

If, after overhaul, an injection pump is being stored for a period exceeding 30 days, it should be left filled with test oil and all connections sealed with the special plugs and caps.

## INJECTORS

The injector consists of a nozzle assembly and a nozzle holder clamped together axially by the nozzle nut (see Figs. 37 and 40). The steel nozzle holder body incorporates lugs for clamping the injector into the cylinder head and contains a spring, spring seat, adjusting screw and spindle. The nozzle consists of a nozzle body with four spray holes and a needle valve.

Fuel from the injection pump enters the injector inlet adaptor and passes through the injector body before reaching the needle valve seat (see Fig. 37). 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 four holes in the nozzle tip. At the end of injection the spring returns the needle valve on to its seat. The spring pressure can be adjusted by the adjusting screw to give a nozzle the specified opening pressure of atmospheres. (Refer to Specifications).

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.

The injectors should normally be removed every 400 running hours for resting and servicing.

Injector nozzle and holder assemblies manufactured by C.A.V. are now available in Service for use with Bosch fuel injection pumps on the 2710 engine range.

They are, nozzle and holder assy. 733F-9K546-AAA. and nozzle assy. 733F-9K527-AAA.

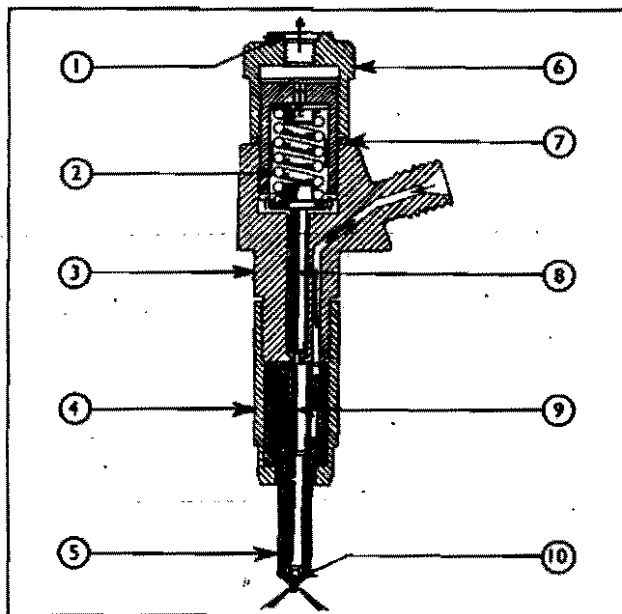


Fig. 37

1 Leak Off Pipe Connection	6 Cap Nut
2 Spring	7 Copper Washer
3 Nozzle Holder	8 Spindle
4 Nozzle Nut	9 Needle Valve
5 Nozzle	10 Valve Seat

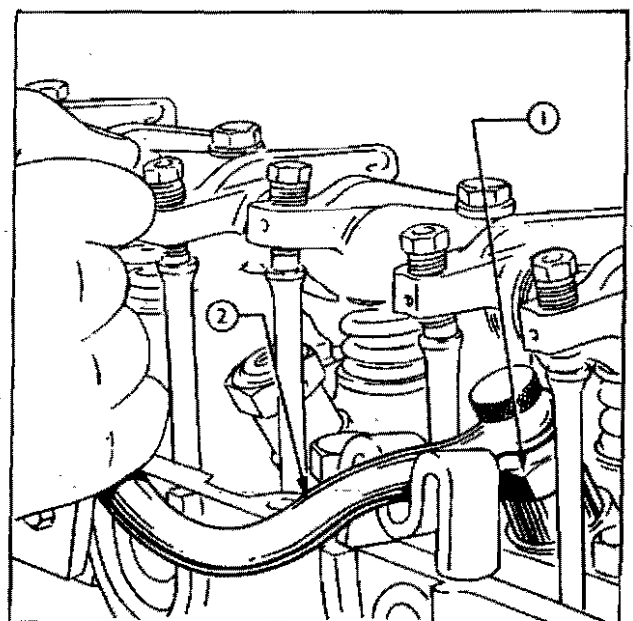


Fig. 38

1 Injector
2 Injector Remover Pt. No. EIADDN-17098

## TO REMOVE THE INJECTORS

1. Disconnect air cleaner hose (where fitted) or breather pipe from the emission valve.
2. Remove the rocker cover and gasket.
3. Remove the injector leak-off pipe by unscrewing the union nut at the rear of the cylinder head and the special bolts connecting the leak-off pipe to the injectors. Take care not to drop any of the bolts into the engine.
4. Slacken the injector inlet adaptor seal nuts, and unscrew the adaptor from the injector. Slacken the union nut at the injection pump.

**NOTE:**—It may be necessary to disconnect other injector pipes in order to obtain easy access to the required one.

5. Fit the appropriate blanking plugs and caps to the injectors and injector pipes.
6. Remove the injector after unscrewing the two securing bolts. If the injector is tight in its housing the injector lifting bar, Part No. EIADDN-17098, should be used (see Fig. 38).
7. Remove the copper seating washer from the housing, unless this has been withdrawn with the injector.

## TO REPLACE THE INJECTORS

1. Check the injector housing in the cylinder head to ensure that it is clean and free from any carbon deposit. Fit the rubber "O" sealing ring to the inlet adaptor connection on the injector, using protection cap Tool No.C.9079, a new copper washer in the housing, and insert the injector.
2. Connect the injector pipes to the injectors after first removing the blanking plugs and caps. Ensure that the olives are seated correctly.
3. Carefully tighten the injector bolts evenly to a torque not exceeding 20.3 Nm (2.07 kgf m or 15 lbf ft).

**NOTE:**— These bolts are of very high tensile steel and are fitted without lockwashers. It is important that only the correct type bolts are used.

4. Fit the injector leak-off pipe after checking that it is in good condition with no leaks at the unions and adaptors. Reconnect the external leak-off pipe to the fuel tank.
5. Tighten the union nut at the injection pump and the adaptor at the injector, Tighten the inlet adaptor seal nuts, so that there is an efficient seal against the cylinder head face.
6. Run the engine for a short time to ensure that the injector is making a gastight seal in its housing and that there are no leaks from the leak-off pipe and injector inlet adaptor.
7. Fit the rocker cover and gasket.
8. Connect the air cleaner hose (where fitted) or breather pipe to the emission valve.

## TESTING AN INJECTOR

Care should be taken when testing injectors that the fuel spray does not contact the hands, as it will penetrate the skin due to the high pressure and atomisation of the fuel.

Before dismantling an injector it is advisable to clean it externally with test oil and to test it as follows:—

### Nozzle Opening Pressure

Connect the injector to the nozzle testing machine and slacken the injector cap nut. Adjust the nozzle opening pressure to 185 atmospheres by rotating the spring adjusting nut through the leak-off pipe drilling in the cap nut. Tighten the cap nut securely, taking care that the spring adjusting nut does not turn (see Fig. 39).

**NOTE:**—To obtain a more accurate reading of the pressure, open the valve on the tester not more than a half turn from the closed position.

### Needle Valve Stem Back Leakage

Fully open the valve on the nozzle tester, bring the test pressure up to 150 atmospheres and check the time for it to fall to 100 atmospheres. The time taken should be 10 seconds for new and 6 seconds for reconditioned injectors (see Fig. 40).

**NOTE:**—If the time taken is less than that specified the lapped faces on the nozzle and injector body may be damaged or distorted or there may be dirt between the nozzle and injector body faces.

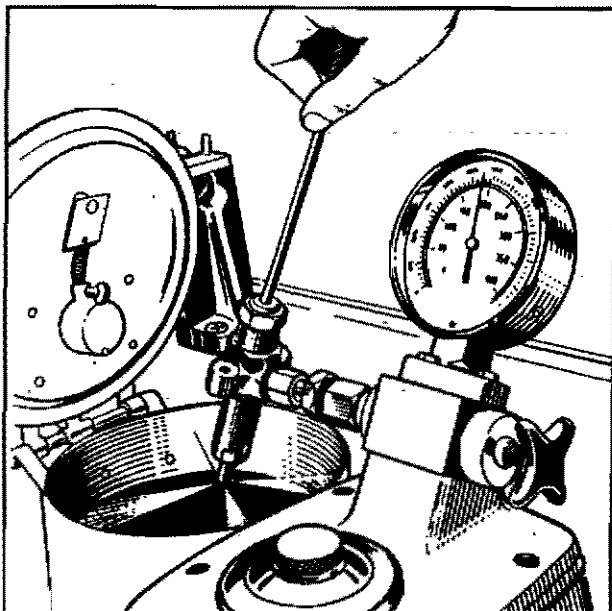


Fig. 39

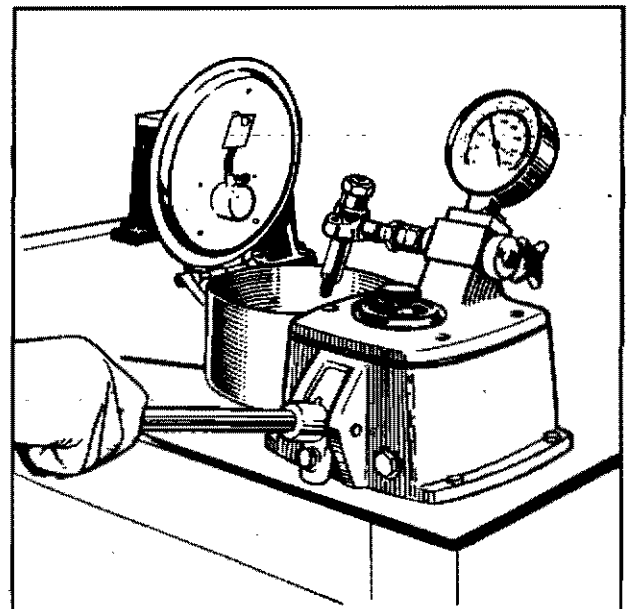


Fig. 40

## NEEDLE SEAT LEAKAGE

Wipe the nozzle tip dry. Operate the tester and the nozzle tip should remain dry. Hold the pressure at the specified atmospheres for 10 secs. when the nozzle tip should still be dry – dampness is permissible but a drop must not be visible.

## ATOMISATION

Close the valve on the nozzle tester, and operate the machine until it reaches the specified pressure  $\pm 2.5$  atmospheres. Maintain this pressure and examine the four sprays. Each spray should atomise well with no visible streaks or distortion, spreading out about 51 mm (2 in) before striking the side of the container. The injector should break with a hard note.

NOTE:—When checking the atomisation the valve on the nozzle tester must be kept closed to prevent damage to the gauge and give a true picture of the condition of the nozzle.

If the injector satisfactorily passes the above tests it can be refitted to the engine. If, however, it fails the needle seat leakage test or if the spray is distorted or does not atomise properly, the injector should be completely dismantled, cleaned, reassembled and tested again.

NOTE:—When testing injectors removed from an engine, if the nozzle opening pressure is to the specified pressure  $\pm 2.5$  atmospheres and the injector passes all other tests, do not adjust the opening pressure as these limits are acceptable.

## TO DISMANTLE THE INJECTOR

1. Fit the injector to a dismantling jig.
2. Remove the injector cap nut and copper washer, then, with a screwdriver, unscrew the spring adjusting nut. Lift off the upper spring disc, injector spring and spindle.
3. Unscrew the nozzle nut, using a special socket Tool No.CT.9009 and remove the nozzle and the needle valve.

NOTE:—As nozzles and needle valves are a lapped fit, **THEY SHOULD NEVER BE INTERCHANGED.**

4. Wash all the injection parts in clean test oil and using a soft brass wire brush remove all carbon from the nozzle and needle valve.

Inspect the Injector Parts as follows:—

1. If the tip of the needle is blued from overheating, or if the seat is seriously scored or damaged, the nozzle and needle valve are unfit for further service.
2. Check that the spring is not broken or rusty and that the ends are perfectly square.
3. Examine the concave surface in the bore at the bottom end of the spindle. This should not be seriously flattened.
4. Inspect the nozzle and nozzle holder joint faces for scratches or trapped foreign particles.
5. Ensure that the needle is free to fall under its own weight in the nozzle, when wet with test oil, and falls freely from the nozzle seat when inverted.

If any of the above components are faulty the injector must be renewed.



## TO CLEAN THE INJECTORS

Use the tools in the injector cleaning kit, Tool No. CT.9014, to remove all carbon from the interior of the nozzle (see Fig. 43).

If necessary the spray holes in the nozzle can be cleaned out, using the wire probes fitted in the small hand chuck. Only use wire suitable for a 0.254 mm (0.010 in) dia. hole, and have just a small amount protruding from the chuck to prevent breakage. Rotate the chuck slowly without applying undue pressure to the wire probe.

When a hard carbon deposit is formed in the spray holes, 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 or substitute fuel oil to prevent corrosions on the highly finished surfaces.

Alternatively, the nozzles may be treated as follows:—

1. Dissolve 55 gm (2 oz.) of caustic soda in 0.5 litre (1 pint) of water. Also add 14 gm (½ oz) of detergent.
2. Place the nozzles 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 of caustic soda exceed 15%, then the needle valve bore and joint face on the nozzle body may be roughened, making the injector unserviceable.

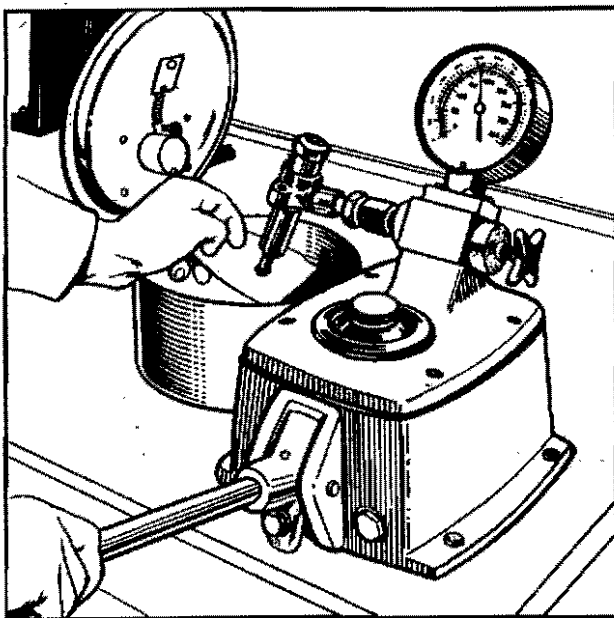


Fig. 41

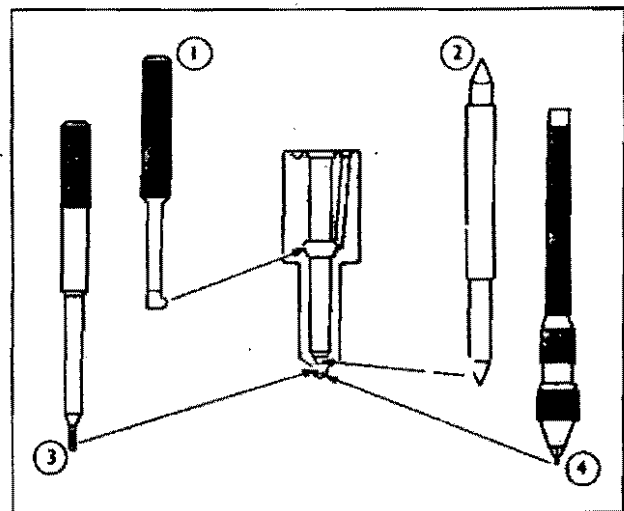


Fig. 42 1 Recess Scraper 4 Spray Hole  
2 Seat Scraper Probe and  
3 Tip Scraper Chuck

## FUEL LIFT PUMP – Diaphragm Type – Standard and High Pressure

The fuel lift pump is mounted at the rear of the engine block on the same side as the injection pump. It is driven from an eccentric on the engine camshaft.

On rotation of the engine, the eccentric on the camshaft pivots the fuel pump rocker arm and link and pulls the diaphragm inwards against the pressure of the return spring. This creates a partial vacuum in the pump chamber, causing the inlet valve to open and draw fuel through the pipe line into the diaphragm chamber.

Further movement of the camshaft eccentric allows the rocker arm to return and the diaphragm is pushed outwards by the return spring, causing the inlet valve to close and the outlet valve to open. The fuel is then forced through the replaceable element filter to the injection pump. The pulsator diaphragm works in sympathy with the pump diaphragm and reduces fuel delivery surge.

When the injection pump is full of fuel, pressure created in the diaphragm chamber holds the diaphragm in against the action of the return spring until fuel is delivered by the injection pump.

During the time the diaphragm is held in by the fuel pressure, the rocker arm idles on the camshaft eccentric without operating the link.

On the 2710 engine range, an improved lift pump has been introduced, incorporating a convoluted diaphragm to reduce the possibility of diaphragm rupture, together with a more effective hand priming linkage.

The complete pump is interchangeable with earlier pumps and a conversion kit is available to modify the earlier models.

### REPLACEMENT PARTS:

Description	Ford Part No.	Finis Code	Quantity
Fule lift pump	683F-9350-AB	6038718	As Required
Conversion kit	753F-9K340-AA	1563606	As Required
Consisting of:			
Diaphragm and Valve	753F-9398-AA	6039028	One
Spring	753F-9396-AA	6039027	One

## FUEL LIFT PUMP – Plunger Type – High Pressure

The fuel lift pump is mounted to an adaptor at the rear of the engine block, on the same side as the injection pump.

A plunger rod housed in the adaptor contacts the eccentric on the camshaft at one end and the fuel lift pump plunger rod at the other end.

On rotation of the engine, the eccentric cam forces the plunger rods and plunger in the direction of the pump suction chamber, fuel is thereby forced out of the suction chamber through the balancing channel into the compression chamber. At the same time the plunger spring is compressed.

As the eccentric cam goes beyond the highest point, the plunger is forced back by the plunger spring.

The fuel is then forced out of the compression chamber, through the balancing channel to the fuel filter and the injection pump.

At the same time, the receding plunger creates a vacuum in the suction chamber, the suction valve opens and fuel is again drawn from the fuel tank.

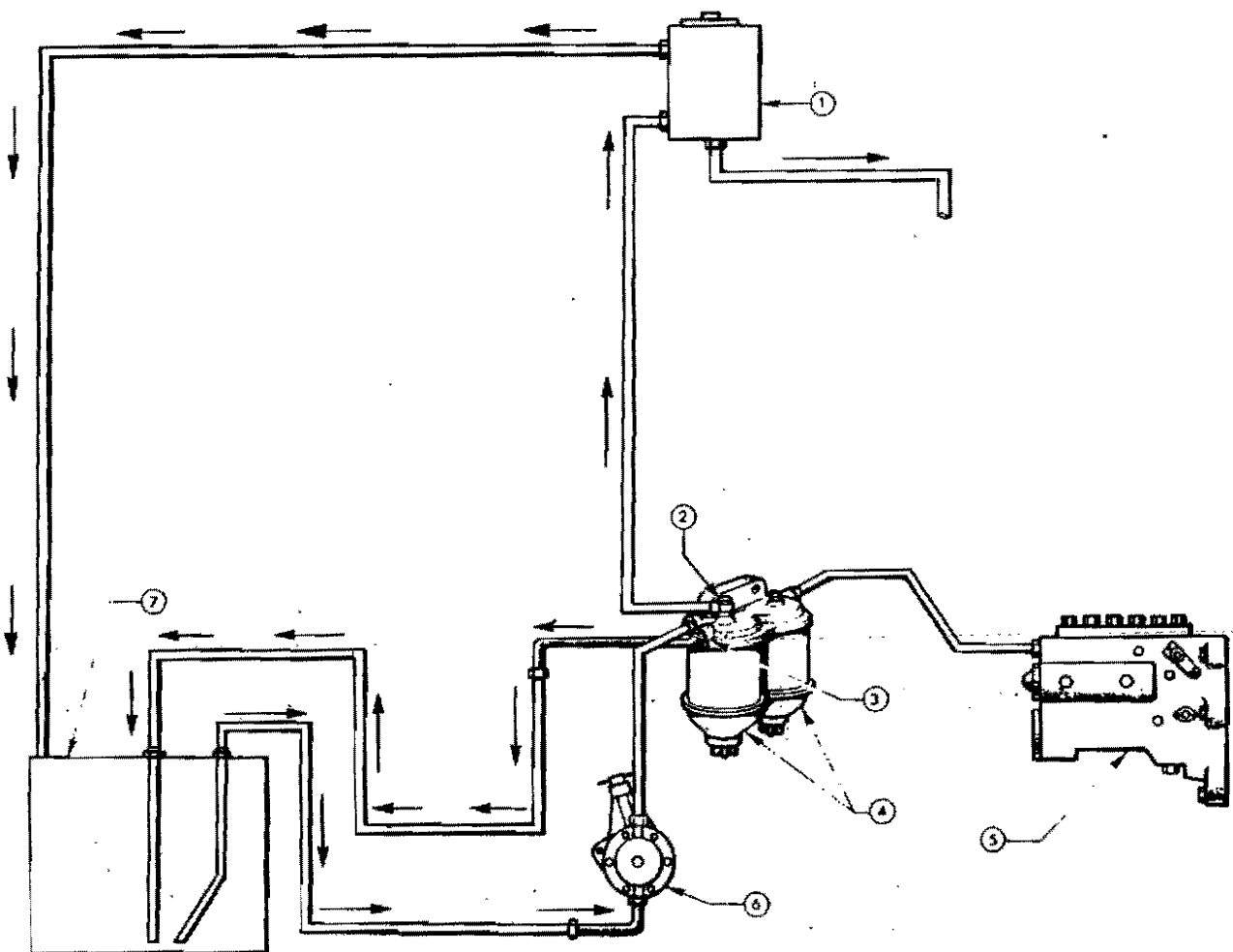
### FUEL LIFT PUMP (Plunger Type) (Cont'd)

If more fuel than necessary is pumped, the pressure in the compression chamber rises. This pressure acts through the balancing channel on the plunger against the force of the plunger spring. If the force exerted by the plunger is exceeded by the force exerted by the pressure in the compression chamber, the plunger no longer moves as far towards the cam, and so the amount of fuel pumped is reduced.

Exploded views of the fuel lift pumps are shown in Figs. 47, 48 and 49.

Note:—When fitting the constant displacement and/or variable displacement high pressure fuel lift pump, the use of a recirculatory fuel system is mandatory and as always the use of a primary fuel filter is recommended.

A non-return, spring loaded valve should be fitted to the No. 2 port of the fuel filter, a fuel line 8 mm. (5/16 in.) O.D. must be connected between this valve and the fuel tank independent of the injector leak-off return, Refer to Fig. 46.



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Fig. 46 High Pressure Fuel Lift Pump and Recirculatory Fuel System

- |                    |                  |
|--------------------|------------------|
| 1 Reservoir        | 5 Injection Pump |
| 2 Non-Return Valve | 6 Fuel Lift Pump |
| 3 Non-Return Valve | 7 Fuel Tank      |
| 4 Fuel Filters     |                  |

## TESTING THE FUEL LIFT PUMP

Providing there are no air leaks or obstruction in the fuel system, a quick check on the pump efficiency can be made as follows:—

1. Remove the air bleed screw from the inlet side of the fuel filter.
2. Operate the hand priming lever in the normal manner when there should be a well defined surge of fuel for each working stroke of the pump. If there is no resistance of the diaphragm spring it is likely that the diaphragm is held down, due to the operating lever being on the high point of the eccentric, and it will be necessary to rotate the engine approximately one turn.

If the pump does not operate correctly, check the inlet depression and delivery pressure by Diagnosis Test Set, Gang Gauge Set No.500—X or a suitable vacuum pressure gauge.

## FUEL PUMP INLET DEPRESSION TEST

1. Operate the lift pump hand primer to fill the injection pump gallery.
2. Disconnect the fuel inlet pipe from the pump and connect the vacuum gauge to the pump inlet union.
3. Start the engine and allow to run at idling speed. The vacuum reading should be at least 21.59 cm of Hg. (8½ in.) of mercury.
4. Stop the engine and check the leak-down time for the specific pumps as follows:—

Diaphragm type pumps

Standard	—	0.0172 bar (0.0176 kgf/cm <sup>2</sup> or 0.25 lbf/in <sup>2</sup> in 25 minutes
High Pressure	—	0.552 bar (0.563 kgf/cm <sup>2</sup> or 8 lbf/in <sup>2</sup> ) in 25 minutes
Plunger type pump	—	0.207 bar (0.21 kgf/cm <sup>2</sup> or 3 lbf/in <sup>2</sup> ) in 25 minutes

Should the reading drop quicker than this, it indicates an air leak or faulty outlet valve.

5. Bleed the fuel system as described in the appropriate section.

NOTE:—This test can be carried out at any connection between the lift pump and fuel tank to check for air leaks in the fuel system as a whole. By starting the tests at the fuel tank and working towards the fuel lift pump, it will be possible to determine the faulty component.

## FUEL PUMP DELIVERY PRESSURE TEST

1. Operate the lift pump hand primer to fill the injection pump gallery.
2. Disconnect the fuel outlet pipe from the pump and connect the pressure gauge to the pump outlet.
3. Start the engine and observe the pressure at idling speed. Increase the speed and check throughout the speed range that the pressure is between:—

0.34 to 0.55 bar (0.35 to 0.56 kgf/cm <sup>2</sup> or 5 to 8 lbf/in <sup>2</sup> )	diaphragm standard
2.76 to 3.58 bar (2.8 to 3.7 kgf/cm <sup>2</sup> or 40 to 52 lbf/in <sup>2</sup> )	diaphragm high pressure
1.03 to 1.24 bar (1.05 to 1.27 kgf/cm <sup>2</sup> or 15 to 18 lbf/in <sup>2</sup> )	plunger — high pressure

NOTE:—Low fuel pump pressure may affect engine performance due to lack of fuel.

4. Bleed the system as outlined.



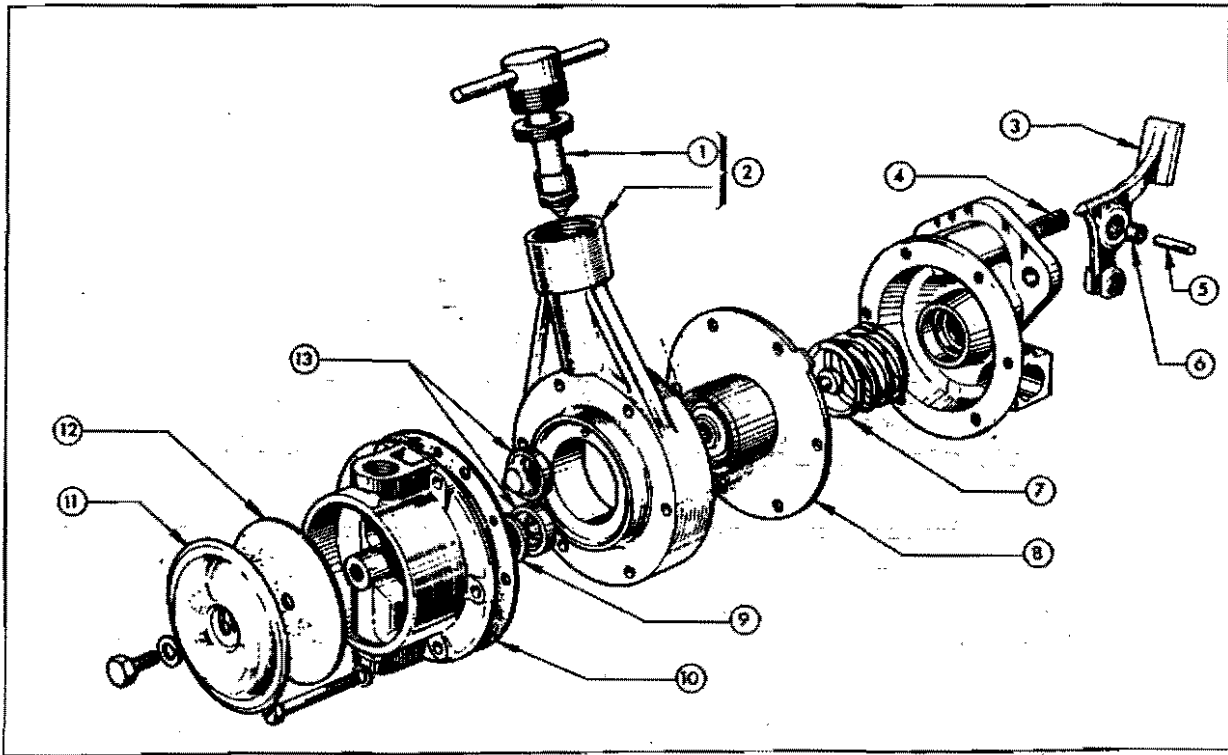
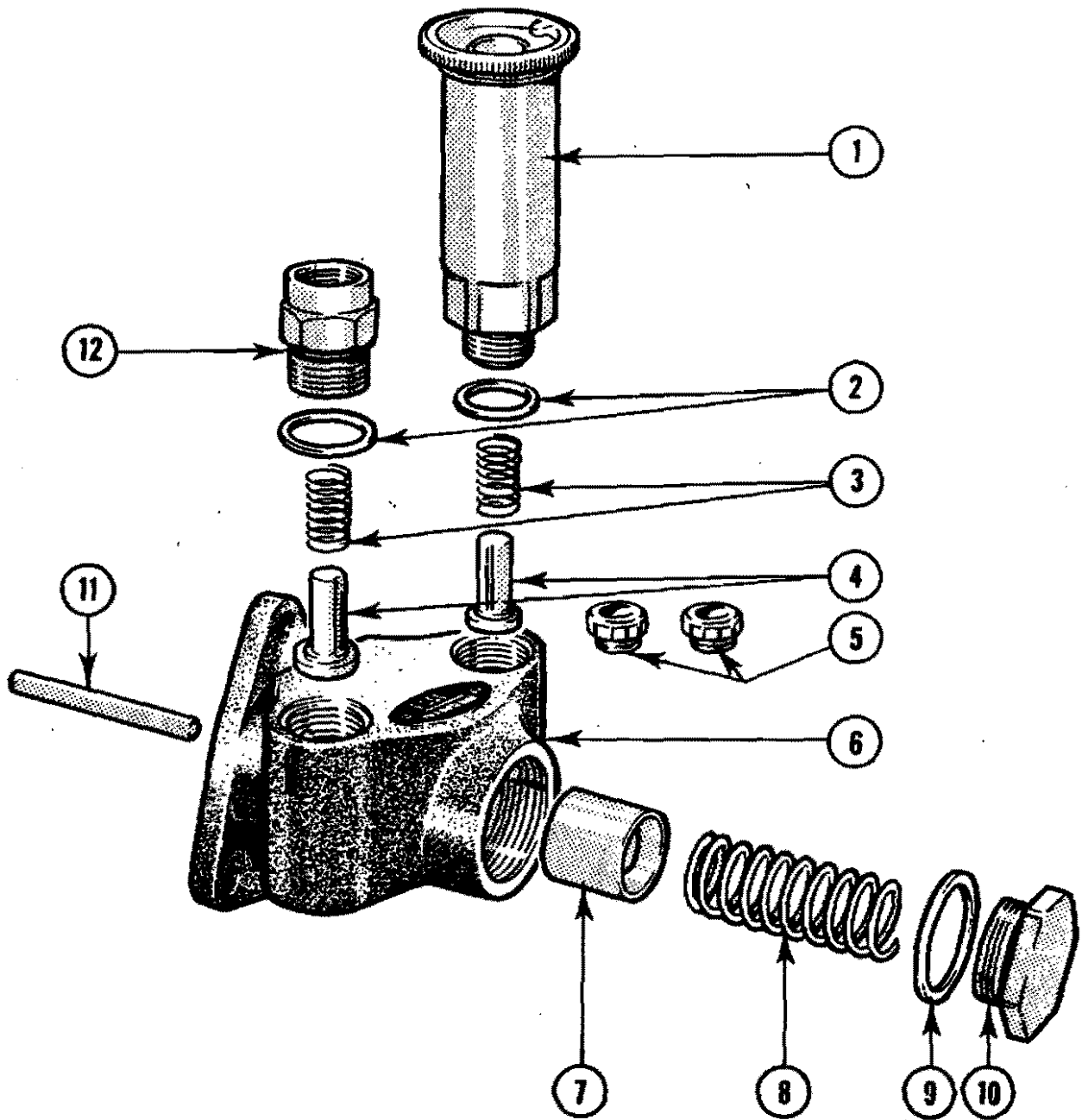


Fig. 48 Diaphragm Type – High Pressure

- |                      |                        |
|----------------------|------------------------|
| 1. Plunger           | 8. Diaphragm           |
| 2. Primer Assy.      | 9. Gasket              |
| 3. Rocker Arm        | 10. Gasket             |
| 4. Rocker Arm Spring | 11. Cover              |
| 5. Pin               | 12. Pulsator Diaphragm |
| 6. Bush              | 13. Valves             |
| 7. Diaphragm Spring  |                        |

#### TO DISMANTLE THE FUEL LIFT PUMP – Plunger Type

1. Disconnect the fuel outlet pipe and connectors and the sealing washers.
2. Unscrew the priming plunger assembly.
3. Withdraw the valve springs and valves.
4. Unscrew the plug, remove the sealing washer and withdraw the spring, plunger sleeve and rod.
5. Thoroughly clean the pump body.



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Fig. 49

PLUNGER TYPE

- |                         |            |                   |
|-------------------------|------------|-------------------|
| 1. Primer Plunger Assy. |            | 7. Plunger Sleeve |
| 2. Seal                 |            | 8. Spring         |
| 3. Spring               |            | 9. Seal           |
| 4. Valve                | } Optional | 10. Plug          |
| 5. Valve                |            | 11. Plunger Rod   |
| 6. Body                 |            | 12. Connector     |

## TO REASSEMBLE THE FUEL LIFT PUMP – Diaphragm Type

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, link and pin to the inner body, locating the return spring between the rocker arm and the housing. Stake the housing at either end of the pivot pin to ensure that it is securely retained.
3. Fit the oil seal and the oil seal retaining washer to the inner body. Dent the locating tube in three equidistant places to retain the washer and oil seal.
4. Locate the return spring on the pump diaphragm spring seat and assemble the diaphragm to the inner body with the lug on the spring seat adjacent to the priming lever bore and the small tab next to the mark on the body. Engage the link with the pull rod.
5. Compress the pump diaphragm and return spring and insert the priming lever shaft, with the "O" sealing ring in the outer groove, into the inner body so that the flat located behind the spring seat lug. Locate the priming lever return spring in the small hole. Replace the priming lever retaining pin, which locates in a groove in the shaft and drive home.
6. Locate the two halves of the pump body together in the marked positions, insert the six screws until fingertight. Operate the rocker arm a few times to centralise the diaphragm and tighten the screws, holding the rocker lever fully down.
7. Replace the pump cover plate and pulsator diaphragm and secure with a screw and lock-washer. Tighten to a torque of 5.1 to 6.2 Nm (0.52 to 0.64 kgf m or 45 to 55 lbf in).

## TO REASSEMBLE THE FUEL LIFT PUMP – Plunger Type

1. Examine the valves and ensure correct seating in the housing. If satisfactory, refit valves together with springs.
2. Fit the primer plunger assembly and connector union nut together with the sealing washers. Tighten the screwed joints well.
3. Before replacing the plunger and rod, examine carefully for any damage that may prevent easy movement of these parts when assembled to the pump housing. Check free movement also when assembled.

NOTE:—Ensure the plunger is assembled in the correct way.

4. Replace the spring, sealing washer and plug, tighten the plug.

## TO REPLACE THE FUEL LIFT PUMP

1. Ensure that the pump mounting face is clean, fit a new gasket and secure the pump to the engine and/or adaptor housing with the two nuts and spring washers.
2. Reconnect the fuel inlet and outlet pipes.
3. Bleed the fuel system as described in the appropriate section.



## FUEL FILTER

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 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 REPLACE THE FILTER ELEMENT

1. Unscrew the securing bolts and remove the filter bowl/s and element/s (See Fig. 45).
2. Discard the element/s, also upper and lower seals.
3. Wash out the bowl/s with clean fuel oil.

**ON NO ACCOUNT USE RAG FOR THIS OPERATION.**

4. Unpack the new element/s and sealing rings.
5. Fit new rings to the filter head and filter bowl/s.
6. Assemble the element/s and filter bowl/s to the filter head. Replace and tighten the securing bolt/s.
7. Bleed the fuel system as described later in this section.

### SEDIMENT BOWL (where fitted)

Every 200 running hours or sooner if required, the fuel sediment bowl and filter screen should be removed and cleaned.

#### To Clean the Filter Screen

1. Unscrew the retaining nut and move the retainer to one side.
2. Remove the sediment bowl and gauze filter screen. Thoroughly wash the bowl and filter screen in fuel oil or substitute test fuel.

**DO NOT WIPE WITH CLOTH**

3. Ensure that the gasket fitted to the body is in good condition. Refit the filter screen and bowl and tighten the retaining nut.
4. Bleed the system.

## FUEL PIPES

The fuel feed and leak-off pipes require little attention except for periodic checks on the tightness of the unions and the securing clips. The union nuts must only be tightened to a torque of 17.6 to 19 Nm (1.8 to 1.93 kgf m or 13 to 14 lbf ft).

## INJECTOR PIPES

The injector pipes are of heat treated steel fitted with detachable steel olives. It will be seen that the olive is fitted with the small diameter taper towards the end of the pipe. When fitting them, they should be pressed home into the cones of the unions and the nuts tightened carefully. It should not be necessary to use excessive pressure when tightening the nuts to ensure a leak-proof seat.

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.

When the pipes are removed blanking plugs must be fitted to the pipe nuts, and caps fitted to the appropriate delivery valve holders and injector inlet adaptors.

To renew the pipe olives. Remove the pipe, grip the olive by rotating and pulling, ease the olive off the pipe.

Fit a new olive with the conical seat to the end of the pipe so that it is flush with the pipe. Press the pipe into its location and tighten the nut to contract the olive on to the pipe.

When fitting new olives to the pipes, it is advisable to have the other end of the pipe free when tightening the nut to grip the olive on the pipe.

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.

After prolonged service it is not unusual for the ends of an injector pipe to close up slightly giving rise to a heavy knock on the cylinder concerned. In such cases the ends of the pipe can be cleared, using a 1.75 mm. dia. drill to a depth of approximately 19 mm. ( $\frac{3}{4}$  in.). Ensure that the pipe is thoroughly cleaned afterwards.

## AIR CLEANERS

There are one of two types of Air Cleaners fitted to the 2700 engine range, an oil bath type or a paper element type.

### OIL BATH TYPE AIR CLEANER

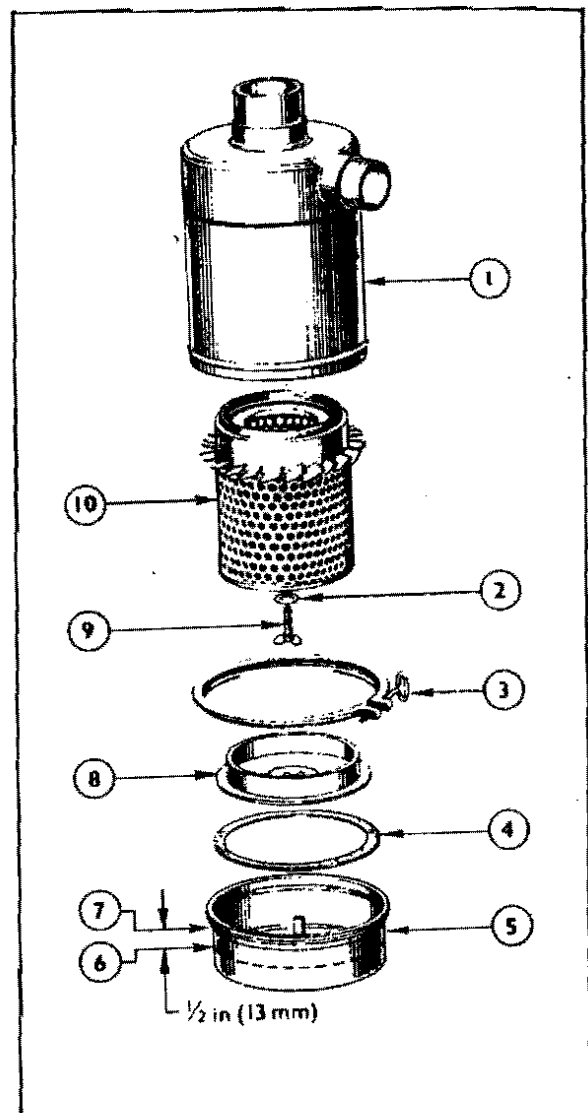
Under normal operating conditions the air cleaner should be cleaned and the oil changed after every 50 hours running. However, should the engine be operating in a heavily dust-laden atmosphere it should be cleaned more frequently.

To Remove and Dismantle:

1. Disconnect the air inlet hose and engine breather pipe (where fitted).
2. Unscrew the wing bolt from the top of the air cleaner and remove the air cleaner assembly (see Fig. 57).
3. Remove the top cover gauze element.

Fig. 50

- 1 Body
- 2 Washer
- 3 Clamp
- 4 Gasket
- 5 Dust Cap
- 6 Dust Level
- 7 Slot
- 8 Baffle
- 9 Wing Nut
- 10 Element



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### OIL BATH TYPE AIR CLEANER (Cont'd).

#### To Clean and Reassemble :

1. Wash the gauze element with paraffin or petrol. Dip the element in clean engine oil and allow to drain.
2. Empty the oil bath reservoir and wash with paraffin or petrol.
3. Clean the air cleaner casing thoroughly with a non-fluffy rag moistened with paraffin or petrol.
4. Place the air cleaner body on a level surface and fill the reservoir with clean engine oil to the level mark indicated by the arrow inside the reservoir.
5. Replace the gauze element and fit the top cover.

#### To Replace:

Fit the air cleaner onto the mounting bracket and connect the air inlet hose and engine breather pipe. Secure the air cleaner assembly to the bracket with the central wing bolt.

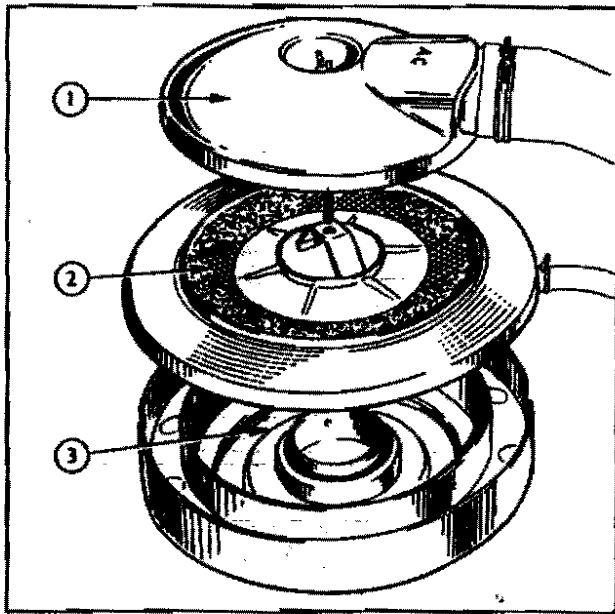


Fig. 51  
 1 Cover  
 2 Element  
 3 Oil Level

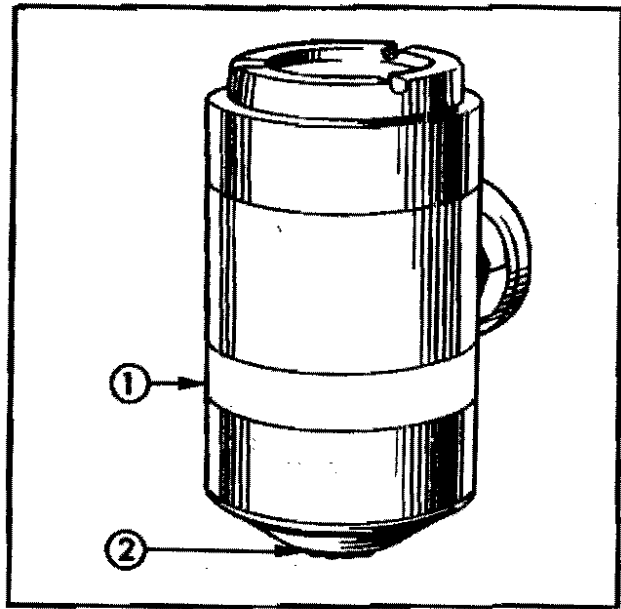


Fig. 52  
 1. Red Signal  
 2. Reset Button

## PAPER ELEMENT AIR CLEANER

In normal operating conditions this air cleaner should have the dust cap (where fitted) emptied after every 10 hours running, and the paper element cleaned or replaced after every 50 hours running.

### To Empty Dust Cup:

1. Slacken off the clamp screw (Fig. 50) and remove the clamp and dust cup.
2. Empty all the dust from the cup.
3. Check that the wing nut retaining the baffle to the dust cup is tight.
4. Replace the dust cup and clamp screw.

NOTE:—The level of dust in the cup should not be allowed to build up to less than 13 mm (0.5 in) from the slot in the dust cap (see Fig. 50). Empty more frequently in dust-laden atmospheres.

### To Clean or Renew Paper Element:

To clean the upper element a Compressed Air Line not exceeding a pressure of 6.89 bar (7 kgf/cm<sup>2</sup> or 100 lbf/in<sup>2</sup>) is needed.

1. Slacken off the clamp screw and remove the clamp and dust cup (Fig. 50).
2. Empty all dust from cup.
3. Remove the wing nut and washer and extract the elements from the air cleaner body.

## PAPER ELEMENT AIR CLEANER (Cont'd)

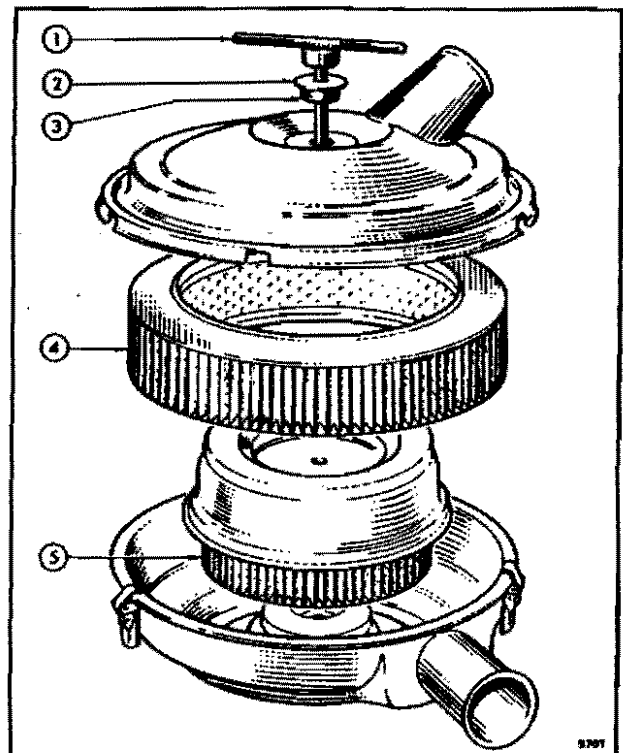
4. Clean the element by directing the compressed air nozzle up and down the pleats on the inside of the element. Maintain a reasonable distance between the nozzle and the element.
5. Check the condition of the element by placing a bright light inside. The slightest hole in the element will render it unfit for further use. Replace by a new element if necessary.
6. Refit the element to the air cleaner body. Screw in and tighten the wing nut and washer.
7. Replace the dust cup and clamp.

NOTE:—If a restriction indicator is fitted (Fig. 52), the air cleaner should be serviced when the red signal shows.

## PAPER ELEMENT AIR CLEANER — Cylinder Head Mounted

1. Release the clip securing the hose to the air cleaner.
2. Unscrew the centre retaining bolt and release the air cleaner cover clips (Fig. 53).
3. Remove the elements.
4. Clean the elements by directing a compressed air nozzle up and down on the inside of the elements (Pressure not to exceed 6.89 bar (7kgf/cm<sup>2</sup> or 100 lbf/in<sup>2</sup>).
5. Check the condition of the elements, replace by new if necessary.
6. Empty all dust from the cup.
7. Replace elements, cover and mount air cleaner to bracket, secure centre bolt and connect hose.

Fig. 53  
 1. Bolt  
 2. Washer  
 3. Seal  
 4. Element-Outer  
 5. Element-Inner



## AIR CLEANER RESTRICTION INDICATOR

These indicators are fitted with dry type air cleaners and signal when air cleaner service is required.

Dirt trapped by the air gradually lowers the green blind of the indicator exposing the red signal until, when the signal is fully exposed, the blind is automatically locked down.

When the red signal is fully exposed the air cleaner should be serviced or the element renewed. After servicing the indicator is reset by pressing the button at the base, this releases the green blind which will again cover the red signal.

## 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 that there is sufficient fuel in the tank.
2. Loosen the two bleed screws on the top of the filter two or three turns and operate the priming lever on the fuel lift pump. 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, it will render the fuel lift pump priming lever inoperative. If this occurs, rotate the engine until the priming lever can be operated.

3. Tighten first the inlet and then the outlet bleed screw on the filter as the priming lever returns to its downward position.

4. Loosen the bleed screws on the injection pump body approximately two or three turns (see Fig. 54), operate the lift 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 become seriously damaged.

5. When fuel free from air bubbles issues from the bleed screws, tighten the screw furthest from the inlet connections first and then the other one.

6. Wipe all surplus oil from the exterior of the filter and fuel injection pump.

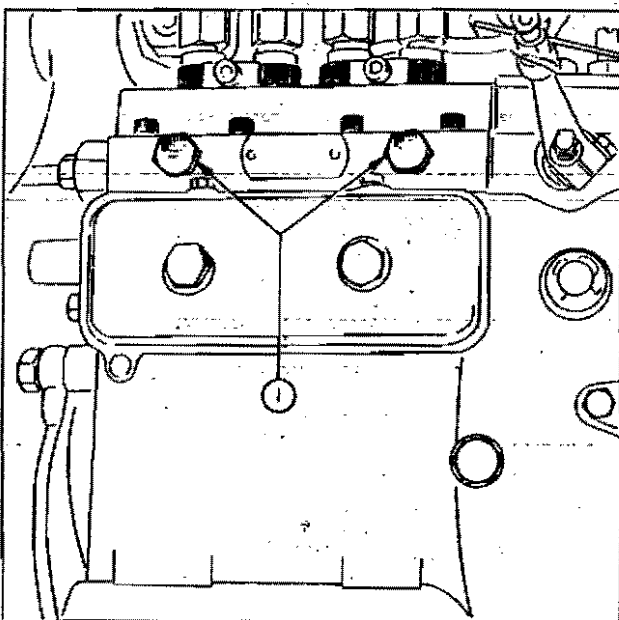


Fig. 54 1 Bleed Screws

\* \* \* Communication Result Report ( 10.Feb. 2006 16:52 ) \* \* \*

Fax Header)

Date/Time: 10.Feb. 2006 16:48

File No.	Mode	Destination	Pg(s)	Result	Page Not Sent
7181	Memory TX	908453001538	P. 7	OK	

Reason for error  
 (1) Hang up or line fail  
 (2) Busy  
 (3) No answer  
 (4) Exceeded max. E-mail size  
 (5) No facsimile connection

10.02.06 12:40:37

Page 5/16

**HIRE PURCHASE AGREEMENT REGULATED BY THE CONSUMER CREDIT ACT 1974**

Proposed customer: <b>AN-JIM SICHENSWAN</b>	Special named customer
Trading as (if business):	Substance:
Full address: <b>38 Cady Street</b>	
<b>Cherrytree Limited, UNITED KINGDOM, BL90 1AT</b>	

**KEY FINANCIAL INFORMATION**

[New-Purchase]		[Consumer Loan]			
Amount of Cash (A) - <b>104 800.00</b>	Amount of Cash (A) - <b>104 800.00</b>	The loan term for this agreement is 60 months			
Total Amount Payable (A + C) <b>2 16,977.00</b>		Total Amount Payable (A + C) <b>2 16,977.00</b>			
No of Installments (B)	Amount of Hire-Purchase Installment (B)	Amount of Installment (B)	Total Installment (B)	Date Payable	APR for Hire-Purchase and Consumer Loans
1	21697.70	21697.70	21697.70	1 month (1st date of this Agreement, and then on the corresponding day each month thereafter)	APR 16.0%

**OTHER FINANCIAL INFORMATION**

Vehicle Make & Model: <b>MINI COOPER S</b>	Reg No: <b>YH62242</b>
Vehicle Make & Model: <b>MINI COOPER S</b>	Date of Registration: <b>10/02/06</b>
Registration No: <b>YH62242</b>	Current/Previous Registration:

	Total Cash Price (see W17) (A)	Loan Repaid (C)	Charges (D)	Registration Fee (included in the first installment) (E)	Credit Facility Fee (included in the first installment) (F)	Option Fee (included in the first installment) (G)	Total Charge for Cash (D+E+F+G) (H)
New-Purchase	104800	0	0	0	0	0	0
Consumer Loan	0	104800	0	0	0	0	0

The Available Interest Rate for New-Purchase is 11.9% p.a. (fixed) and for Consumer Loans is 6.9% p.a. (fixed). Interest (and repayments) are rounded up to the nearest penny. We will accept a cash settlement on a daily basis after 10:00 am on a working day. All the amounts are subject to change without notice. If you pay less than the full amount due at any time, we will apply the amount you have paid to the most expensive credit facility first and then the other credit facilities in order of increasing interest rate.

Dealer Number: **17996 0002**  
 Version Number: **4**  
 Page: **1 of 8**

1/0/00 Plan 02





## FAULT DIAGNOSIS

Fault diagnosis on the diesel engine can be a straight-forward operation if this is carried out methodically.

To distinguish between a mechanical knock and a fuel knock, run the engine at maximum speed and pull the stop control, if the knock is no longer present it is due to the fuel, if it is still audible, it is due to mechanical reasons. When the fuel supply to the engine is cut off, the mechanical knock will be reduced in volume, but will still be present.

Running faults will be due mainly to faults arising in one or more of the following sections. By checking through as outlined, the faulty component or section can be isolated.

### FUEL SYSTEM

1. Bleed all air from the fuel system in the normal manner, if this cannot be eliminated, check back over the pipeline from the lift pump to the fuel tank.
2. Loosen off the injection pipes at the injection pump, and operate the starter motor, observing approximate equal delivery from each fuel pipe.
3. With the pipes still disconnected from the injection pump, pull the stop control and operate the lift pump hand primer. Any flow of fuel indicates a faulty delivery valve or broken delivery valve spring.
4. Reconnect the pipes to the injection pump and start the engine if possible. As a rough check of injector condition, run the engine just above the idling speed, and loosen the injector pipes one at a time. As each injector is cut out in this way, a definite drop-off in speed should be noticed, if the injector is operating correctly.

### TIMING

1. Insert a timing tool No.C.9077 into the aperture in the injection pump mounting flange, and rotate the engine until the spring-loaded plunger locates in the centre punch mark in the rear face of the gear. The timing mark in the crankshaft pulley should then be in line with the specified line on the timing scale. If incorrect, the pump may be rotated until the timing is correct.
2. If any doubt arises as to the accuracy of the timing marks, the fuel injection pump should be spill-timed to the engine. To carry out this operation set the engine on the firing point for No.1 cylinder as outlined in the previous paragraph. Disconnect No.1 injector pipe, remove the delivery valve holder and extract the volume reducer, delivery valve and spring. Refit the delivery valve holder to the injection pump body. Fit the spill pipe Tool No. CT.9023 to the delivery valve holder, slacken the mounting flange bolts and fully retard the pump. Operate the hand primer on the lift pump, and fuel should run from the end of the spill pipe. Slowly advance the injection pump until the flow of fuel from the spill pipe just ceases. Tighten the mounting flange bolts and the injection pump is now timed correctly to the engine. Refit the delivery valve, spring, volume reducer, and reconnect the injector pipe.

## AIR SUPPLY

1. Remove and clean the air cleaner element—see “Air Cleaners”. If an oil bath type is fitted, wash out and refill the oil bath with the correct grade oil to the correct level. Ensure that the element is free from obstructions and refit to the air cleaner.
2. Examine the air hoses and inlet manifold for any obstruction.
3. Check all valve clearances.
4. Check the evenness of the cylinder compressions by turning the crankshaft with the engine turning bar Fig. 55.

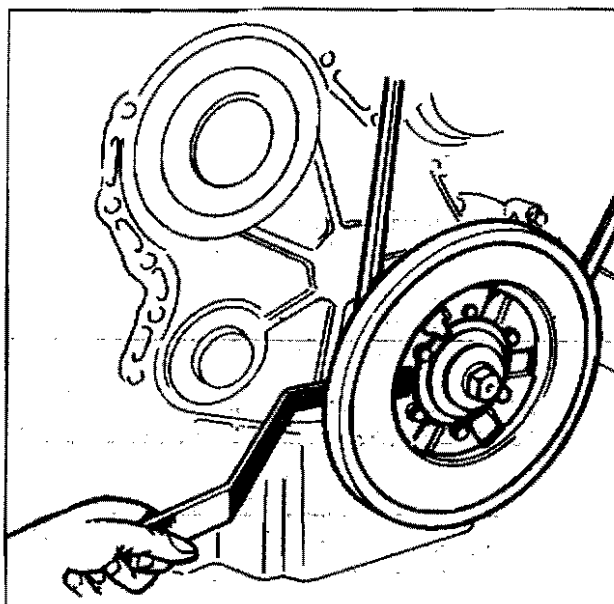


Fig. 55 Engine Turning Bar  
located in Barring  
Plate

## GOVERNOR

1. Check the engine idling and maximum no/load speeds. If incorrect adjust the respective stop screws to obtain the correct speeds, re-position the control lever on the cross-shaft if necessary. Check the governor spring if the correct speeds cannot be obtained.
2. If the engine surges at any point in its speed range ensure that the injection pump oil level and grade of lubrication is correct. Operate the excess fuel device and stop control to check for any tightness in the control rod movement. Examine the governor mechanism and linkage for tightness or excessive wear.

## BOOST CONTROL UNIT

### Description

The boost control unit, provides automatic control of the maximum fuel delivery under low speed conditions by sensing the inlet manifold air pressure generated by the turbocharger.

It reduces the amount of fuel that may be fed to the engine, when the manifold pressure drops below a pre-determined figure, thereby reducing the smoke emission at low engine speed.

The unit consists basically of a spring loaded diaphragm, spindle, cam and fuel rod. The unit is fitted to the top of the injection pump governor case so that the fuel rod replaces the original fuel stop Fig. 56.

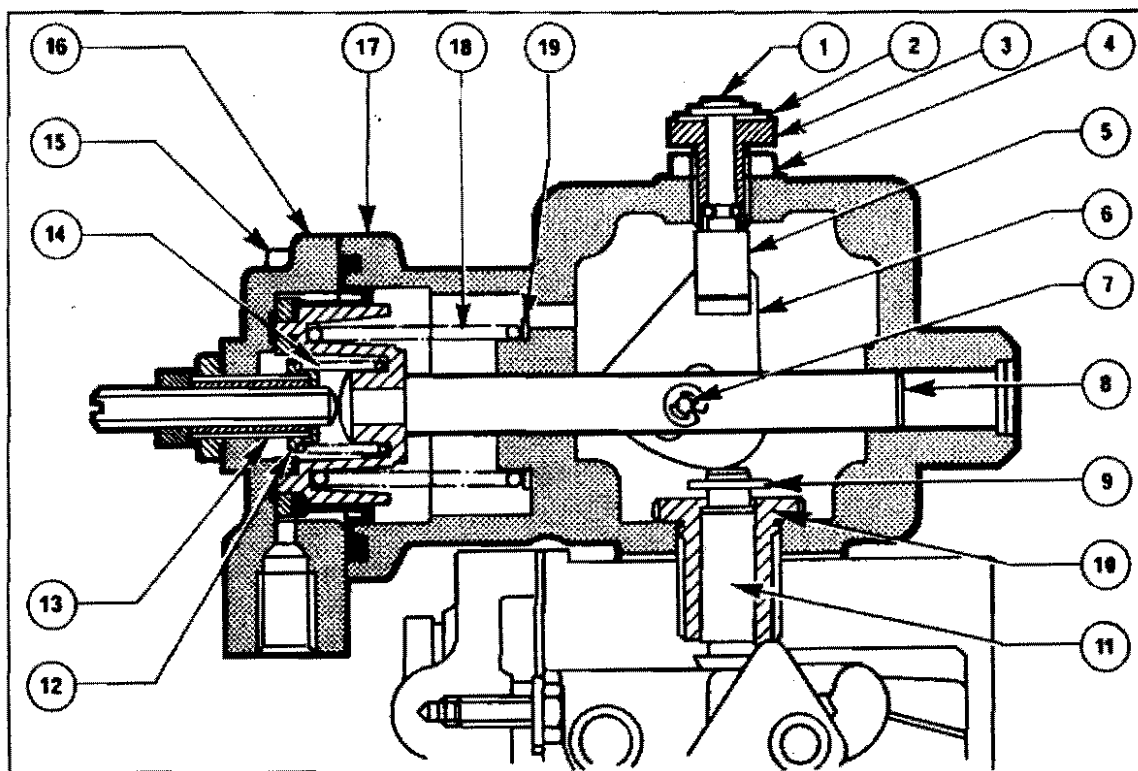


Fig. 56 Boost Control Unit

- |                                   |                           |
|-----------------------------------|---------------------------|
| 1. Clevis Pin                     | 11. Maximum Fuel Rod      |
| 2. Bowed Washer                   | 12. Spring Locator        |
| 3. Adjusting Screw                | 13. Adjusting Spring      |
| 4. Locknut                        | 14. Retain Spring         |
| 5. Pin Retainer                   | 15. Cover Retaining Screw |
| 6. Lift Cam                       | 16. Cover                 |
| 7. 'E' Clip and Operating Rod Pin | 17. Housing               |
| 8. Piston and Diaphragm Assembly  | 18. Diaphragm Spring      |
| 9. 'E' Clip                       | 19. Thrust Washer         |
| 10. Fixing Sleeve                 |                           |

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## BOOST CONTROL UNIT (Cont'd)

At high engine speeds, the boost pressure (taken from a point on the manifold via a pipe to the boost control) thrusts the diaphragm against its spring thus moving the spindle horizontally. The spindle turns the cam, which allows the fuel rod to rise to its normal operating position, where it acts as a maximum fuel stop. When the engine speed falls, the boost pressure drops, and the diaphragm returns towards its original starting point. The spindle turns the cam, which pushes the fuel rod vertically downwards, thus reducing the effective maximum fuel setting. Adjustable minimum and maximum stops are provided for setting purposes.

**NOTE:** If the injection pump is being completely dismantled, then the boost control unit should be the first major component removed.

### Dismantling The Boost Control Unit

1. Unscrew the eight side cover securing screws and washers, noting on which side the breather cap is fitted. Remove and discard both gaskets.
2. Slacken the locknut Fig. 57, then turn the adjusting screw up to its top limit to lift the cam.
3. Depress the maximum fuel rod to enable the special tool ST.172 to be fitted to serrations on the fixing sleeve. Unscrew the fixing sleeve from the governor case and remove the boost control unit from the pump. Discard the gasket.
4. Remove the 'E' clip Fig. 58, and bowed washer. Remove the adjusting screw and lift out the cam and clevis pin from housing. Remove the pin retainer and push out pin to remove the cam.

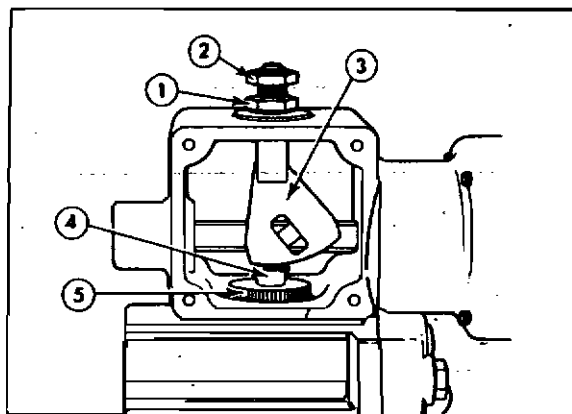


Fig. 57 Removing Boost Control Unit

1. Locknut
2. Adjusting Screw
3. Lift Cam
4. Maximum Fuel Rod
5. Fixing Sleeve

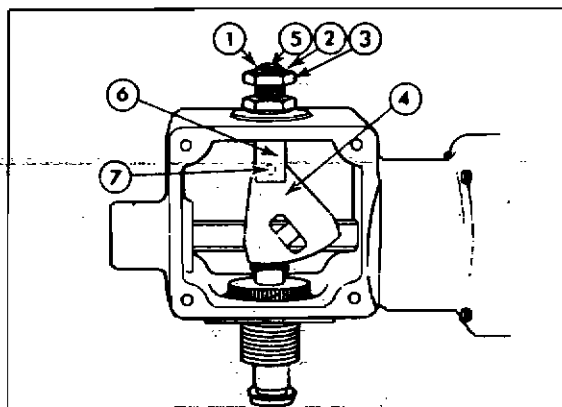


Fig. 58 Removing Cam Assembly

1. 'E' Clip
2. Bowed Washer
3. Adjusting Screw
4. Cam
5. Clevis Pin
6. Pin Retainer
7. Pin

## BOOST CONTROL UNIT (Cont'd)

5. Lightly scribe a line across edge of cover and housing (Fig. 59) to ensure correct position when reassembling. Slacken the four screws, apply slight pressure on the cover and remove the four screws and spring washers.

Remove the cover gently also the retain spring. Remove the 'E' clip and withdraw the operating rod pin while restraining the piston and diaphragm assembly. Slowly release the piston and withdraw it complete with the diaphragm spring.

Remove the thrust washer, also 'E' clip to enable the maximum fuel rod to be removed from the housing. Remove the fixing sleeve together with its washers.

Remove the nut and washer and lift off the breather cap from the side cover. Extract the filter capsule and wash it in a suitable cleaning agent. When dry replace in breather cap, refit the breather cap and secure with nut and washer.

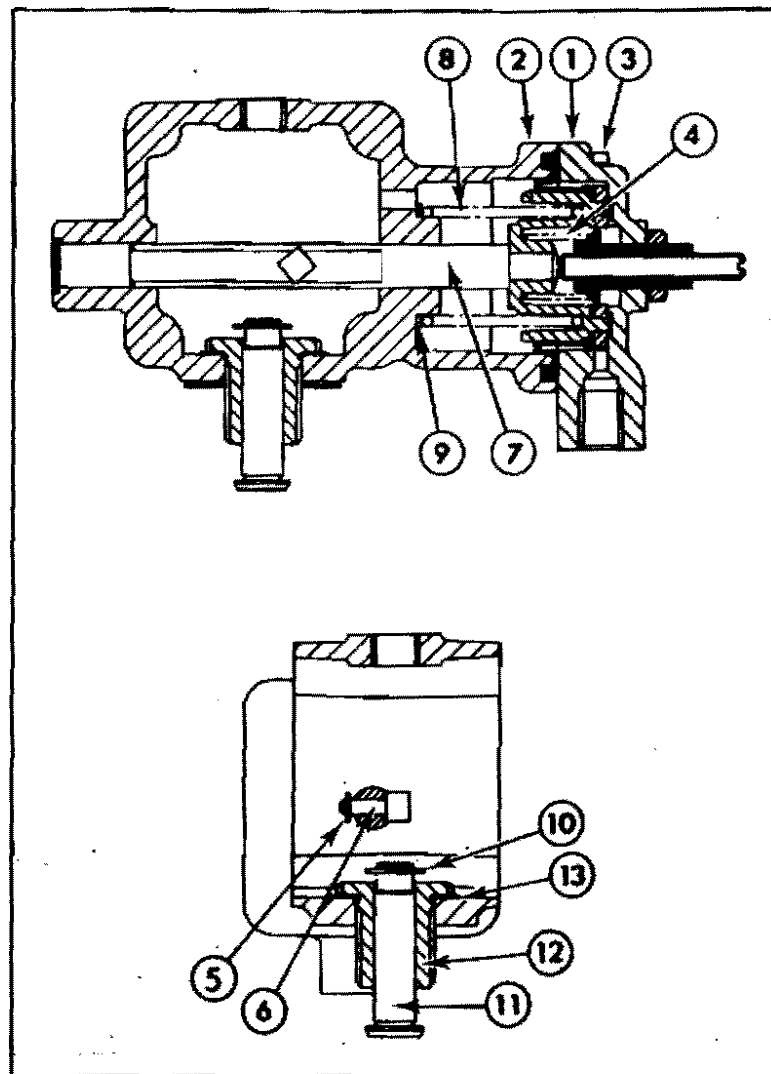


Fig. 59

## Removing Diaphragm Assembly

- |             |                               |                   |
|-------------|-------------------------------|-------------------|
| 1. Cover    | 6. Operating Rod Pin          | 11. Max. Fuel Rod |
| 2. Housing  | 7. Piston and Diaphragm Assy. | 12. Fixing Sleeve |
| 3. Screw    | 8. Diaphragm Spring           | 13. Washer        |
| 4. Spring   | 9. Thrust Washer              |                   |
| 5. 'E' Clip | 10. 'E' Clip                  |                   |

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## Examination of Parts

Thoroughly clean all parts before inspection.

Examine all moving parts for any signs of excessive wear, renew any suspect parts. Should the diaphragm need replacing, then the complete spindle assembly must be renewed.

Ensure that the fuel rod moves easily in the bore of the fixing sleeve without any excess play being present. Check all other moving parts for freedom of operation.

## To Re-assemble

It is recommended that new gaskets, circlips and sealing rings are fitted when re-assembling the booster control unit.

When fitting new 'O' ring seals over shafts having sharp corners, grooves or splines, use a suitable guide or other means of protection.

1. Place the fixing sleeve with its washer into position from inside the housing Fig. 60.
2. Insert the maximum fuel rod through the fixing sleeve in position with the 'E' clip.
3. Insert the cam into the clevis and secure in place with pin. Position the pin retainer over the clevis and fit a new 'O' ring into the groove or clevis shaft.

Insert assembly into place from inside the housing, as shown in Fig. 60.

Assemble the adjusting screw and locknut. Fit bowed washer and 'E' clips.

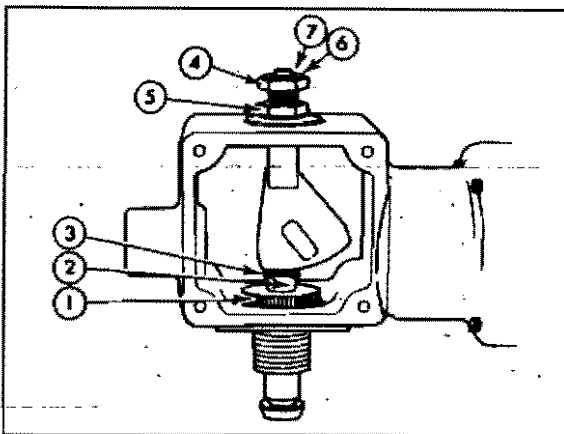


Fig. 60 Replacing Cam Assy.

- |                     |                 |
|---------------------|-----------------|
| 1. Fixing Sleeve    | 5. Locknut      |
| 2. Maximum Fuel Rod | 6. Bowed Washer |
| 3. 'E' Clip         | 7. 'E' Clip     |
| 4. Adjusting Screw  |                 |

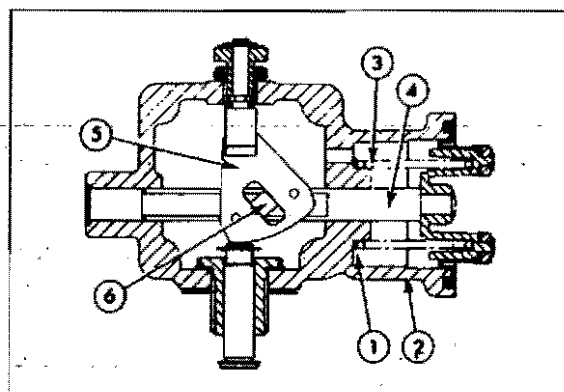


Fig. 61 Replacing Diaphragm Assy.

- |                     |                      |
|---------------------|----------------------|
| 1. Thrust Washer    | 4. Spindle Assy.     |
| 2. Housing          | 5. Cam               |
| 3. Diaphragm Spring | 6. Operating Rod Pin |

## To Reassemble (Cont'd)

4. Coat both sides of diaphragm with 'Molecote Z' powder and apply anti-scuffing paste to moving parts. Place the thrust washer into the housing and assemble diaphragm spring and spindle assembly Fig. 61, ensuring that the flat on spindle lies against the side of the cam.

Line up the hole in the spindle with the slot in the cam and insert the operating rod pin through cam into the spindle. Secure with 'E' clip.

5. Assemble the adjusting spring Fig. 62 and spring locator in their correct position and replace the cover so that the scribed lines coincide. Ensure that the diaphragm is not pinched between the cover and housing. Secure with the four screws and washers and tighten to the correct torque of 2.7 to 4.0 Nm (0.28 to 0.42 kgf m or 2 to 3 lbf ft).

Apply an air pressure of 1.03 bar (1.05kgf/cm<sup>2</sup> or 15lbf/in<sup>2</sup>) to the boost control inlet and test for leaks between the cover and housing.

## Replacing the Booster Unit on Injection Pump

1. Fit a new gasket, coated both sides with 'Hylomar L33' sealing compound, between the boost control unit and the governor case Fig. 63. Coat the fixing sleeve with 'Loquic T' primer and 'A V Loctite', alternatively use 'Loctite 241' or an approved equivalent.

2. Position the unit on the governor housing so that it locates directly on the dowel pin.

3. Turn the adjusting screw up to its top limit to lift the cam from the maximum fuel rod. Depress the maximum stop lever against the spring while screwing the fixing sleeve into the governor case, using special tool ST. 172. Tighten to correct torque 54.2 Nm (5.53 kgf m or 40 lbf ft).

4. Turn adjusting screw down so that there is a gap of 2 mm. (0.080 in.) between the top of the locknut and underside of the screw head.

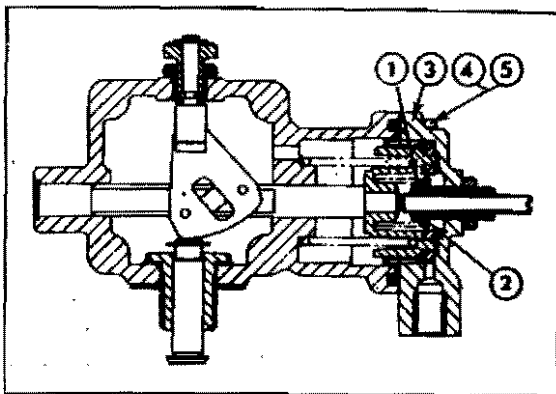


Fig. 62 Replacing Cover Assy.

- |                     |           |
|---------------------|-----------|
| 1. Adjusting Spring | 4. Screw  |
| 2. Spring Locator   | 5. Washer |
| 3. Cover            |           |

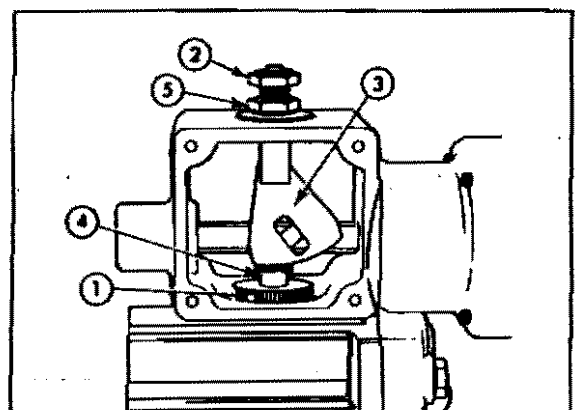


Fig. 63 Fitting Boost Control Unit

- |                    |                     |
|--------------------|---------------------|
| 1. Fixing Sleeve   | 4. Maximum Fuel Rod |
| 2. Adjusting Screw | 5. Locknut          |
| 3. Lift Cam        |                     |

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## Checking the Booster Unit

Maximum fuel delivery and overall spread, measured over 200 shots, using BDN12SD12 nozzles.

- (a) With the boost pressure at 0.85 bar (0.86 kgf/cm<sup>2</sup> or 12.3 lbf/in<sup>2</sup>) average delivery at 100 r.p.m. to be 17.4 to 18.6 c.c.'s (Hartridge 1100) or 16.8 to 18.0 c.c.'s (Hartridge 650) the overall spread not to exceed 0.8 c.c.
- (b) With the boost pressure at 0.24 bar (0.25 kgf/cm<sup>2</sup> or 3.5 lbf/in<sup>2</sup>) average delivery at 600 r.p.m. to be 11.3 to 12.5 c.c.'s (Hartridge 1100) or 11.4 to 12.6 c.c.'s (Hartridge 650) the overall spread not to exceed 1.2 c.c.'s.
- (c) With boost at zero, average delivery at 400 r.p.m. to be 8.4 to 9.6 c.c.'s (Hartridge 1100) or 9.0 to 10.2 c.c.'s (Hartridge 650) the overall spread not to exceed 1.2 c.c.'s.
- (d) With the pump running at 400 r.p.m., ensure the boost control cam starts to move with 0.16 to 0.24 bar (0.17 to 0.25 kgf/cm<sup>2</sup> or 2.4 to 3.5 lbf/in<sup>2</sup>) boost pressure, and that travel finishes at 0.48 to 0.58 bar (0.49 to 0.59 kgf/cm<sup>2</sup> or 7 to 8.5 lbf/in<sup>2</sup>) boost pressure.

## Booster Unit Permissible Delivery

Following the rectification of the booster unit (new or service injection pumps)

- (a) Adjust the maximum fuel screw 'B' Fig. 64, to give an average delivery at 1000 r.p.m. of 17.9 to 18.1 c.c.'s (Hartridge 1100) or 17.3 to 17.5 c.c.'s (Hartridge 650) with 0.85 bar (0.86 kgf/cm<sup>2</sup> or 12.3 lbf/in<sup>2</sup>) boost pressure.
- (b) After making this adjustment ensure that the average delivery at 600 r.p.m. and 0.24 bar (0.25 kgf/cm<sup>2</sup> or 3.5 lbf/in<sup>2</sup>) boost pressure is in the range of 11.6 to 12.2 c.c.'s (Hartridge 1100) or 11.7 to 12.3 c.c.'s (Hartridge 650) and that average delivery at 400 r.p.m. and zero boost pressure is in the range of 8.5 to 9.5 c.c.'s (Hartridge 1100) or 9.1 to 10.1 c.c.'s (Hartridge 650).

NOTE:—If it is not possible to obtain these figures, recalibrate the fuel injection pump.

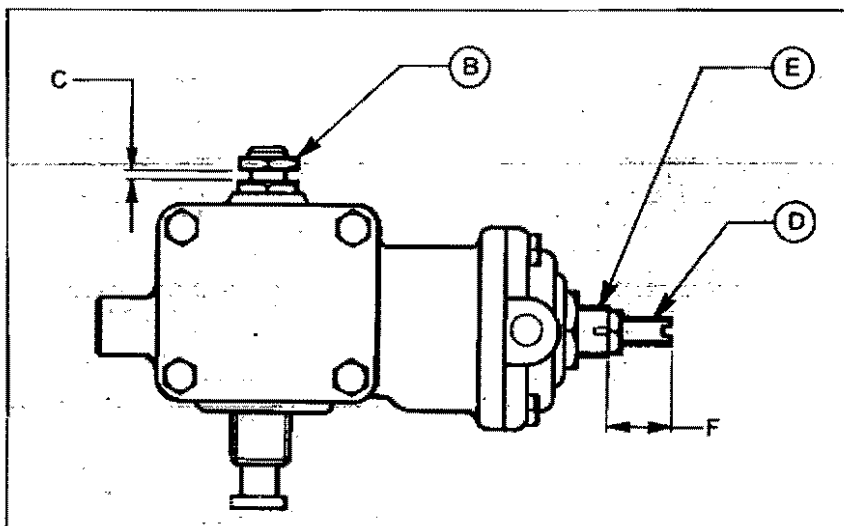


Fig. 64 Recalibration



## Recalibration

- (a) Set the gap between head of maximum fuel screw 'B' Fig. 64 and locknut to  $2.00 \pm 1.00$  mm. ( $0.080 \pm 0.040$  in.).
- (b) Adjust the boost pressure to 0.85 bar ( $0.86 \text{ kgf/cm}^2$  or  $12.31 \text{ lbf/in}^2$ ). Adjust No. 6 fork to give 17.9 to 18.1 c.c.'s (Hartridge 1100) or 17.3 to 17.5 (Hartridge 650) from No. 6 element at 1000 r.p.m.
- (c) Adjust remaining forks to give an average overall spread of 0.4 c.c.
- (d) Adjust the boost pressure to 0.24 bar ( $0.25 \text{ kgf/cm}^2$  or  $3.5 \text{ lbf/in}^2$ ). Adjust screw 'E' to give fuelling of 11.8 to 12.0 c.c.'s (Hartridge 1100) or 11.9 to 12.1 c.c.'s (Hartridge 650) at 600 r.p.m. overall spread not to exceed 0.8 c.c.

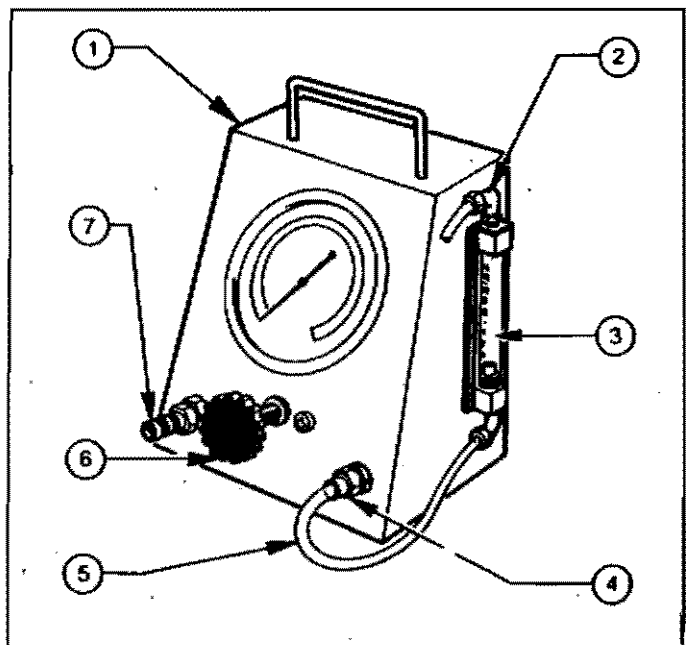
When making this adjustment, ensure that the fuel screw 'D' is protruding a minimum of 15 mm. (0.6 in.) from screw 'E'.

- (e) With zero boost pressure, adjust minimum fuel screw 'D' to give 8.9 to 9.1 c.c.'s (Hartridge 1100) or 9.5 to 9.7 c.c.'s (Hartridge 650) at 400 r.p.m., overall spread not to exceed 0.6 c.c.
- (f) With the boost control side cover removed and the pump speed at 400 r.p.m., check that the cam starts to move between 0.16 to 0.24 bar ( $0.17$  to  $0.25 \text{ kgf/cm}^2$  or  $2.4$  to  $3.5 \text{ lbf/in}^2$ ) boost pressure and that travel finishes between 0.48 to 0.58 bar ( $0.49$  to  $0.59 \text{ kgf/cm}^2$  or  $7$  to  $8.4 \text{ lbf/in}^2$ ).
- (g) With the boost pressure at zero and the control rod in excess fuel position, delivery not to be less than 21 c.c.'s when measured at 1000 r.p.m. and over the 200 strokes.
- (h) With the boost pressure at zero, the idling delivery set to 3.0 c.c.'s per 200 strokes at 600 r.p.m. balance between all lines to be within  $\pm 0.8$  c.c.

After calibration has been completed, assemble both side covers, using new gaskets coated on both sides with "Hylomar L33" sealing compound. Ensure that the cover containing the breather cap is in the same position it occupied prior to dismantling. Secure the covers with the eight screws and washers and torque to 2.7 to 4.0 Nm ( $0.28$  to  $0.42 \text{ kgfm}$  or  $2$  to  $3 \text{ lbf ft}$ ).

Fig. 65

1. Pressure Gauge
2. Flowmeter outlet Connection
3. Flowmeter
4. Outlet Connection
5. Nylon Pipe
6. Pressure Control Valve
7. Inlet Connection



## Recalibration (Cont'd)

If the pump is to be pressure tested for leakage, remove the nut and washer and detach the breather cap and gauze from the side cover, then seal the breather spindle and boost pressure inlet hole.

On completion of pressure testing, remove the sealing devices and replace the gauze and breather cap. Secure the cap with nut and washer.

## Testing Equipment

To calibrate and check the boost control unit, a Hartridge boost control testing kit (HE 107) Fig. 65 should be used.

Alternative testing equipment is shown in Fig. 66 illustrating two ways of testing the boost control pressure. 'A' is used where a compressor is available to give an air line pressure in excess of 1.38 bar (1.4 kgf/cm<sup>2</sup> or 20 lbf/in<sup>2</sup>) and 'B' for where no compressor is available. Both systems use a constant bleed valve to vary the pressure feed to the boost control. Pressure is measured by means of a mercury filled manometer.

Where an existing compressor is used, an isolation valve is included.

This should be set to give a maximum pressure of 1.32 bar (1.34 kgf/cm<sup>2</sup> or 19.2 lbf/in<sup>2</sup>) with the constant bleed valve closed. This will prevent mercury from being accidentally blown out of the manometer when the compressor is supplying excessively high air line pressure.

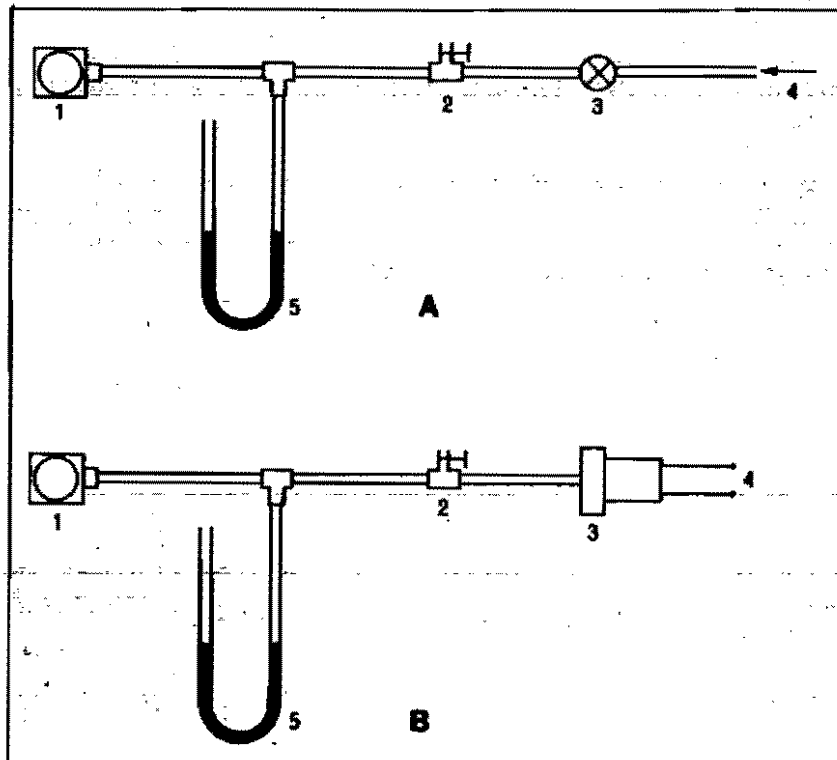


Fig. 66

### SYSTEM 'A'

For use where air compressor is available.

1. Boost Control
2. Constant Bleed Valve
3. Isolating Valve
4. Air Supply from Compressor
5. Mercury Filled Manometer Capable of Measuring Up to 625 mm. (25 in.) HG

### SYSTEM 'B'

For use where no external air supply is available.

1. Boost Control
2. Constant Bleed Valve
3. Air Pump
4. A C Supply
5. Mercury Filled Manometer Capable of Measuring up to 625 mm (25 in.) HG

'Molycote Z' may be obtained in an aerosol container, and is obtainable from the distributors shown below.

#### LUBRICANT DISTRIBUTOR LIST

Action Bearings Ltd., Westfield Road, Wallasey, Cheshire	Tel: 051-652 6664
J. T. Chadwick Limited Doncaster Hall, Montgomery Terrace Road, Sheffield S6 3DE	Tel: Sheffield 28702
The Ironside Lubricants Limited, Shield Street, Stockport, Cheshire	Tel: 061-480 7588/2419
Kinwil (Barrow) Limited, St. George's Square, Barrow-in-Furness	Tel: B.I.F. 25871
W. Pond & Co. Ltd., 192 Corporation Street, Birmingham B4 6QJ	Tel: 021-236 3032
R. and J. Rankin Limited Blackburns Building, Country Road, Ormskirk, Lancs.	Tel: Ormskirk 74313/4
Claude Rye Bearing Limited, 460-462 Fulham Road, London S.W.6	Tel: 01-385 9776
Sealine Services (Marine Supplies) Ltd., Prestley Road, Basingstoke, Hants.	Tel: Basingstoke 0256 29191
R. D. Taylor and Co. Ltd., 332 Broomloan Road, Glasgow S.W.1	Tel: 041-445 3684
Witty and Wyatt (Asbestos and Gaskets) Ltd., 895 High Road, Chadwell Heath, Romford, Essex.	Tel: 01-599 3971

If any difficulty is experienced in obtaining 'Molocote Z' from the distributors, it may be ordered direct from:

Dow Corning Ltd.,  
Reading Bridge House,  
Reading, Berks.

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# SPECIFICATIONS

Type	'Minimec' multi-element operated by an enclosed camshaft
Rotation	Clockwise from drive end
Cold Starting device	By excess fuel control
Plunger bore, stroke and helix angle:	
2701/3/4E and 2704ET Class 'A'	8 mm. dia. x 7 mm. x 45°
2701/3/4C and 2711/12/13/14E	8.5 mm. dia. x 7 mm. x 45°
2704ET General Purpose, Marine and Automotive	9 mm. dia. x 7 mm. x 45°
2704ET Turbo Plus	9.5 mm. dia. x 7 mm. x 45°
Fuel delivery	Refer to chart – page 17
Element efficiency	Maximum difference between 200 shots at 600 and 200 rev./min. should not exceed 2.6 cc
Camshaft end-float	0.051 to 0.127 mm (0.002 to 0.005 in.)
Camshaft end-float shims	0.102 and 0.203 mm (0.004 and 0.008 in) thick
Phasing tolerance	± 1° Pump
Idling tolerance	± ½° Pump
Timing	Refer to plate attached to injection pump
Idling speed	Refer to chart – page 17r
Delivery valve holder tightening torques	
– With NYLON seating washer	40.7 to 48.8 Nm (4.15 to 4.98 kgf m or 30 to 36 lbf ft)
– With STEEL seating washer	51.5 to 56.9 Nm (5.26 to 5.81 kgf m or 38 to 42 lbf ft)
Timing gear nut tightening torque	62.3 Nm (6.36 kgf m or 46 lbf ft)
Lubricant	As for engine
Capacity	
– 4 cyl.	0.35 litres (0.62 pints)
– 6 cyl.	0.42 litres (0.75 pints)

## PHASING SPACERS:

Grade	Thickness
1	3.85 to 3.90 mm (0.152 to 0.154 in.)
2	3.95 to 4.00 mm (0.156 to 0.158 in.)
3	4.05 to 4.10 mm (0.160 to 0.161 in.)
4	4.15 to 4.20 mm (0.163 to 0.165 in.)
5	4.25 to 4.30 mm (0.167 to 0.169 in.)
Stroke to close inlet port	2.9 to 3.1 mm (0.114 to 0.122 in.)
Plunger head clearance	1.5 to 2.0 mm (0.059 to 0.079 in.)
Plunger arm to spring seat clearance	0.05 to 0.2 mm (0.002 to 0.008 in.)

## SPRING SEAT:

Grade	
1B	0.60 to 0.65 mm (0.024 to 0.026 in.)
2B	0.70 to 0.75 mm (0.028 to 0.030 in.)
3B	0.80 to 0.85 mm (0.031 to 0.033 in.)
4B	0.90 to 0.95 mm (0.035 to 0.037 in.)
5B	1.00 to 1.05 mm (0.039 to 0.041 in.)
6B	1.10 to 1.15 mm (0.043 to 0.045 in.)
7B	1.20 to 1.25 mm (0.047 to 0.049 in.)
8B	1.30 to 1.35 mm (0.051 to 0.053 in.)
9B	1.40 to 1.45 mm (0.055 to 0.057 in.)
10B	1.50 to 1.55 mm (0.059 to 0.061 in.)
11B	1.60 to 1.65 mm (0.063 to 0.065 in.)
12B	1.70 to 1.75 mm (0.067 to 0.069 in.)
13B	1.80 to 1.85 mm (0.071 to 0.073 in.)
14B	1.90 to 1.95 mm (0.075 to 0.077 in.)
15B	2.00 to 2.05 mm (0.079 to 0.081 in.)
16B	2.10 to 2.15 mm (0.083 to 0.085 in.)

## FUEL INJECTORS

## NORMALLY ASPIRATED ENGINES

3.964 l. (242 cu.in.) 5.416 l. (330 cu.in.) 5945 l. (363 cu.in.)

	SIMMS	C.A.V.
Type	4 hole long stem	—
Colour Code:		
New injectors	Red/Green paint spots	—
Reconditioned injectors	Purple/Green paint spots	—
Injector nozzle number	NL 582	—
Spray cone angle	150° at 20° to injector axis	—
Diameter of spray holes	0.29 to 0.30 mm (0.0114 to 0.0118 in.)	—
Length of spray hole	0.50 mm (0.020 in.)	—
Nozzle opening pressure	185 ± 2.5 ATS	—
Needle lift	0.40 to 0.35 mm (0.0157 to 0.0138 in.)	—

4.150 l. (255 cu.in.) 5.950 l. (365 cu.in.) 6.220 l. (380 cu.in.)

	SIMMS	C.A.V.
Type	4 hole long stem	4 hole long stem
Colour code:		
New injectors	Yellow/Purple paints spots	None
Reconditioned injectors	Brown/Blue paint spots	None
Injector nozzle number	NL 645	BDLL 140S6422
Spray cone angle	140° at 20° to injector axis	140° at 20° to injector axis
Diameter of spray holes	0.30 mm (0.0118 in.)	0.29 mm (0.0114 in.)
Length of spray hole	0.70 mm (0.0276 in.)	0.60 mm (0.0236 in.)
Nozzle opening pressure	185 ± 2.5 ATS	185 ± 2.5 ATS
Needle lift	0.27 to 0.22 mm (0.011 to 0.009 in.)	0.25 to 0.20 mm (0.010 to 0.008 in.)

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## NORMALLY ASPIRATED ENGINES (Cont'd)

4.150 l. (255 cu.in.) 5.950 l. (365 cu.in.) 6.220 l. (380 cu.in.)

Type	—	4 hole long stem
Colour code	—	White
Injector nozzle number	—	* BDLL 140S6622
Spray cone angle	—	140° at 20° to injector axis
Diameter of spray holes	—	0.29 to 0.31 mm
Length of spray hole	—	(0.0114 to 0.0122 in.)
Nozzle opening pressure	—	0.80 mm (0.0315 in.)
Needle lift	—	185 ± 2.5 ATS
	—	0.35 to 0.30 mm
	—	(0.0138 to 0.0118 in.)

\* Replace NL 645 and/or BDLL 140S6422 in engine sets

## TURBOCHARGED ENGINE – INDUSTRIAL AND MARINE

5.945 l. (363 cu.in.)

	<b>SIMMS</b>	<b>C.A.V.</b>
Type	4 hole long stem	4 hole long stem
Colour code:		
New injectors	Grey/Green paint spots	Green/Yellow paint spots
Reconditioned injectors	Green/Blue paint spots	—
Injector nozzle number	NL 547	*E LL 140S6608A
Spray cone angle	140° at 20° to injector axis	140° at 20° to injector axis
Diameter of spray holes	0.32 to 0.34 mm (0.0126 to 0.0134 in.)	0.32 to 0.34 mm (0.0126 to 0.0134 in.)
Length of spray hole	0.50 mm (0.020 in.)	0.60 mm (0.0236 in.)
Nozzle opening pressure	190 ± 2.5 ATS	205 ± 2.5 ATS
Needle lift	0.30 to 0.25 mm (0.0118 to 0.010 in.)	0.37 to 0.28 mm (0.0146 to 0.0110 in.)

\* Replaces NL 547 in engine sets

## TURBOCHARGED ENGINES – INTERCOOLED TURBO PLUS AND COMBINE HARVESTERS

5.945 l. (363 cu.in.)

Type	4 hole long stem	4 hole long stem
Colour code:		
New injectors	Green/Brown paint spots	Green/White paint spots
Injector nozzle number	NL 639	*BDLL140S6609
Spray cone angle	140° at 20° to injector axis	140° at 20° to injector axis
Diameter of spray holes	0.34 to 0.36 mm (0.0134 to 0.0142 in.)	0.34 to 0.36 mm (0.0134 to 0.0142 in.)
Length of spray hole	0.70 mm (0.0276 in.)	0.70 mm (0.0276 in.)
Nozzle opening pressure	190 ± 2.5 ATS	205 ± 2.5 ATS
Needle lift	0.40 to 0.35 mm (0.0157 to 0.0138 in.)	0.40 to 0.35 mm (0.0157 to 0.0138 in.)

\* Replaces NL 639 in engine sets

Back leak test time for pressure to drop  
from 150 to 100 atmospheres:

New injectors	10 to 45 secs.
Reconditioned and service injectors	6 to 45 secs.

**NEEDLE SEAT LEAKAGE:**

New injectors	Nozzle tip to be dry after operating the injector and after holding the pressure at 140 atmospheres for 10 secs. i.e. No drops visible.
Reconditioned and service injectors	Hold the pressure at 170 atmospheres for 60 secs. when leakage should not cause a blot larger than 38.0 mm (1.5 in.) dia. on filter paper (Whatmans)
Nozzle nut tightening torque	81.4 to 102 Nm (8.3 to 10.37 kgf m or 60 to 75 lbf ft)
Cap nut tightening torque	50.2 to 58.3 Nm (5.12 to 5.95 kgf m or 37 to 43 lbf ft)
Injector bolt tightening torque	20.3 Nm (2.07 kgf m or 15 lbf ft)

**TEST BENCH REQUIREMENTS**

Type	Variable speed
Master injector nozzle	C.A.V. BDN125D12 or Simms N4S1
Nozzle opening pressure	Refer to pages 36 and 36r
Back leakage, time for a pressure drop from 150 to 100 atmospheres	10 sec. minimum (New) 6 sec. minimum (Recon.)
High pressure pipes	6 mm (O.D. x 2 mm I.D. x 76.2 cm (30 in.))

**SUBSTITUTE FUEL OIL:**

Amoco (U.K.) Limited	
Castrol Limited	H 111/60
Alexander Duckham & Company Limited	
Esso Petroleum Company Limited	TSD 815
Mobil Oil Company Limited	
Petrofina (Great Britain) Limited	
Regent Oil Company Limited	
Shell-Mex & B.P. Limited	Shell Fusus Oil "A"; Shell DT 11
Oil Temperature	15.6 to 48.9°C. (60 to 120°F.)

**FUEL LIFT PUMP**

Type	
Standard	Diaphragm with hand primer
High pressure	Diaphragm with piston primer Plunger and spindle with piston hand primer Mechanical by eccentric on engine camshaft
Drive	
Fuel delivery	
Standard	14.8 litre/hr (3.25 gal/hr) at 0.14 bar (0.14 kgf/cm <sup>2</sup> or 2 lbf/in <sup>2</sup> ) at 1000 r.p.m. engine speed
High Pressure — diaphragm type	54.5 litre/hr (12 gal/hr) at 1.03 bar (1.05 kgf/cm <sup>2</sup> or 15 lbf/in <sup>2</sup> ) at 1000 r.p.m. engine speed
— plunger type	77.5 litre/hr (17.5 gal/hr) at 1.03 bar (1.05 kgf/cm <sup>2</sup> or 15 lbf/in <sup>2</sup> ) at 1000 r.p.m. engine speed
Delivery pressure	
Standard — diaphragm type	0.34 to 0.55 bar (0.35 to 0.56 kgf/cm <sup>2</sup> or 5 to 8 lbf/in <sup>2</sup> )
High pressure — diaphragm type	2.76 to 3.59 bar (2.81 to 3.66 kgf/cm <sup>2</sup> or 40 to 52 lbf/in <sup>2</sup> )
— plunger type	2.07 to 2.41 bar (2.10 to 2.32 kgf/cm <sup>2</sup> or 30 to 35 lbf/in <sup>2</sup> )
Inlet depression	
Standard	35.6 cm of Hg (14 in of mercury)
High pressure	20.3 cm of Hg (8 in of mercury)

## FUEL LIFT PUMP (Cont'd)

### Diaphragm spring test load and compression length

Standard

6.8 to 7.1 kg. at 15.9 mm. (15 to 15.7 lb. at 5/8 in.)

High pressure

6.7 to 6.9 kg. at 16.3 mm. (14.7 to 15.2 lb. at 41/64 in.)

### Free length

Standard

51 mm (2 in.) approx.

High pressure

44.5 mm (1.7 in.) approx.

### Identification colour

Standard

Violet paint

High pressure

Brown paint

### Body screw torque

2.3 to 3.4 Nm (0.23 to 0.35 kgf m or 20 to 30 lbf in)

### Cover bolt torque

5.1 to 6.2 Nm (0.52 to 0.63 kgf m or 45 to 55 lbf in)

## FUEL FILTERS

### Primary (where fitted)

Sediment bowl and gauze screen or water separator

### Secondary

Replaceable element/s

## AIR CLEANERS

### Type

Oil Bath

### Oil Capacity

0.30 litres (0.64 Imp. pint)

### Oil Grade

As for engine

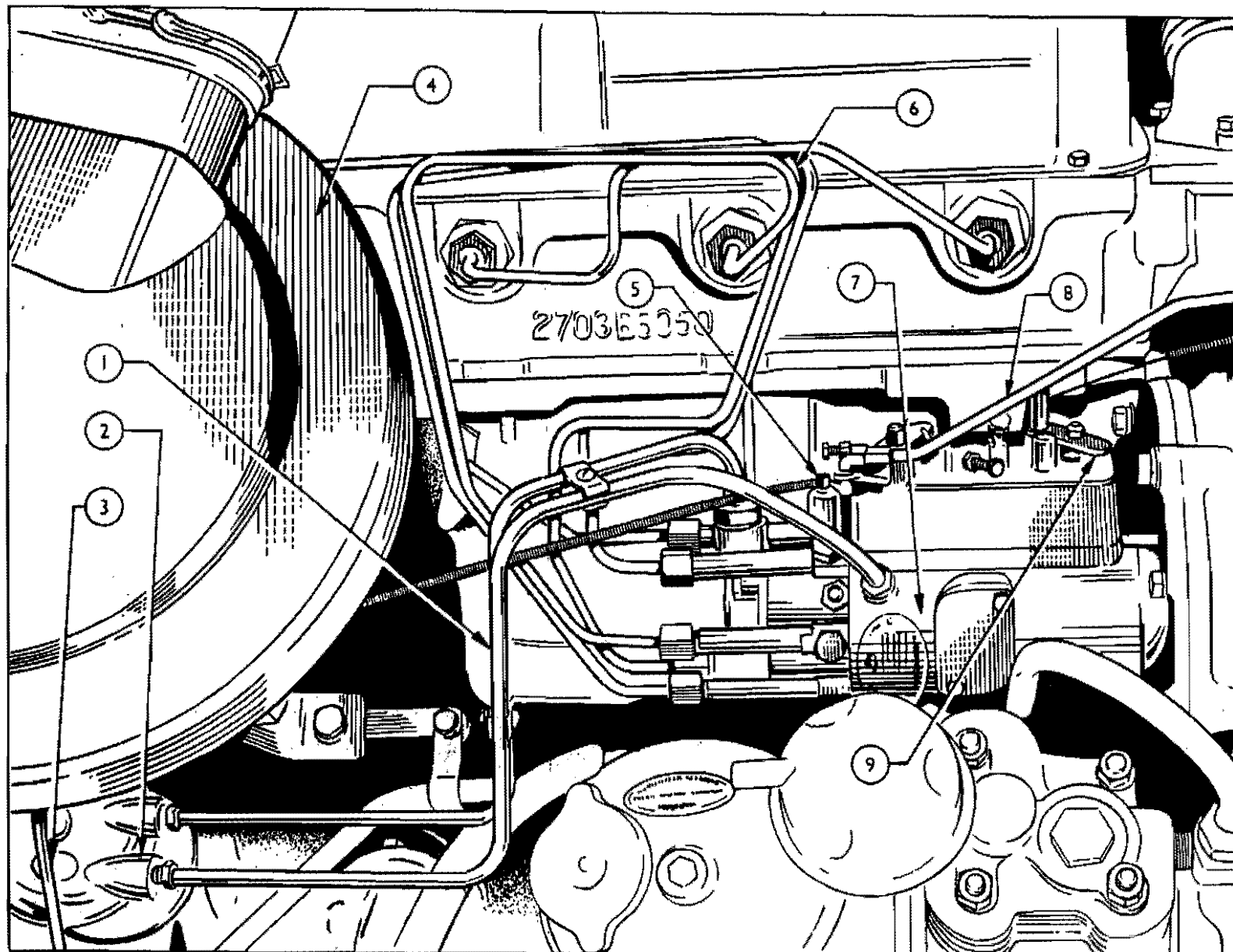
### Type

Paper Element



Fig. 67

- 1 Fuel Feed and Return Pipes
- 2 Fuel Filter
- 3 Filter Leak-off Pipe
- 4 Air Cleaner
- 5 Excess Fuel Lever
- 6 Injector Pipes
- 7 Injector Pump
- 8 Throttle Linkage
- 9 Stop Control Lever



# THE DISTRIBUTOR TYPE INJECTION PUMP (360 cu. in. ENGINE)

## DESCRIPTION

The distributor type injection pump (see Fig. 67) consists of a shuttle charged single pumping element (two opposed plungers) revolving in a cam ring. This pumping element delivers fuel under high pressure to all the injectors in turn by means of a distributing rotor integral with the pump rotor. A vane type transfer pump attached to the end of the distributing rotor supplies fuel to the shuttle chamber via a metering valve, transfer pressure being determined by a regulating valve in the end cover. The maximum shuttle stroke can be adjusted externally and this controls the maximum fuel delivery.

The mechanical governor consists of a fly-weight and cush drive assembly splined to the injection pump driveshaft and connected by a sleeve, control arm and link to the metering valve. A governor spring and idling spring connect the control arm to the throttle lever Fig. 68.

Stop screws are provided to limit the movement of the throttle lever and set the maximum and idling speeds.

The injection pump also incorporates an excess fuel device for cold starting, an automatic advance and start retard mechanism and a stop control.

## INJECTION PUMP OPERATION

Fuel from the fuel pump is filtered by a replaceable element-type filter and enters the injection pump at the fuel inlet connection (see Fig. 69). After passing through a nylon filter an eccentric sliding vane-type transfer pump increases the pressure. This pressure increase is proportional to the engine speed and is controlled by an adjustable regulating valve. The regulating valve is a spring-loaded plunger in a sleeve situated beneath the inlet connection between the inlet and outlet side of the transfer pump. The fuel pressure lifts the plunger up against the regulating spring until the regulating port is partially open and fuel bleeds back to the inlet side of the transfer pump, thus regulating the transfer pressure.

Fuel at transfer pressure flows through drillings in the hydraulic head to the metering valve, which is connected to a mechanical governor, and then to the metering port. The metering port opens into an annular groove, connected to which is a series of six equally spaced segmental grooves, in the distributor rotor. When the shuttle port is in alignment with one of the six inlet segments in the rotor a metered quantity of fuel enters the shuttle chamber. Displaced fuel from the reverse side of the shuttle flows through the drillings and another series of grooves in the rotor, but with the segments phased at  $30^{\circ}$  to the inlet segments, and then via dump ports to the pump body. Under full load operation the shuttle stroke, which can be adjusted by an external stop screw, controls the maximum fuel delivery.

Rotation of the pump brings one of the six equally spaced inlet ports in the rotor into alignment with the shuttle port, the dumping segments now being in alignment with transfer ports and transfer pressure is applied to the top of the shuttle to positively charge the pumping element (see Fig. 72).

Injection commences when further rotation of the pump brings the pumping element rollers into contact with a pair of diametrically opposed cam lobes and the rollers ride up the flanks to force the plungers together (see Fig. 69). At this instant, the distributing port will be in alignment with one of the six delivery ports and fuel at high pressure will be delivered to the appropriate injector. One of the inlet segments is again in line with the shuttle port and shuttle charging occurs simultaneously with injection.

Each cam lobe has two peaks and injection ceases when the roller reaches the first, which is the highest. The valley between the two peaks ensures a rapid reduction in pressure in the injector pipe line preventing dribble and carbon formation at the injector nozzle at the end of injection. The second, lower, peak maintains residual pressure in the pipe lines. The cam ring between the lobes is relieved and the rollers do not at any time contact this surface.

## INJECTION PUMP OPERATION (Cont'd).

Fuel dumped in the pump body during shuttle operation together with fuel bled past the rotating parts for lubrication purposes is returned to the inlet side of the fuel filter by a pressurising valve (see Fig. 70) incorporated with the right-hand locking screw on the hydraulic head. This valve consists of a valve body and retainer, clamped in the adaptor body by the outlet connection, a valve, located in the valve body, and a small plunger in the adaptor shank.

A groove machined inside the pump body provides an outlet from the pump body to the pressurising valve. Pressure build-up inside the pump body acts on the large area of the valve until it is sufficient to overcome transfer pressure acting on the small area of the plunger. The valve then opens and surplus fuel is returned to the inlet side of the fuel filter. The pressure inside the pump body is thus, always proportional to transfer pressure and damps pumping element plunger operation to prevent cavitation.

## ADVANCE MECHANISM OPERATION

The cam ring is not fixed to the injection pump but is attached by a ball stud to an automatic advance and start retard mechanism (see Fig. 71). This consists of a spring-loaded plunger in a housing attached to the underside of the pump body. The plunger is in two parts, a piston into which the ball stud locates and a spring plate, the piston and spring plate being separated by a retard spring. The spring plate is located in the housing by a circlip and is pressurised by two advance springs fitted in a cap screwed into the end of the housing. When the pump is not operating, the piston is held in a fully retarded position by the retard spring to facilitate starting. As soon as the engine is started transfer pressure acts on the piston, to oppose the retard spring, which then moves into abutment with the spring plate. As engine speed increases transfer pressure increases and the piston and spring plate move together against the advance springs to progressively advance the injection pump timing.

The advance rate is adjusted by shims located in the advance cap. Cam ring torque, caused by the rollers striking the cam lobes, is dampened by a ball valve in the transfer pressure feed to the advance mechanism.

## GOVERNOR OPERATION

Engine speed is controlled by the throttle lever. Movement of this lever towards the maximum speed position tensions the governor spring and prevents outward movement of the fly-weights by means of the control arm and sleeve. The metering valve, which is connected to the control arm by a spring-loaded hook link, is thus opened fully allowing maximum fuel to be supplied to the engine. Engine speed can now increase until the centrifugal force on the fly-weights balances the governor spring and the metering valve is then partially closed to give the correct amount of fuel for operation at the selected speed. Any variation in engine load will affect the speed and the governor will then automatically adjust the metering valve, and hence the fuel supply, to meet the new conditions.

Movement of the throttle lever to the idling position removes the tension from the governor spring, allowing the fly-weights to move outwards and close the metering valve. Engine speed then decreases until the idling spring balances the fly-weights' centrifugal force and opens the metering valve to the idling position. A small relief in the metering valve groove prevents stalling when decelerating.

Should it be necessary to carry out repairs to the injection pump fitted to 2713E/2715E Combine Harvester engines, it is important that reference be made to the manufacturer's number plate attached to the pump body.

The letter "W" stamped on the plate indicates that the governor assembly has been modified from a 2 weight to 4 weight in Service and the additional weights should not be removed.

The calibrating specifications remain as originally quoted.

## CONTROL ROD DAMPER:

From Engine No. S980178, the CAV type injection pumps used on 2713E and 2715E normally-aspirated Clayson Combine Harvester engines, have been fitted in production with a control rod damper assembly, to overcome governor instability when running at light loads.

It is recommended that where cases of governor instability are reported that cannot be rectified in Service, then the injection pump should be fitted with the control rod damper assembly. When modified, the injection pump assy. part numbers are:

Engine		Old Part No.		New Part No.
2713E	=	703F-9A543-BEC	becomes	703F-9A543-BED
2715E	=	703F-9A543-CJC	becomes	703F-9A543-CJD



**FITTING INSTRUCTIONS:**

The control rod damper assembly is fitted as follows:

1. Remove the cap nut and washer from the body of the pump.
2. Release the locknut, and turn the adjusting screw fully anti(counter)-clockwise.
3. Fit the spacing washer inside the body of the pump, followed by the control rod damper assembly.
4. Start the engine and allow to "run" until normal operating temperature is reached.
5. Ensure that ALL loads are removed from the engine, then increase speed to maximum "no load" speed. Measure the engine speed with a hand-held independent tachometer.
6. Turn the adjusting screw clockwise to obtain an increase of 10 rev./min., on the speed recorded in paragraph 5.
7. Turn the adjusting screw three-quarters-of-a-turn (270°) anti(counter)-clockwise, and lock in that position with the locknut. Check the engine speed through its entire range, then stop engine.
8. Finally, replace and lock the outer cover.

**PARTS REQUIRED:**

Part No.	Description	Finis Code	Quantity
763F-9K566-AA	Control Rod Damper Assy.	1575252	1
830635-S	Spacing washer	1575251	1

**EXCESS FUEL DEVICE**

The maximum fuel delivery is controlled by adjusting the shuttle stroke, but for cold starting when excess fuel is required a valve can be released to by-pass the shuttle charging system, thus charging the pumping element direct, in addition to normal shuttle operation. The quantity of excess fuel is pre-set by fixed stop plates which limit the pumping element plungers stroke. The excess fuel valve, when released, also closes the fuel line to the advance mechanism. The cam ring is thus held in the fully retarded position, to assist starting, until the excess fuel valve is returned automatically to the normal running position by transfer pressure acting on the valve end—refer to Fig. 73.

The excess fuel device control is situated between Nos.1 and 4 injector pipe banjo connections on the injection pump. Move the toggle lever fully to one side by pulling the excess fuel remote control knob (see Fig. 67) and release immediately to provide excess fuel for cold starting.

**STOP CONTROL**

To stop the engine, the stop lever on the injection pump governor cover is turned by pulling the stop control. A crank on the stop lever shaft is connected with a cut-off bar inside the governor cover. Movement of the stop lever causes the cut-off bar to close the metering valve against the hook link springs and thus stop the engine.

**REGULATING VALVE**

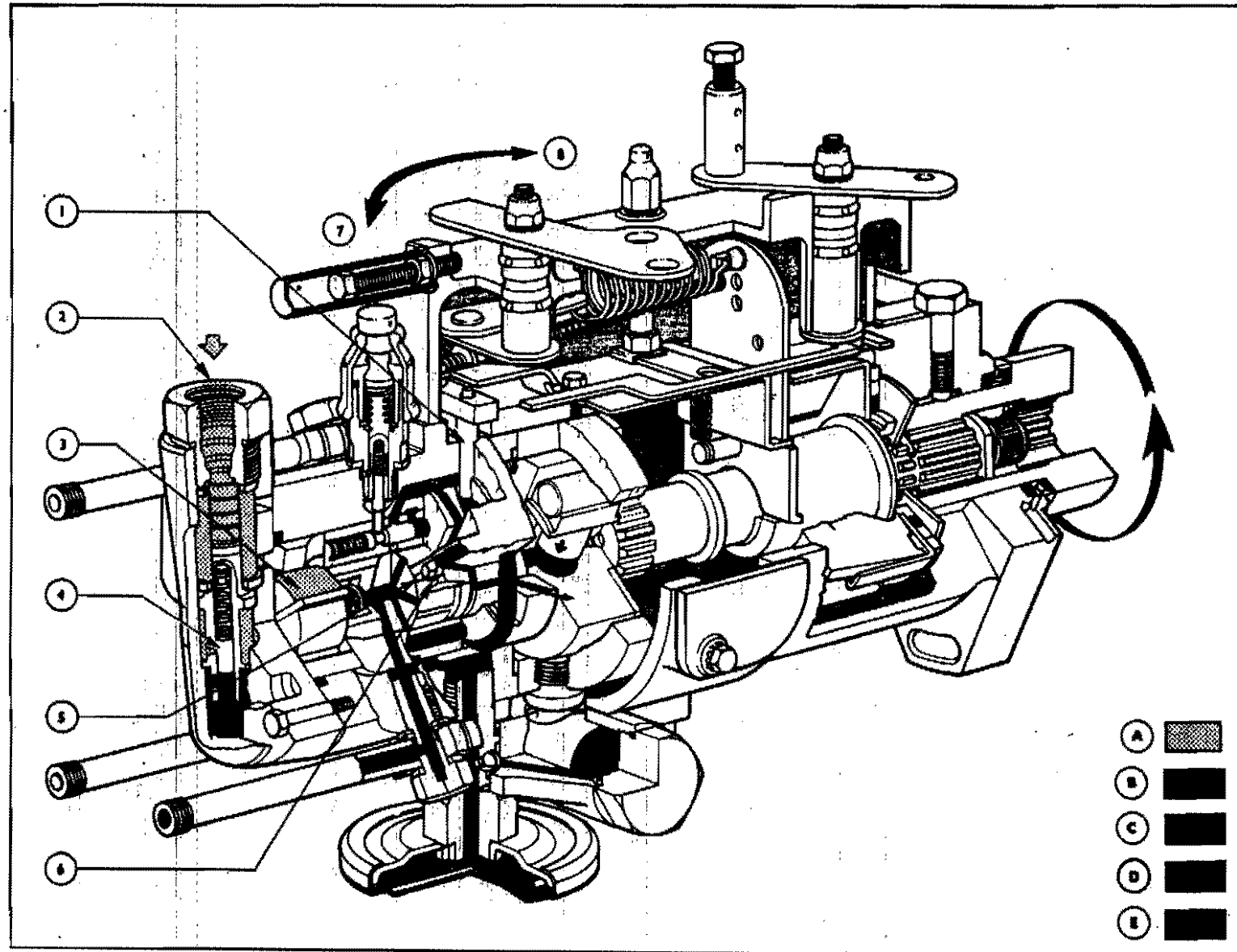
The regulating valve performs an additional function to transfer pressure regulation, described previously. Provision is made in the regulating valve for by-passing the sliding vane type transfer pump to enable the injection pump to be primed or bled. When the injection pump is not operating the regulating plunger is in the lower part of the regulating sleeve bore and rests on a priming by-pass spring (see Fig. 74 At Rest). Operation of the lift pump priming lever forces fuel at lift pump pressure through the inlet connection and into the regulating sleeve bore. This pressure forces the plunger downwards compressing the priming by-pass spring and uncovering the priming port in the sleeve (see Fig. 74, Priming). The transfer pump is then by-passed and the injection pump may then be primed and bled. The regulating plunger returns to its normal position after bleeding has been completed.

JULY 1977

Fig. 69

- 1 Metering Valve
- 2 Inlet Connection
- 3 Transfer Pump
- 4 Regulation Valve
- 5 Shuttle Port
- 6 Shuttle
- 7 Maximum Speed
- 8 Idling

- A Line Pressure
- B Pump Body Pressure
- C Metered Fuel
- D Transfer Pressure
- E Injection Pressure



Injection Pump Operation—Shuttle Charging and Injection

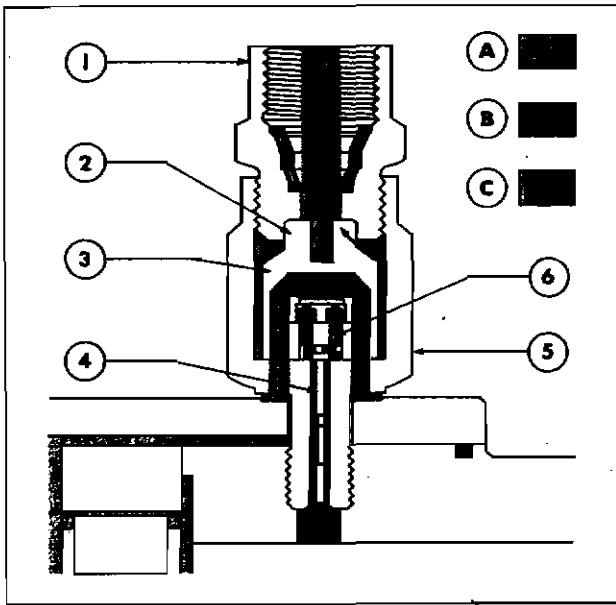


Fig. 70

- 1 Outlet Connection
- 2 Retainer
- 3 Valve Body
- 4 Plunger
- 5 Adaptor Body
- 6 Valve

- A Line Pressure
- B Transfer Pressure
- C Pump Body Pressure

Fig. 70 The Pressurising Valve

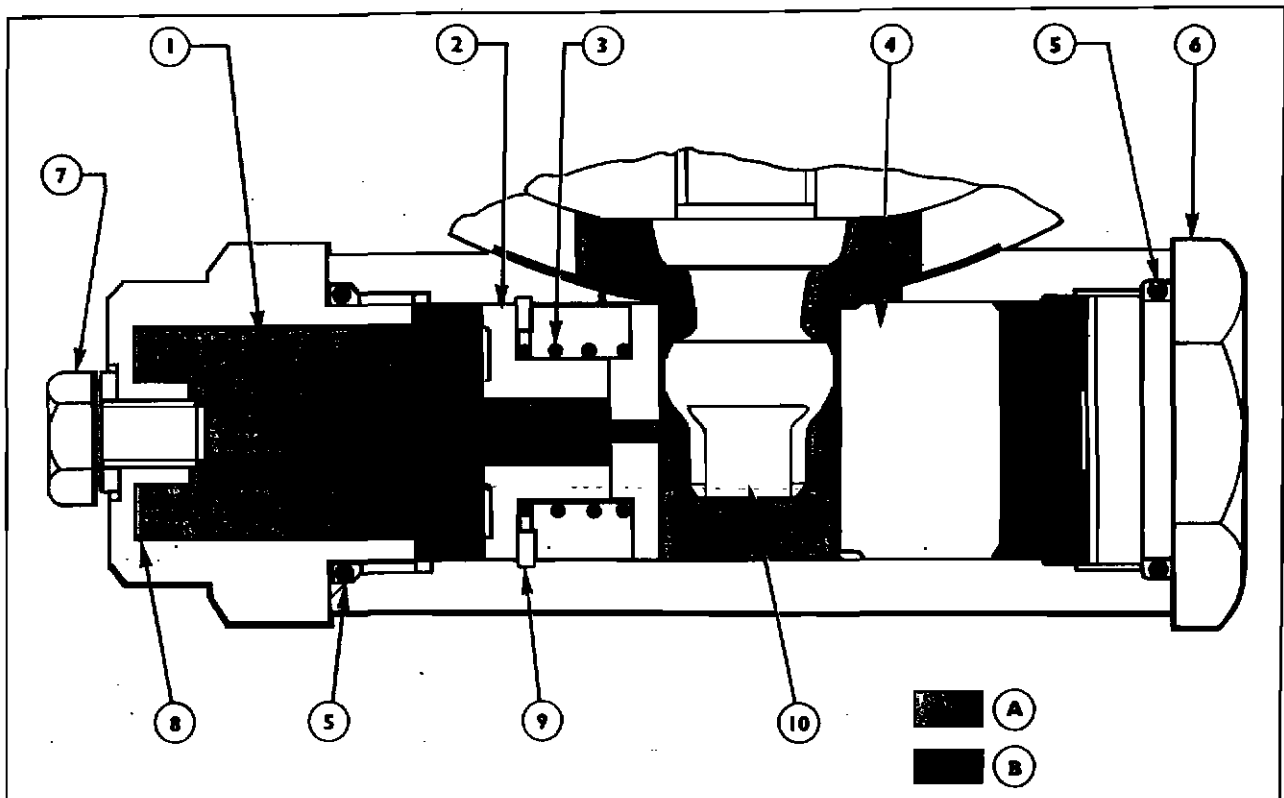


Fig. 71 The Advanced Mechanism

Fig. 71

- |                   |                    |                       |
|-------------------|--------------------|-----------------------|
| 1 Advance Springs | 5 "O" Ring         | 9 Circlip             |
| 2 Spring Plate    | 6 Piston Plug      | 10 Cam Ring Ball Stud |
| 3 Retard Spring   | 7 Spring Cap       | A Pump Body Pressure  |
| 4 Piston          | 8 Adjustment Shims | B Transfer Pressure.  |

Fig. 72

- 1 Idling
- 2 Maximum Speed
- 3 Inlet Port
- 4 Pumping Element

- A. Line Pressure
- B Pump Body Pressure
- C Metered Fuel
- D Transfer Pressure
- E Injection Pressure

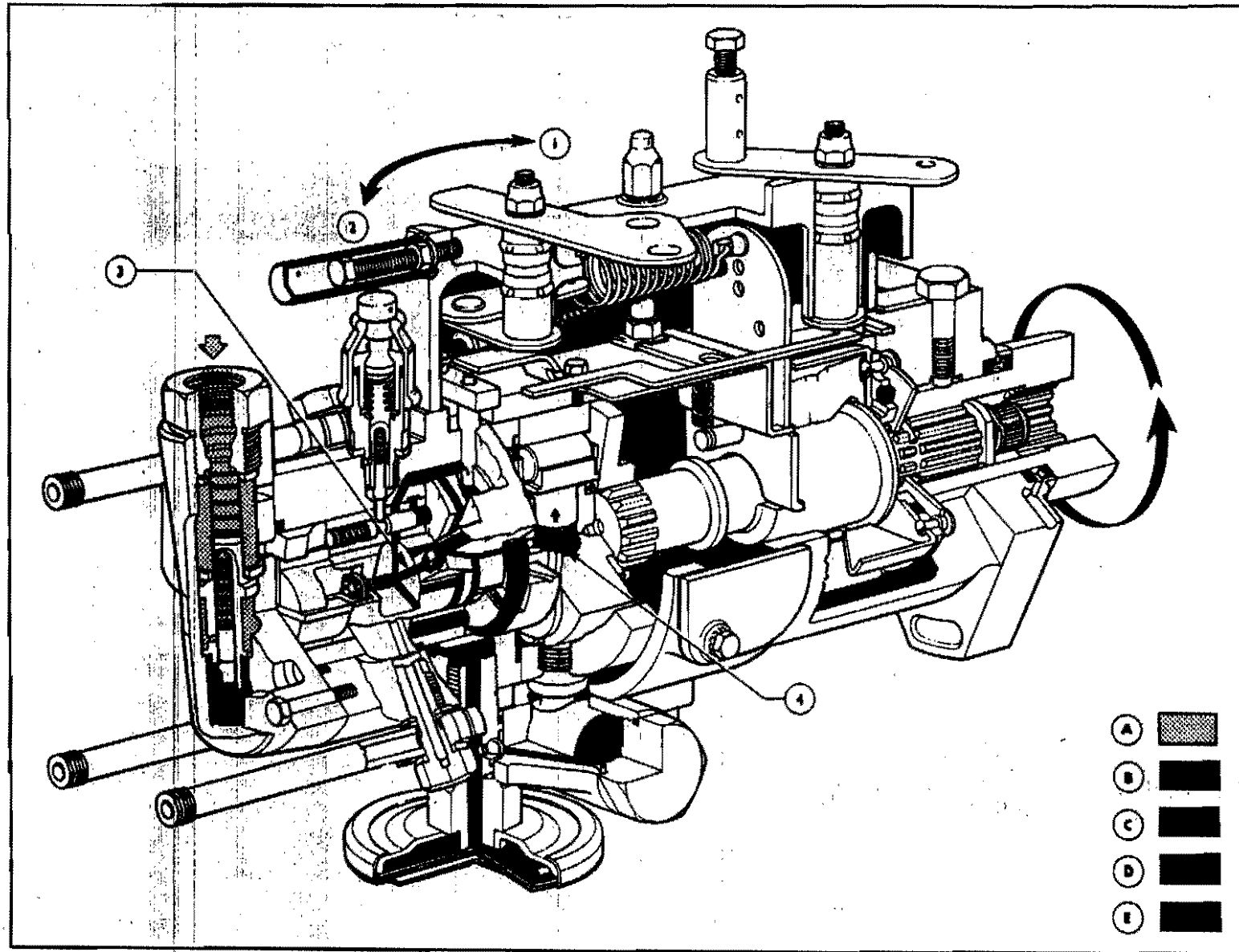


Fig. 72 Injection Pump Operation--Pumping Element Rotor Charging



Fig. 73

- 1 Excess Fuel Valve
- 2 Stop Plate
- A Line Pressure
- B Pump Body Pressure
- C Metered Fuel
- D Transfer Pressure
- E Injection Pressure

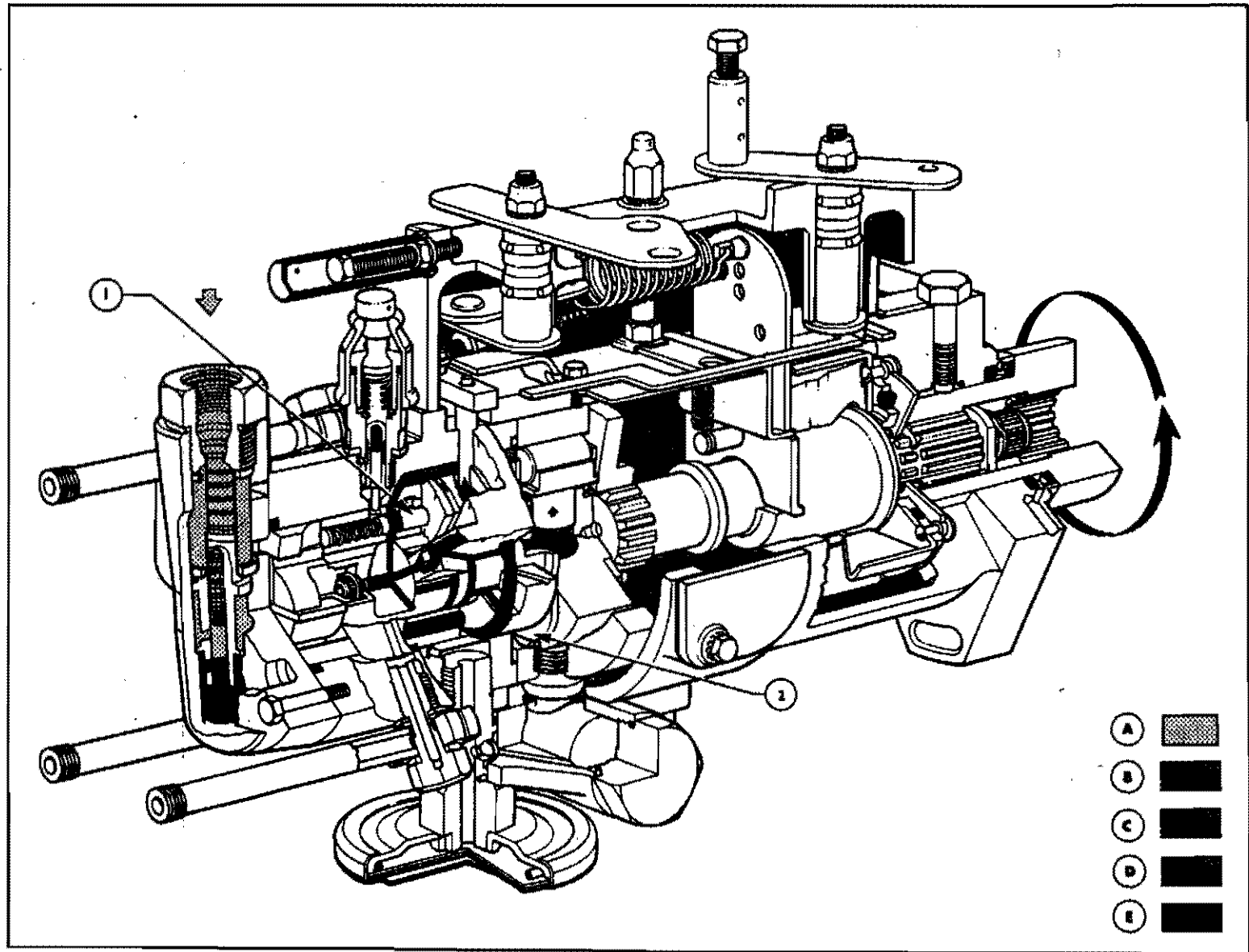


Fig. 73 Injection Pump Operation—Excess Fuel

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## **PUMP LUBRICATION**

The body of the injection pump is completely filled with fuel oil, which is continuously being re-circulated, and requires no additional lubrication.

## **TO REMOVE THE INJECTION PUMP**

1. Disconnect the injector pipes. Fit caps and plugs to the injector pipes and injection pump.
2. Disconnect the feed and return pipes from the inlet and outlet connections on the injection pump and fit plugs to these connections.
3. Disconnect the throttle linkage, stop control and excess fuel cables.
4. Remove the injection pump from the engine. Unscrew four bolts and one nut from the mounting plate and remove the injection pump, mounting plate and gear assembly from the engine.
5. Remove the gear. Unscrew the three bolts holding the gear and wrench Tool No.C.9078 and pull the gear off the drive hub.
6. Remove the injection pump mounting plate. Unscrew the three bolts and remove the mounting plate.

## **PRELIMINARY CHECKING**

Before the injection pump is dismantled or a replacement unit 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 that have seen very extensive service should be checked for general performance to ascertain (a) if any faults exist, and (b) whether a complete overhaul is necessary.

To check the operation of the pump it is only necessary to complete the operations detailed in the test procedure, without making any adjustments.

## **TO REPLACE THE INJECTION PUMP**

1. Locate the injection pump on the mounting plate and retain with the lower bolt spring and plain washer but do not tighten. The timing locking bolt and bracket should not be removed until the injection pump is fitted on the engine.
2. Fit the gear to the drive hub. Locate the dowel in the slot in the drive hub and retain the gear with three bolts fitted with internally toothed lock-washers. Tighten these bolts to 20.3 to 24.4 Nm (2.07 to 2.49 kgf m or 15 to 18 lbf ft) torque, holding the gear with timing gear holding wrench Tool No. C.9080.

## TO REPLACE THE INJECTION PUMP (Cont'd.)

3. Set the engine timing marks to  $9^{\circ}$  B.T.D.C. Rotate the crankshaft until the timing mark (see Fig.75) is in line with the  $9^{\circ}$  mark on the flywheel timing scale with No. 1 piston approaching the top of the compression stroke. When the engine is on the correct stroke a timing mark on the rear face of the camshaft gear will be visible in the injection pump mounting aperture.

4. Install the injection pump, mounting plate and gear assembly on the engine. Turn the injection pump clockwise on the mounting plate, so that the single retaining bolt is at the end of the slotted hole in the flange, to allow for the gear teeth helix. Locate a new "O" ring on the mounting plate and install the assembly in the engine, secure the mounting plate with four bolts, one nut and spring washer.

NOTE:—If the injection pump is not locked in the timed position it will be necessary to remove the inspection cover on the pump body and assemble the pump to the engine so that the timing marks on the drive plate and cam ring are in alignment (see "Timing").

5. Secure the injection pump to the mounting plate. Nip up the one bolt already fitted to hold the pump in the timed position and remove the timing locking bolt and bracket. Fit the two remaining bolts, spring and plain washers and tighten. Install a sealing bolt with a copper washer in the pump body flange and tighten to prevent leaks.

6. Connect the throttle linkage, stop control and excess fuel cable and exhaust brake linkage when fitted. Ensure that they operate correctly and adjust if necessary.

7. Connect the feed and return pipes to the inlet and outlet connection on the injection pump after removing the plugs.

8. Connect the injector pipes. Remove the plugs and caps from the injection pump and injector pipes. Connect the pipes to the banjo connectors on the injection pump and the corresponding injectors.

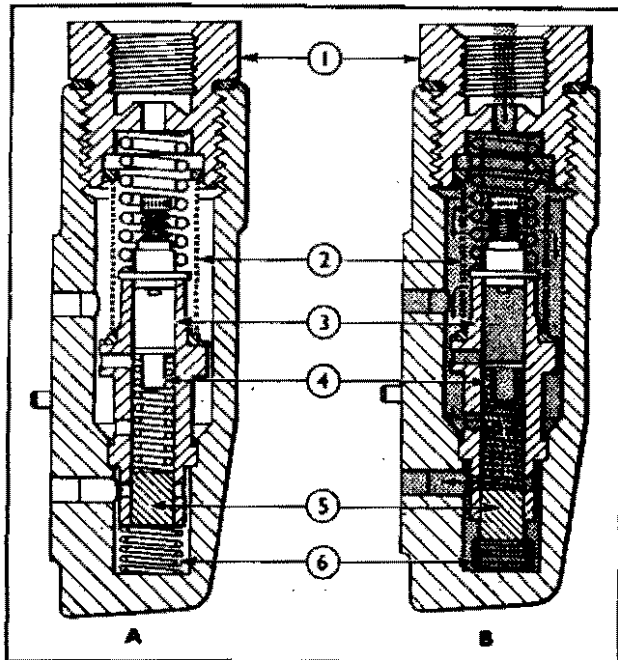


Fig. 74 1 Inlet Connection  
2 Nylon Filter  
3 Sleeve  
4 Regulating Spring  
5 Plunger  
6 Priming By-pass Spring

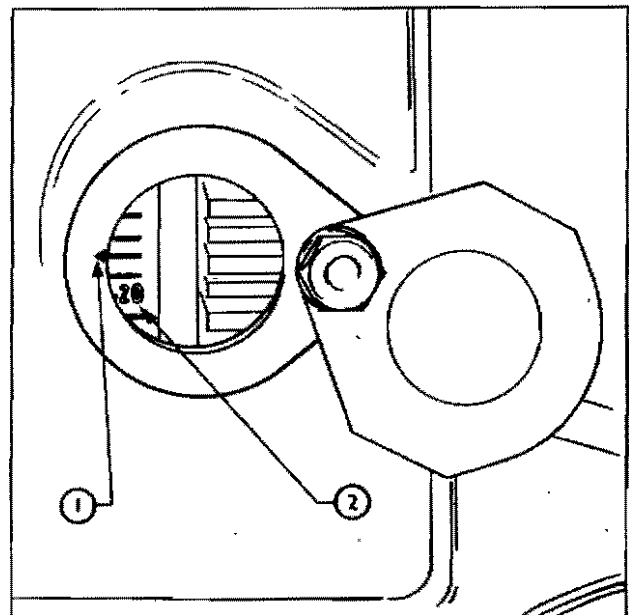


Fig. 75 1 Timing Mark  
2 Timing Scale

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## TO DISMANTLE THE INJECTION PUMP

1. Mount the injection pump on a dismantling jig Tool No.C.A.62 and clamp in a vice.
2. Remove the throttle and stop levers. Unscrew the self-locking nuts and remove the washer, lever and dustcap from each shaft.
3. Break the seal and unscrew the control cover cap nuts. Remove the fibre washers.
4. Screw a protection cap Tool No.C.A.75 onto the throttle shaft and lift the governor cover off, pushing on the protection cap to remove the throttle shaft (see Fig. 76).
5. Screw a protection cap Tool No.CA.75 onto the stop shaft and press through the governor cover to remove the shaft.
6. Disconnect the governor spring from the swivel link on the throttle shaft lever (see Fig. 77).
7. Push the idling spring guide through, disconnect the governor spring and remove the governor spring, idling spring and guide.
8. Slide out the cut-off bar.
9. Bend back the locking tabs and unscrew the control bracket screw.
10. Unscrew the control cover studs and remove the locking plates and keep plate.
11. Lift the control bracket and governor control arm out complete with hook line and metering valve.

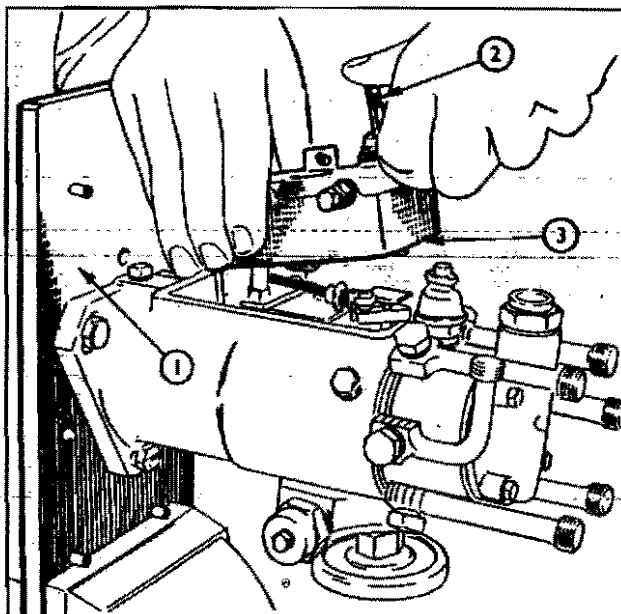


Fig. 76 1 Dismantling Jig Tool No. CA.62  
2 Protection Cap Tool No. CA.75  
3 Governor Cover

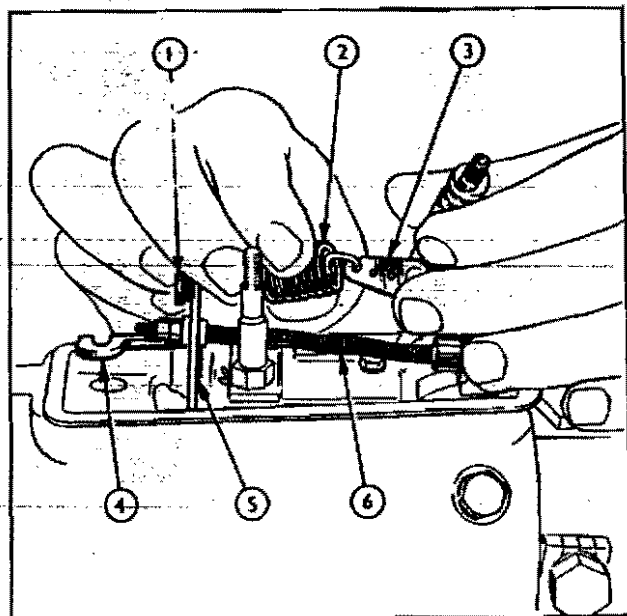


Fig. 77 1 Idling Spring and Guide  
2 Governor Spring  
3 Swivel Link  
4 Cut-off Bar  
5 Control Arm  
6 Governor Link

**TO DISMANTLE THE INJECTION PUMP (Cont'd).**

12. Disconnect the governor link. Unscrew the self-locking nut, locknut and remove the nylon pivot washer. Withdraw the link and remove the fibre washer, springs, and spring retainers to disconnect the metering valve.
13. Unscrew the banjo bolts and remove the high pressure banjo connections.
14. Slacken the inlet adaptor, end cover screws, excess fuel device and maximum fuel adjuster assembly.
15. Remove the inspection cover. Unscrew the two bolts and remove the cover and gasket.
16. Remove the injection pump and dismantling jig from the vice, invert the pump and clamp back in the vice.
17. Slacken the advance spring cap and piston plug.
18. Remove the advance mechanism, unscrew the cap nut and head locating fitting and damper assembly taking care not to drop the steel ball.
19. Unscrew the advance spring cap and remove the advance springs. Remove the spring plate and retard spring.
20. Unscrew the piston plug and remove the piston.
21. Unscrew the cam ring ball stud using socket Tool No.CA.66.A
22. Remove the pressurising valve assembly by unscrewing the adaptor adjacent to the pump body. Do not unscrew the outlet connection from the adaptor body.
23. Unscrew the head locking screw and remove the hydraulic head and cam ring.
24. Remove the end cover. Unscrew the bolts, holding the cover in place as the cover and transfer pump liner are pressurised by the excess fuel spring and carefully lift off the cover.
25. Remove the transfer pump liner, vanes and seal and extract the excess fuel valve spring and retainer.
26. Unscrew the inlet adaptor and extract the retaining spring, nylon filter, pressure adjuster, regulating sleeve, regulating spring and button, regulating plunger and priming spring.
27. Unscrew the excess fuel device and lift out the spring and latch pin and then extract the excess fuel valve.
28. Slacken the transfer pump rotor, using socket Tool No.CA.58 and holding the drive plate with spanner Tool No.CA.112. Ensure that the socket is fully engaged to prevent damaging the rotor.
29. Unscrew the maximum fuel adjuster assembly and extract the shuttle.
30. Unscrew the drive plate screws, with a 5/16 in. AF bi-hexagon socket, holding the drive plate with spanner Tool No.CA.112, and remove the drive plate (see Fig. 78).

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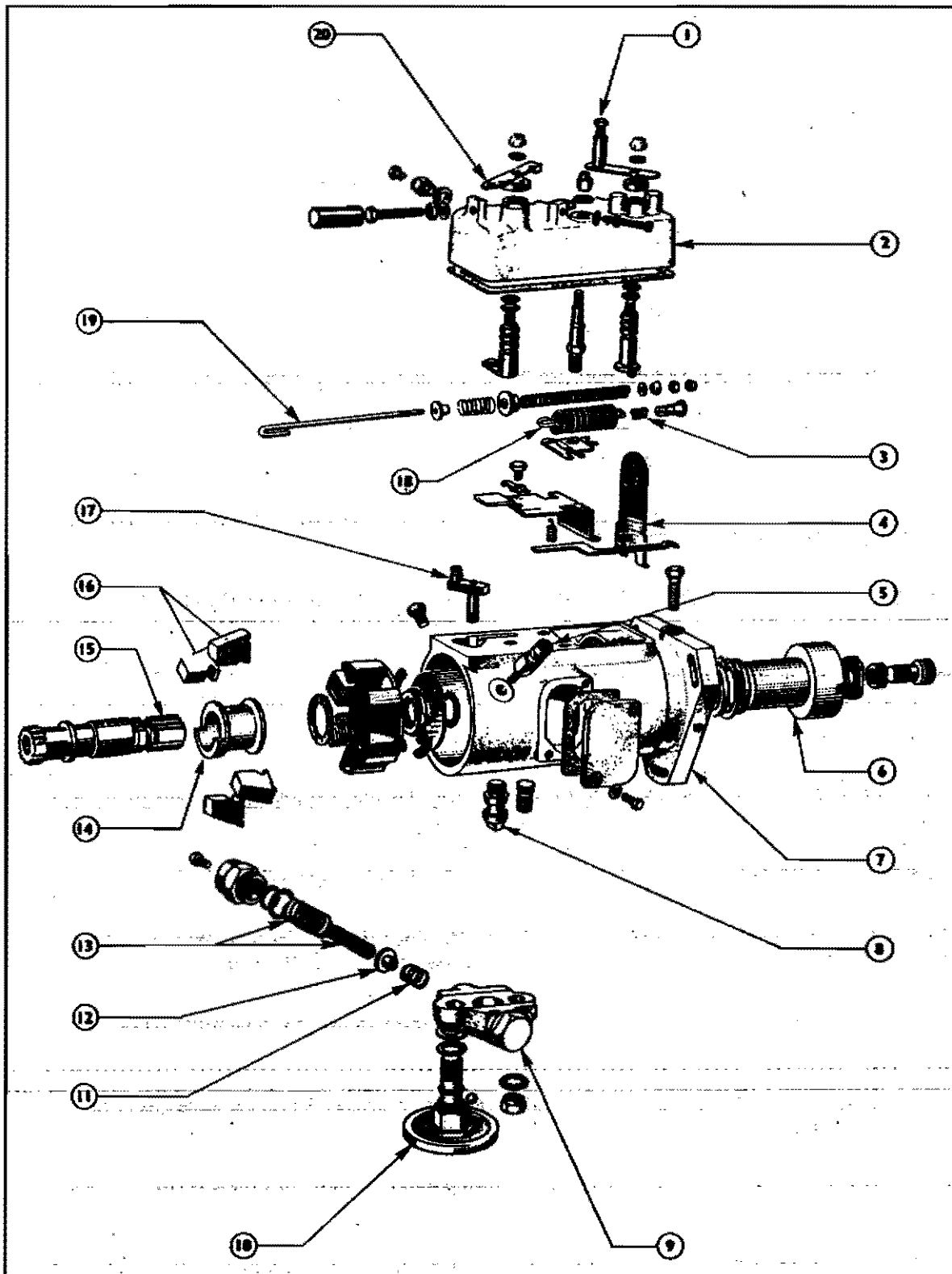


Fig. 78

- |                        |                                     |                     |
|------------------------|-------------------------------------|---------------------|
| 1 Stop Control Lever   | 8 Ball Stud                         | 13 Advance Springs  |
| 2 Control Cover        | 9 Automatic Advance Mechanism       | 14 Governor Sleeve  |
| 3 Idling Spring        | 10 Head Locating Fitting and Damper | 15 Drive Shaft      |
| 4 Governor Control Arm | 11 Retard Spring                    | 16 Governor Weights |
| 5 Pressurising Valve   | 12 Spring Plate                     | 17 Metering Valve   |
| 6 Drive Hub            |                                     | 18 Governor Spring  |
| 7 Pump Body            |                                     | 19 Governor Link    |
|                        |                                     | 20 Throttle Lever   |

## TO REMOVE

1. Disconnect the air and oil breather hoses and remove the air cleaner from its bracket.
2. Disconnect the excess fuel device remote control cable, (if fitted).
3. Slacken the bolt securing the stop control cable to the stop control lever, and disconnect the cable.
4. Disconnect the throttle linkage from the control linkage.
5. Disconnect the injector pipes from the delivery valve holders by unscrewing the union nuts.
6. Unscrew the unions at the rear of the injection pump and at the filter, and remove the fuel feed pipe.
7. Disconnect the injection pump drain pipe after unscrewing the retaining bolt.
8. Undo the four bolts and one nut attaching the injection pump to the engine, and remove the pump and gear.

## PRELIMINARY CHECKING

Before the injection pump is dismantled or a replacement unit 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 that have not seen very extensive service should be checked for general performance to ascertain (a) if any faults exist, and (b) whether a complete overhaul is necessary.

The procedure for preliminary checking is given in the section on "Testing and Adjusting the Fuel Injection Pump". 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 assembly.

## TO REPLACE

1. Turn the engine until No. 1 piston is on the compression stroke, and the notch in the crankshaft pulley is in line with the specified timing mark on the timing plate (see Fig. 16). A timing mark on the rear face of the camshaft gear will be visible in the injection pump aperture when the engine is on the correct stroke.
2. Remove the plug in the mounting flange of the injection pump, and insert Tool No. C.9077. (Fig. 17). Rotate the gear until the spring-loaded plunger drops into the centre punch mark in the rear face of the gear. Release the plunger and turn the gear 15.88 mm. (5/8 in.) anti-clockwise.
3. Position a new rubber "O" sealing ring to the front face of the injection pump.
4. Refit the injection pump and gear to the engine, keeping the stud in the centre of its slotted fixing hole. Turn the pump until the plunger re-engages with the timing mark.
5. Fit and tighten the four bolts and one nut to attach the pump to the engine. Remove the timing tool and re-insert the plug.
6. Refit the overflow drain pipe to the side of the injection pump, securing with a bolt. If necessary replace the two fibre washers.

## INJECTION PUMP REPLACEMENT (continued)

From July 1975, some Combine Harvester engines have been fitted with Bosch injection equipment as detailed below:

Engine	Ford Part No.	Supplier's Part No	Finis Code
2711E	743F-9A543-AAA	0400864036	6028637
2713E	743F-9A543-BAA	0400866068	6029935
2714E	743F-9A543-CAA	0400866067	6028638

## RECALIBRATION PROCEDURE FOR THE ABOVE PUMPS

1. If necessary set hydraulic unit as Bosch instructions WPP0014B-A—all injection pumps.
2. Set governor first, move as Bosch instructions WPP001/4E Supplement 1—all injection pumps.
3. Line to line balance set at 9.0 mm. rack travel to a delivery of 6.4-6.6 cc. over 100 strokes at 1 000 r.p.m. (less governor) for 743F-9A543-AAA injection pump.  
Line to line balance set at 9.0 mm. rack travel to a delivery of 5.3-5.5 cc. over 100 strokes at 1 000 r.p.m. (less governor) for 743F-9A543-BAA injection pump.  
Line to line balance set at 9.0 mm. rack travel to a delivery of 6.0-6.2 cc. over 100 strokes at 1 000 r.p.m. (less governor) for 743F-9A543-CAA injection pump.
4. With speed control lever in maximum speed position, set fuel to 65.0-66.0 cc. over 1,000 strokes at an average of 1,000 r.p.m. using maximum fuel adjusting screw (with governor) and BDN 125D12. nozzles, for 743F-9A543-AAA injection pump.  
With speed control lever in maximum speed position set fuel to 53.5-54.5 cc. over 1,000 strokes at an average of 1,000 r.p.m. using maximum fuel adjusting screw (with governor) and BDN 125D12 nozzle, for 743F-9A543-BAA injection pump.  
With speed control lever in maximum speed position, set fuel to 60.0-61.0 cc. over 1,000 strokes at an average of 1,000 r.p.m. using maximum fuel adjusting screw (with governor) and BDN 125D12 nozzle, for 743F-9A543-CAA injection pump.

## Injector Nozzle Assemblies:

713F-9K546-KAA	Nozzle and Holder assy.
713F-9E527-KAA	Injector nozzle
Fuel Filter Assembly:	713F-9155-AAA
Filter Element:	2704E-9150

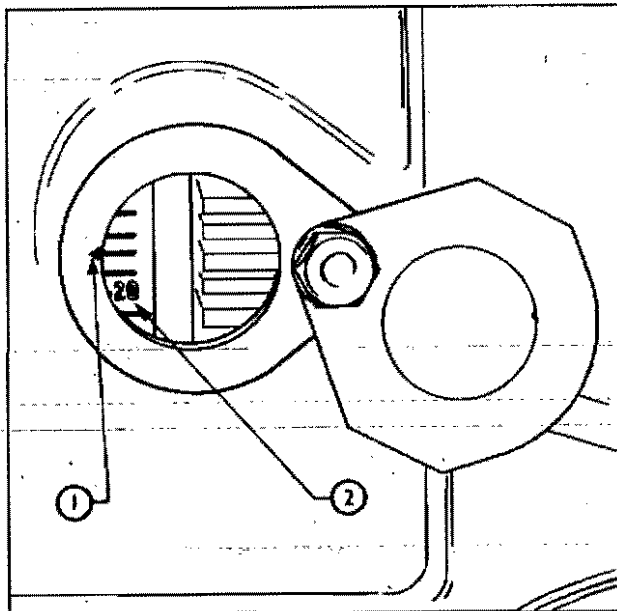


Fig. 16

- 1 Timing Mark
- 2 Timing Scale

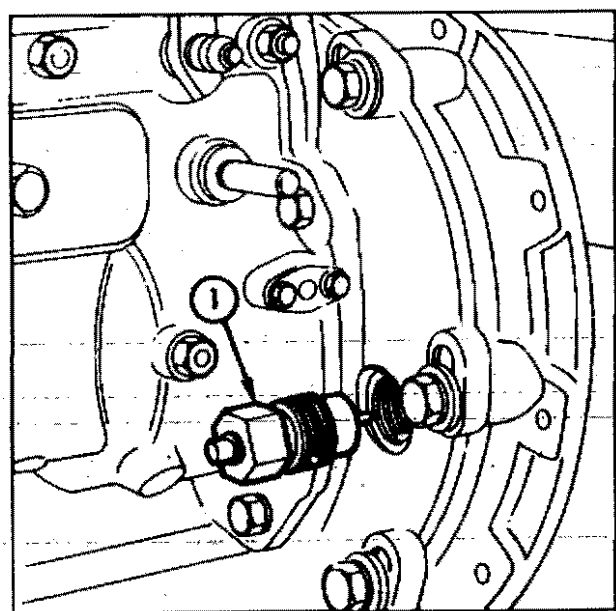


Fig. 17 Timing Aperture Location

- 1 Timing Tool No. C.9077

## PUMP CONDITION

A guide to the condition of the injection pump can be obtained from the engine performance. Erratic idling coupled with excessive "leakoff" from the cambox gives an indication of worn plungers and barrels. A careful visual inspection of the delivery valves will reveal any scores which may be present. If scores are visible the plungers may be similarly scored due to inefficient filter maintenance and the unit must be dismantled.



## GOVERNOR OPERATION (GE and GX MASS GOVERNORS) (Cont'd.)

Should the engine speed continue to increase when the control rod has reached this position, the centrifugal force of the governor weights will overcome the spring load and move the weight carrier and hub along the camshaft. The rocking lever will then push the control rod backwards, reducing the volume of fuel delivered and the speed of the engine.

The engine speed is therefore, at all times proportional to the governor spring load, enabling accurate and sensitive speed control to be maintained throughout the engine speed range.

### EXCESS FUEL DEVICE AND STOP CONTROL

The excess fuel device and stop control are incorporated in the top of the governor housing (see Fig. 2).

To engage the excess fuel device, the button on the end of the stop control lever is pressed in (see Fig. 15 G). The throttle lever must be moved to the maximum speed position at the same time. The maximum fuel stop bell crank is then moved out of engagement with the control rod stop, against the action of the return spring and the control rod is pulled forward by the rocking lever under the action of the governor spring. In this position the edge of the control rod prevents the bell crank from returning to its original position, and the plungers are in the excess fuel position.

The engine should now be started with the throttle lever fully open to maintain the governor spring pressure.

When the engine starts, its speed will rise until the centrifugal force of the governor weights overcomes the governor spring force, and causes the control rod to be pushed forward by the rocking lever. The spring will then return the maximum fuel stop bell crank to its original position.

The stop control consists of a sleeve, free to rotate on the excess fuel device spindle, with a control lever on one end and an operating lever on the other end. When the control lever is moved in a clockwise direction, the operating lever pushes the control rod forward by means of the stop, until the "no delivery" position (Fig. 15) is reached. The engine will then stop.

### LUBRICATION

The camshaft and governor housing are filled with engine oil through a filler plug on top of the governor housing. Fuel oil back leakage from the plungers mixes with this oil, the surplus being drained by an overflow pipe at the front of the injection pump.

After every 200 hours running time this oil should be drained off through the drain plug in the base of the governor housing. Refill the injection pump and governor housing with the correct grade and quantity of engine oil.

### INJECTION PUMP REPLACEMENT

The "Minimec" injection pump is flange-mounted to the rear of the timing gear housing on the right-hand side of the engine and is driven, from the governor end, at half engine speed by a gear meshing with the camshaft gear. The pump and gear can be removed as a unit by undoing four bolts and one nut.

When refitting the pump to the engine, the engine should first be rotated until the timing mark on the timing aperture is in line with the line on the timing scale on the flywheel, and the No. 1 piston is on the compression stroke (See Specifications for appropriate Static Spill timing). A timing mark on the rear face of the camshaft gear will be visible in the injection pump aperture when the engine is on the correct stroke. A timing Tool No. C.9077 should then be inserted into the timing hole in the pump mounting flange (Fig. 17) and the gear rotated until the tool makes positive contact with the indent in the gear, when the pump and gear can be refitted to the engine in correct alignment.

## OPERATION OF THE INJECTION PUMP (Cont'd).

The sudden, if slight, reduction in pipe line pressure, is sufficient to allow the injector needle valve to snap shut under the force of its spring. This prevents fuel dribbling from the injector which would result in carbon build up on the injector tip and low fuel delivery.

A flat is sometimes ground on the piston portion of the delivery valve which modifies the fuel delivery when the engine is operating at low speeds.

The plunger continues to rise completing its stroke, although the helical groove in the plunger prevents further fuel being delivered. The cam holds the plunger at the top of its stroke and only returns to the bottom when the corresponding engine cylinder is on the compression stroke again. This prevents the engine running in the reverse direction in the event of a backfire.

The commencement of fuel delivery to the injectors is constant and occurs at position "B" i.e. immediately the rising plunger covers the inlet port. The amount of fuel injected however, need not be constant, and is dependent upon the distance the plunger moves before the helical groove uncovers the spill port position "D", when pressurised fuel may flow back into the pump body. By rotating the plunger, the position of the helical groove relative to the spill port, and consequently, the effective stroke of the plunger, can be altered. This can be more clearly seen in Fig.6 where positions E and F are those of idling and maximum fuel under normal running conditions, and G and H those of excess fuel for stopping the engine. No fuel is delivered when the plunger is in position H, as the helical groove uncovers the spill port before the plunger completely covers the inlet port, and during the remainder of the stroke the spill port is always uncovered by the helical groove. As pressure cannot therefore be developed, no fuel is delivered to the injectors.

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.

## GOVERNOR OPERATION (GE and GX MASS GOVERNORS)

With the control lever in the idling position, the "dumbbell" shaped roller is at the top of the ramp, and the governor spring load is small. Under these conditions the weights are thrown outwards and the rocking lever operated by the hub or sleeve on the camshaft pushes the control rod backwards, reducing the volume of fuel injected until a steady idling speed is obtained. If the engine speed decreases for any reason, the centrifugal force of the governor weights will also decrease and will be overcome by the governor spring load. The rocking lever will therefore pull the control rod forwards increasing the volume of fuel injected and consequently the engine speed. As the engine speed increases, the centrifugal force of the governor weights will again overcome the spring load and cause the rocking lever and control rod to reduce the volume of fuel injected. Engine speed fluctuations are therefore damped by the governor.

With the control lever in the maximum speed position, the roller is moved down the ramp and subsequently increases the governor spring load. The spring load is then sufficient to overcome the centrifugal force of the governor weights and move the weight carrier and hub along the camshaft. This motion is transmitted to the control rod by the rocking lever, which pulls the control rod forwards, increasing the volume of fuel injected and the engine speed. The maximum fuel position is reached when the stop bell crank which is prevented from rotating by the maximum fuel stop screwed into the top of the governor housing.

JULY 1977

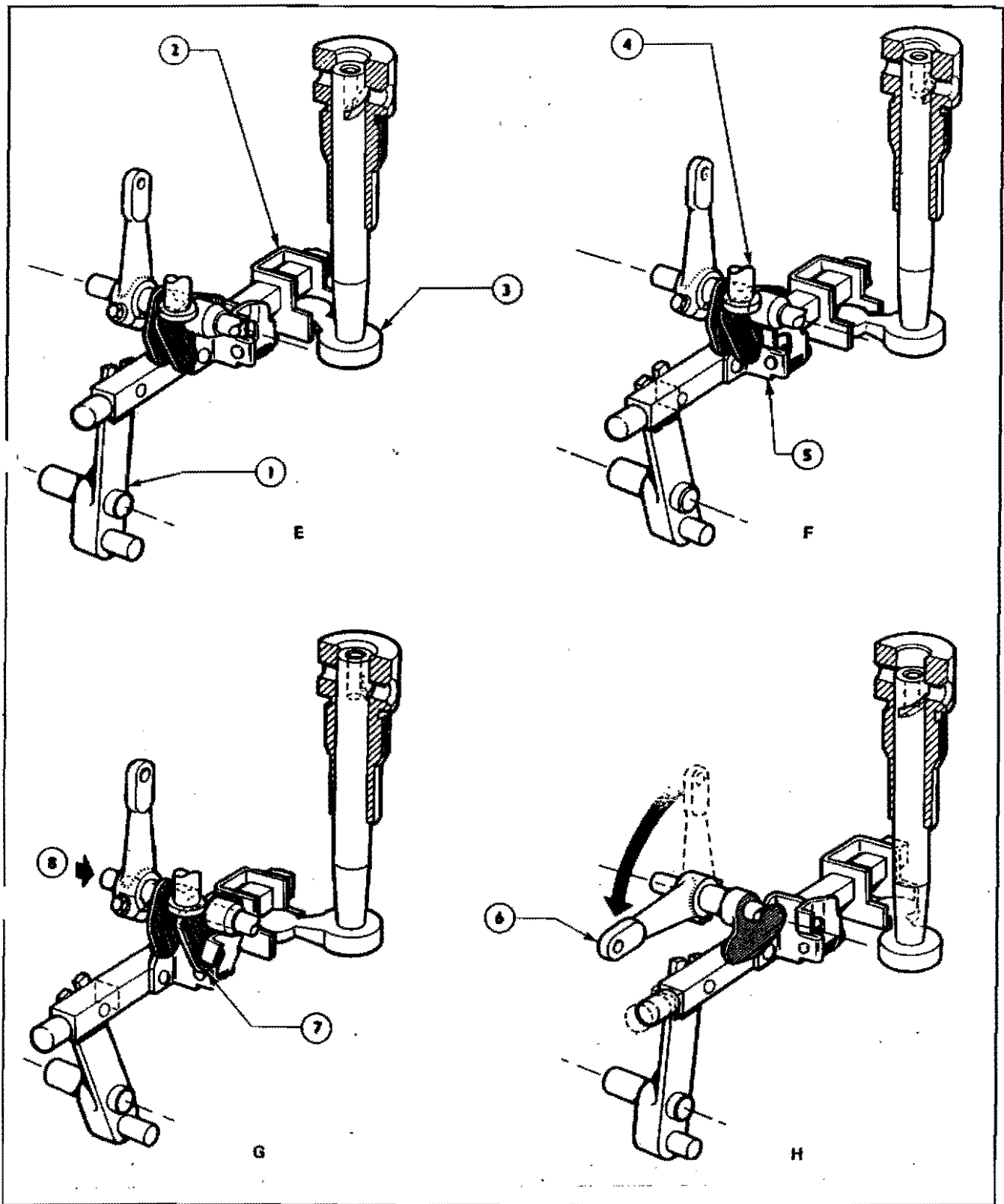


Fig 15

E Idling  
 F Maximum Fuel  
 G Excess Fuel  
 H No Delivery

1 Rocking Lever  
 2 Control Rod and Fork  
 3 Plunger Arm  
 4 Maximum Fuel Stop

5 Control Rod Stop  
 6 Stop Control Lever  
 7 Maximum Fuel Stop Bell Crank  
 8 Excess Fuel Button

## OPERATION OF THE INJECTION PUMP (Cont'd.)

When the fuel pressure is sufficient to lift the delivery valve completely off its seat, and the piston clear of its guide (position "C"), fuel passes along the pipe line to the injector. The fuel pressure developed by the plunger lifts the injector needle valve off its seating against the action of the spring and allows fuel in a highly atomized state to be sprayed into the cylinder.

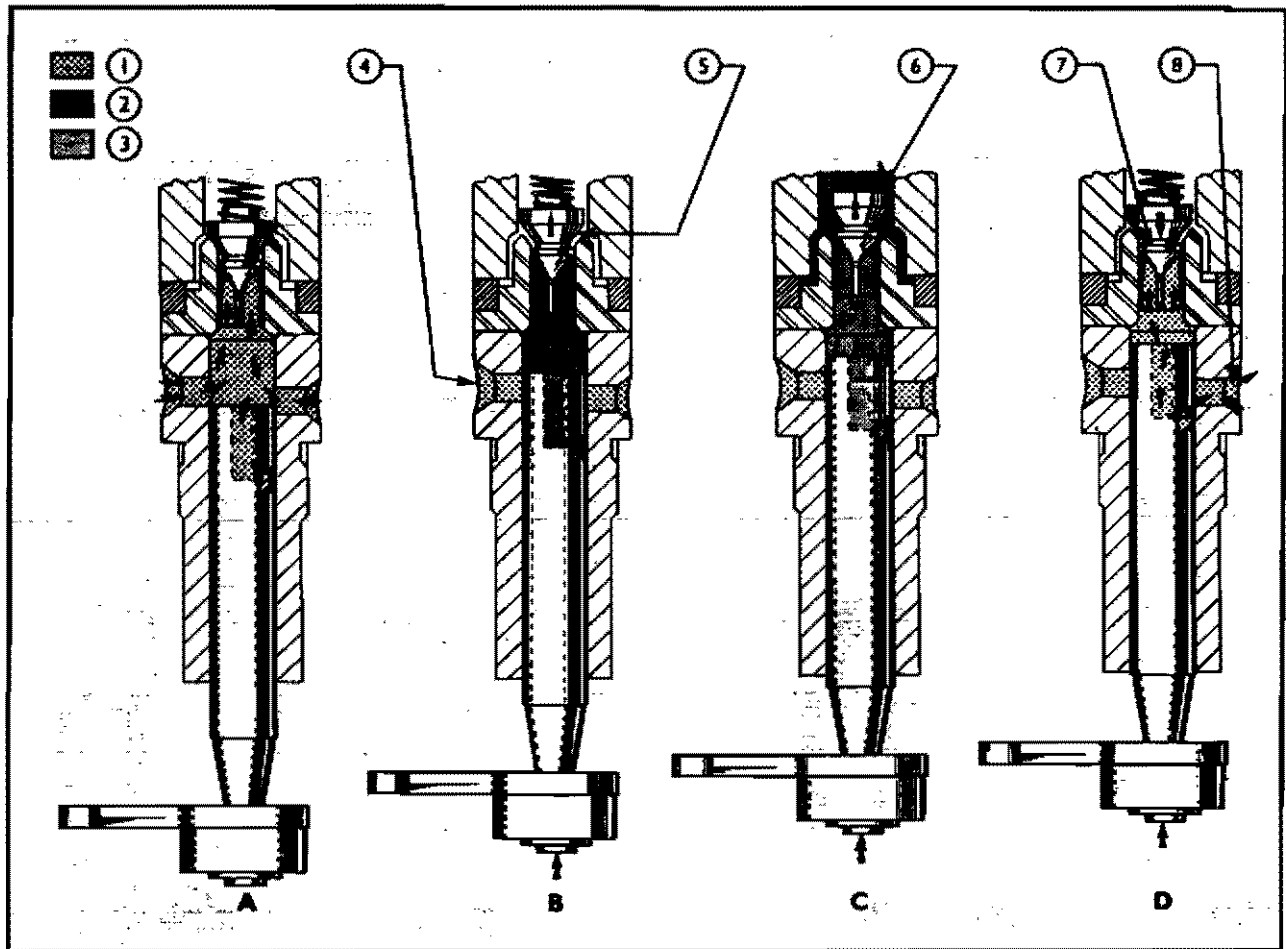


Fig. 14

- |                      |                  |              |
|----------------------|------------------|--------------|
| 1 Lift Pump Pressure | 4 Inlet Port     | 7 Piston     |
| 2 Injection Pressure | 5 Conical Seat   | 8 Spill Port |
| 3 Residual Pressure  | 6 Delivery Valve |              |

Fuel continues to be injected until the plunger reaches position "D", when the upper edge of the helical groove has uncovered the lower edge of the spill port and allows fuel under high pressure to leak back down the centre drilling in the plunger and out through the helical groove into the fuel galleries of the pump body. This reduces the fuel pressure in the barrel, and the delivery valve spring assisted by the high pressure remaining in the pipe line causes the valve to close rapidly.

The delivery valve serves a dual purpose; the piston entering its guide causes a slight but sharp reduction in the pressure of the fuel in the pipe line. The effect can be more clearly understood if it is compared with that of withdrawing a piston from its cylinder. As the piston is withdrawn the volume in the cylinder increases, and providing fuel or air, etc. is not allowed to enter or leave the cylinder, a reduction in pressure must result. The delivery valve acts as a non-return valve and maintains residual pressure in the injector pipe line.

## DESCRIPTION OF THE INJECTION PUMP

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. Fuel enters the individual elements via ports in the barrels when the plungers are in the lowest position, and the action of the plungers causes the fuel to be delivered to each injector in turn at high pressure; the quantity of fuel being accurately controlled by the mechanical governor.

Each pumping element consists of steel barrel and plunger assembly, hardened, ground and lapped to each other to give a very close fit. The barrels are positively located in the pump body by serrations and a master spline machined on each barrel, which engage with corresponding serrations and master splines in the barrel locating bores. The plungers have a constant stroke, and are operated, through roller tappets, by a camshaft driven at half engine speed by a gear in mesh with the engine camshaft gear. Coil springs return the plungers on their down stroke.

At the lower end of each plunger is an arm which engages with a fork on the control rod. This control rod is connected, by a link, to the governor. Any movement of the governor is thus transmitted to each plunger simultaneously, causing them to turn in the barrels to control the fuel delivery by changing the position of the helical groove, machined in each plunger, relative to the ports in the barrels.

Above each pumping element is a delivery valve and guide. The valve has a conical seat and the stem is divided into two parts. The lower part has four vertical flutes, whilst the upper part forms a small piston which is lapped to fit in the bore of the valve guide.

The delivery valve is held on its seat by a spring, which is located in the top of the delivery valve holder by a volume reducer. This reduces the volume of fuel in the delivery valve holder.

The delivery valves, springs and guides are retained by delivery valve holders which also retain the pumping element barrels. The delivery valve holders are serrated on the outside to facilitate removal and are sealed by large nylon washers and also have top face sealing.

The maximum fuel delivery is controlled by an adjustable stop screw on top of the governor housing which limits the control rod movement by means of a bell crank between a stop fitted on the control rod and the maximum fuel stop screw. An excess fuel device for starting purposes and a stop control are incorporated in the side of the governor housing.

## OPERATION OF THE INJECTION PUMP

The operation and construction of all the pumping elements is identical, and each plunger is operated by a separate cam on the camshaft; the cams being equally spaced on the camshaft in the engine firing order sequence.

A pumping element is shown in the various stages of its operating cycle in Fig. 14 and 15.

At "A" the plunger is at the bottom of its stroke, and fuel under lift pump pressure fills the pumping element via the two ports in the barrel. At this stage the pressure in the barrel is not sufficient to lift the delivery valve off its seating against the action of the spring.

As the camshaft rotates, the plunger rises until position "B" is reached. At this point, fuel can no longer enter or leave the element via the ports in the barrel, and further upward movement of the plunger compresses the fuel and begins to lift the delivery valve off its seat.

## THE GX TYPE MASS GOVERNOR (Cont'd.)

With the governor mass in the fully closed position, obtain dimension 'A', and fit appropriate spacing ring. Fig. 13.

Dimension 'B' (governor sleeve travel) should then be 6.2 to 5.9 mm.

DIM 'A'	SPACING RING PART NO.	
	FORD	SIMMS
7.5 7.75	TBA	505353
7.76 8.00	TBA	505354
8.01 8.25	TBA	505355
8.26 8.50	TBA	505356
8.51 8.75	TBA	505357
8.76 9.00	TBA	505358
9.01 9.25	TBA	505359

Fig. 13

MAY 1975

The following injection pumps have the modified governor:—

General Purpose		Combine	
Ford Part No.	Simms Part No.	Ford Part No.	Simms Part No.
2704E-9A543-AF	P5060	2703E-9A543-H	P5012/1B
693F-9A543-GBA	P5060/1A	2704E-9A543-AE	P5012/C
693F-9A543-GBB	P5060/2A	2701E-9A543-H	P4899/A
693F-9A543-GBC	P5060/3A	693F-9A543-AAA	P5079
		693F-9A543-BAA	P5080/A
		693F-9A543-CAA	P5080
Class 'A'		703F-9A543-AJA	P5084/1A
2703E-9A543-G	P5012	703F-9A543-BEA	P5085/B
2704E-9A543-AD	P5012/A	703F-9A543-BEB	P5085/2B
2704E-9A543-Y	P5021/1	703F-9A543-BEC	P5085/3B
703F-9A543-ANA	P5127	703F-9A543-CJA	P5085/C
703F-9A543-ANB	P5127/1	703F-9A543-CJB	P5085/2C
703F-9A543-ANC	P5127/2	703F-9A543-CJC	P5085/3C
703F-9A543-CLA	P5129		
703F-9A543-CLB	P5129/1		
703F-9A543-CLC	P5129/2		

THE GX TYPE MASS GOVERNOR (Cont'd.)

THRUST PAD MARK No.	DIM 'X'
2	31.0 31.5
3	31.51 32.00
4	32.01 32.50
5	32.51 33.00
6	33.01 33.50

Fig. 11

To obtain the specified dimensions Fig. 11 assemble the thrust pad with the identification groove in the position shown.

With the governor mass in the fully closed position and without the governor gasket fitted, obtain dimension 'X' by fitting the appropriate thrust pad, refer Fig. 11, Dimension 'Y' should then be 19.9 to 20.6 mm.

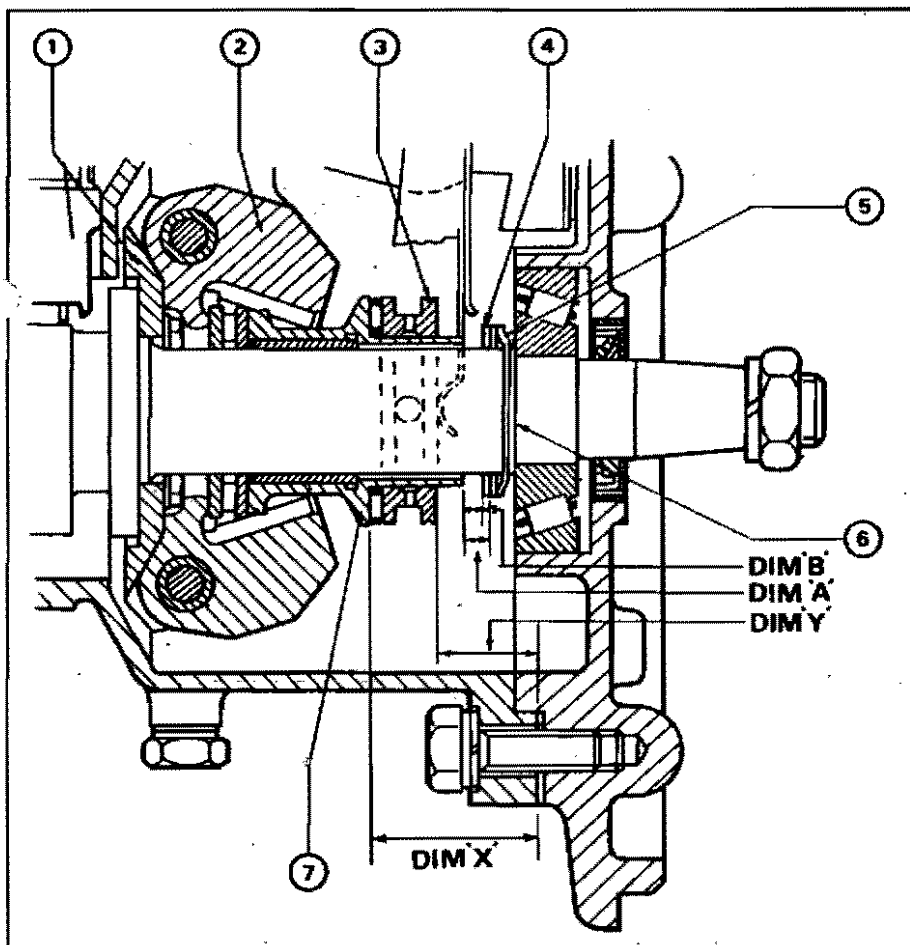


Fig. 12

1. Weight Carrier
2. Weight
3. Thrust Pad
4. Spacing Ring
5. Stop Disc
6. Shims
7. Sleeve

**THE GE TYPE MASS GOVERNOR (Cont'd.)**

**NOTE:**—If the roller ramp is removed during pump dismantling, the faces of the three ramp retaining screws on the governor cover and the screw threads should be coated with 'Autogel No. 2' before reassembling.

**THE GX TYPE MASS GOVERNOR**

The details of a typical pump, fitted with a GX governor, are shown in Fig. 12. The roller weights have been replaced by flyweights mounted on a weight carrier fixed to the camshaft; as there are no roller weights, there is no back plate. The thrust ball bearing of the GE governor has been replaced by two needle roller bearings. As the camshaft revolves the governor assembly, which is bolted to the camshaft, revolves with it. Centrifugal force causes the flyweights to be thrown out. The toes on the governor weights push the sleeve along the axis of the camshaft against the action of the governor leaf spring. The rest of the operational details are as for the GE Mass Governor.

**Note:**—Modifications have been made to some GX governors, whereby the governor sleeve travel is limited by a stop disc. Also the weight carrier assembly incorporates re-designed weights which are rounded at the back, Fig. 6, the square end at the back of the original weights functioned as a stop to limit weight movement.

The sleeve is slightly shorter in length than the original one, and is identified by a 'V' groove Fig. 7.

The original baffle washer Fig. 8, has been superseded by a stop disc, Fig. 9 and a spacing ring Fig. 10 which is supplied in graded thicknesses from 1.55 to 3.10 mm. The appropriate spacing ring when fitted limits the governor sleeve to 5.9 to 6.2 mm.

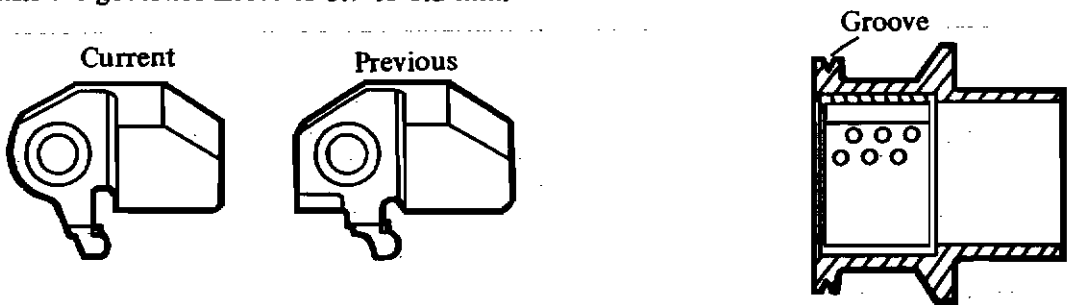


Fig. 6 Governor Weights

Fig. 7 Sleeve



Fig. 8 Baffle Washer



Fig. 9 Stop Disc

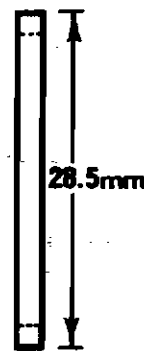


Fig. 10 Spacing Ring

SPACING RING THICKNESS mm
1.55 – 1.60
1.8 – 1.85
2.05 – 2.1
2.3 – 2.35
2.55 – 2.6
2.8 – 2.85
3.05 – 3.1

MAY 1974



## TO DISMANTLE THE INJECTION PUMP (Cont'd).

31. Remove the cam ring.
32. Remove the drive end stop plate and extract the locating dowel from the pumping element rotor. (see Fig. 79). Withdraw the rollers and shoes keeping them in their respective positions. Retain the twin pumping plungers in positions with corks.
33. Unscrew the transfer pump rotor.
34. Withdraw the rotor and remove the other stop plate.
35. Unscrew the drive hub retaining screw, using adaptor key Tool No.CA.69, and holding the drive hub with spanner Tool No.CA.67 (see Fig.80). Remove the drive hub and extract the double coil spring washer.
36. Remove the shaft and governor weight assembly ensuring that the governor weights or carrier do not jam against the advance device stud.
37. Remove the "O" sealing ring from the drive shaft and withdraw the shaft.
38. Remove the governor weights, sleeve and thrust washer from the weight carrier.
39. Turn the cush drive back plate until the scallops in the periphery are in alignment with the rivets and then remove the plate. Extract the cush hub and inserts.
40. Remove the two oil seals from the pump body. Prise out the outer seal and then extract the circlip before removing the inner seal.

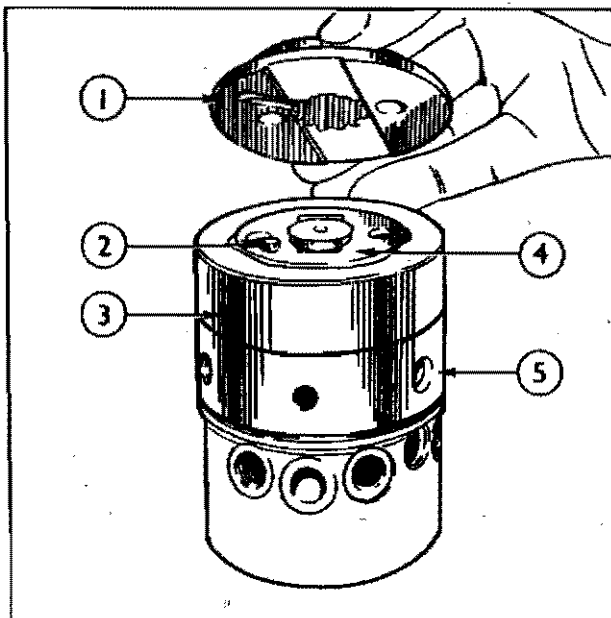


Fig. 79 1 Drive Plate 4 Stop Plate  
2 Locating Dowel 5 Hydraulic Head  
3 Cam Ring

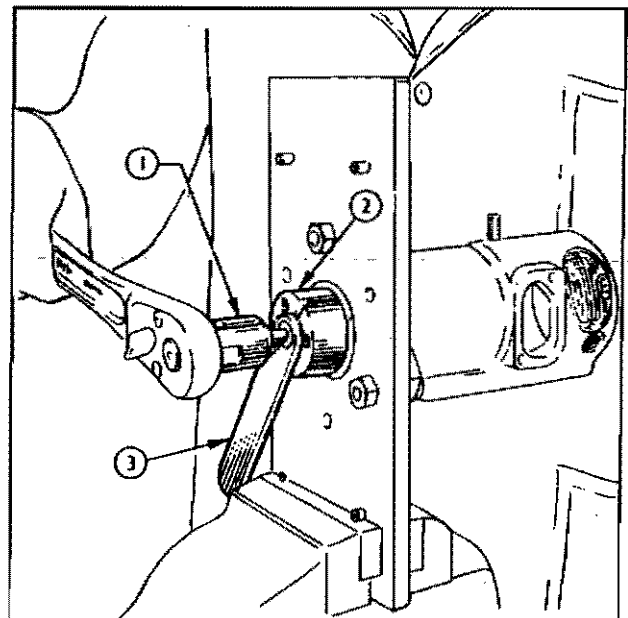
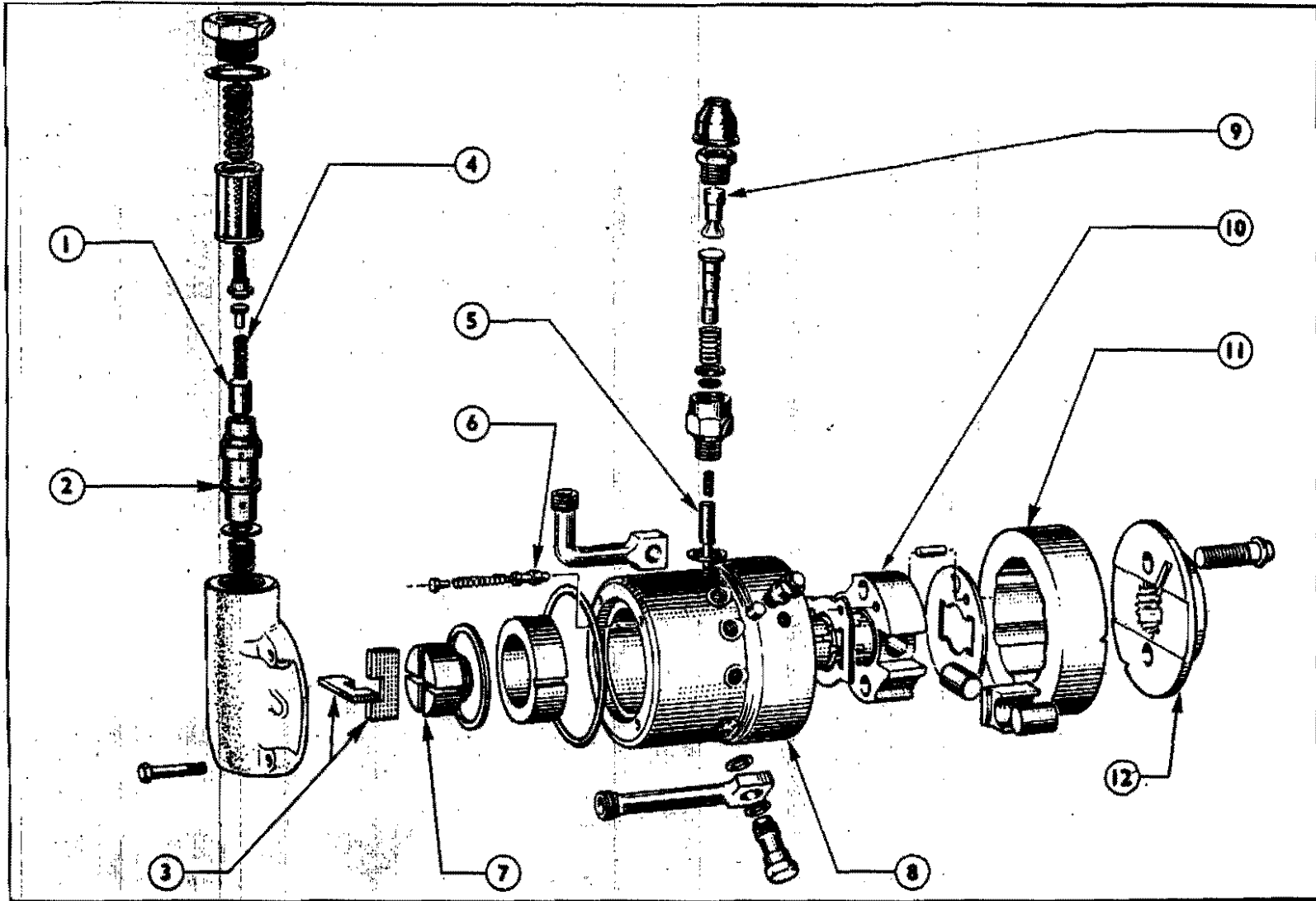


Fig. 80 1 Adaptor Key Tool No. CA.69  
2 Drive Hub  
3 Spanner Tool No. CA.67

APRIL 1973

Fig. 81

- 1 Plunger
- 2 Sleeve
- 3 Vanes
- 4 Regulation Spring
- 5 Latch Pin
- 6 Excess Fuel Valve
- 7 Transfer Pump Rotor
- 8 Hydraulic Head
- 9 Excess Fuel Lever
- 10 Pumping Element and Distributor Rotor
- 11 Cam Ring
- 12 Drive Plate



## TO REASSEMBLE THE INJECTION PUMP

1. Fit new oil seals to the pump body. Press the inner seal, lip facing inwards, into the pump body, using replacer Tool No. CA.72.A. Locate the circlip in the bore, using circlip pliers Tool No.7065 fitted with "A" type points, so that the ends are adjacent to the tell-tale hole in the housing. Fit the outer seal, lip outwards.

2. Assemble the cush drive. Locate the hub in the reverse side of the weight carrier, the reduced diameter being towards the weights and fit two inserts diametrically opposite to one another in the space between the hub and the retainer ring (see Fig.83). Turn the hub until the ears are touching the inserts and fit the other two inserts. Align the scallops in the periphery of the back plate with the rivets and locate in position. Turn the plate until the master splines are in alignment with the splines in the hub.

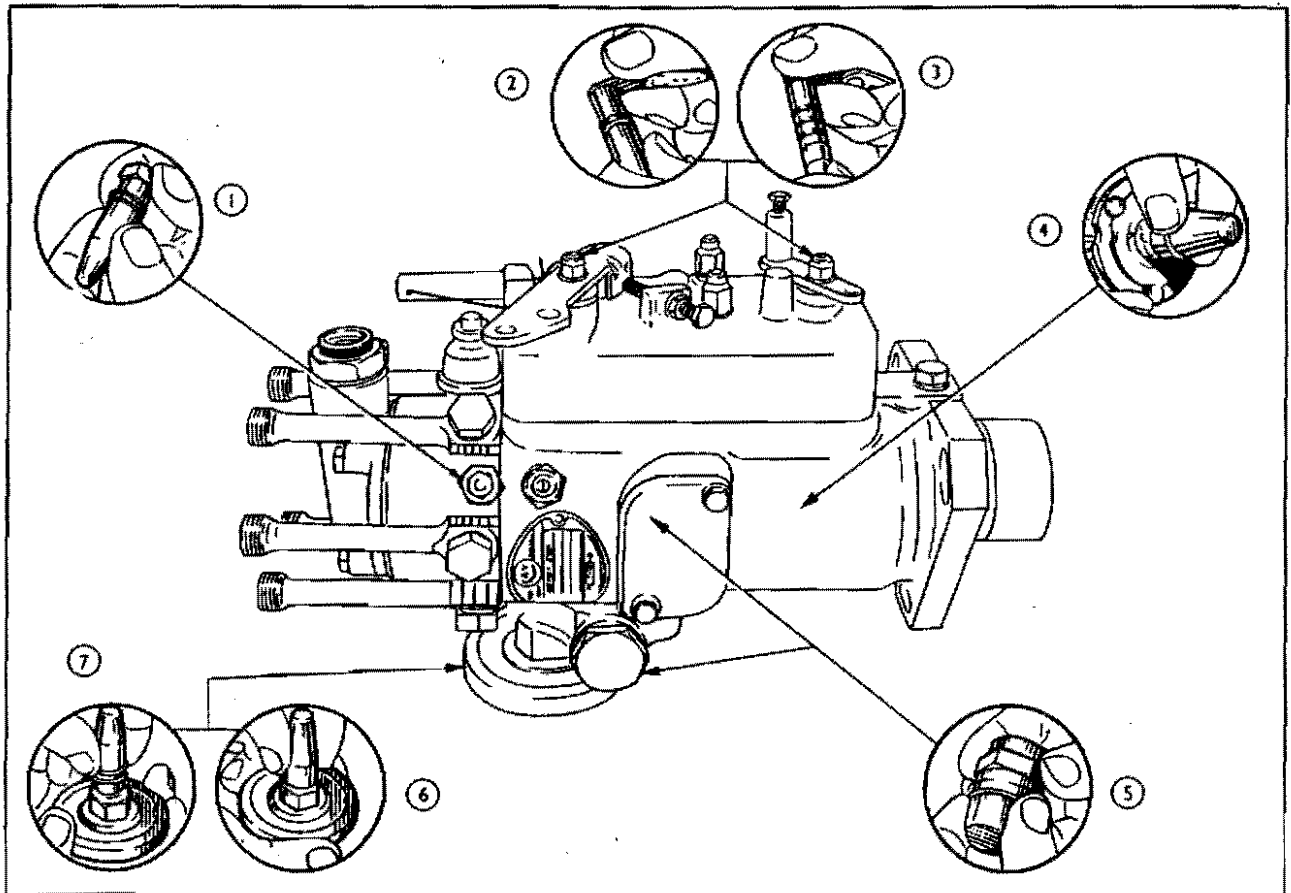


Fig. 82

1 Maximum Fuel Adjuster Assembly Tool No. CA.51	6 Head Locating Fitting and Damper Assembly, Tool No. CA.53
2 Throttle and Stop Shaft, Tool No. CA.51	7 Head Locating Fitting and Damper Assembly, Tool No. CA.54
3 Throttle and Stop Shaft, Tool No. CA.75	
4 Drive Shaft, Tool No. CA.76	
5 Piston Plug and Spring Cap, Tool No. CA.52	

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**TO REASSEMBLE THE INJECTION PUMP (Cont'd).**

3. Assemble the governor weights. Insert the drive shaft into the governor sleeve so that the flange is adjacent to the stepped end of the sleeve and then fit the thrust washer.

Stand the weight carrier on the rivets and engage the drive shaft splines with those in the cush hub and retaining plate, holding the sleeve and thrust washer against the flange. Balance the weights (two pairs diametrically opposite one another) on the edge of their respective pockets with the hooked end located under the thrust washer (see Fig. 84). A slight downward pressure on the sleeve will cause it to drop and the weights will fall into their pockets, correctly engaging with the sleeve.

Pick up the weight carrier and fully insert the drive shaft. Fit a new "O" ring to the drive shaft, using protection cap Tool No.CA.76.

4. Insert the drive hub into the pump body.

5. Fit the governor and drive shaft assembly into the pump body and engage the shaft with the drive hub. Slide the retaining washer into the drive hub and turn into position. Fit the retaining bolt and double-coiled spring washer and tighten to 32.5 Nm (3.32 kgf m or 24 lbf ft) torque, using key Tool No. CA.69. Hold the hub with spanner Tool No. CA.67.

6. Assemble the low inertia stop plate to the distributor rotor and insert the rotor into the hydraulic head.

7. Screw the transfer pump rotor into the end of the distributor rotor.

8. Position the stop plate so that the slots are parallel to the pumping element and locate with the dowel through the pump rotor.

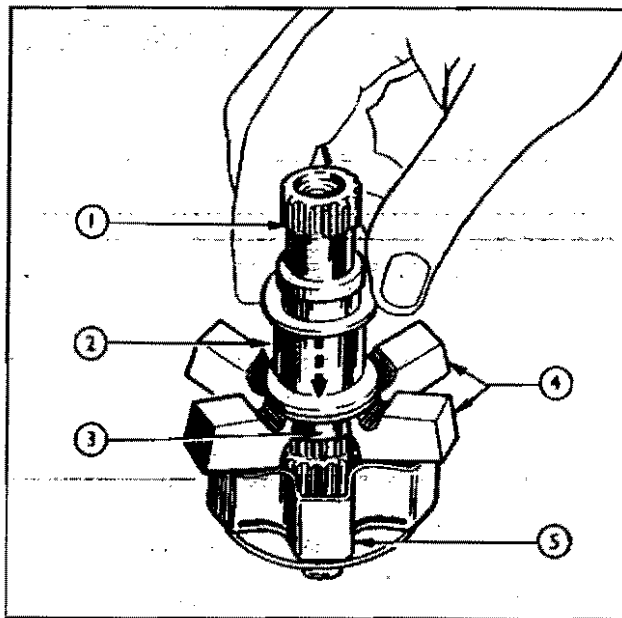
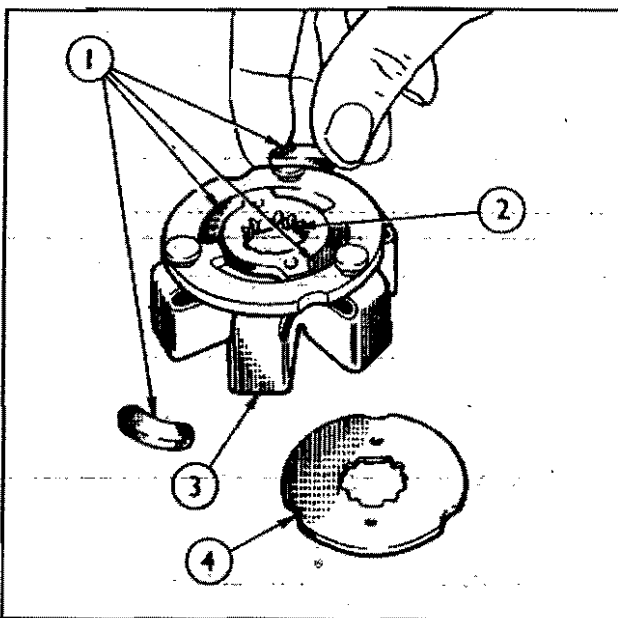


Fig. 83    1 Inserts    3 Weight Carrier  
          2 Hub        4 Back Plate

Fig. 84    1 Drive Shaft    4 Weights  
          2 Sleeve        5 Weight Carrier  
          3 Thrust Washer

## TO REASSEMBLE THE INJECTION PUMP (Cont'd).

9. Fit the rollers to their respective shoes. Remove the corks retaining the pumping plungers and fit the rollers and shoes to the injection pump rotor and then the other stop plate.
10. Locate the cam ring on the rotor. Note the direction of rotation by the arrows marked on each side and that the timing notch goes to the front (i.e. adjacent to the drive plate).
11. Fit the drive plate, locating the dowel in the slot, and retain with the drive plate screws.
12. Tighten the drive plate screws to 39.3 Nm (4.0 kgf m or 29 lbf ft) torque with (5/16 in) AF bi-hexagon socket and holding the drive plate with spanner Tool No. CA.112. Slacken the screws and then re-tighten to 28.5 Nm (2.91 kgf m or 21 lbf ft).
13. Assemble the hydraulic head to the pump body. Fit a new "O" ring to the hydraulic head, align the drive shaft and drive plate spines and insert the hydraulic head into the pump body. Screw in the head locating fitting and damper assembly to centralise the hydraulic head. Fit the hydraulic head locking screw and the pressurising valve and outlet connection, but do not tighten. Then remove the head locating fitting and damper assembly.
14. Fit the cam ring ball stud and tighten to 44.7 Nm (4.57 kgf m or 33 lbf ft) using socket Tool No. CA.66.A. Check that the cam ring is free to turn after tightening the ball stud.

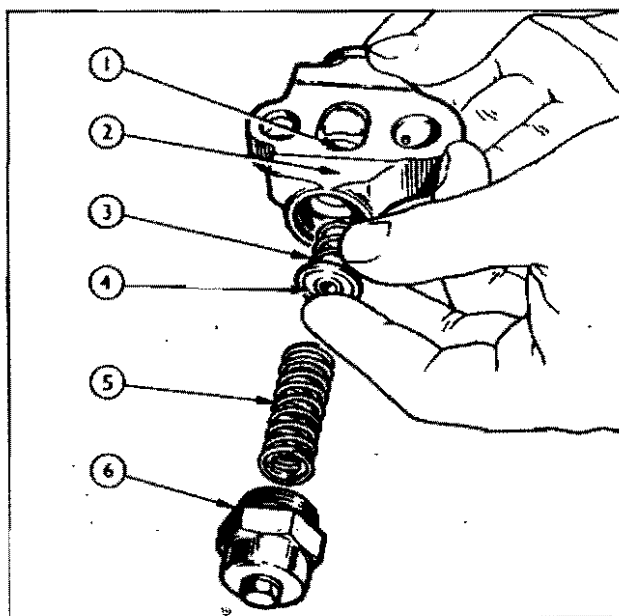


Fig. 85 1 Piston  
2 Advance Body  
3 Retard Spring  
4 Spring Plate  
5 Advance Springs  
6 Spring Cap

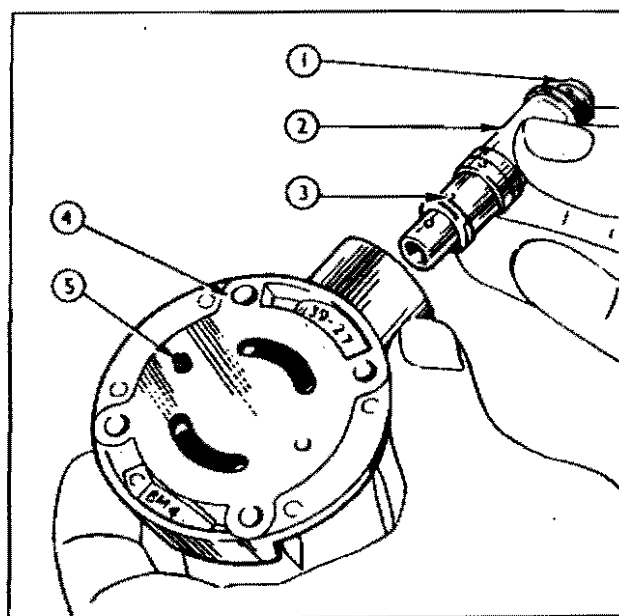


Fig. 86 1 Retaining Spring  
2 Nylon Filter  
3 Regulating Sleeve  
4 End Cover  
5 Transfer Pump  
Liner Locating Dowel

## TO REASSEMBLE THE INJECTION PUMP (Cont'd).

15. Assemble the advance device. Insert the advance piston into the advance body so that the plain end is away from the circlip. Screw in the piston plug after first fitting a new "O" ring, using protection cap Tool No. CA.52., see Fig. 82.

Fit a new "O" ring to the advance spring cap, using protection cap Tool No. CA.52. Insert the retard spring, spring plate and the two advance springs into the advance body (see Fig. 85) and then screw in the advance spring cap complete with any adjustment shims removed.

NOTE:—A 0.5 mm thick assembly shim must be fitted in this cap to prevent damage by the springs.

16. Fit new "O" rings to the damper assembly. Assemble the "O" ring under the hexagon head with protection cap Tool No. CA.53 and the "O" ring under the flange with protection cap Tool No. CA.54.A.

17. Fit the advance mechanism to the pump body with a new gasket, engaging the cam ring ball stud with the bore in the piston. Locate a steel ball in the damper assembly and fit the steel washer before screwing the damper assembly into the hydraulic head. Fit the cap nut and sealing washer.

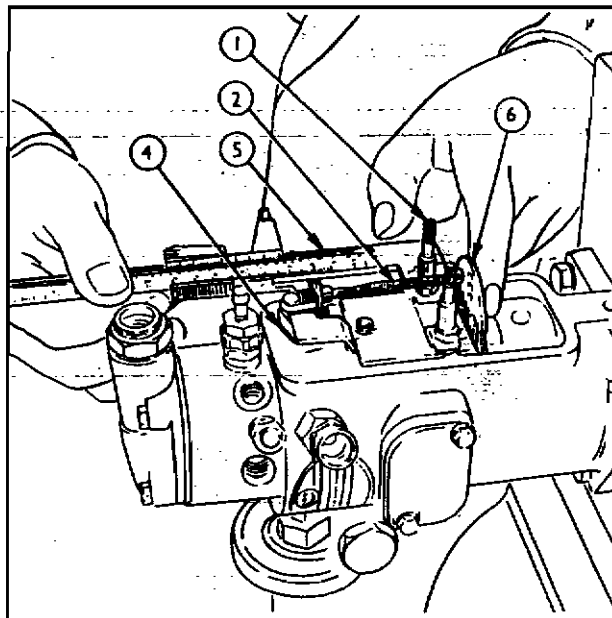
18. Tighten the hydraulic head locking screw and the pump body pressurising valve adaptor. Tighten the head locating fitting and advance mechanism damper assembly with torque adaptor Tool No. CA.111, and then tighten the cap nut.

Torques:—

Head locking screw	19 Nm (1.94 kgf m or 14 lbf ft)
Pressurising valve adaptor	
Damper assembly	39.3 Nm (4.0 kgf m or 29 lbf ft)
Cap nut	12.2 Nm (1.24 kgf m or 9 lbf ft)

Fig-87

- 1 Control Cover Stud
- 2 Governor Link
- 3 Control Arm
- 4 Metering Valve
- 5 Vernier Gauge



## TO REASSEMBLE THE INJECTION PUMP (Cont'd)

19. Tighten the advance piston plug and spring cap to 28.5 Nm (2.91 kgf m or 21 lbf ft).
  20. Tighten the transfer pump rotor to 6.8 Nm (0.69 kgf m or 5 lbf ft) torque, using socket Tool No. CA.58 and holding the drive hub with spanner Tool No. CA.67.
  21. Remove the injection pump and dismantling jig from the vice, invert and re-clamp back in the vice. Insert the shuttle, pintle end first, into the hydraulic head and then fit the maximum fuel adjuster assembly after fitting a new "O" ring, using protection cap Tool No. CA.51. Tighten to 19 Nm (1.94 kgf m or 14 lbf ft) torque.
  22. Insert the excess fuel valve, short spigot first, into the hydraulic head and align the annular groove with the excess fuel device bore, using assembly rod Tool No. CA.60.
  23. Fit a sealing washer to the excess fuel device and engage the excess fuel device with the latch pin and spring. Screw in and tighten.
  24. Assemble the priming spring, regulating sleeve, fitted with a new gasket, regulating plunger, regulating spring, button regulating adjuster, retaining spring and nylon filter to the end cover (see Fig. 62). Screw in the inlet adaptor fitted with a copper washer to retain the regulating valve assembly.
  25. Insert the excess fuel spring retainer into the hydraulic head.
  26. Fit the transfer pump rotor liner. Locate the rotor liner in the end of the hydraulic head, compressing the excess fuel spring and retainer.
  27. Hold the liner in position and fit the vanes, seal and end cover locating the liner with the dowel pin. Tighten the four end cover screws to 5.1 Nm (0.52 kgf m or 45 lbf ft) torque.
- NOTE:—The dowel pin must be located in the hole marked "C".
28. Tighten the inlet connection to 40.6 Nm (4.15 kgf m or 30 lbf ft) torque.
  29. Fit special radial connections and washers for test purposes, these connections can be identified by the drilling through one corner of the hexagon.
  30. Connect the governor hook link to the metering valve arm and assemble the spring retainers, springs and fibre washer to the link. Insert the link into governor control arm and fit the nylon pivot washer, the locknut and self-locking nut.
  31. Position the governor sleeve with the flat uppermost and fit the governor control arm and control bracket, inserting the metering valve into the hydraulic head at the same time. Locate the keep plate with the open end to this inspection cover side. Fit the locking plates, with plain tabs to rear, and the cover retaining studs. Fit the control plate screw and tab washer which locates in the corner of the control plate. After tightening the studs and screw bend up the locking tabs.

## TO REASSEMBLE THE INJECTION PUMP (Cont'd.)

32. Adjust the governor link length to 54 mm. Using a vernier gauge parallel to the pump axis measure this distance between the rear face of the left-hand control cover stud above the hexagon and the metering valve lever pin below the groove (see Fig. 87). Apply light pressure to the governor lever and metering valve to hold them in the fully open position during this operation. Adjust the link length by screwing or unscrewing the nut on the link.
33. Locate the cut-off bar in the control bracket and under the keep plate.
34. Fit new "O" rings to the throttle and stop shafts. Fit the lower "O" rings, using protection cap Tool No.CA.51 and the upper ones with protection cap Tool No.CA.75 screwed onto the ends of the shaft. Fill the grooves between the "O" rings with a lithium base corrosive resistant grease.
35. Fit the stop shaft to the cover.
36. Locate the idling spring to the guide and insert the guide into No.1 hole in governor control arm. Connect the governor spring.
37. Connect the free end of the governor spring to the throttle lever link, again in No.1 hole.
38. Locate a new gasket on the pump body and fit the control cover to the body, inserting the throttle shaft into the cover at the same time. Ensure that the stop shaft crank engages with the cut-off bar. Fit the cover retaining cap nuts with new fibre washers and tighten to 5.1 Nm (0.52 kgf m or 45 lbf in).
39. Fit the inspection cover, using a new gasket.
40. Refit the throttle and stop shaft dust-caps, control levers, washers and self-locking nuts. Tighten the nuts to 3.4 Nm (0.35 kgf m or 30 lbf in).

## TESTING AND ADJUSTING THE FUEL INJECTION PUMP

The distributor type pump has only one pumping element, thus each injector receives an equal volume of fuel when the engine is operating at constant speed and load. Also, injection will occur at regular intervals as the cam lobes which operate the single pumping element (two opposed plungers) are evenly spaced and accurately machined in the cam ring. Phasing and calibration, operations which are essential when a conventional multi-element type injection pump is overhauled are, therefore, not required. Pre-set timing marks are also accurately machined on the cam ring and drive plate and as these are fixed, no timing adjustment is necessary.

It is necessary, however, to check and adjust the maximum fuel delivery and also to check the operation of the injection pump on a calibrating machine. As this injection pump has to be tested at varying speeds, the calibrating machine used must have a variable speed drive (see Figs. 88 and 89).

Where it is only necessary to check the operation of the pump, i.e. when a fault is suspected or prior to overhaul, complete the operations on the test procedure but do not make any adjustments.



## TEST BENCH MAINTENANCE

Fuel injection pumps must be accurately tested 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, after testing 200 pumps, the filter element renewed.
3. Where testing 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 a substitute test fuel in the calibrating machine as the variation of this fuel is less than that of diesel fuel so that more accurate readings can be obtained. Also the test fuel gives better protection to the master injectors.

## TYPICAL VARIABLE SPEED TEST BENCHES

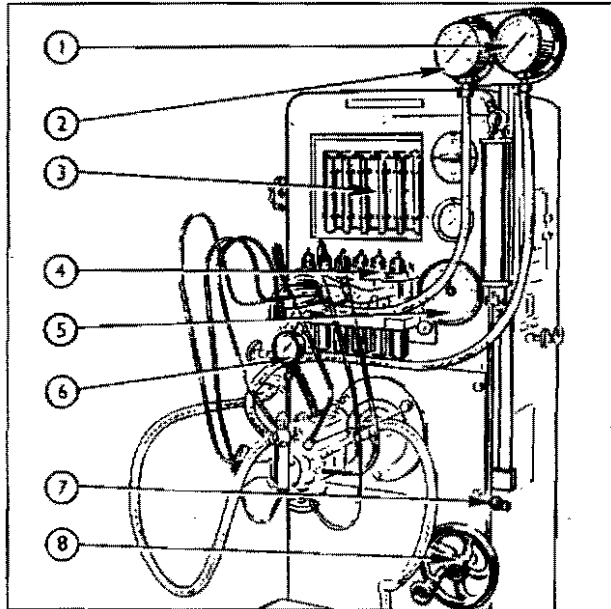


Fig. 88

- 1 Transfer Pressure Gauge
- 2 Vacuum Gauge
- 3 Graduated Test Tubes
- 4 Master Injectors
- 5 Tachometer
- 6 Pump Body Pressure Gauge
- 7 Trip Lever
- 8 Speed Control Handle

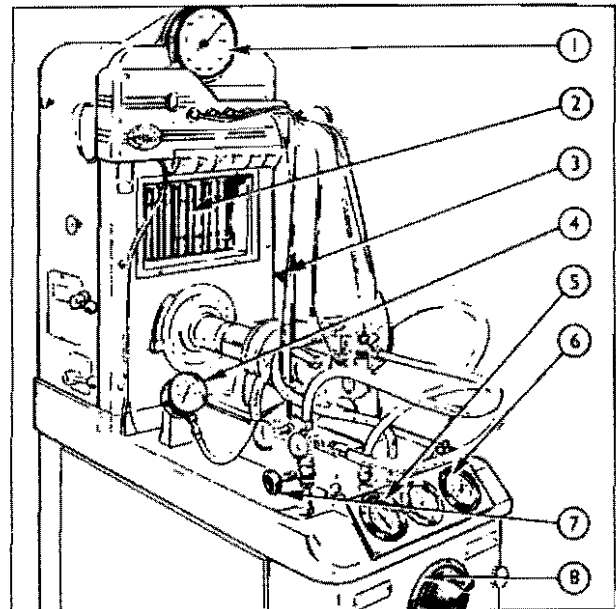


Fig. 89

- 1 Tachometer
- 2 Graduated Test Tubes
- 3 Trip Lever
- 4 Pump Body Pressure Gauge
- 5 Vacuum Gauge
- 6 Transfer Pressure Gauge
- 7 Fuel Tap
- 8 Speed Control Handle

## MASTER INJECTORS

The master injectors must be checked regularly for balance. To carry out this test, mount an in-line injection pump on the calibrating machine, connect all pipes and run the machine for at least 15 minutes to allow everything to reach normal operating temperature. It is essential that this is strictly observed when carrying out this test.

Adjust one pump element to deliver 15cc for three consecutive readings, running at 600 rev./min. for 300 shots of fuel. Note:—All readings must be taken from the bottom of the meniscus. Connect this pump element to each master injector in turn, using the same pipe and test tube throughout this test. Running at 600 rev./min. collect 300 shots of fuel, allowing 15 seconds after delivery has ceased for the fuel to settle before taking the readings, and 30 seconds for the tube to drain when emptying. Take the mean of three readings from each injector in turn and the variation between the highest and lowest readings should not exceed 0.3cc. If the variation exceeds this figure a fresh set of master injectors should be fitted. Do not attempt to balance master injectors by cleaning or pressure adjustment.

## INJECTOR PIPES

After a prolonged period of use on the calibrating machine it may be found that the ends of the injector pipes have closed up slightly thus reducing the bore. This condition will affect the pump delivery and if it is found to exist, the pipes should be renewed. As an emergency measure the ends of the pipes can be cleared by using a 2mm. diameter drill to a depth of 20 mm (0.75 in.) and then the pipe bore thoroughly cleaned (preferably with pressure equipment) before refitting.

## TEST EQUIPMENT SPECIFICATION

Master injectors fitted with BDN12SD12 nozzles set at 175 atmospheres opening pressure. Nozzle back leakage must not be less than 10 secs., for a drop from 150 to 100 atmospheres.

High pressure pipes 6 mm by 2 mm by 86.4 cm (34 in.) long with special radial connections identified by a drilling through a corner of the hexagon.

Gravity feed 0.069 bar (0.07 kgf/cm<sup>2</sup> or 1 lbf/in<sup>2</sup>) minimum with a minimum flow of 1,200 cc./min.

Special substitute fuel oil, see Specification and Repair Data.

Oil temperature 15.6 to 48.9°C (60 to 120°F).

## BASIC SPECIFICATION OF FUEL INJECTION PUMP

1. Pump Rotation: Clockwise, looking on drive end.
2. Speed advance and automatic start retard.
3. Excess fuel device.
4. Transfer pressure adjuster in the end plate assembly.

**BASIC SPECIFICATION OF FUEL INJECTION PUMP (Cont'd).**

5. External maximum fuel adjuster.
6. Pump body pressurised by pressure dividing valve in the outlet connection.
7. Mechanical governor.
8. Governor spring—No. 1 hole in governor control arm and No. 1 hole in throttle lever link, numbered from the top and the end respectively.
9. Governor lever link length 54 mm.  $\pm$  1 mm.

**MOUNTING THE FUEL INJECTION PUMP ON THE TEST EQUIPMENT**

1. Mount the fuel injection pump on the test equipment, using the distributor type pump mounting bracket and drive. (This is usually supplied with the test equipment).

**NOTE:**—The mounting flange spigot diameter on this injection pump is larger (50 mm.) than those on previous distributor type injection pumps and protrudes 9.5 mm. An additional adaptor is therefore required to mount this injection pump together with a pressure gauge to check the pump body pressure. A complete kit will be available from the test bench manufacturers.

2. Align the master spline on the injection pump drive shaft with the corresponding spline of the test equipment drive. Secure the pump in position with three bolts fitted through the pump mounting flange and adaptor.
3. From the base of the injection pump remove the stop pin located in one of the end plugs fitted to the advance and retard mechanism. In place of the stop pin fit an automatic advance gauge Tool No.CA.65 with adaptor Tool No.CA.65-1 (see Fig. 90).

Zero the gauge before commencing any test as described in General Data.

4. Unscrew the hydraulic head locking screw if a pressure adaptor has not already been fitted. In its place fit a pressure adaptor. Couple up the test pressure gauge pipe to this adaptor.
5. Connect up the pipe line from the back leakage measuring cylinder of the test equipment to the outlet connection of the fuel injection pump.
6. If high pressure banjo connections are fitted (i.e. on a pump just removed from a vehicle) they must be removed and special radial connectors fitted in their place. Couple up the radial connectors and the test equipment master injectors with the correct length high pressure pipes.
7. Fit the fuel supply pipe from the test equipment to the inlet union on the regulating valve connection of the fuel injection pump with a transfer pressure adjusting Tool No.CA.113.
8. Remove the governor cover vent screw and fit the pump body pressure gauge.
9. Prime all test bench fuel lines, including the line to the vacuum gauge.

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## GENERAL DATA

Test the injection pump in accordance with "Test Procedure" previously outlined. The throttle and stop control levers to be fully opened except where otherwise stated.

Where marked thus\* use for 30 seconds glass draining time and allow fuel to settle for 15 seconds before taking a reading.

**Leaks.** All pumps must be completely free from leaks both while running and when stationary.

**Delivery values.** All calibration and setting values are for 200 strokes except where otherwise stated.

Unscrew the maximum stop screw and idling stop screw to allow full movement of the throttle arm before commencing tests.

Screw out the transfer pressure adjusting screw fully and then screw in 1½ turns before commencing test.

Screw the maximum fuel adjusting screw in fully and screw out 2 turns before commencing test.

Do NOT run the pump for long periods with the shut-off lever closed.

Do NOT run the pump for long periods at high speed with small delivery.

Zero the advance gauge Tool No. CA.65, before commencing any tests, by adjusting the scale to zero.

Note the points in the test procedure where priming and venting is required.

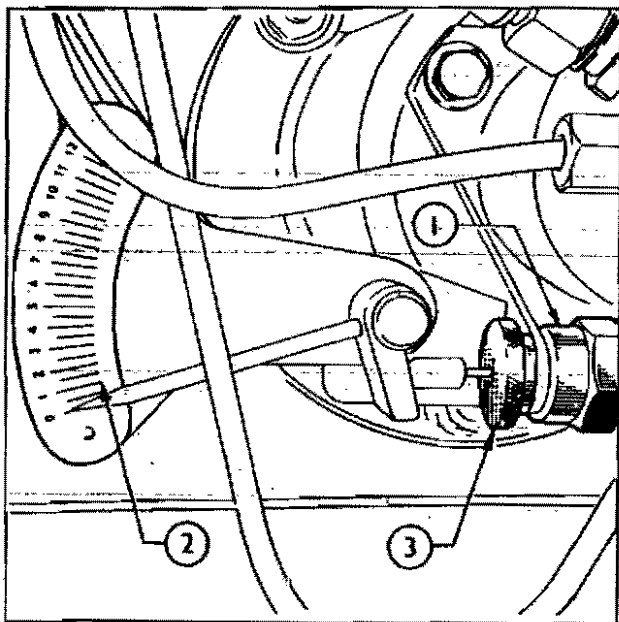


Fig. 90 1 Advance Spring Cap  
2 Automatic Advance Gauge  
Tool No. CA.65  
3 Adaptor, Tool No. CA.65-1

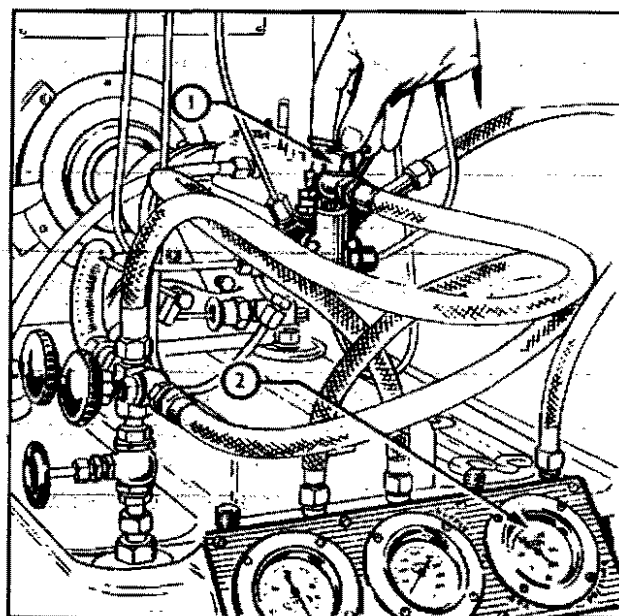


Fig. 91 1 Transfer Pressure Adjusting  
Tool No. CA.113  
2 Pressure Gauge

## PRIMING AND VENTING

With this pump, correct and consistent operation of the auto-advance is dependent upon the exclusion of air from the auto-advance housing.

Venting should be carried out at the vent screws whilst running the injection pump at 100 r.p.m.

Operate the throttle lever and press inwards and release the automatic advance gauge Tool No. CA.65 indicator pin several times to ensure venting.

## AUTOMATIC ADVANCE

The automatic advance mechanism is adjusted by shimming the springs (see Fig. 71) as follows:—

1. Remove the automatic advance gauge Tool No.CA.65 and the cap into which it is screwed.
2. If the advance is low remove shims to rectify.

NOTE:—A 0.5 mm. shim is fitted to this cap on assembly. This must NOT be removed.

3. If the advance is high add shims to rectify.

NOTE:—The amount of shimming, in addition to the 0.5 mm. assembly shim, that may be added to meet the test requirements may vary from 0 to 3.5 mm. Shims 0.051 (0.002 in.) 0.102 mm. (0.004 in.); 0.203 mm. (0.008 in.); 2.032 mm. (0.080 in.) and 0.5, 1 and 3.5 mm. thick are available.

4. Replace the cap and the advance gauge Tool No.CA.65, zero if necessary. Prime and vent the injection pump as described previously.

## TRANSFER PRESSURE

The transfer pressure is adjusted by means of an adjusting screw in the end plate assembly, accessible through the inlet connection. This can be adjusted with the pump running with adjuster Tool No. CA.113 (see Fig. 91). Screw the adjuster in to increase pressure and out to reduce the pressure.

## MAXIMUM FUEL DELIVERY

The maximum fuel delivery is controlled by the shuttle stroke. This can be adjusted externally by removing the blanking screw from the adjuster assembly and turning the adjusting screw with an hexagonal key (see Fig. 92). Screw the adjuster in to reduce delivery and out to increase.

## FUEL INJECTION PUMP REMOVAL FROM THE TEST EQUIPMENT

1. Disconnect all pipes.
2. Unscrew the transfer pressure adjuster Tool No. CA. 113 and remove the adjuster assembly and banjo connection.
3. Remove the pump body pressure gauge and refit the vent screw to governor cover.
4. Remove the automatic advance gauge Tool No. CA.65 from the injection pump. Replace the stop pin in the advance mechanism end plug.
5. Remove the transfer adaptor and replace the hydraulic head locking screw. Tighten to 19.2 Nm (1.96 kgf m or 14.2 lbf ft).
6. Unscrew the radial connections from the hydraulic head and refit the long banjo connections, with the pipes horizontal, to outlet ports U, W, X, Y and Z. Fit the right-angle connection, with the pipe upwards, to outlet V. Use new steel washers and tighten the bolt to 40.7 Nm (4.15 kgf m or 30 lbf ft) torque to prevent leaks. These banjo bolts have the threads relieved for 3 mm and can be identified by a drilling through a corner of the hexagon.
7. Fit dust caps or plugs to all connections.
8. Unscrew the three bolts through the injection pump mounting flange and remove the pump from the test equipment.

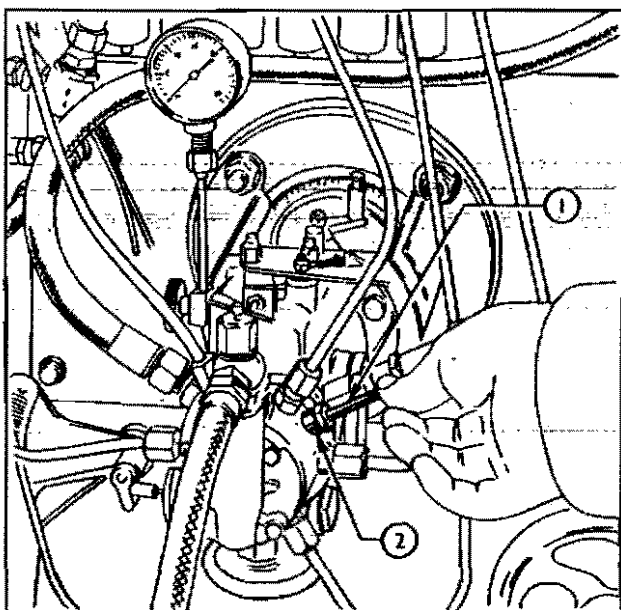


Fig. 92 1 Hexagonal Key  
2 Maximum Fuel Adjuster Assembly

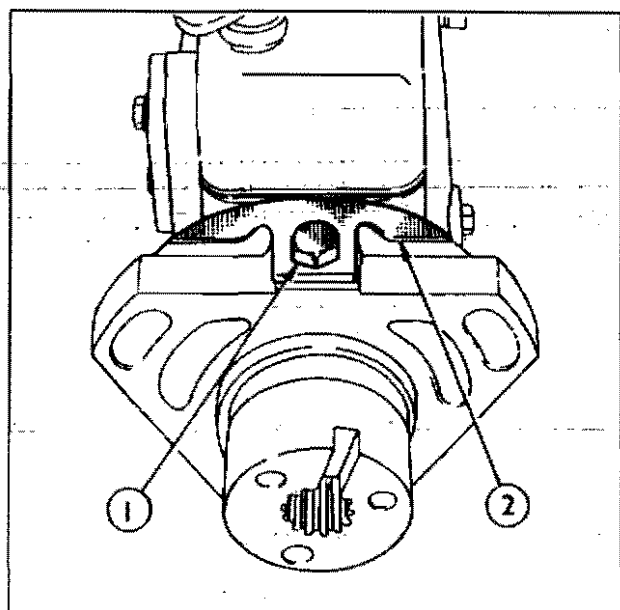


Fig. 93 1 Timing Locking Bolt  
2 Bracket

## DRIVE HUB SCREW

Slacken the drive hub screw, using key Tool No. CA.69 and holding the hub spanner Tool No. CA.67 and then re-tighten to 32.5 Nm (3.32 kgf m or 24 lbf ft). This must be done three times after testing the pump.

## TIMING

Pre-set timing marks are accurately machined on the drive plate and cam ring and, as these are fixed, no timing adjustment is necessary. However, the injection pump can be set in the timed position on the completion of testing to facilitate subsequent assembly on the engine, as follows:—

1. Remove the inspection cover from the injection pump body.
2. Turn the injection pump until the timing marks on the drive plate and cam ring are in alignment (see Fig. 94).
3. Remove the sealing bolt from the pump flange.
4. Substitute the timing locking bolt for the sealing bolt and tighten to 2.8 Nm (0.29 kgf m or 25 lbf in) torque. Lock the pump in the timed position. The bracket attached to the locking bolt masks the two upper holes in the pump mounting flange, thus ensuring removal of the locking bolt on assembling the pump to the engine, refer to Fig. 93.
5. Refit the inspection cover. Tighten the bolts and seal with a wire and lead seal.

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## LEAK CHECK

Apply a pressure 1.38 bar (1.4 kgf/cm<sup>2</sup> or 20 lbf/in<sup>2</sup>) to the outlet connection and immerse the pump completely in test oil for two minutes. Air leaks should not occur except at the high pressure outlets and the time locking ball.

## PUMP SEALS

Wire the governor cover cap nuts together and seal with a lead seal. After adjusting the maximum fuel delivery fit the blanking screw, wire to the adjuster body and seal with a lead seal.

## IDLING AND MAXIMUM SPEED ADJUSTMENTS

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.

Fit the injection pump to the engine, as described previously, and adjust the idling and maximum speeds, with the engine and gearbox at normal operating temperature. Use a tachometer to ensure an accurate setting, this can be driven by the tachometer drive slots in the oil pump gear using a suitable adaptor, after first removing the plug from the cylinder block.

## IDLING SPEED

Slacken the idling stop screw locknut and then screw the stop screw in or out until the idling speed is between 400 and 550 rev./min. Tighten the locknut and then "blip" the throttle to ensure a consistent return to this setting.

**NOTE:**—A completely cold engine, with the correct idling adjustment, may stall but will run satisfactorily after approximately 30 seconds warm-up. Do not increase the idling speed to compensate for this stalling condition when the engine is cold.

## MAXIMUM SPEED

Open the throttle fully, slacken the maximum speed stop screw locknut and then screw the stop screw in or out until the maximum speed is between 3,075 and 3,090 rev./min. Tighten the locknut and re-check the speed. Fit the sealing cover and twist the sealing wire around the stop screw bracket. Seal the wire with a lead seal.

## BLEEDING THE 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:—

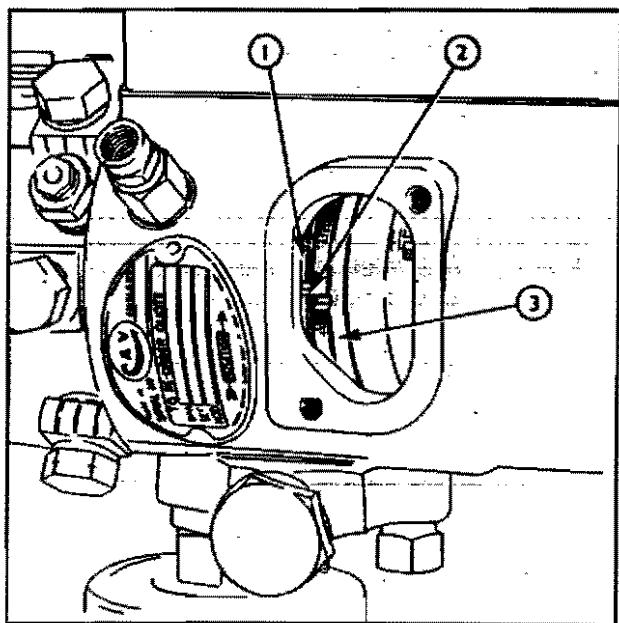


Fig. 94 1 Cam Ring  
2 Timing Marks  
3 Drive Plate

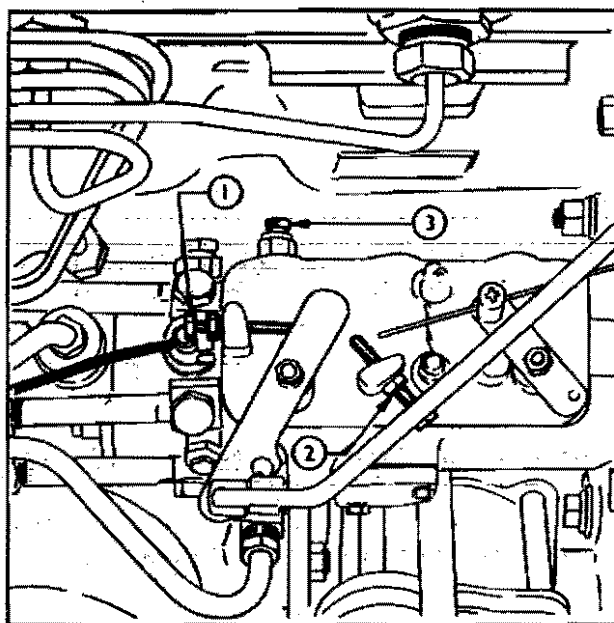


Fig. 95 1 Maximum Speed Stop Screw  
2 Idling Stop Screw  
3 Bleed Valve Screw



**BLEEDING THE SYSTEM (Cont'd).**

1. Ensure that all fuel pipe connections are tight and that there is sufficient fuel in the tank.
2. Operate the lift pump priming lever when the filter will be bled automatically by the permanent bleed in the filter head. After fitting a new element slacken the plugged connection on the filter head and operate the lift pump priming lever until fuel flows from this connection to indicate that the filter is primed. Tighten the plug.

**NOTE:**—If the cam on the engine camshaft is on maximum lift, it will render the fuel lift pump priming lever inoperative. If this occurs, rotate the engine until the priming lever can be operated.

3. Repeat this procedure at the injection pump inlet connection.

On initial installation, or after running out of fuel additional priming of the injection pump and injector pipes will also be necessary.

4. Slacken the bleed valves on the governor housing and operate the lift pump priming lever until the fuel flow is free of air. Tighten the governor housing bleed valve (see Fig. 95).
5. Unscrew any two injector inlet adaptor seal nuts and slacken the corresponding inlet adaptors. Ensure that the stop control is pushed right in and, with the throttle lever in the fully open position, operate the starter motor until the engine fires on the remaining cylinders. Tighten the injector inlet adaptors and then the seal nuts.

Wipe all surplus fuel from the injection pump and filter body.

Take care to expel all air from the system, or misfiring and erratic running may result.

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# INJECTION PUMP TEST PROCEDURE

DESCRIPTION	R.P.M.	REQUIREMENTS
(1) Operation	100 max.	Prime and vent the injection pump, see Note (e), to ensure fuel delivery from all nozzles.
(2) Transfer pump vacuum	100	Turn the two-way tap, in the fuel feed pipe, to connect the vacuum gauge. 406 mm. (16 in.) Hg. must be reached within 60 seconds. Prime the pump after this test.
(3) Transfer pressure pump	1,000	Adjust to give 5.03 bar (5.13 kgf/cm <sup>2</sup> or 73 lbf/in <sup>2</sup> ), see Note (g).
(4) Pump body pressure	1,000	0.76 to 1.24 bar (0.77 to 1.26 kgf/cm <sup>2</sup> or 11 to 18 lbf/in <sup>2</sup> )
(5) Automatic advance	700	8¼° to 8¾° adjust as necessary, see Note (f).
N.B.—Prime and vent the injection pump after adjustment, see Note (e), before continuing the test.		
(6) Automatic advance	1,300	11½° to 12½°
(7) Maximum fuel delivery	1,220	Adjust to give average delivery of 12.3 ± 0.1 c.c., see Note (h).
(8) Maximum fuel delivery check	150	Average delivery to be not less than average at (7) minus 3.4 c.c.
(9) Automatic advance	180	4¾° to 5¼°
(10) Excess fuel delivery (engage excess fuel)	100	Average delivery to be 21 c.c. minimum
(11) Transfer pump pressure	100	0.69 bar (0.70 kgf/cm <sup>2</sup> or 10 lbf/in <sup>2</sup> ) minimum
(12) Excess fuel delivery check	450	Average delivery to be 17 c.c. minimum
(13) Fuel delivery (excess fuel valve return check)	700	Average delivery to be not more than average at (7) plus 0.4 c.c.
(14) Fuel delivery (excess fuel valve return check)	450	Average delivery to be not more than average at (7) plus 0.4 c.c.

DESCRIPTION	R.P.M.	REQUIREMENTS
(15) Stop control operation	200	With stop control lever closed, average delivery not to exceed 0.8 c.c.
(16) Throttle operation	200	With throttle lever closed, average delivery to be 0 to 2.0 c.c.
(17) Fuel delivery check	1,400	Record average delivery
(18) Governor setting	1,610	Set average delivery by maximum speed adjusting screw to 1 to 2.5 c.c. No line to exceed 3.0 c.c. Lock stop screw.
(19) Fuel delivery check	1,400	With throttle set as at (18), average delivery to be not less than average at (17) minus 0.4 c.c.
(20) Timing (after removal from the test equipment)		Align the timing marks on the drive plate and cam ring, see "Timing" Lock in this position by fitting a locking bolt and bracket to the pump body flange.

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# INJECTION PUMP — FAULT FINDING

## INCORRECT VACUUM

1. Loose or damaged inlet connections.
2. Unserviceable copper washer on inlet adaptor to end plate.
3. Damaged gasket on regulating sleeve.
4. Regulating spring missing or broken.
5. End-plate not tightened square to hydraulic head.
6. Faulty transfer pump seal.
7. Worn or damaged transfer pump blades.
8. Transfer pump liner not located by dowel pin.
9. Air in pipe to vacuum gauge.
10. Priming spring missing or broken.

## LOW TRANSFER PRESSURE

1. Incorrect adjustment.
2. Regulating sleeve gasket damaged.
3. Regulating spring or piston missing.
4. Incorrect regulating spring or sleeve.
5. Worn or damaged transfer pump blades.
6. Faulty transfer pump seal.
7. Loose or incorrectly tightened end-plate.
8. Faulty washers on head locking screw and pressurising valve.
9. Damaged seals on head locating fitting and damper assembly.
10. Worn pressurising valve.

## HIGH TRANSFER PRESSURE

1. Incorrect adjustment.
2. Sticking regulating piston.
3. Incorrect regulating spring and/or sleeve.
4. Test bench operating on pressure feed.
5. Damaged pressurising valve or blocked return.

## LOW AND FLUCTUATING TRANSFER PRESSURE

1. Regulating sleeve inner seal faulty.
2. One transfer pump blade chipped or broken.

## LOW ADVANCE READING

1. Low transfer pressure.
2. Too many shims fitted.
3. Springs too stiff, incorrect type fitted.
4. Sticking advance piston.
5. Sticking cam ring.
6. Excessive clearances between piston and housing.

## HIGH ADVANCE READING

1. High transfer pressure.
2. Insufficient shims fitted.
3. Incorrect springs too weak.

**INCORRECT MAXIMUM FUEL DELIVERY**

1. Throttle not fully open.
2. Incorrect maximum fuel setting.
3. Faulty washer on rotor plug screw.
4. Loose rotor plug screw.
5. Sticking metering valve.
6. Air in system.
7. Sticking plungers on roller shoes.
8. Damaged washers on radial connections.
9. Incorrect transfer pressure.
10. Shut off mechanism fouling metering valve.
11. Governor link adjustment incorrect.
12. Governor spring linkage incorrectly assembled.
13. Cam ring reversed.
14. Cam ring worn.

**LOW FUEL DELIVERY AT 100 r.p.m.**

1. Low transfer pressure.
2. Throttle not fully open.
3. Rotor plug screw washer damaged.
4. Rotor plug screw loose.
5. Sticking metering valve.
6. Sticking plungers and roller shoes.
7. Damaged washers on radial connections.
8. Plungers scored.
9. Outlet ports scored.
10. Excessive clearance, rotor to hydraulic head.
11. Air in system.
12. Scored metering valve.

**CUT-OFF NOT WORKING**

1. Stop control lever fitted incorrectly to shaft.
2. Stop control shaft not engaging with cut-off bar.
3. Cut-off bar fouling control cover or control bracket.
4. Governor link binding in control arm.
5. Governor link length too long.
6. Excessive clearance, metering valve to hydraulic head.
7. Sticking metering valve.
8. Scored metering valve.

**LOW DELIVERY DURING FUEL DELIVERY CHECK AT MAXIMUM SPEED**

1. Maximum speed stop screw incorrectly adjusted.
2. Faulty or incorrect governor spring.
3. Governor spring linkage coupled to wrong holes.
4. Sticking metering valve.
5. Governor link length incorrect.

**DIFFICULTY IN SETTING DELIVERY BY MAXIMUM SPEED STOP SCREW**

1. Governor spring damaged or of wrong type.
2. Governor link setting incorrect.
3. Governor spring linkage incorrectly coupled.
4. Drive hub securing screw loose.
5. Sticking metering valve.
6. Sticking governor thrust sleeve.

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## SPECIFICATIONS

Type	Distributor
Rotation	Clockwise from drive end
Pumping element plunger diameter	9 mm.
Governor type	Mechanical
Idling speed	400 to 550 rev/min.
Governor link length	54 mm.
Idling spring rate	0.021 kg./mm.
Idling spring free length	7.6 mm.
Idling spring active coils	3
Idling spring identification	No legs
Regulating valve sleeve identification	V
Regulating spring rate	1.1 kg./mm.
Regulating spring free length	12.5 mm.
Regulating spring active coils	8.2
Cold starting device	Excess fuel
Excess fuel valve spring rate	0.048 kg./mm.
Excess fuel valve spring free length	27.25 mm.
Excess fuel valve spring total coils	19
Advance mechanism	Automatic advance and start retard
Maximum advance	5½° to 8°
Start retard	4½° to 5½°
Outer advance spring rate	0.369 kg./mm.
Outer advance spring free length	34.3 mm.
Outer advance spring active coils	7½
Inner advance spring rate	0.525 kg./mm.
Inner advance spring free length	30.4 mm.
Inner advance spring active coils	9½
Advance adjustment	Shims
Shim thickness	0.051 mm. (0.002 in.); 0.102 mm. (0.004 in.); 0.203 mm. (0.008 in.); 0.254 mm. (0.010 in.); 2.032 mm. (0.080 in.) and 0.5 mm; 1 mm; 3.5 mm.
Retard spring rate	0.28 kg./mm.
Retard spring free length	17 mm.
Retard spring active coils	3
Piston plug identification	A
Spring plate identification	H

## GOVERNOR SPRINGS

Type of Pump	British Standard Pump		Combine Pump 2000–2250*	General Purpose Pump 2500	Automotive Pump 2800*
	1500*	1800*			
Spring Rate (kg./mm.)	0.098/0.014		0.135/0.141	0.246/0.260	0.304/0.320
Free length inside loops (mm.)	38.8		38.8	35.8	35.8
Total coils	14½		18	11½	13½
Location in throttle control	Hole 2		Hole 2	Hole 1	Hole 1
Location in control arm	Hole 3	Hole 2	Hole 2	Hole 2	Hole 1
Max. Full Load Speed	1500 rpm.	1800 rpm.	2250 rpm.	2500 rpm	2800 rpm
Max. No Load Speed	1545/1565 rpm.	1860/1880 rpm.	2339/2350 rpm	2640/2660 rpm.	3075/3090 rpm.

\*These pumps have British Standard 649 Class A governing characteristics.

## TIGHTENING TORQUES

	Nm	kgf m	lbf ft	lbf in
End plate screws	5.1	0.52	—	45
Fuel inlet connections	40.7	4.15	30	—
Distributor rotor screw	3.2	0.33	—	28
Transfer pump rotor	7.3	0.75	—	65
Head locking screw	18.9	1.93	14	—
Pressurising valve body	18.9	1.93	14	—
Outlet connection (sealed with EM-4G-52 plastic sealer)	13.6	1.38	10	—
Head locating fitting and damper	39.3	4.0	29	—
Advance device cap nut	12.2	1.24	9	—
Advance device housing stud	6.8	0.69	—	60
Cam advance screw	44.8	4.56	33	—
Auto advance spring cap and piston plugs	28.5	2.91	21	—
High pressure connection (radial and banjo)	40.7	4.15	30	—
Drive plate screws — First tighten to	39.3	4.0	29	—
— then slacken and retighten to	28.5	2.91	21	—
Control cover studs	6.8	0.69	—	60
Control cover cap nuts	4.5	0.46	—	40
Throttle and cut-off shaft nuts	3.4	0.35	—	30
Control bracket screw	2.4	0.24	—	21
Drive shaft screw	32.5	3.32	24	—
Slacken and retighten to this figure three times after testing pump				
Governor vent screw body	7.3	0.75	—	65
Maximum fuel adjuster body	18.9	1.93	14	—
Excess fuel device body	18.9	1.93	14	—
Excess fuel device pivot sleeve	17.63	1.80	13	—

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## TEST BENCH REQUIREMENTS

Type	Variable speed
Master injector nozzle	C.A.V. BDN125012
Nozzle opening pressure	175 atmospheres
Back leakage time for pressure drop from 150 to 100 atmospheres	10 secs. minimum (new) 6 sec. minimum (recon.)
High pressure pipes	6 mm. O.D. x 2 mm. I.D. 76.2 cms. x (30 in.) long
Substitute fuel oil:	
Amoco (U.K.) Limited	
Castrol Limited	HI11/60
Alexander Duckham & Company Limited	
Esso Petroleum Company Limited	T.S.D. 815
Mobil Oil Company Limited	
Petrofina (Great Britain) Limited	
Regent Oil Company Limited	
Shell-Mex & B.P. Limited	Shell Fusus Oil "A" Shell D.T.11
Oil temperature	15.6 to 48.9°C (60 to 120°F)

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# TURBOCHARGER AND CHARGE AIR COOLER

## INTRODUCTION

The turbocharger is a turbine-driven compressor which utilises the waste energy of the engine to increase the mass of air charge to the cylinders.

Five versions of the 3LD type turbocharger are fitted, industrial, marine, marine Class A, marine with intercooler and turbo-plus respectively. The industrial version and the marine Class A gives a maximum boost of 1.21 bar (1.23 kgf/cm<sup>2</sup> or 17.6 lbf/in<sup>2</sup>) at 90,000 r.p.m., the marine version gives a maximum boost of 0.84 bar (0.85 kgf/cm<sup>2</sup> or 12.25 lbf/in<sup>2</sup>) at 60,000 r.p.m. which effectively increases the nett engine B.H.P. and torque. The Intercooled turbocharger gives a maximum boost of 1.24 bar (1.26 kgf/cm<sup>2</sup> or 18 lbf/in<sup>2</sup>) at 60,000 r.p.m. and the turbo-plus gives a maximum boost of 1.52 bar (1.52 kgf/cm<sup>2</sup> or 22 lbf/in<sup>2</sup>) at 105,000 r.p.m. respectively increasing the power output and torque of the engine.

The following information identifies the turbochargers specified for the 2704ET range of engines.

Engine Usage	Turbocharger		
	Ford Part No.	Finis Code	Manufacturers Part No.
Industrial and Combine Harvesters	723F-6K690-GAA	6005525	†50916/P/10/5
Standard Marine	723F-6K690-JBA	6005526	53371/C/10/4
Intercooled Marine	723F-6K690-KAA	6005527	53497/C/10/4
Standard Marine Class "A"	743F-6K690-JBA	6030675	55041/A/10/4
Turbo-Plus	—	—	*54049/A/10/4
Turbo-Plus	H713F-6K682-AAA	T.B.E.	54396/A/10/4

† Original turbocharger used on Industrial engines was 2704E-6K690-A—Manufacturers Part No. 50916/G/10/4.

Note: The manufacturers basic number e.g. 50916 is suitable for Industrial and Combine Harvester Engines. The letter following the basic number indicates that modifications have been made to the original design which do not affect the application.

\* The original Turbocharger was supplied by the Specialist Dealer Hendy-Lennox (Industrial Engines) Ltd., of Chandler's Ford, Hampshire, SO5 3LY, England. The latest type turbocharger should be used if a replacement assembly is required.

## DESCRIPTION

The turbocharger unit consists of three basic assemblies:— (see Fig. 96 below).

1. Compressor housing
2. Centre core (or rotor) assembly
3. Turbine housing

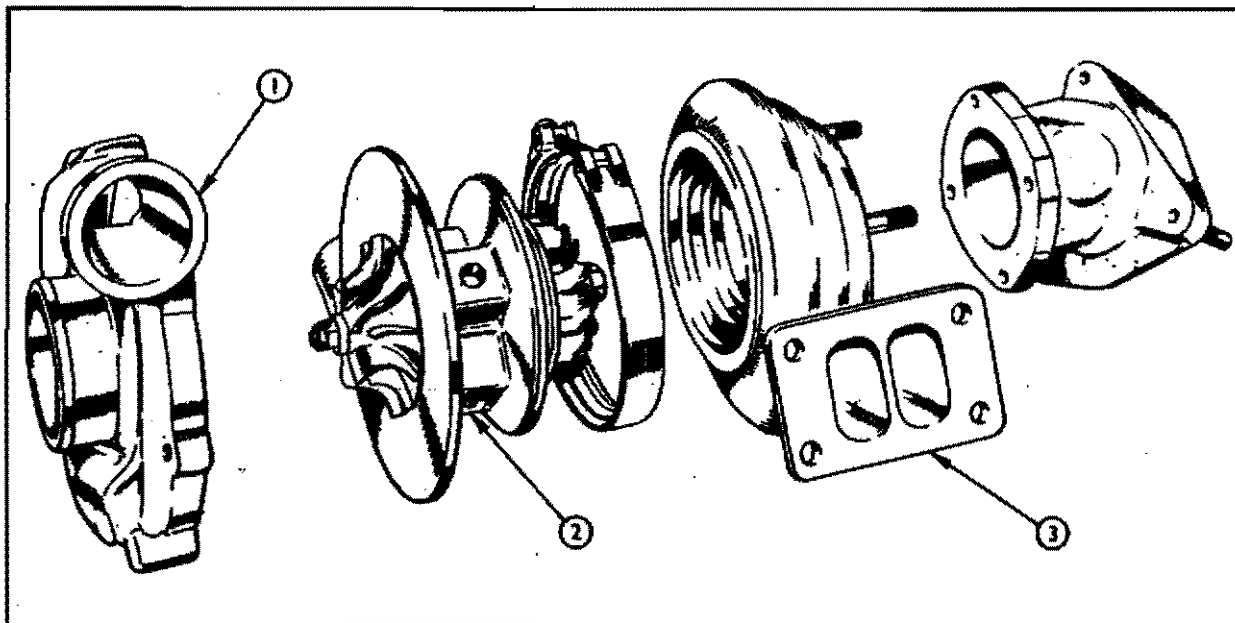


Fig. 96 Turbocharger — Exploded

## TURBOCHARGER (Cont.)

### (a) Compressor Housing

The aluminium compressor housing is retained to the centre core assembly by bolts and flat washers, the bolts locating in the compressor housing whilst the flat washers lip over the centre core assembly.

### (b) Centre Core Assembly

This consists of a centre housing which carries the turbine and shaft assembly, bearing, thrust washers and ring, oil deflectors, spacer, insert and the compressor wheel

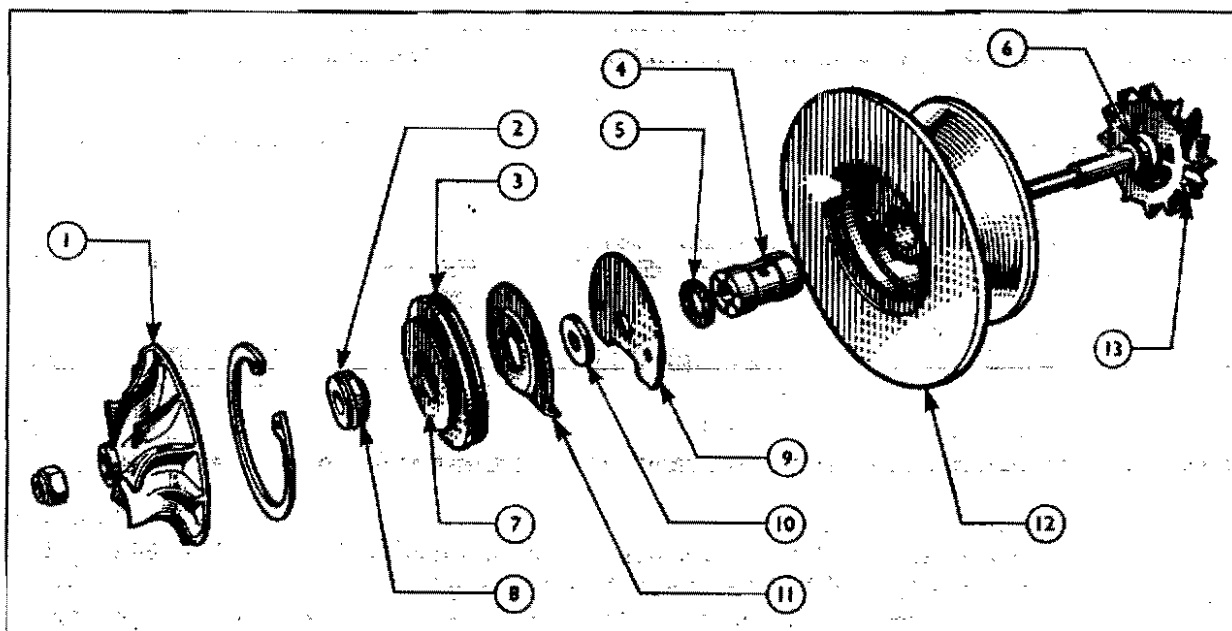


Fig. 97 Centre Core Assembly - Exploded

- |                      |                   |                     |                              |
|----------------------|-------------------|---------------------|------------------------------|
| 1. Compressor Wheel. | 5. Thrust Washer. | 9. Thrust Plate     | 13. Shaft and Turbine Wheel. |
| 2. Piston Ring.      | 6. Piston Rings   | 10. Thrust Ring     |                              |
| 3. O Ring            | 7. Insert         | 11. Oil Deflector   |                              |
| 4. Bearing           | 8. Spacer Sleeve  | 12. Bearing Housing |                              |

### (c) Turbine Housing

The cast steel turbine housing is retained to the centre housing by a steel locking ring. A stainless steel gasket is interposed between the turbine housing and the exhaust manifold to ensure an airtight joint.

## LUBRICATION

The oil feed to the turbocharger is from a tapping in the cylinder block, the oil serving both as a lubricant and a coolant. The oil is returned to the engine via a drain tube attached to the sump.

The oil pressure should never fall below 2.07 bar (2.10 kgf/cm<sup>2</sup> or 30 lbf/in<sup>2</sup>) under normal working conditions. At idling speeds a minimum pressure of 0.69 bar (0.70 kgf/cm<sup>2</sup> or 10 lbf/in<sup>2</sup>) must be maintained to ensure satisfactory lubrication and cooling.

The oil flow through each type of turbocharger is 880 grams/min. (31 oz./min.).

**TURBOCHARGER (Cont.)**

The following information supersedes all previously published information on this subject, including the instructions on Page 35 of the "Operator's Instruction Book" (English language edition October 1976).

Serious damage to the turbocharger bearing can result from inadequate lubrication if the following recommendations are not observed.

On start up the engine should be allowed to idle (1,000 r.p.m. maximum) for 30 seconds before operating on load, to ensure an adequate oil supply to the turbocharger bearing. The engine should also be allowed to idle without load for one minute before shut down to enable the oil to dissipate the heat from the turbocharger bearing.

If any one or more of these circumstances apply the following Priming Procedure **MUST** be carried out.

- After an oil change.
- If the oil supply to the turbocharger has, for any reason, been disconnected.
- If the engine or turbocharger is newly installed.
- If no oil pressure is registered on the oil pressure gauge, or the oil pressure warning light is not extinguished after a "dead crank" i.e. cranking the engine with the "stop" control fully in operation, for a period of 10 seconds. This test **MUST** be carried out if the engine has been out of use for a period of four weeks or more.

**PRIMING PROCEDURE:**

- (a) Check there is sufficient oil in the engine sump, but do not top up at this stage. Disconnect the oil feed pipe at the turbo-charger end and fill the housing with oil. Reconnect the pipe.
- (b) Remove the square headed plug from the lubrication oil filter head and using a suitable syringe, inject a minimum of 2.3 litres (4 pints) of clean engine oil through the aperture. Refit the plug. Note: On engines prior to S.988767 this aperture is not present and the oil must be injected through the oil pressure gauge connection.
- (c) Start the engine and allow to idle for one minute before increasing speed.
- (d) Stop the engine and check that the oil level is correct, after allowing sufficient time for the oil to return to the sump. If necessary top up with clean engine oil. If the oil level is above the full mark the surplus oil should be drained off.
- (e) Before stopping, allow the engine to idle for one minute without load to allow the lubricant to cool the bearings. Unless this procedure is carried out oil starvation and subsequent bearing damage may result.

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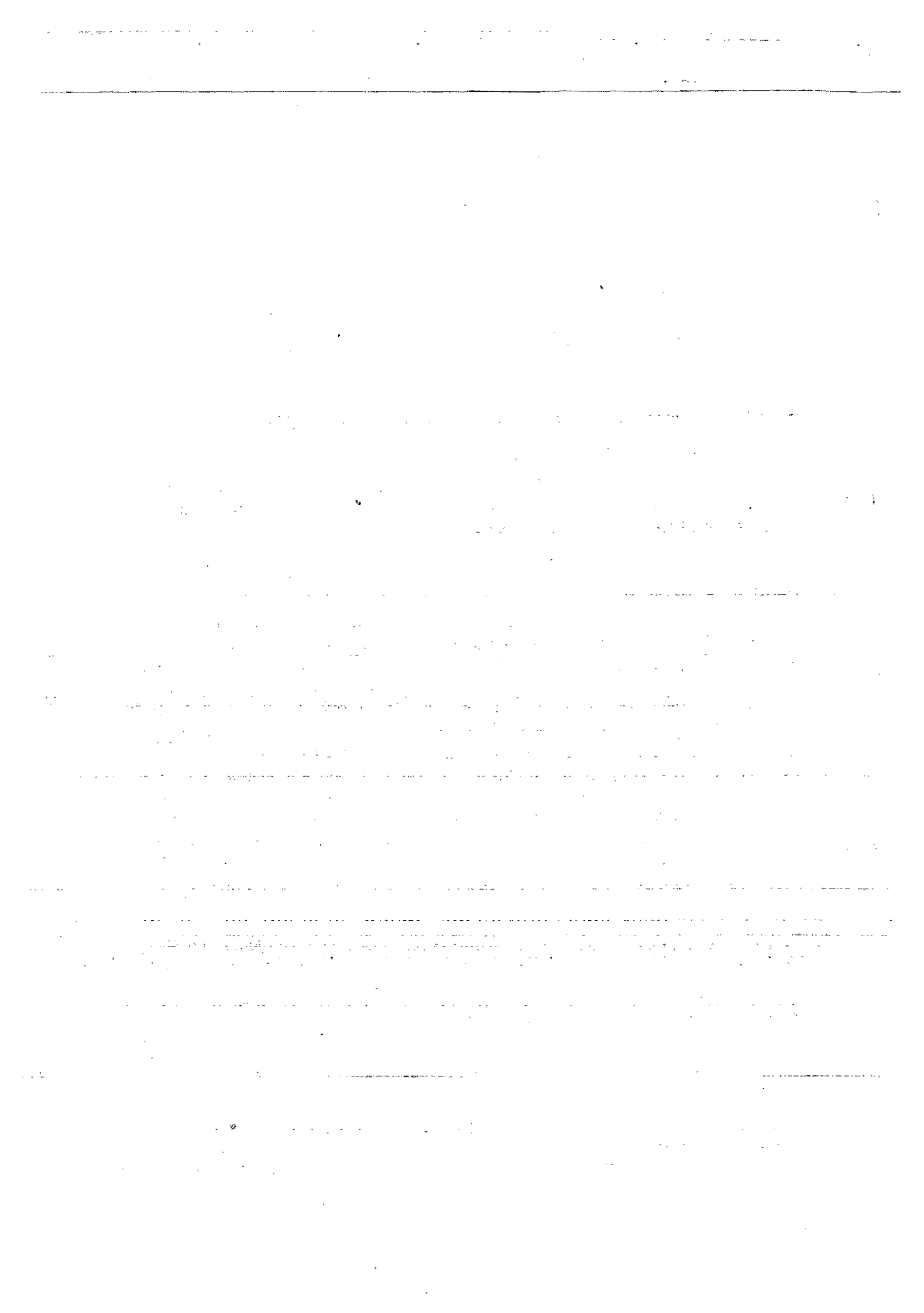
**N.B. STANDBY GENERATOR AND ALTERNATOR SETS**

Because standby generator and alternator sets make fewer starts and stops than other industrial applications the idling requirement of the stop/start procedure can be waived without undue risk of reduced life.

The "dead crank" test and if required, the priming procedure for engines inoperative for periods of four weeks or more must however be carried out.

**OPERATION**

The exhaust gas from the engine flows around the turbine housing and radially inward through the nozzles (exhaust passages). These nozzles give the gas a high velocity before it enters the turbine wheel, which rotates at approximately 80,000 to 90,000 r.p.m. when operating at maximum speed on full load.



**TURBOCHARGER (Cont.)**

The turbine and compressor wheels rotate at the same speed and thus air is drawn through the air filter into the centre of the compressor wheel, where it is compressed and driven radially outwards through a tangential outlet and into the engine intake manifold.

Because the air has been compressed, more air enters the cylinders and thus proportionally more fuel may be burnt, giving an increase in power output.

**NOTE**—Before starting a turbocharged engine for the first time (i.e. after the engine has been overhauled or a new turbocharger has been fitted) ensure that the bearing housing of the turbocharger is filled with oil.

Never attempt to overfuel the engine as a means of increasing the power output from the engine. Increased fuelling will cause excessive exhaust temperatures which in turn will lead to engine and/or turbocharger failure.

**OVERHAUL PROCEDURES**

Before dismantling the turbocharger for repair, the serial number should be obtained from the manufacturers detail plate attached to the compressor housing. The serial number determines the overhaul kit required.

**KIT PART NUMBERS:**

Description	Ford Part No.	Finis No.	Quantity
Kit turbocharger hardware, for use with turbochargers up to Serial No. 140608	743F-6L616-AA	1560780	As required
Kit turbocharger hardware, for use with turbochargers from Serial No. 140609 onwards.	743F-6L616-BA	1560781	As required

**To Remove the Turbocharger**

1. Remove engine canopies.
2. Disconnect the batteries.
3. Disconnect oil supply pipe from cylinder block.
4. Disconnect the oil drain tube. Slacken the drain tube clamps and slide the rubber tube up the metal drain tube to disconnect it from the sump adaptor. Remove heat shield case (where fitted).
5. Disconnect the exhaust pipe. Unscrew the exhaust pipe clamp nuts and disconnect the exhaust pipe from the turbocharger.
6. Slacken the air intake pipe clamp on the turbocharger inlet and disconnect the intake pipe.
7. Slacken the turbocharger to inlet manifold pipe and air intake pipe clamps.
8. Unscrew the nuts retaining the turbocharger to the exhaust manifold.
9. Remove the turbocharger. Unscrew the mounting bracket retaining bolts and remove the turbocharger.

**To Dismantle the Turbocharger**

1. Clamp the unit in a vice on the turbine inlet flange.
2. Remove the oil inlet and drain tubes.
3. Mark the compressor housing, centre core assembly, turbine housing, exhaust pipe adaptor and mounting bracket to ensure correct alignment on reassembly.
4. Remove the compressor housing. Remove the bolts and lockwashers retaining the compressor housing to the centre core assembly and remove the housing.

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## TURBOCHARGER (Cont.)

5. Remove the turbine housing. Unscrew the 'V' clamp locknut and remove the 'V' clamp. Remove the centre core assembly.
6. Remove the exhaust pipe adaptor and mounting bracket. Unscrew the four retaining nuts and remove the exhaust adaptor and mounting bracket.

### To Overhaul the Centre Core Assembly (Export Territories only)

#### To Dismantle the Centre Core Assembly

1. Remove the compressor wheel. Suitably support the centre core assembly, hold the turbine wheel hub, using a (5/8 in.) A.F. spanner, unscrew the compressor wheel retaining nut and withdraw the compressor wheel.
2. Remove the insert. Remove the circlip retaining the insert and lift the insert from the bearing housing using two screwdrivers as levers.
3. Remove the spacer sleeve by gently pushing it through the insert.
4. Remove the 'O' ring from the insert.
5. Remove the oil deflector, thrust ring, thrust plate and thrust washer from the bearing housing.
6. Remove the turbine wheel and shaft.
7. Remove the bearing from the bearing bore.
8. Remove the piston rings from the spacer sleeve and turbine wheel and shaft assembly.
9. Clean and inspect all parts.

(a) To clean the components, soak them in a non-caustic metal cleaner until all the deposits are loosened, use a plastic scraper or bristle type brush on all aluminium parts to remove any remaining deposits. Clean all drilled passages using compressed air. Ensure that all surfaces adjacent to the wheels are free of deposits and are clean and smooth.

(b) Inspect all parts as follows:—

**Shaft and wheel assembly.** Inspect bearing journals and piston groove walls for excessive scratches and wear, minor scratches are acceptable. Check for cracked, bent or damaged turbine blades—DO NOT ATTEMPT TO STRAIGHTEN BLADES—renew if necessary.

**Bearing.** Renew the bearing if excessive scratching or wear is apparent.

**Bearing housing.** Check the bearing and piston ring bores, renew the housing if they are excessively scratched or worn.

**Spacer sleeve.** Replace the spacer sleeve if the piston ring groove or spacer are damaged.

**Thrust ring and plate.** Renew the parts if they are worn excessively, unevenly, or are badly scratched or otherwise damaged. The small oil feed grooves must be clean and undamaged.

**Compressor wheel.** Check for cracked, bent or damaged blades, renew the wheel if necessary.

**TURBOCHARGER (Cont.)****To Reassemble the Centre Core Assembly**

Before reassembly lubricate all parts with clean engine oil.

1. Fit new piston rings to the spacer sleeve and turbine wheel shaft.
2. Locate the bearing in the bearing housing.
3. Replace the turbine wheel and shaft assembly, do not force the piston rings into the bearing housing.
4. Replace the thrust washer.
5. Replace the thrust plate, ensure that the holes in the thrust plate locate over the dowel pins in the bearing housing.
6. Replace the thrust ring.
7. Replace the oil deflector plate, ensure that the holes in the deflector plate locate over the dowel pins in the bearing housing with the cranked portion of the plate towards the oil gallery in the housing.
8. Fit a new 'O' ring in the insert.
9. Position the spacer sleeve in the insert. Gently push the spacer sleeve into the insert from the 'inside' with the stepped end of the spacer pointing away from the insert.
10. Replace the insert and spacer sleeve assembly, ensure that the 'O' ring is not disturbed.
11. Refit the circlip with the bevelled side facing outwards.
12. Replace the compressor wheel, secure with a new locknut and tighten to 17.6 Nm (1.8 kgf m or 13 lbf ft).

**To Reassemble the Turbocharger**

1. Soak the end housings in a non-caustic metal cleaner until all deposits are loosened. Use a plastic scraper or bristle type brush to remove any remaining deposits.
2. Inspect the compressor and turbine wheels for cracked or damaged blades, do not attempt to straighten the blades.
3. Clean all gasket faces and mating faces.
4. Replace the oil supply and drain tubes and tighten securely.
5. Replace the centre core assembly. Align the turbine housing and centre core assembly mating marks, reposition the 'V' clamp and tighten the locking nut to 13.6 Nm (1.38 kgf m or 10 lbf ft).
6. Replace the compressor housing. Align the compressor housing and centre core assembly mating marks, refit the bolts, spring washers and washers and tighten the bolts to 6.8 Nm (0.69 kgf m or 5 lbf ft).
7. Spin the rotor shaft to check for free rotation.
8. Refit the mounting bracket and the exhaust pipe adaptor. Position a new gasket over the turbine housing studs. Align the mounting bracket to the turbine housing, position the second new gasket over the turbine housing studs, align the exhaust pipe adaptor and turbine housing mating marks and replace the adaptor, refit the spring washers and nuts and tighten securely.

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## TURBOCHARGER (Cont.)

### To Replace the Turbocharger

1. Clean all gasket faces.
2. Replace the turbocharger. Locate a new gasket on the exhaust manifold studs and relocate the turbocharger. (Ensure that the inlet manifold to turbocharger and air intake pipe to turbocharger joining sleeves are correctly positioned). Refit the spring washers and nuts and tighten the nuts securely.
3. Refit the mounting bracket retaining bolts and tighten securely.
4. Tighten the inlet manifold to turbocharger and air intake pipe to turbocharger pipe clamps.
5. Reconnect the exhaust pipe and tighten the nuts securely.
6. Reconnect the oil drain tube, reposition the tube clamps and tighten.
7. Reconnect the oil supply pipe
8. Reconnect the batteries.
9. Replace engine canopies.

### WARNING

It is essential that the turbocharger oil supply line and filters are primed before starting an engine:—

- (a) After an engine oil change.
- (b) After the oil supply has, for any reason, been disconnected.
- (c) When the engine has been inoperative in excess of four weeks or when the turbocharger is newly installed, proceed as follows:
- (d) Check there is sufficient oil in the engine sump, but do not top up at this stage. Disconnect the oil feed pipe at the turbocharger end and fill the housing with oil. Reconnect the pipe.
- (e) Remove the square headed plug from the lubrication oil filter head and using a suitable syringe, inject a minimum of 2.3 litres (4 pints) of clean engine oil through the aperture. Refit the plug.

Note: On engines prior to S 988767 this aperture is not present and the oil must be injected through the oil pressure gauge connection.

- (f) Start the engine and check that oil pressure is correct; allow to idle for one minute before opening the throttle, after one minute the engine speed can be increased.
- (g) Stop the engine and check that the oil level is correct, after allowing sufficient time for the oil to return to the sump. If necessary top up with clean engine oil. If the oil level is above the full mark the surplus oil should be drained off.

Note: ON ENGINES IN NORMAL USE, WHEN STARTING FROM COLD, THE ENGINE MUST BE RUN AT IDLE SPEED FOR ONE MINUTE TO OBTAIN ADEQUATE OIL CIRCULATION TO THE BEARINGS BEFORE APPLYING LOAD.



## 2. Stopping the engine

Before shutting down, allow the engine to idle for one minute, to reduce "heat soak" from the turbine housing to the bearings and seals of the turbocharger by enabling the lubricant to cool same.

Unless this action is taken, oil starvation and subsequent bearing failure will result.

### TURBO-CHARGER FAULT DIAGNOSIS/OVERHAUL PROCEDURE

When investigating complaints of poor engine performance, or excessive exhaust smoke, proceed as follows.

1. Obtain normal engine operating temperature, and check that maximum engine no. load speed is in accordance with Table 1. If a tachometer is not fitted, connect a suitable tachometer to the engine drive.

Table 1

	Type of pump fitted				
	British Standard 649 Class A 1500 r.p.m.	British Standard 649 Class A 1800 r.p.m.	Combine 2000 to 2250 r.p.m.	General Purpose 2500 r.p.m.	Automotive 2800 r.p.m.
Maximum No. load speed in r.p.m.	1545/1565	1860/1880	2339/2350	2640/2660	3075/3090

2. Examine the air cleaner/induction system to ensure that excessive manifold depression is not evident due to the following:
  - (a) Dirty or wet air cleaner element
  - (b) Intake stack pipe cap restriction
  - (c) Induction hose collapse at full no-load engine r.p.m.
3. Examine the exhaust system to determine possible defects likely to create excessive system back pressure. Pay particular attention to retention of the muffler internal baffle plate.
4. Run the engine at a fast idle speed (1200 r.p.m.) and carry out the following checks to determine turbocharger boost pressure leakage and/or exhaust gas pressure leakage.
  - (a) Check for turbocharger boost pressure leakage as follows:
    - (1) Manifold core plugs (4 off)
    - (2) Hose connections from turbocharger to manifold (2 off)
    - (3) Manifold to cylinder head gasket
    - (4) Thermostat (and aperture blanking plug on  $-10^{\circ}$  cold start package)
    - (5) Examine the injection pump aneroid boost control to manifold pipe, to ensure that the pipe is sound, and connections are leak free. (Automotive engine only.)
  - (b) Check for exhaust pressure leakage as follows:
    - (1) Exhaust manifold to cylinder head gasket.
    - (2) Turbocharger to exhaust manifold mounting gasket.
    - (3) Turbocharger to exhaust pipe adaptor flange.
    - (4) Exhaust adaptor to exhaust pipe joint.
    - (5) Exhaust manifold centre joint rings.
5. If the previous checks fail to establish the reason for poor engine performance/excessive exhaust smoke, then the following tests should be implemented to determine turbocharger performance.

NOTE: It is essential that the following performance tests be conducted on full load.

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TURBO-CHARGER FAULT DIAGNOSIS/OVERHAUL PROCEDURE (continued)

6. The following test procedure should be strictly adhered to in order to maintain maximum turbocharger boost pressure.

- (a) Fit a new air cleaner element.
- (b) Equip the engine with instruments as follows:  
Mount a pressure gauge with a maximum reading of 1.72 bar (1.75 kgf/cm<sup>2</sup> or 25 lbf/in<sup>2</sup>) in a suitable position and connect it to the boost side of the intake manifold by removing the threaded blanking plug (-10°C cold start pack) or the forward mounted thermostart (-20°C cold start pack).
- (c) Operate the engine until normal operational temperature is obtained.
- (d) Simulate the maximum load conditions for the engine and ensure that the maximum load conditions are maintained throughout the boost pressure recording test.
- (e) With the engine speed at 2000 r.p.m. (1250 r.p.m. for British Standard pump and 1500 r.p.m. for Combine pump) adjust the speed control and allow engine speed to build up to attain maximum governed speed in accordance with Table 2. Read off the maximum boost pressure obtained.

Table 2

	Type of pump fitted			
	British Standard Pump 1500-1800	Combine Pump 2000-2250	General Purpose Pump 2500	Automotive Pump 2800
Max full load speed	1500 r.p.m., 1800 r.p.m.	2250 r.p.m.	2500 r.p.m.	2800 r.p.m.
Location of Control arm	Hole 3, Hole 2	Hole 2	Hole 2	Hole 1

NOTE: The maximum turbocharger boost pressure will be attained immediately below the governor cut-in speed; when the governor cuts in the boost pressure will be seen to drop suddenly. If a suitable tachometer is not available, carry out the above procedure and read off the maximum boost pressure attained i.e. immediately prior to the governor cut-in.

- (f) For satisfactory operation, the minimum turbocharger boost pressure should be in accordance with the figures given in Table 3. If the turbocharger boost pressure is below the specified minimum, then the induction manifold and turbocharger assembly should be removed for examination.

Table 3

	Type of pump fitted			
	British Standard Pump 1500-1800	Combine Pump 2250	General Purpose Pump 2500	Automotive Pump 2800
Max full load speed	1500 r.p.m., 1800 r.p.m.	2250 r.p.m.	2500 r.p.m.	2800 r.p.m.
Minimum Boost pressure	0.414 bar (0.42 kgf/cm <sup>2</sup> or 6 lbf/in <sup>2</sup> )	0.621 bar (0.63 kgf/cm <sup>2</sup> or 9 lbf/in <sup>2</sup> )	0.759 bar (0.77 kgf/cm <sup>2</sup> or 11 lbf/in <sup>2</sup> )	0.828 bar (0.84 kgf/cm <sup>2</sup> or 12 lbf/in <sup>2</sup> )

NOTE: If the turbocharger boost pressure is above the specified minimum and the performance is still poor or there is still excessive exhaust smoke, then a recheck of the fuel system should be carried out in line with the relevant fault diagnosis procedure.

- 7. Prior to removing and examining the turbocharger, the items detailed in paragraphs (4a) and (4b) should be rechecked to confirm that no other reasons exist for poor performance and/or excessive exhaust smoke.
- 8. If, after following procedure (7) no reason can be found, then the turbocharger should be dismantled, inspected and repaired in line with the procedure given on pages 58 to 59r inclusive.

## CHARGE AIR COOLER

The Shell and tube type Charge Air Cooler used with the Intercooled engine is mounted on the right hand side of the engine and is retained by brackets bolted to the fuel oil filter head location.

The Charge Air Cooler used with the Turbo-Plus engine is mounted on the left hand side of the cylinder head. Retention is by two lugs integral with this casing to two special cylinder head bolts together with a bracket bolted to a flanged face on the underside of the cooler shell. The lower end of the bracket being secured to the mounting pad of the cylinder block.

Inlet and outlet air connections are incorporated in the shell bodies. The end covers incorporate the water hose connections.

On the Intercooled engine the earlier cooler had a 76 mm. (3 in.) dia. shell, the current cooler has a 127 mm. (5 in.) dia. shell.

The diameter of the cooler shell for the Turbo-Plus is 178 mm. (7 in.).

The number of tubes to the respective "stacks" are:—

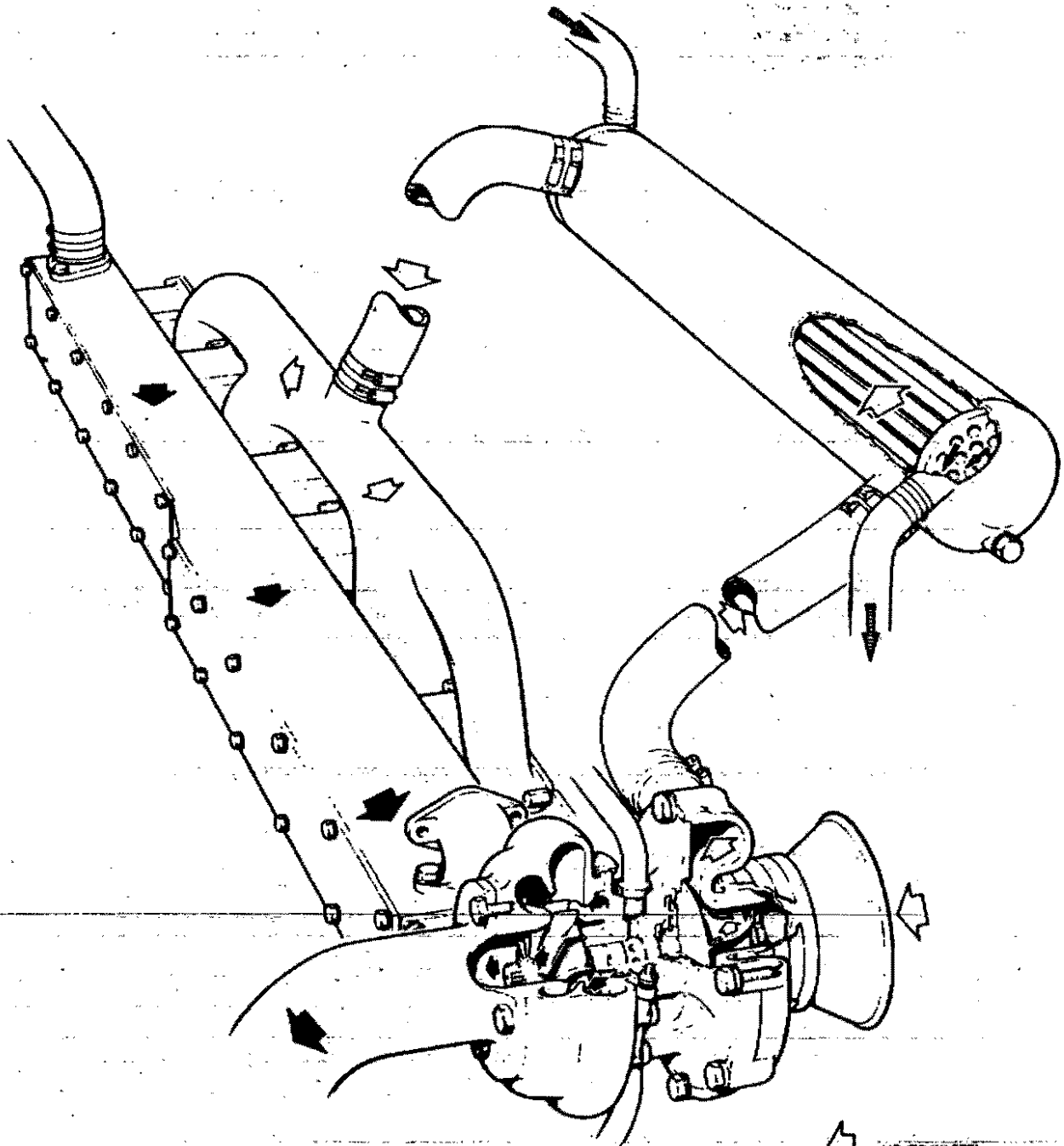
76 mm. (3 in.) dia.	—	175
127 mm. (5 in.) dia.	—	177 — Bowman type
127 mm. (5 in.) dia.	—	32 — Serck type
178 mm. (7 in.) dia.	—	324

Combustion air from the turbocharger enters the charge air cooler via a duct, passes over the tube stack, thereby reducing the temperature of charge air to approximately 40°C (104°F) before entering the intake manifold. Incorporated in the manifold duct is a single cold start plug, provision is made to fit twin cold start plugs if required for low temperature conditions.

### OVERHAUL PROCEDURE 127 mm (5 in. diameter)

1. Disconnect water and air hoses from air cooler inlet and outlet connections.
2. Unscrew the clamp bracket bolts, and remove the clamps.
3. Remove air cooler assembly.
4. Unscrew the end cover retaining nut and remove the end covers, (See Fig. 100).  
NOTE: The through-bolt is attached to the outlet cover, care must be taken when removing the cover and bolt assembly.
5. Remove the seals and press out the tube stack. The tube stack is a press fit in the body, if however corrosion has taken place, locate a block of wood on the end of the tube stack and lightly tap with a hammer.
6. Examine the tubes for blockage and porosity, check the body interior for carbon deposits, if cleaning is necessary, care must be taken to avoid damaging the machined face, especially at the seal locations.
7. Replace the tube stack and fit new seals.
8. Replace the end covers, fit new copper sealing washer, fit the nut and tighten to 13.6 Nm (1.38 kgf m or 10 lbf ft).
9. Pressure test the assembly at 1.38 bar (1.4 kgf/cm<sup>2</sup> or 20 lbf/in<sup>2</sup>).

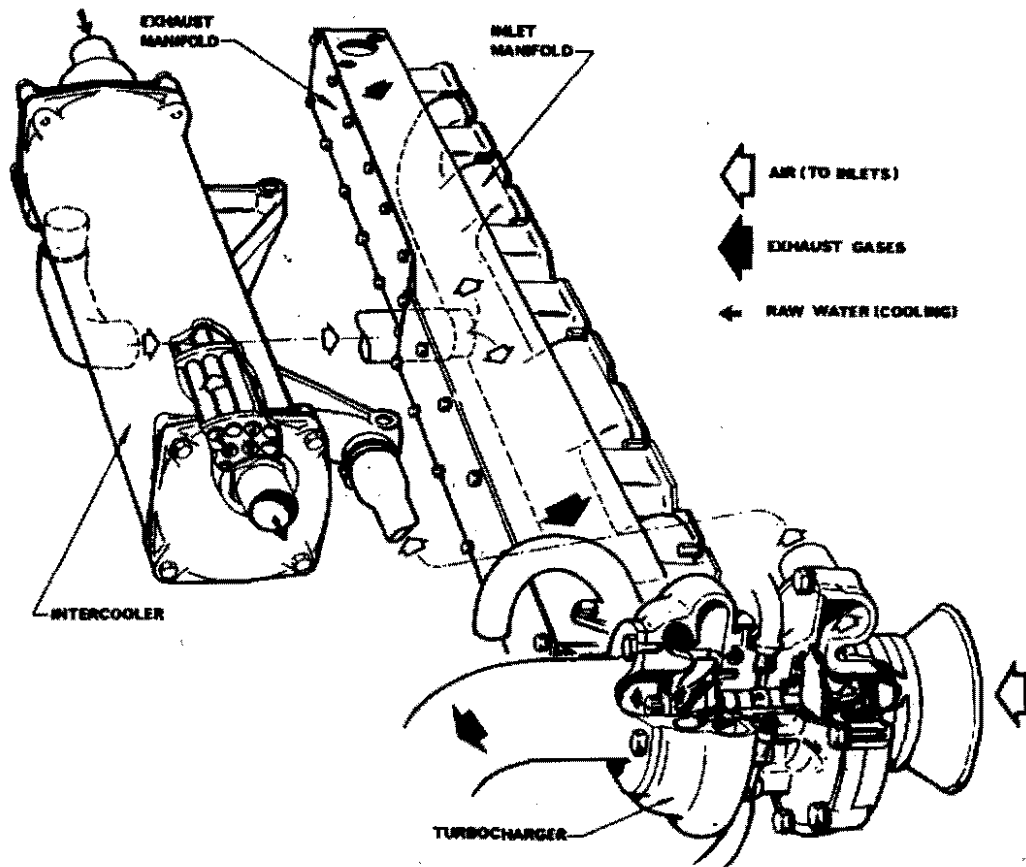
Pressure must hold for 10 minutes.



AIR (TO INLETS)  
 EXHAUST GASES  
 SEA WATER (COOLING)

Fig. 98

The Charge Air Cooling System used with the 2704ET Intercooled Engine



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Fig. 99

The charge air cooling system used with the Turbo-Plus Engine.

## CHARGE AIR COOLER (Cont'd)

### Overhaul Procedure

10. Refit the air cooler assembly to engine. Connect the water hoses and refill the coolant system. Connect the air hoses then start the engine.

The engine should be run slowly for half an hour on completion of the filling operation with the pressure cap removed to disperse any air locks from the system.

**NOTE:**—Disconnecting the hose from the manifold outlet connection will also assist in removing air locks.

The procedure for dismantling the 76 mm. (3 in.) diameter and the 203 mm. (8 in.) diameter Charge Air Cooler assemblies, differs only in that the end cover are retained by 3 and 4 bolts respectively.

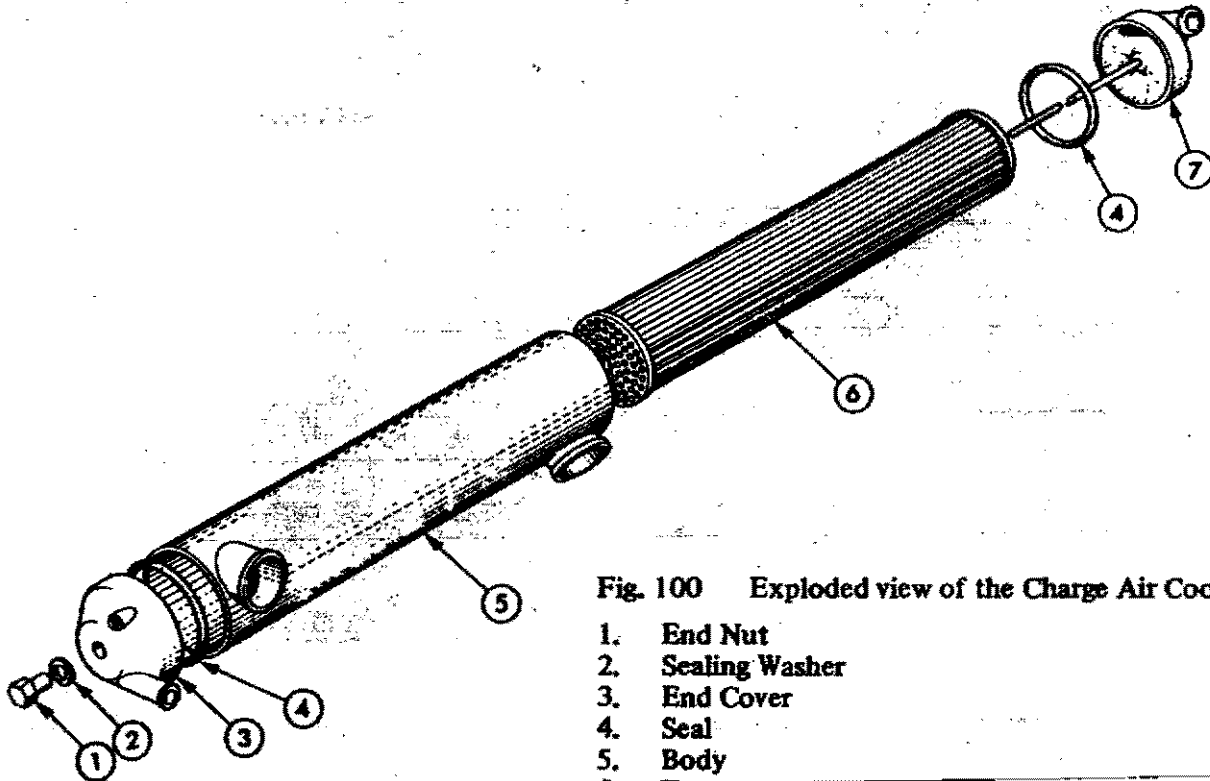
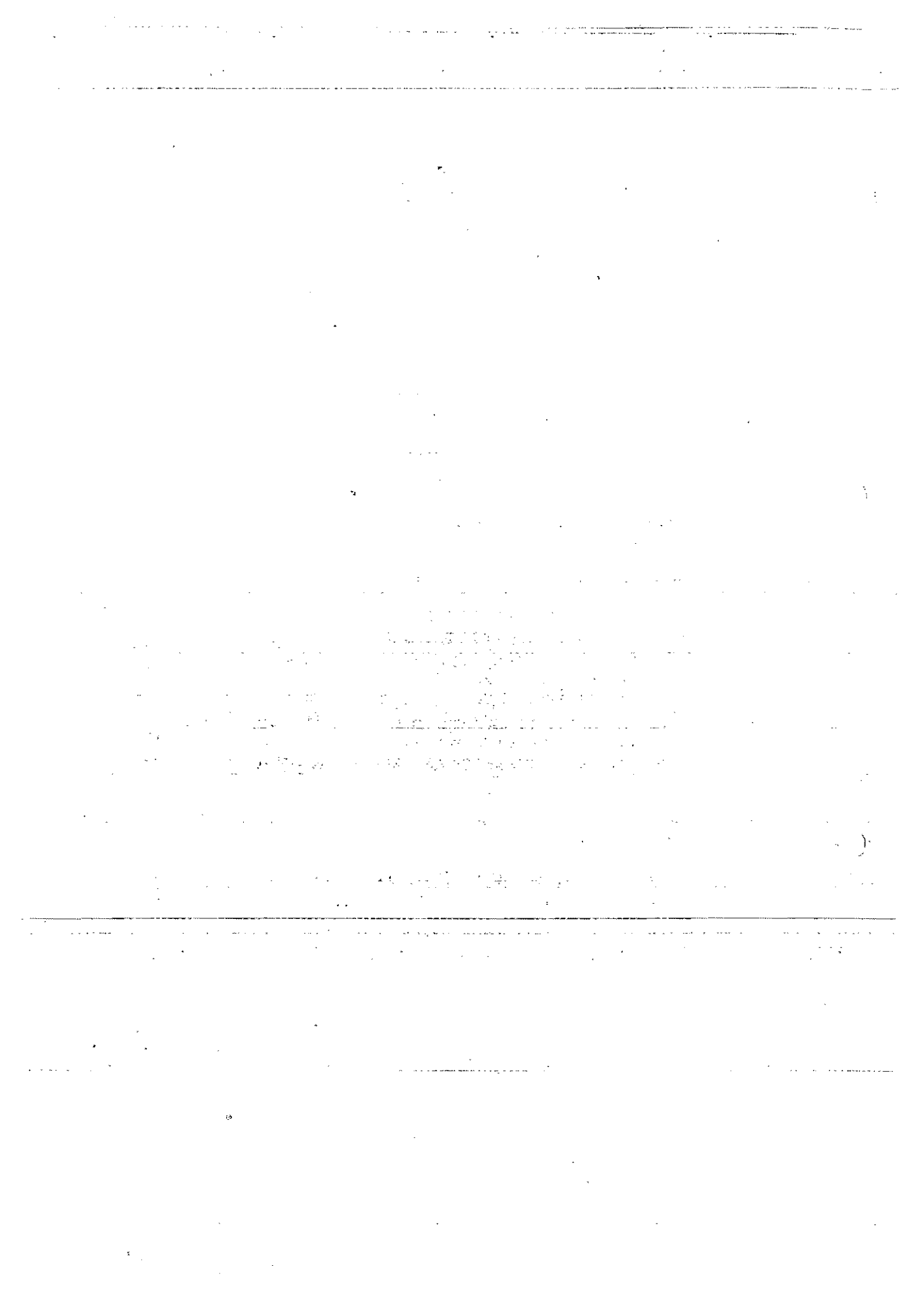


Fig. 100 Exploded view of the Charge Air Cooler

1. End Nut
2. Sealing Washer
3. End Cover
4. Seal
5. Body
6. Tube Stack
7. End Cover & Third Bolt Assy.







## ELECTRICAL SYSTEM

### THE BATTERY

A negative earth system is now used on all diesel engines in this range. Some earlier engines, fitted with dynamos, used a positive earth system.

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.

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### 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 A/H	12 amps.
2.—12 volts in parallel 240 A/H	12 amps.
2.—6 volts in series 185 A/H	18 amps.

# CHARGING SYSTEMS

One of the following charging systems may be incorporated,

- (a) 11 amp Generator with regulator
- (b) 22 amp Generator with regulator
- (c) Alternator - 43 amp - 12 volt (Type Lucas 11 AC)  
Control Unit - Electronic (Type 4 TR)  
Field Isolation - Relay (Type 16 RA)
- (d) Alternator - 36 amp - 12 volt with electronic control unit (Type 17 ACR) or  
Alternator - 45 amp - 12 volt with electronic control unit (Type 18 ACR).
- (e) Alternator - 30 amp - 24 volt (Type AC5)  
Regulator - (Type 440)

A description of each system with relevant servicing and adjustment information follows:—

- (a) GENERATOR—11 amp.
- and (b) GENERATOR—22 amp. (see Fig. 1)

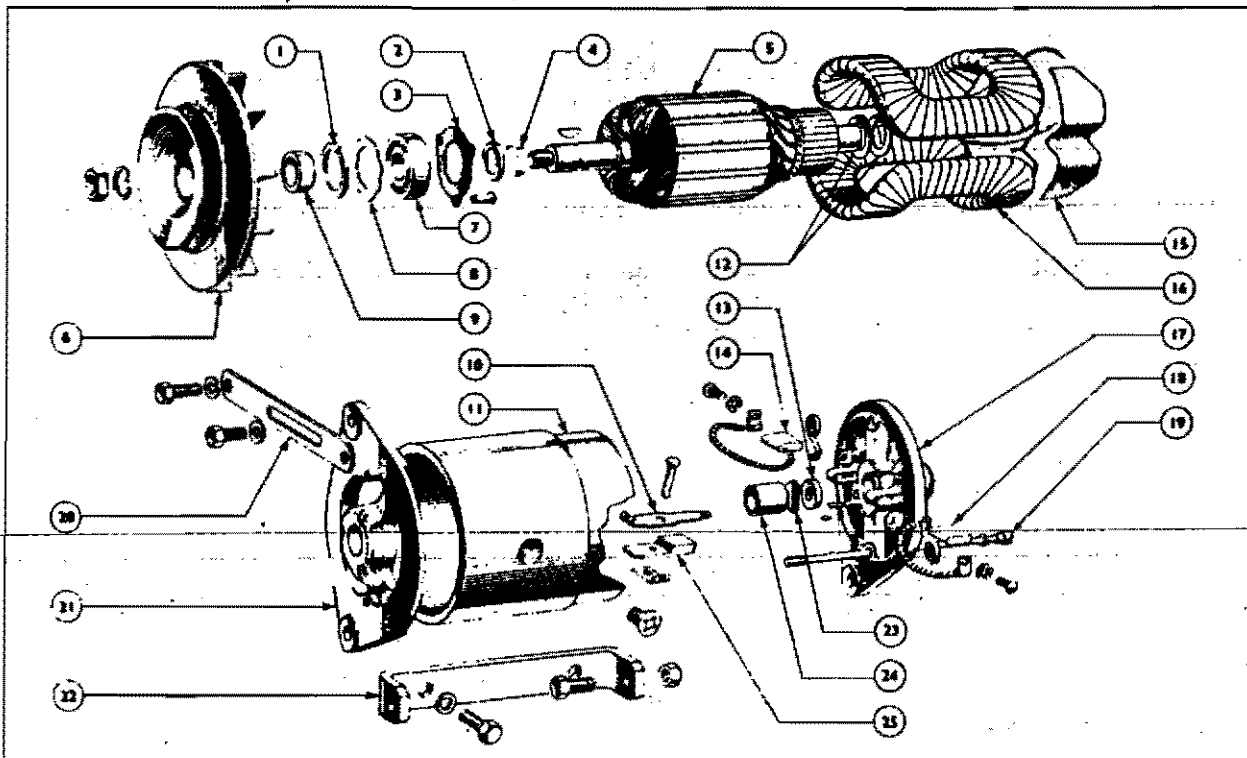


Fig. 1—The 22 amp. (C.40) Generator—Exploded

- |                          |                     |                           |                         |
|--------------------------|---------------------|---------------------------|-------------------------|
| 1 Felt Ring              | 7 Front Bearing     | 13 Lubricating Felt       | 19 Through Bolt         |
| 2 Ring Retainer          | 8 Corrugated Washer | 14 Insulated Brush        | 20 Felt Adjusting Strap |
| 3 Bearing Retainer Plate | 9 Pulley Spacer     | 15 Insulator              | 21 Drive End Bracket    |
| 4 'U' Ring               | 10 Field Terminal   | 16 Field Coils            | 22 Mounting Bracket     |
| 5 Armature               | 11 Yoke             | 17 Commutator End Bracket | 23 Felt Retainer        |
| 6 Generator Pulley       | 12 Thrust Washers   | 18 Insulated Brush        | 24 Bracket Bush         |
|                          |                     |                           | 25 Insulator            |

The generator is a shunt-wound two-pole two-brush non ventilated (11 amp.) or ventilated (22 amp.) 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 state 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.

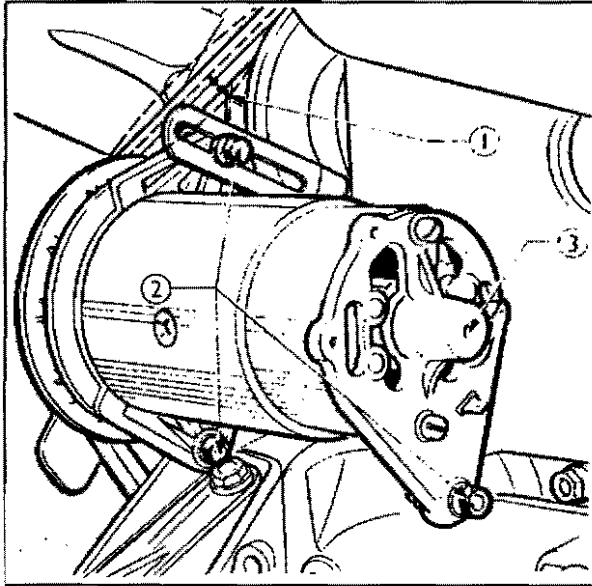


Fig. 2—The Generator in position

- 1 13 mm (0.5 in) total free movement
- 2 Adjustment Bolts
- 3 Lubrication hole

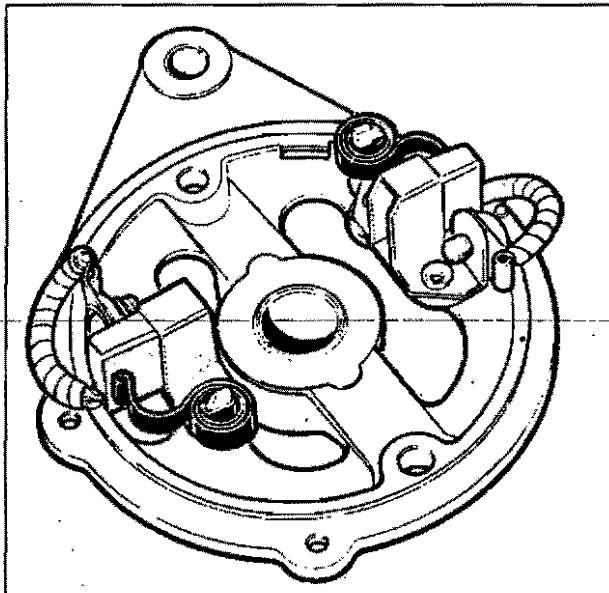


Fig. 3

Brushes held in the raised position

## ROUTINE MAINTENANCE

### (a) LUBRICATION (see Fig. 2)

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.

### (b) BELT ADJUSTMENT (see Fig. 2)

After the first 15 running hours and subsequently every 200 running hours, adjust the fan belt tension to 13 mm (0.5 in) total movement at the longest span of the belt between pulleys. 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 the mis-alignment by slackening off the generator mounting bracket bolts and adjusting the position within the tolerances of the bolt holes. If the alignment fails to meet the permitted tolerances on completion of this operation, remove the generator from mounting brackets and fit washers Part No. 118292-ES between the mounting brackets and generator mounting ears, refit generator and recheck belt alignment.

### (c) INSPECT THE BRUSHGEAR

Every 1,000 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.

### (a) 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.
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 type voltmeter, calibrated 0–20 volts, 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 and without fluctuation. Do not allow the voltmeter reading to reach 20 volts 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 1,000 r.p.m. If the voltage does not rise rapidly and without fluctuation the unit must be dismantled for internal examination.

**TESTING THE GENERATOR (Continued)****(b) 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 0–30 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 amps.

- (i) A high reading on the ammeter is an indication of tight generator bearings.
- (ii) An excessively high reading will indicate a short circuit.
- (iii) A low reading is a general indication of bad commutation.

**(c) 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 50 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 amps.

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.
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.

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## CHECKING THE BRUSHGEAR (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. 3.
2. Fit the commutator end bracket over the commutator and release the brushes.
3. Hold back each of the brush springs and move the brush by pulling gently on its flexible connector. If the movement is sluggish, remove the brush from its holder and ease the sides 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 gms. (30 oz.), maximum when exerted on a new brush and 368 gms. (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. 4.

A moulded commutator can be re-skimmed during service, but care must be exercised to ensure that the finished diameter is not less than 36.8 mm. (1.450 in.) for armatures manufactured before October 1964, or 36.3 mm. (1.430 in.) for armatures manufactured after October 1964.

### Date Identification

The week and year of manufacture are stamped on the armature bearing collar. e.g. 26 – 70 indicates the 26 week 1970.

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. 5, 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 substitution. 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".

## THE COMMUTATOR (Continued)

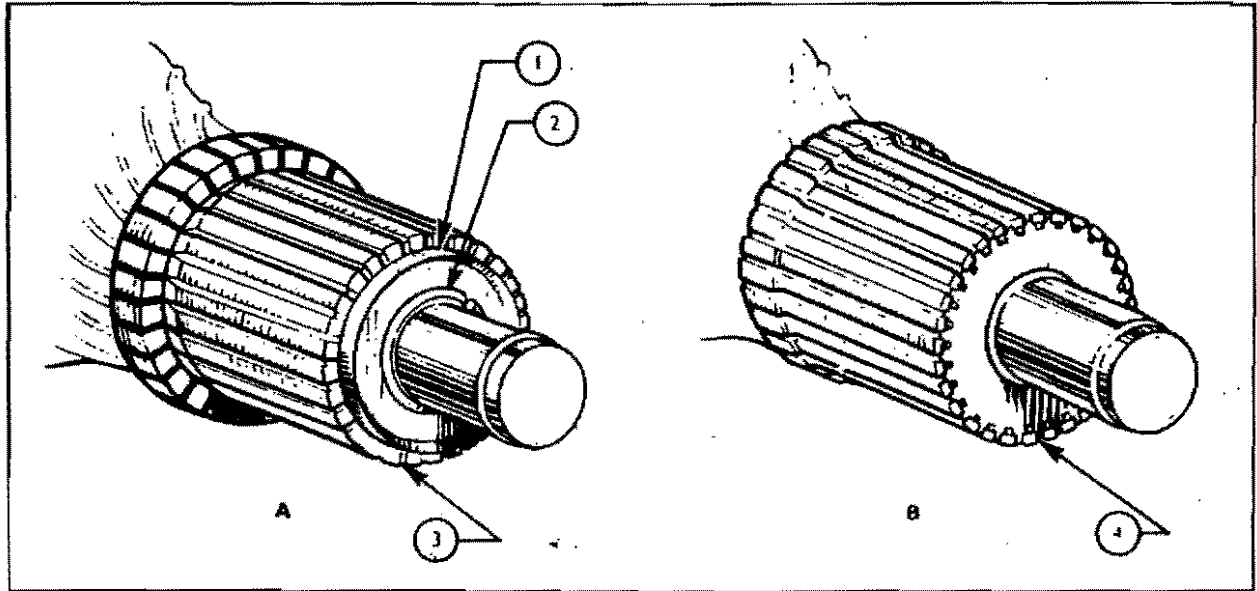


Fig. 4  
The Commutator

## 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.)

## FIELD COILS

Measure the resistance of the field coils, without removing them from the generator yoke, by 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. 6). 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 ohms i.e. the ammeter reading should be approximately 2 amperes. If the current reading is much more than 2 amps., 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.

## 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. 7.
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.

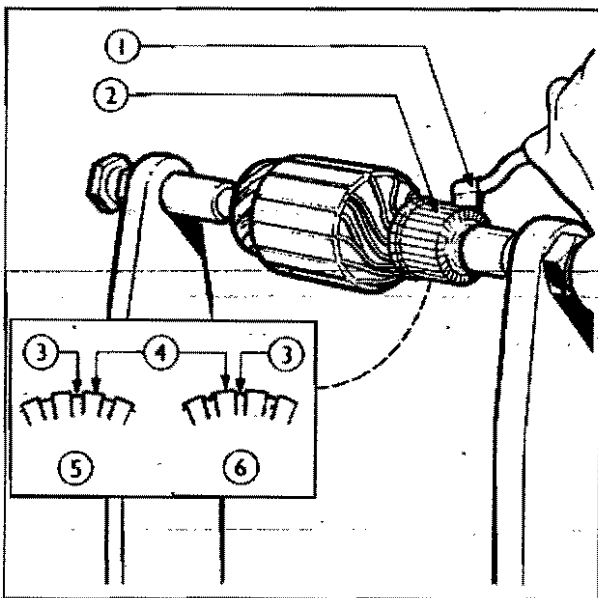


Fig. 5—Undercutting the Commutator segments

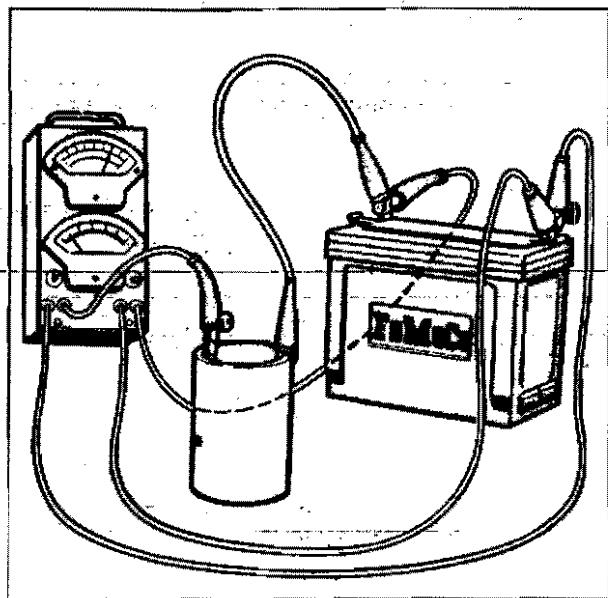


Fig. 6—Testing the Generator Field Coils

- |              |            |
|--------------|------------|
| 1 Hand Tool  | 4 Segments |
| 2 Commutator | 5 Correct  |
| 3 Mica       | 6 Wrong    |



## TO RENEW THE FIELD COILS (Continued)

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 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 is 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.

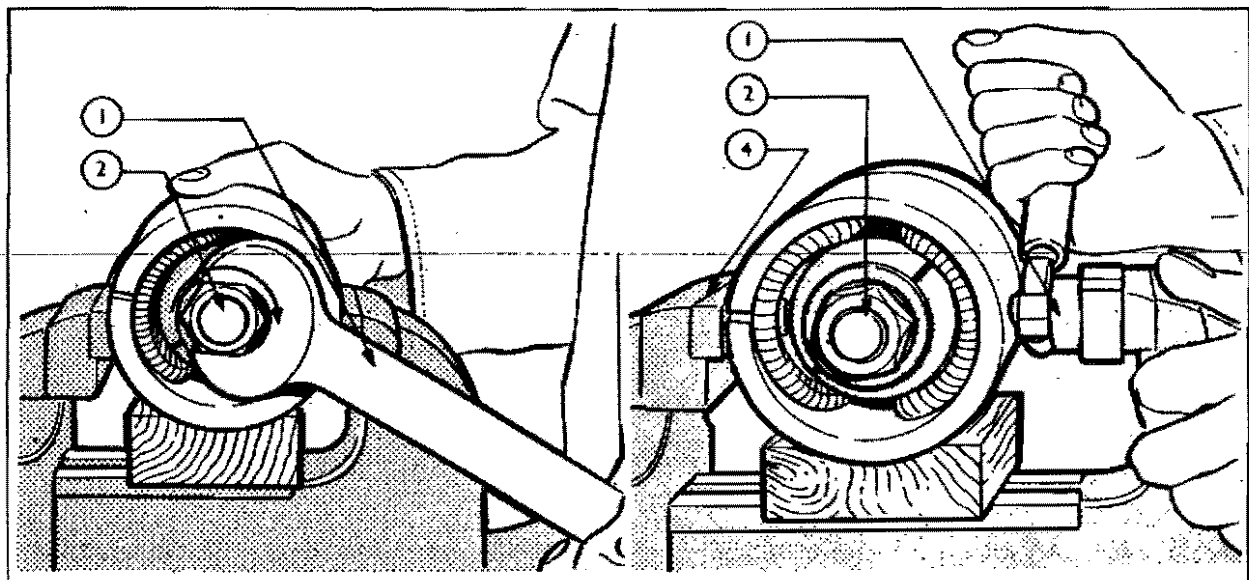


Fig. 7—Removing the Generator Field Coils

- |                         |                          |
|-------------------------|--------------------------|
| 1 Turn to open expander | 3 Pole piece screwdriver |
| 2 Pole expander         | 4 Vice                   |

## TO RENEW THE DRIVE END BRACKET 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.

### Circlip Retained Bearing (See Fig. 8)

1. Using circlip pliers, 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.
4. Thoroughly clean the bearing housing and then clean and re-locate the felt ring, retaining plate and the rubber ring 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 thrust to the bearing outer race.
6. Locate the bearing retaining 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 internal diameter 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. 3)
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 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—11 amp. GENERATOR

Cutting-in Speed	1100 r.p.m. (max.) at 13.0 generator volts.
Max. Output	10.5 amp. at 1700 r.p.m. (max.) with 13.5 generator volts and a resistance load of 1.23 ohm.
Field Resistance	6.0 ohms.

## PERFORMANCE DATA—22 amp. GENERATOR

Cutting-in Speed	1450 r.p.m. (max.) at 13.0 generator volts.
Max. Output	22 amp. at 2250 r.p.m. (max.) with 13.5 generator volts and a resistance load of 0.61 ohm.
Field Resistance	6.0 ohms.

## VOLTAGE CONTROL REGULATOR—used with the 11 amp Generator.

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 overleaf, and should be carefully checked before attempting to effect any replacements.

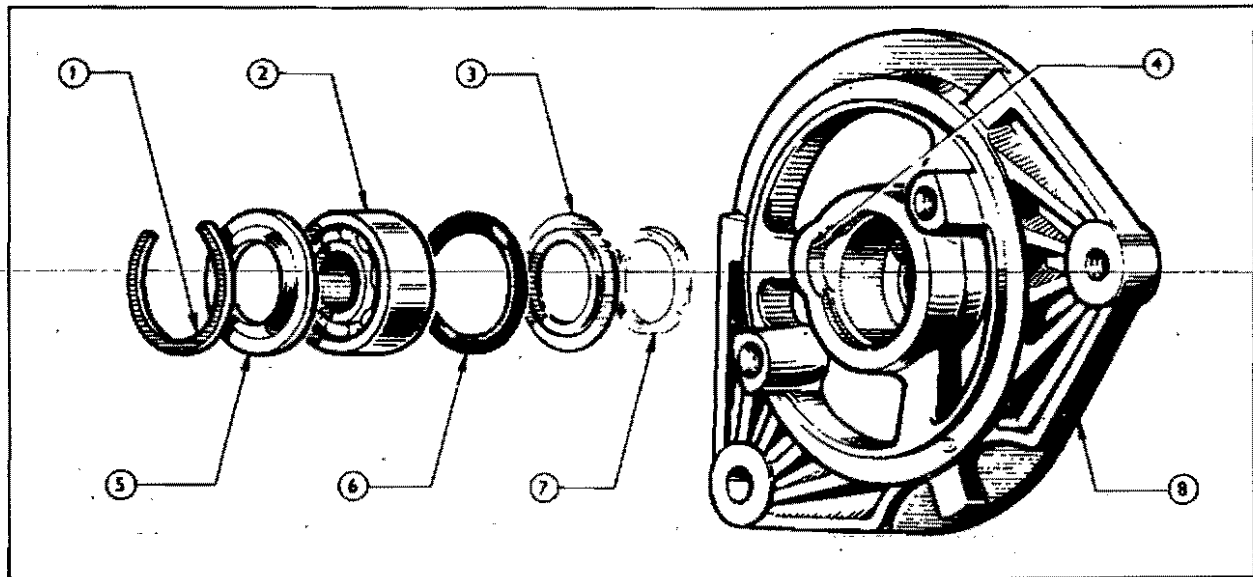


Fig. 8—Exploded view of Circlip Retained Bearing

- |                           |                          |
|---------------------------|--------------------------|
| 1 Circlip Retainer        | 5 Bearing Retainer Plate |
| 2 Front Bearing           | 6 Rubber 'O' Ring        |
| 3 Felt Retaining Washer   | 7 Felt Ring              |
| 4 Circlip Extractor Notch | 8 Drive End Bracket      |

## 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 — refer to paragraph (b), Page 3r.

## 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.

## 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.

Test the generator as outlined in the previous section. If this is satisfactory test the regulator.

The voltage regulators used with the 11 and 22 amp. generators are sealed units. If a fault is diagnosed the voltage regulator must be replaced.

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## ~~VOLTAGE/CURRENT REGULATOR Used with the 22 amp. Generator~~

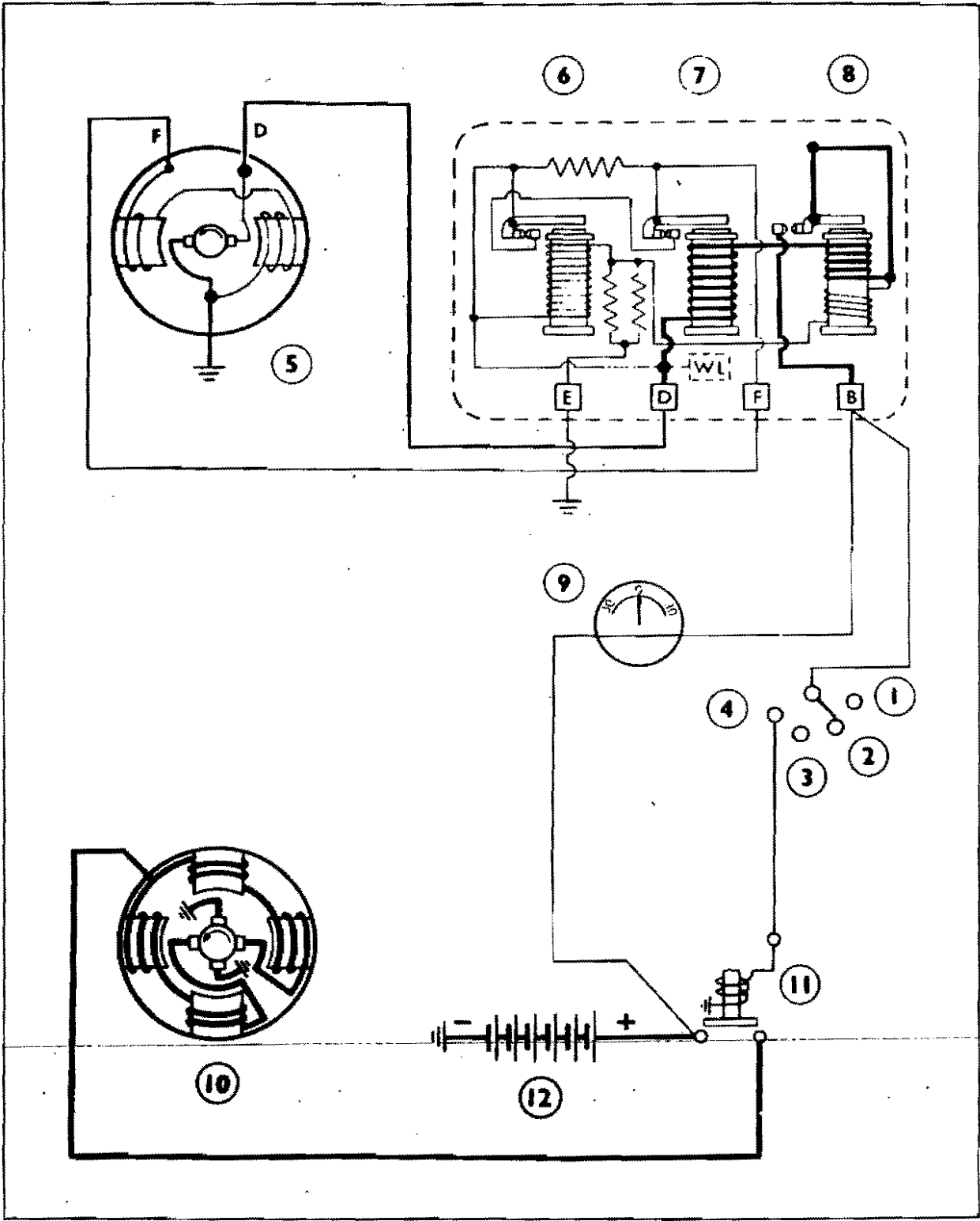
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The three "bobbin" regulator incorporates a cut-out, current regulator coil and voltage regulator coil—see wiring diagram Fig. 9.

## OPERATION

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 limits the generator output by automatically inserting a resistance in the field coil circuit thus reducing the magnetic field strength.



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Fig. 9—Typical Wiring Diagram of 22 amp. Generator

- |                  |   |   |                    |   |                   |    |                         |
|------------------|---|---|--------------------|---|-------------------|----|-------------------------|
| Isolating Switch | } | 1 | Auxiliary Circuits | 5 | Generator         | 9  | Ammeter                 |
|                  |   | 2 | Off                | 6 | Voltage Regulator | 10 | Starter Motor           |
|                  |   | 3 | -                  | 7 | Current Regulator | 11 | Starter Solenoid Switch |
|                  |   | 4 | Start              | 8 | Cut-out           | 12 | Battery                 |

## THE VOLTAGE/CURRENT REGULATOR (Used with 22 amp. Generator)

The cut-out is an automatic switch connected in the charging circuit its function being to prevent the battery discharging through the generator when, at low speeds, the generator voltage falls below that of the battery.

As the generator speed is increased from rest, its open circuit voltage rises. When this reaches a pre-determined value which is above the battery voltage, the electro-magnetic field produced by the shunt wound cut-out coil is of sufficient strength to pull the cut-out armature downwards against its spring, thus closing the contacts and completing the charging unit.

The charging current flows through the cut-out series winding increasing the electro-magnetic field strength, and so assisting the shunt coil, to a degree depending on the load.

Further speed increase causes the generator voltage to continue rising until, under conditions of light electrical load and with a well-charged battery, the voltage regulator operating setting is reached. At this point the voltage regulator armature is attracted to the core by the magnetic effect of the regulator shunt winding, thus causing the regulator contacts to open. The field resistor (see Fig. 10) now inserted in the generator field circuit causes the generator output to fall, the pull of the armature to be reduced, the voltage regulator contacts to close, thus again shorting out the field resistance.

This sequence, being continuous, causes the voltage regulator armature to vibrate, the effect being to limit the generator voltage to a pre-determined value.

In cases where the battery is in a low state of charge, or when a heavy electrical load is imposed on the system, the generator voltage may not then rise to the value at which the voltage regulator operates. Under these conditions an additional method of controlling the generator output to a safe limit is necessary; this is provided by the current regulator.

When the generator current reaches its maximum rated value, the electro-magnetic effect of the current flowing through the current regulator coil attracts the armature towards the core causing the regulator contacts to open. The field resistor now inserted in the generator field circuit, causes the generator output to fall and the current regulator armature to vibrate, thus imposing a safe limit on the generator output.

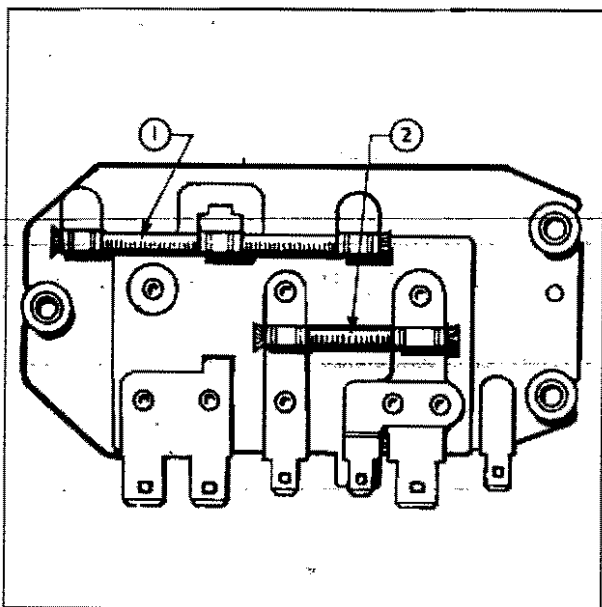


Fig. 10—Underside View

1 Swamp Resistor      2 Field Resistor

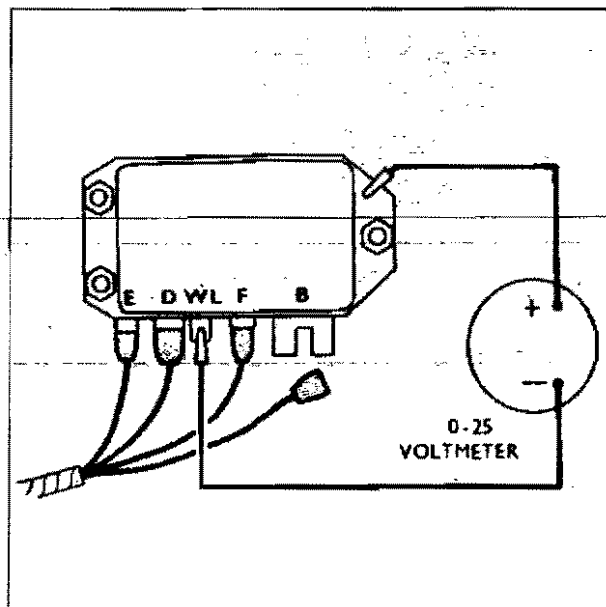


Fig. 11—Voltage Regulator, Open Circuit Setting

**VOLTAGE/CURRENT REGULATOR Used with the 22 amp. Generator (Continued)**

When commencing to charge a flat battery, the current regulator permits the maximum safe generator output to be applied to the charging circuit. This condition continues until the battery approaches a fully charged condition and the applied voltage is sufficient to bring the voltage regulator into operation. The generator output then "tapers off" until a trickle charge condition is reached. For a short period of time both regulators will be in operation.

When the engine speed falls, the generator output must also fall until its voltage falls below that of the battery. Under these conditions, the electro-magnetic pull produced by the cut-out shunt winding is insufficient to retain the armature against its spring thus allowing the cut-out contacts to open. If any slight delay occurs and the battery commences to discharge through the generator, the reversed current flow through the cut-out series coil promotes rapid demagnetisation thus ensuring the contact points opening.

**AUTOMATIC TEMPERATURE COMPENSATION**

The shunt wound cut-out and voltage regulator coils consist of many turns of fine copper wire, consequently, their resistance rises and falls with their temperature.

The temperature variation is caused partly by the ambient conditions and partly by the current heating effect.

Any increase in coil resistance reduces the magnetic pull on the armature and so affects the operating voltage of the respective units.

To compensate in part for this, a bi-metal armature tension spring is incorporated in the cut-out and a bi-metal armature hinge spring is incorporated in the voltage regulator.

The spring pressure decreases as the temperature rises thus maintaining the operating voltage at a constant value under all temperature conditions.

In the voltage regulator, this feature automatically permits the higher voltage required for reducing the battery charging rate in cold weather and also the lower voltage required for reducing the charging rate in warm weather.

In addition to the use of a bi-metal strip, the effects of temperature are further minimised by the use of a two-coil "swamp" resistor which is connected in series with the two shunt coils (see Figs. 9 and 10. This "swamp" resistor has a higher ohmic value than the shunt coils and is constructed from an alloy material whose electrical resistance properties are much less susceptible to changes in temperature than copper.

The current regulator is not compensated, since the resistance of its operating coil is too low to vary significantly with changes in temperature.

**PRELIMINARY CHECKS**

If a faulty regulator is suspected, first check the following items:-

- (a) Fan belt—see page 7r.
- (b) Battery—see page 7r.
- (c) Generator and Connections—see page 7r.

## ELECTRICAL CHECKING

The voltage regulator, should be checked in a complete sequence.

The instruments used for carrying out the electrical tests and settings outlined should be as follows:-

Voltmeter—high grade moving coil      Scale 0-25 volts  
Ammeter—high grade moving coil      Scale 40-0-40 amps.

### VOLTAGE REGULATOR OPEN CIRCUIT SETTING (see Fig. 11)

NOTE:—A generator run at high speed on open circuit will build up a high voltage. Therefore, when testing the voltage regulator, increase the engine-speed slowly until the regulator operates otherwise a false setting will be made.

1. Disconnect the wiring connection from the regulator terminal blade "B".
2. Connect the positive lead of the test voltmeter to the regulator terminal "D" or "WL", and the negative lead to the regulator base plate.
3. Start the engine and gradually increase the speed until the voltmeter needle "flicks" and then steadies (approximately 1,500 generator r.p.m.) This should occur at a voltmeter reading between 14.2 and 14.8 volts at 20°C. (68°F).
4. If the voltmeter reading is steady but is not between the limits specified, the regulator should be replaced.

If the voltmeter reading continues to rise as the engine speed is increased, possibly swinging the needle right over, it is indicative that either the regulator points are not opening or there is a poor or no earth between the regulator and the body.

If the points are not opening, the regulator should be renewed, as it is probable that they are "welded" or shorted, or there is an open circuit in the shunt coil.

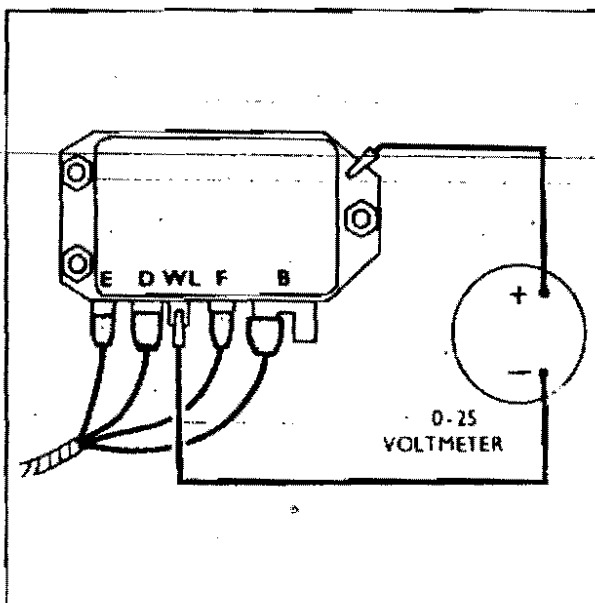


Fig. 12—Cut-out, Cut-in Voltage

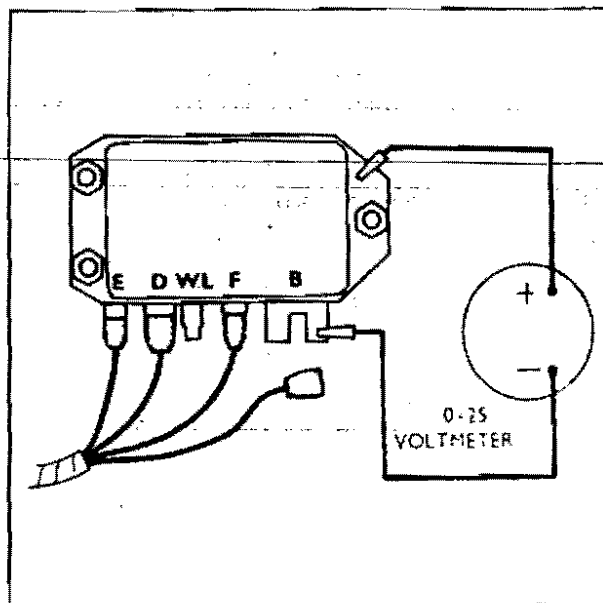


Fig. 13—Cut-out, Drop-off Voltage



**CUT-OUT, CUT-IN VOLTAGE (see Fig. 12)**

**NOTE:**—As when testing the voltage regulator, the electrical readings should be completed as quickly as possible to avoid errors due to the coils heating.

1. Connect the negative lead of the test voltmeter to the regulator terminal “D” or “WL”, and the positive lead to the regulator base plate.
2. Connect a lamp load (about 100 watt) across the battery. This load is necessary to ensure the drop in voltmeter reading (see below), is immediately discernible.
3. Start the engine and slowly increase the speed. Note the maximum reading obtained on the voltmeter, this should be between 12.6 and 13.4 volts.

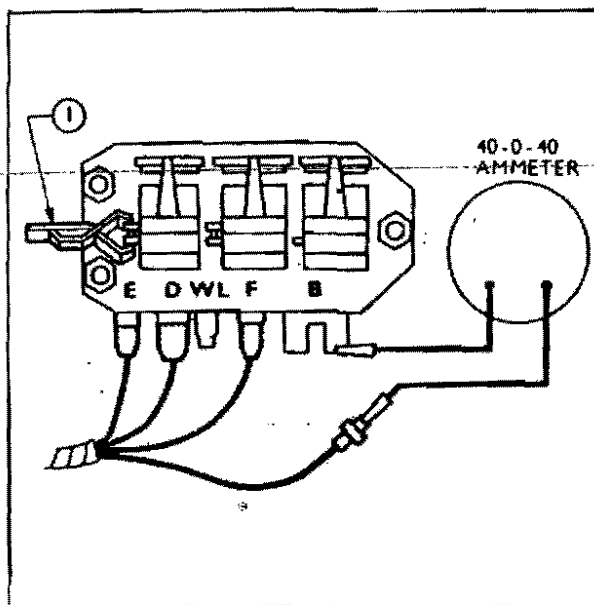
**NOTE:**—After registering the maximum reading, the voltmeter needle should drop suddenly, indicating that the cut-out contacts close.

**CUT-OUT DROP-OFF VOLTAGE (see Fig. 13)**

1. Disconnect the wiring connection from the regulator blade “B”
2. Connect the positive lead of the test voltmeter to terminal “B” and the negative lead to the regulator base plate.
3. Run the engine at about half throttle and then gradually decrease the engine speed, noting the voltage immediately after the needle “flicks” back to zero indicating that the cut-out contacts open.

This should occur between 9.3 and 11.2 volts.

4. Start the engine and re-check as outlined in paragraph 3.
5. Stop the engine, disconnect the voltmeter, reconnect the wiring to terminal “B” and replace the regulator cover.



**Fig. 14—Current Regulator, On-load Setting**

## CURRENT REGULATOR—ON-LOAD SETTING (See Fig. 14)

When checking the current regulator, the generator must develop its maximum rated output whatever the battery state of charge. The voltage regulator must therefore be made inoperative.

To do this, the voltage regulator contacts must be short-circuited by a convenient means such as a spring clip large enough to bridge the adjustable contact and the armature limb (See Fig. 14).

1. Disconnect the wiring connection from the terminal "B" of the regulator and connect the test ammeter between this terminal and the disconnected cable.
2. Connect a lamp load (about 100 watt) across the battery. This load is necessary to enable the generator to develop its full rated output.
3. Start the engine, run the engine at the specified speed (see Figs. 15 & 16) and note the ammeter reading.

This should indicate a current equal to the maximum rated output of the generator i.e. 22 amps.  $\pm 1\frac{1}{2}$  amps.

NOTE:—An unsteady reading may be due to dirty contacts, incorrect mechanical setting, a loose fan belt or a faulty internal connection.

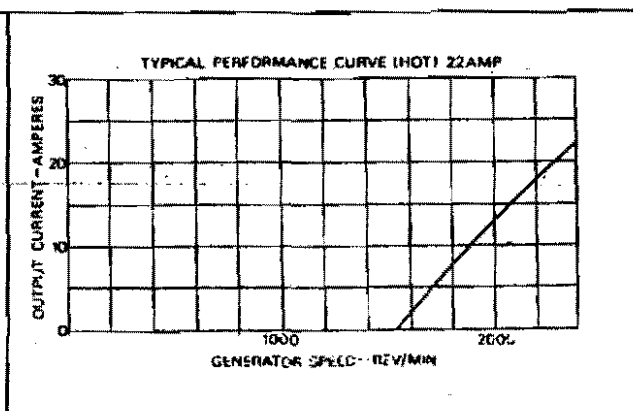
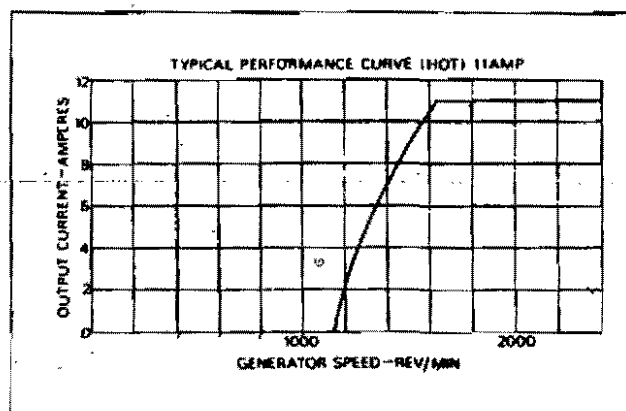


Fig. 15

Fig. 16

## THE LUCAS 11AC ALTERNATOR – 43 amp.

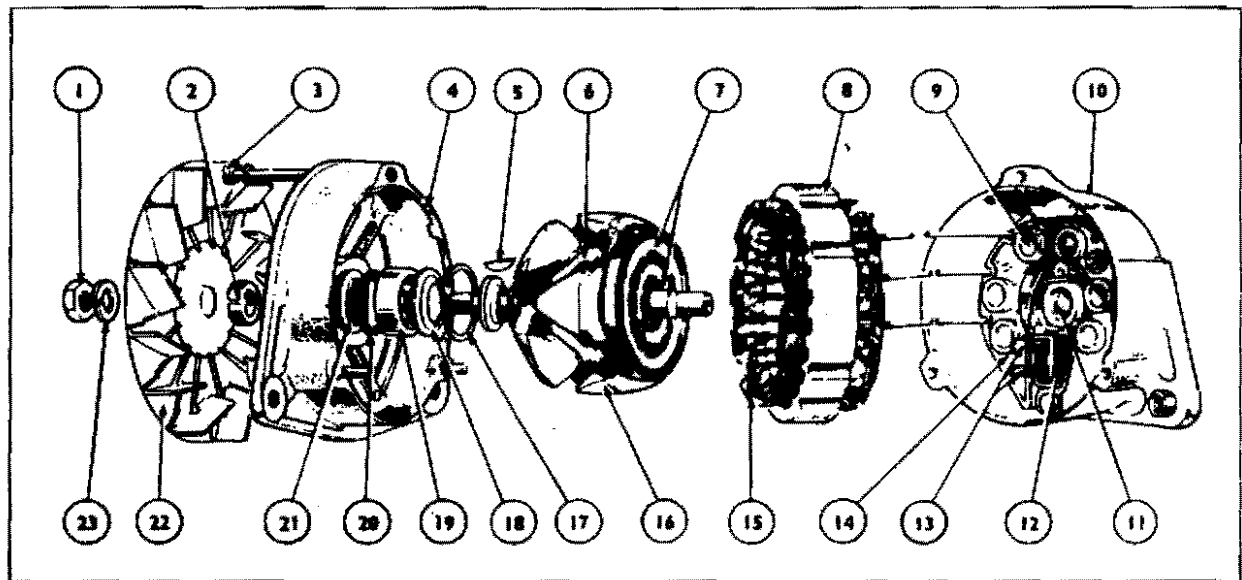


Fig. 17 – The Alternator Exploded

- |                  |                   |                       |                        |
|------------------|-------------------|-----------------------|------------------------|
| 1. Shaft Nut     | 7. Slip Rings     | 13. Brushes           | 19. Ball Bearing       |
| 2. Key           | 8. Stator         | 14. Diode Heat Sink   | 20. "O" Ring Oil Seal  |
| 3. Through Bolt  | Laminations       | 15. Stator Winding    | 21. "O" Ring Retaining |
| 4. Drive End     | 9. Diodes         | 16. Rotor             | washer                 |
| 5. Key           | 10. Slip-ring end | 17. Circlip           | 22. Fan                |
| 6. Rotor (Field) | Bracket           | 18. Bearing Retaining | 23. Spring Washer      |
| Winding          | 11. Needle Roller | Plate                 |                        |
|                  | Bearing           |                       |                        |
|                  | 12. Brush Box     |                       |                        |
|                  | Moulding          |                       |                        |

- (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 12 volts maximum).
- (j) NEVER use a lever on the stator or rear housing when adjusting the fan belt.

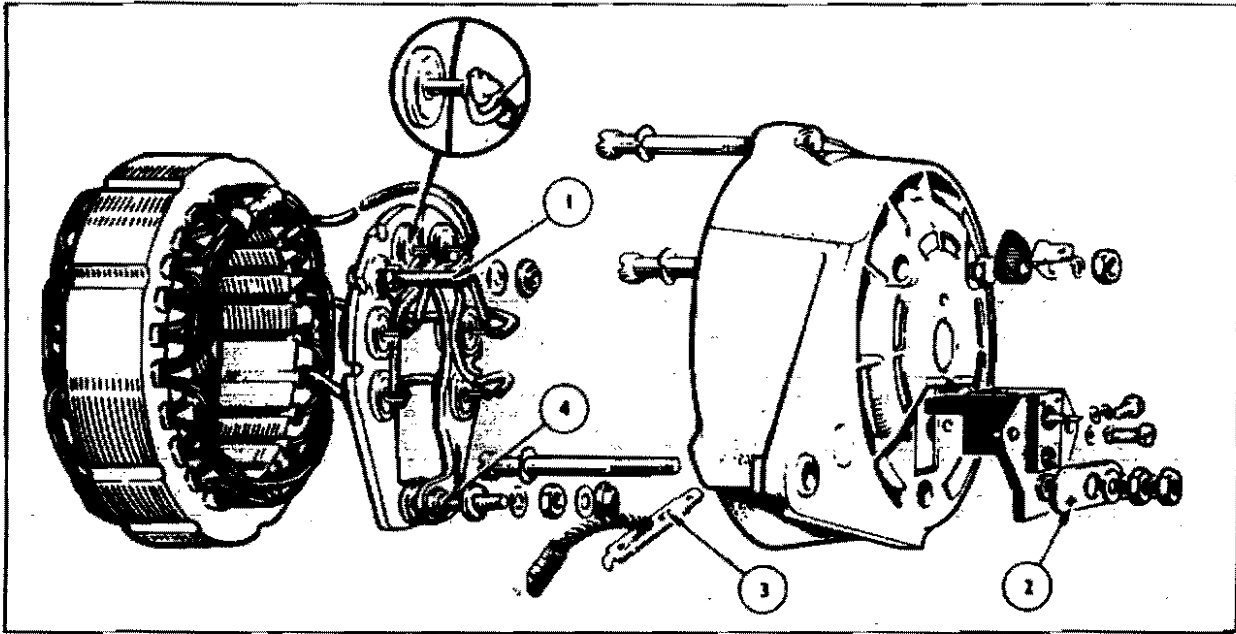


Fig. 18 – Slip-Ring End, showing Heat Sink withdrawn

- |                                  |                                    |
|----------------------------------|------------------------------------|
| 1. Warning Light Terminal "AL"   | 3. Terminal Blade Retaining Tongue |
| 2. Output Terminal Plastic Strip | 4. Output Terminal                 |

- (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

##### 1. CLEANING

Wipe away any dirt or oil which may have collected around the slip-ring end cover ventilating apertures.

##### 2. BELT ADJUSTMENT

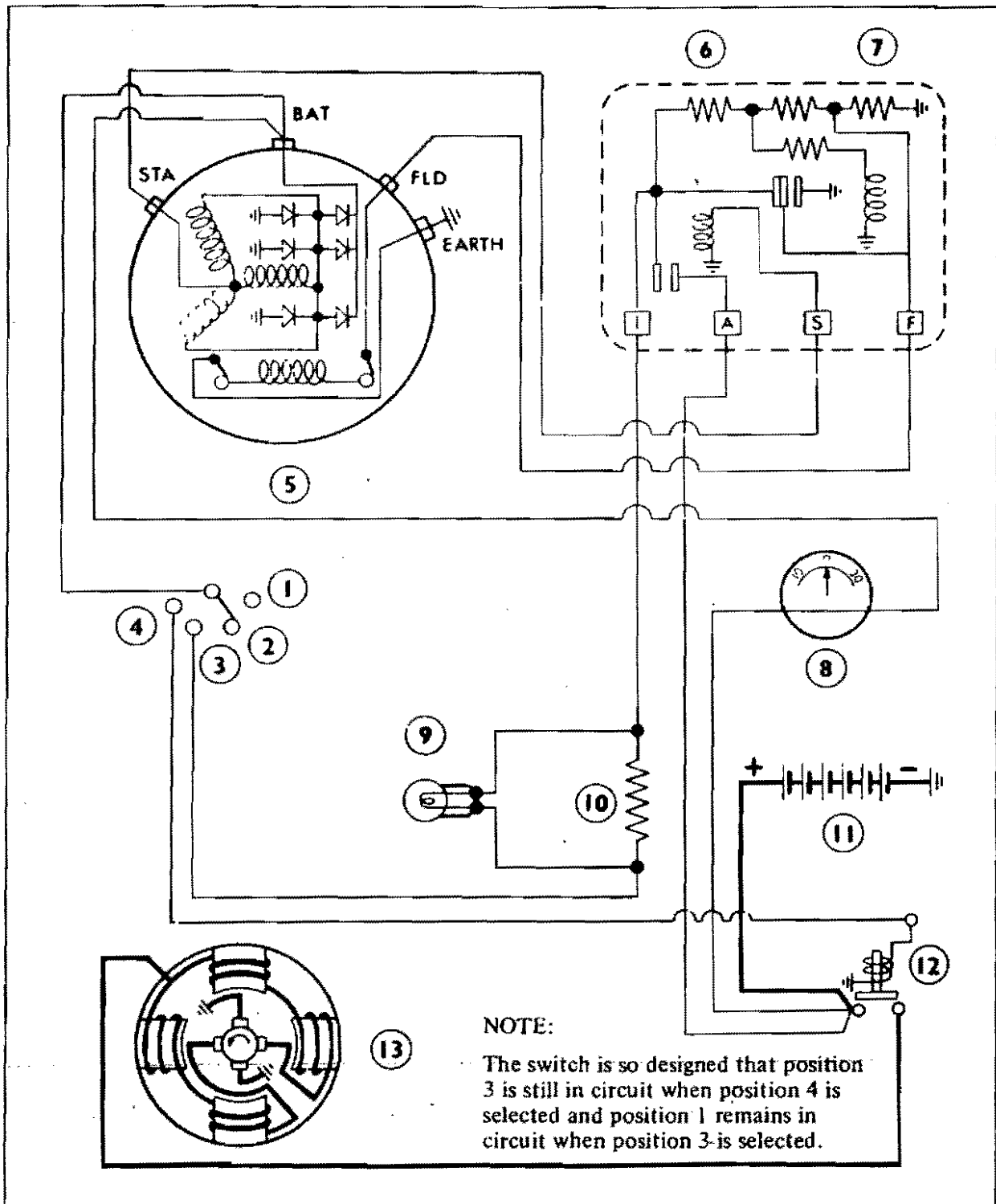
Occasionally inspect the driving belt, for wear and tension. It should be possible to move the belt a total distance of 13 mm (0.5 in) at a point midway along its longest run between pulleys. See that the alternator is properly aligned with respect to the drive, otherwise the rotor bearings will be unduly loaded.

##### 3. LUBRICATION

The bearings are packed with grease during assembly and do not require periodic attention.

##### 4. TERMINAL CONNECTIONS

Ensure that all terminal connections are tight.



MAY 1974

Fig. 19 – 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 (15 Ω)
- 11. Battery
- 12. Starter Solenoid Switch
- 13. Starter Motor

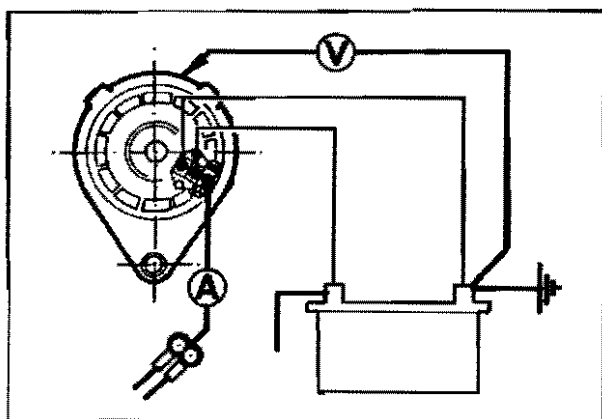


Fig. 20 – Alternator Output Test

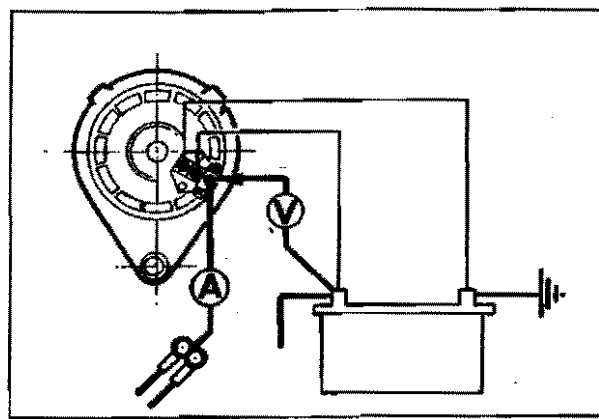


Fig. 21 – Charging Circuit Voltage Drop Test (insulated side)

### 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. 20 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 4,000 rev/min. At this speed the reading on the ammeter should be approximately 40 amperes.

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.

## Testing the Alternator in Position (Cont'd)

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, of low range if available, between the alternator output terminal and the battery insulated terminal (see Fig. 21) and note the voltmeter reading.
8. Now transfer the meter connections to the alternator frame and battery earth terminal, Fig. 22 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.

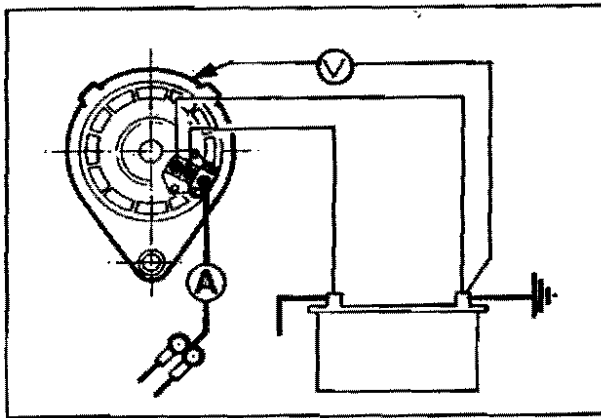


Fig. 22 – Charging Circuit Voltage Drop Test (earth side)

## 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 end 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.

## DISMANTLING (Cont'd)

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.

### Brushgear

1. Measure the brush length. A new brush is 15.9 mm. (5/8 in.) long; a fully worn brush is 4 mm. (5/32 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 227-454 grms. (8-16 oz.). 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.

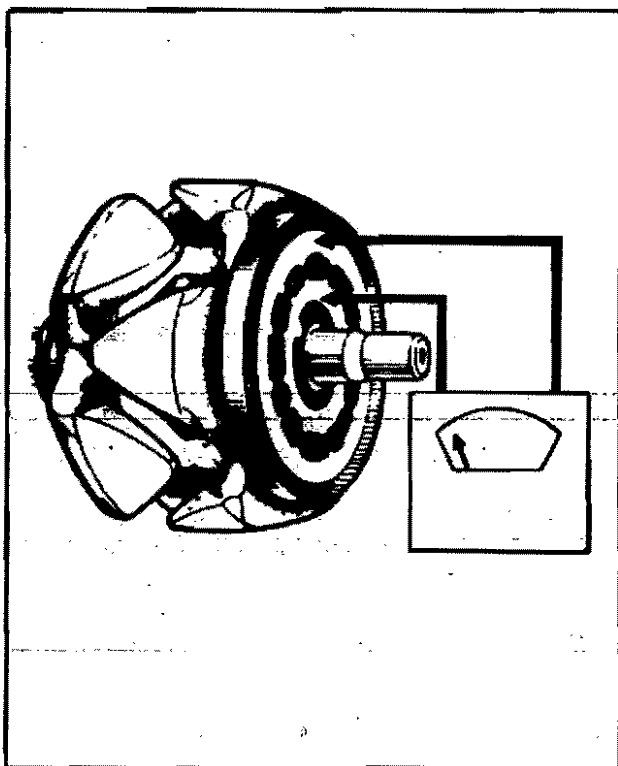


Fig. 23 – Measuring Rotor Winding Resistance with Ohmmeter (Alternator dismantled)

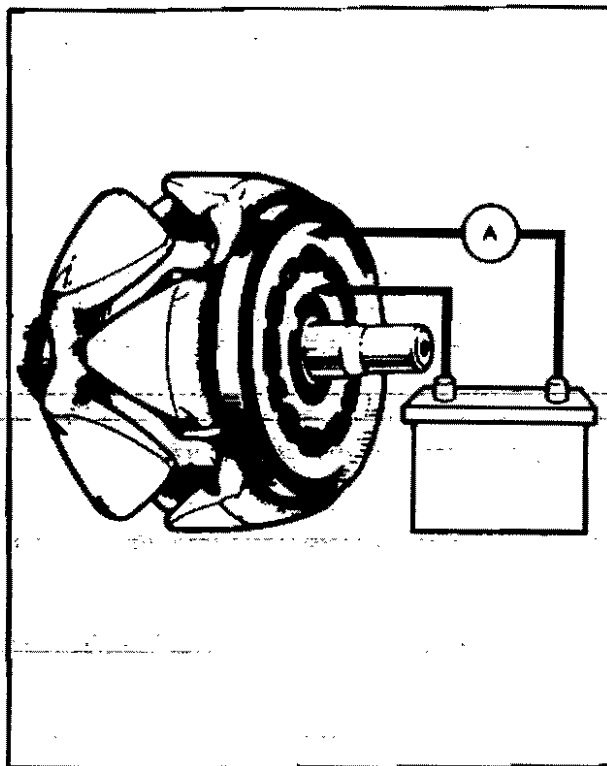


Fig. 24 – Measuring Rotor Winding Resistance with Battery and Ammeter (Alternator dismantled)



### 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.

### Rotor

1. Test the rotor winding by connecting either an ohmmeter (Fig. 23) or the appropriate battery supply (Fig. 24) between the slip-rings. The reading of resistance should be 3.8 ohms. If the alternative test has been made, the value of the current should be approximately 3.2 amperes.
2. Test for defective insulation between one of the slip-rings and one of the rotor poles using a 110-volt A.C. mains supply and 15-watt test lamp (Fig. 25). 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.

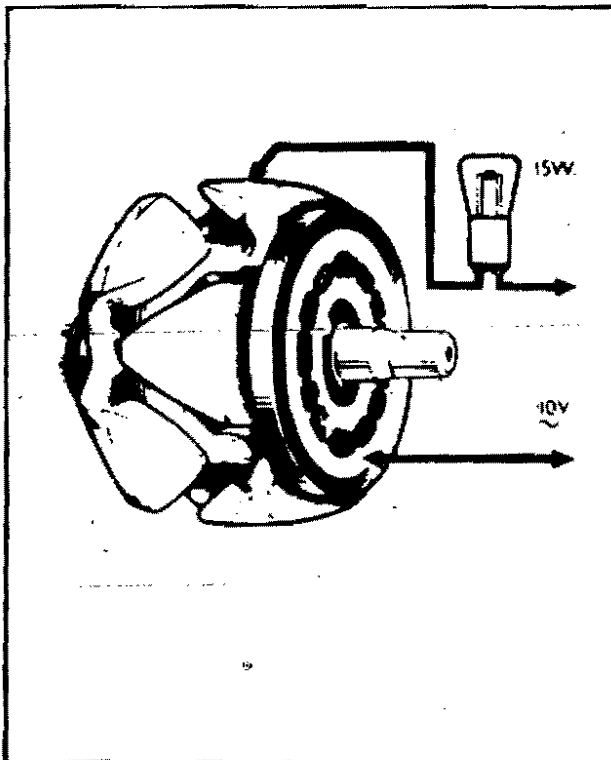


Fig. 25 – Insulation Test  
Rotor Winding

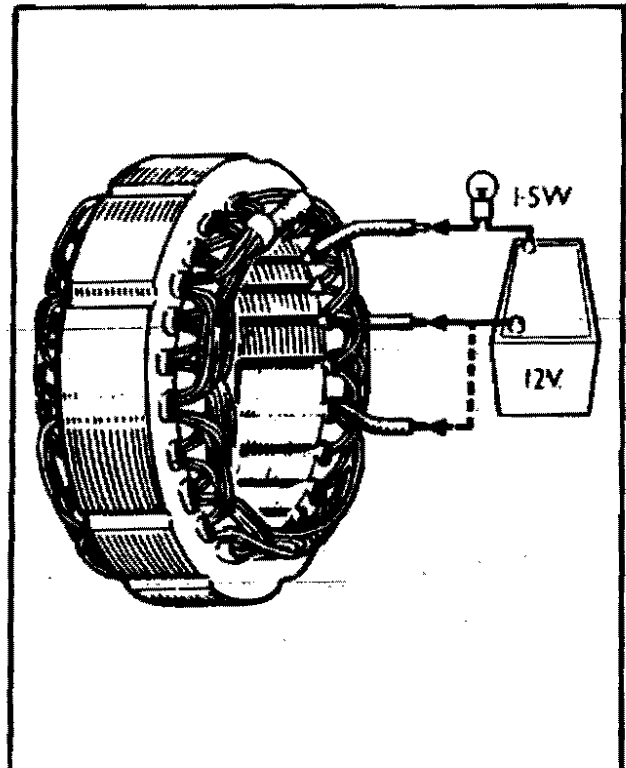


Fig. 26 – Stator Winding  
Continuity Test

## 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 watts and a 12-volt battery as shown in Fig. 26. 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. 27). 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 D.C. supply and then reversing the connections, (Fig. 28).

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 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.

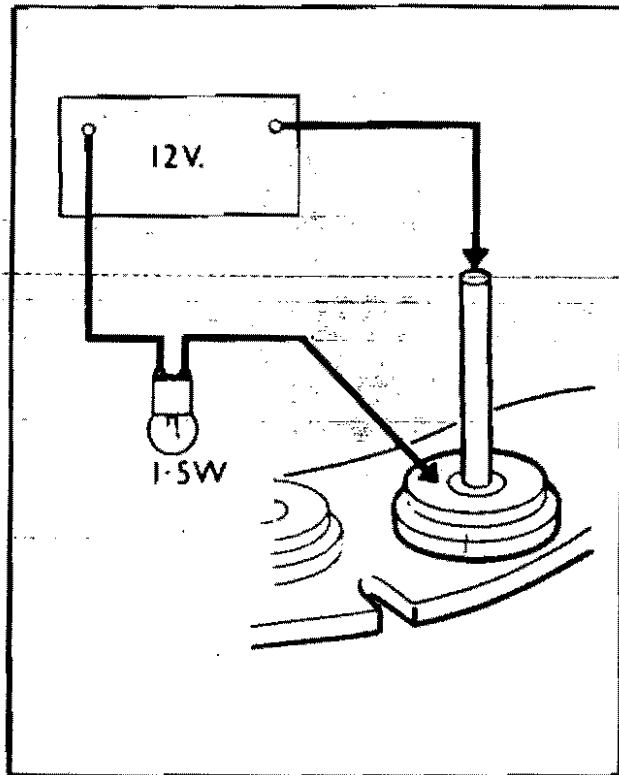
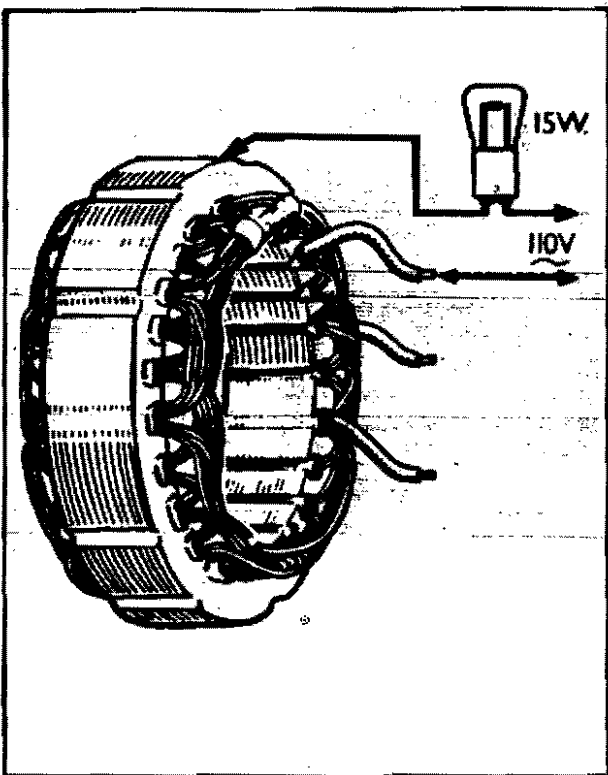


Fig. 27 — Stator Winding Insulation Test

Fig. 28. — Simple Diode Test

### Diode Heat Sink

The alternator heat sink assembly consists of two parts, one of positive polarity and the other negative (see Fig. 41). 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. 29.

After soldering, the connections must be neatly arranged around the heat sinks, to ensure adequate clearance for the rotor, and be tacked down with suitable adhesive where indicated in Fig. 30. 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.

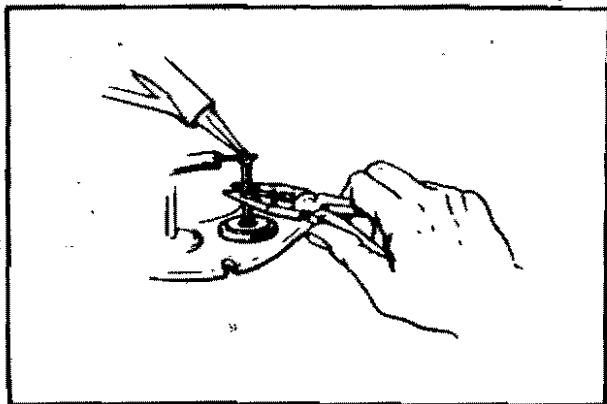


Fig. 29 – Use of Thermal Shunt when soldering Diode connections.

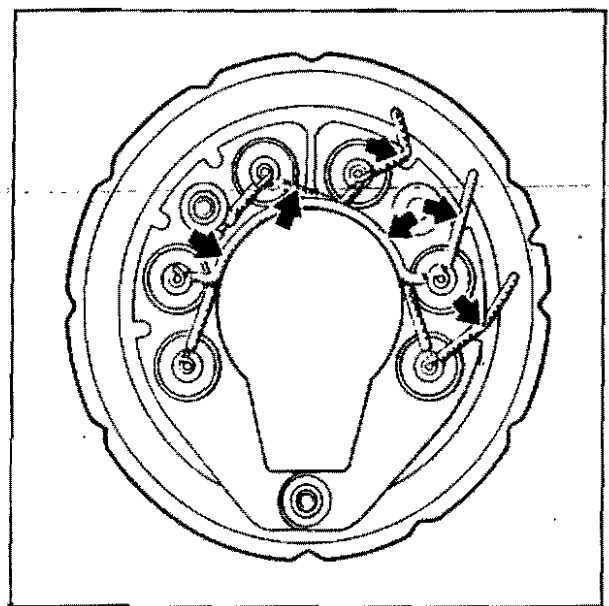


Fig. 30 – Heat Sink Cable securing points.

## Bearings (Cont'd)

- (d) Press the new bearing into its location, applying pressure to the outer race only.
  - (e) Replace the retaining circlip, or reposition the retaining plate and locate in position with the three set-screws/rivets.
2. If required, replace the slip-ring 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.

## 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.

NOTE: 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.

## Technical Data

Nominal D.C. output at 12 volts	43 amps.
Resistance of field coil in ohms at 20°C (68°F)	3.8 ± 5%
Maximum rotor speed in rev/min.	12,500
Stator	3 phase star connected
Slip-ring brushes	
Length new	15.9 mm. (5/8 in.)
Replace at	4 mm. (5/32 in.)
Brush spring loading	227-454 g. (8-16 oz.)
Assembly torques	
Maximum permissible tightening torques	
Brushbox fixing screws	1.1 Nm (0.12 kgf m or 10 lbf in)
Diode heat sink fixings	2.8 Nm (0.29 kgf m or 25 lbf in)
"Through" bolts	5.1 to 5.7 Nm (0.52 to 0.68 kgf m or 45 to 50 lbf in)

Control Unit – (Electronic)  
Type 4TR. with Lucas 11AC and 16RA Relay

General

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.

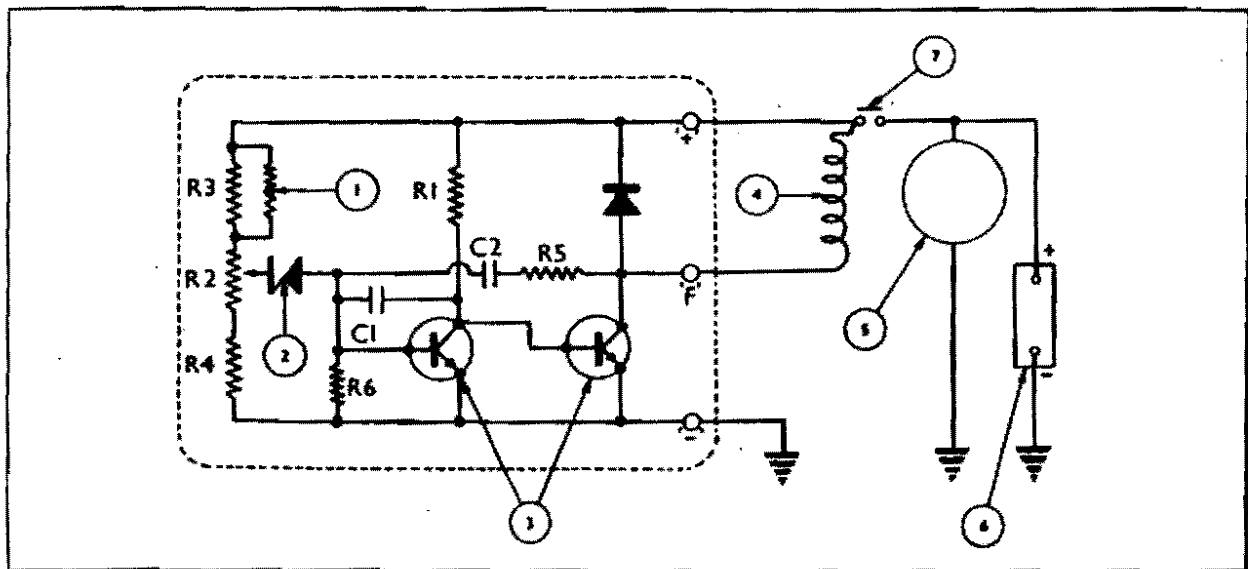


Fig. 31 – Circuit Diagram of Control Unit

- |                        |                           |
|------------------------|---------------------------|
| 1. Thermistor          | 5. Alternator             |
| 2. Zener Diode         | 6. Battery                |
| 3. Transistors         | 7. Field Isolating Device |
| 4. Rotor Field Winding |                           |

**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. 31.

**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 amperes.

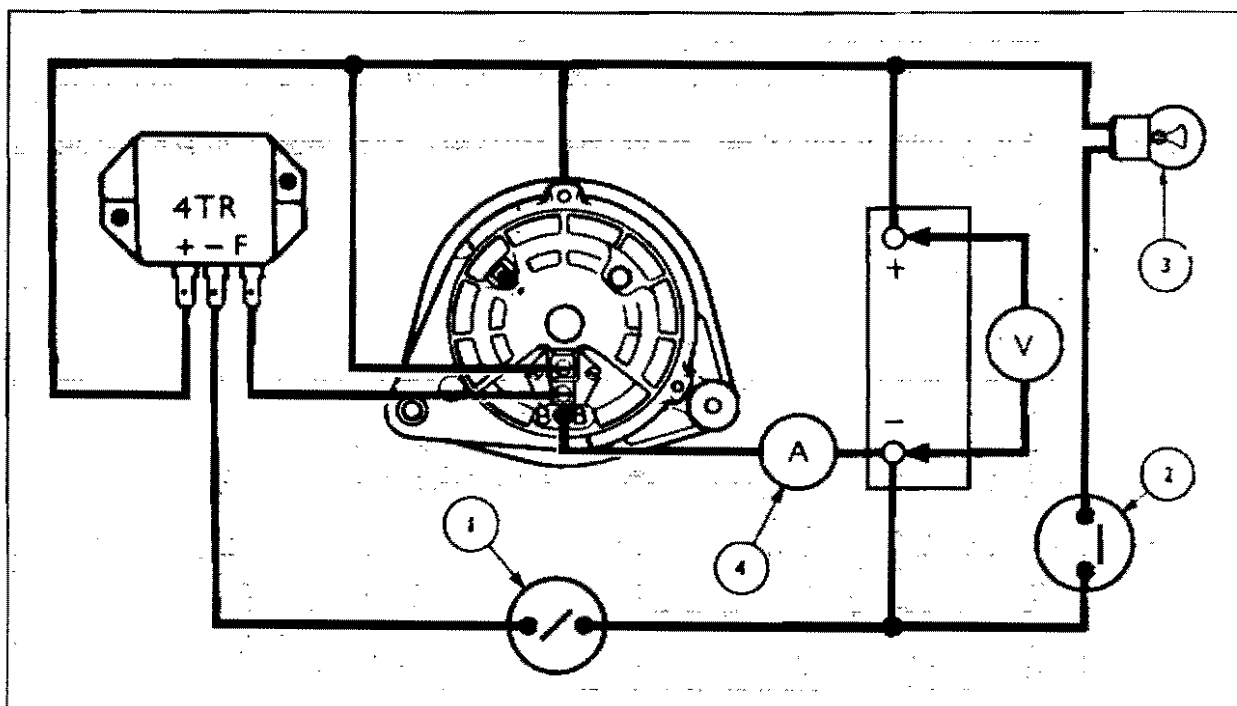


Fig. 32 – Control Unit Test Circuit

- |                           |                      |
|---------------------------|----------------------|
| 1. Field Isolating Device | 3. Testing Lamp Load |
| 2. Load Circuit Switch    | 4. Ammeter           |

## Voltage Checking

1. Leave the existing connection to the alternator and control unit undisturbed. Connect a high-quality voltmeter between control unit terminals “+” and “-”. If available, use a voltmeter of the suppressed-zero type, reading 15 volts 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 amps. The test circuit is shown in Fig. 32.
4. Start the engine and run the alternator at approximately 3,000 rev/min. for at least eight minutes. (This will ensure that the system voltage has stabilised). If the charging current is still greater than 10 amperes, continue to run the engine until this figure is reached. The voltmeter should now give a reading of 13.9 to 14.3 volts.

## Voltage Checking (Cont'd)

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. 33.

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 volts, 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. 33.

Electrical adjustment 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 3.0

Drop-off voltage—1.5 to 2.0

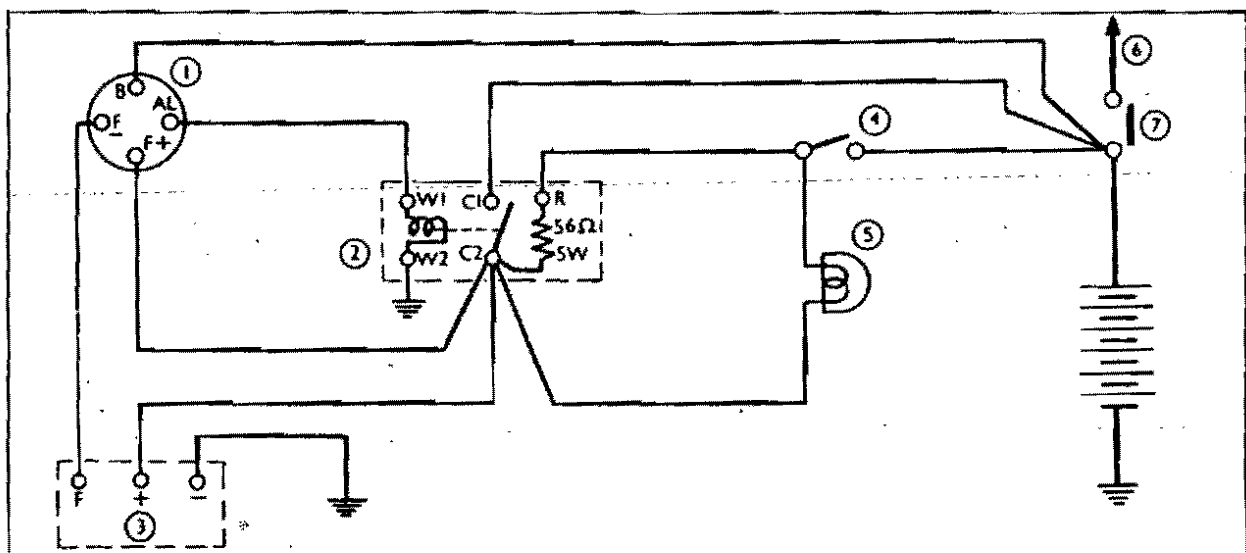


Fig. 33 – Typical Circuit Diagram showing Type 16RA Relay

- |                          |                     |                  |                |
|--------------------------|---------------------|------------------|----------------|
| 1 Alternator             | 2 Low Voltage Relay | 3 Regulator      | 4 Field Switch |
| 5 No-charge Warning Lamp | 6 To Starter Motor  | 7 Starter Switch |                |

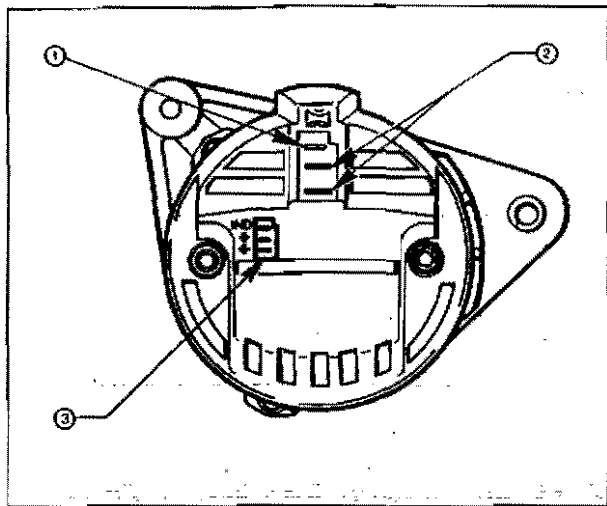


Fig. 34 – 17 ACR/18 ACR alternator  
(machine-sensed European terminations)

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.

The Lucas 17 ACR Alternator – 36 AMP and 18 ACR Alternator – 45 AMP

NOTE: The 18 ACR alternator is similar in appearance to the 17 ACR machine, but has a higher maximum output. (45 amps against 36 amps).  
The frame size is the same for both alternators, but the 18 ACR has a larger fan.  
Maintenance, dismantling and checking the charging system for both models is contained in the following pages.

#### General

##### (a) Components of the alternator.

###### Terminal Arrangement

European Terminations (see Fig. 34).

###### Alternator Out put Control

Integral electronic voltage regulator unit of micro-circuit construction.

- (i) 8TR or 11TR 4-lead regulator (see Fig. 35).
- (ii) 8TR or 11TR 3-lead regulator (see Fig. 35).
- (iii) 14TR 2-lead regulator (see Fig. 35).

###### Rectifier

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

European termination rectifier model 4DS5 Pt. No. 83166.

###### Rotor

Press-claw type.

###### 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 and 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 precaution not to disconnect any of the charging system cables, particularly those at the battery, while the engine is running, should still be observed).



## General (Cont'd)

## (b) Operation of the Alternator

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(s) 'IND' and the carbon brushes contacting the rotor slip-rings, the alternator regulator and earth. At this stage, the warning light is 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 it 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 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 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 regulator senses the alternator generated output voltage, via the regulator connections inside the alternator.

## (c) 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 13 mm (0.5 in) total deflection of the belt when tested 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.

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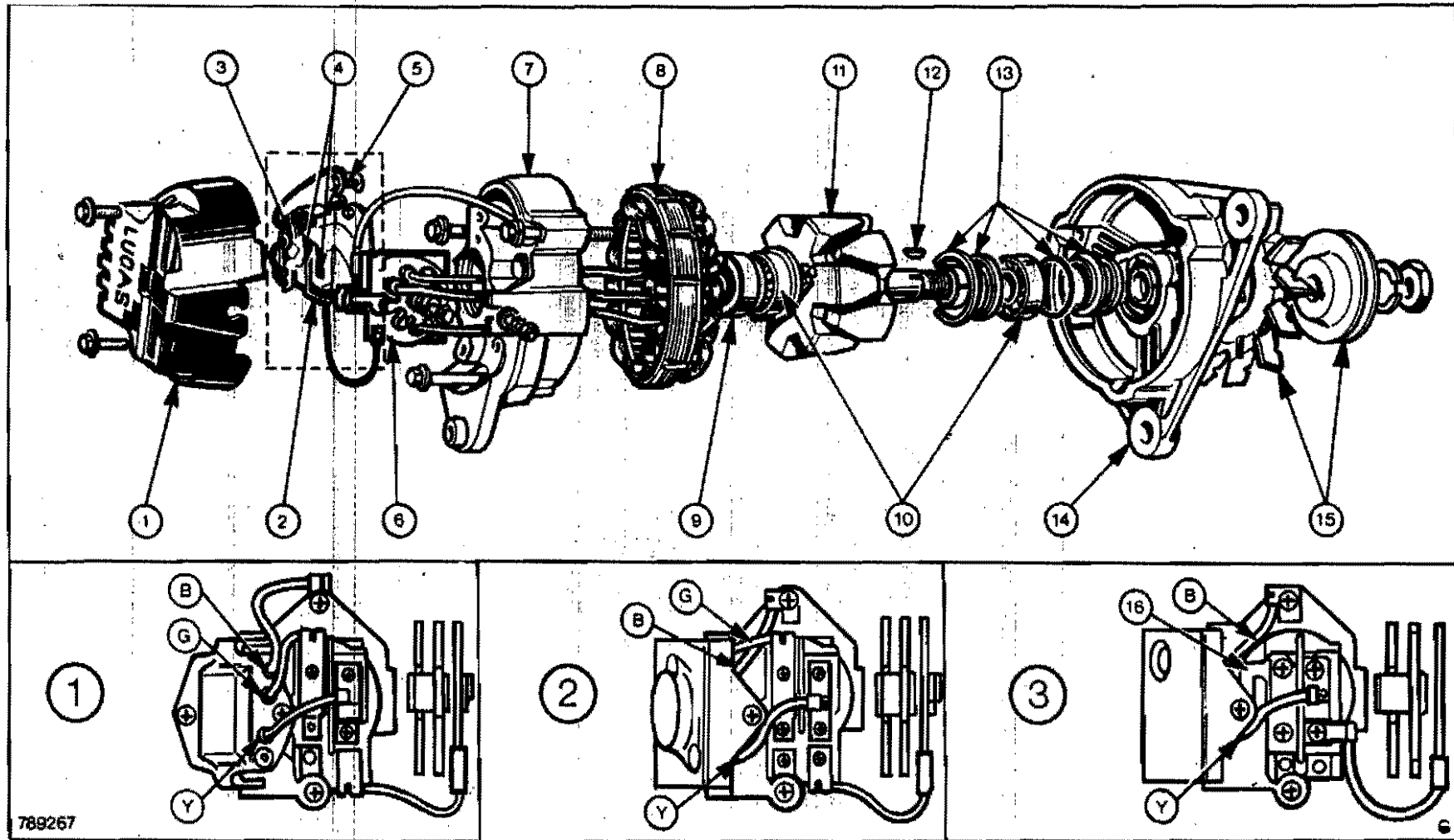


Fig. 35 – Machine-sensing system, 17ACR alternator

1. Cover
2. Brushgear and regulator 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

14. Drive-end bracket
15. Fan and pulley (fixing nut and spring washer)
16. Alternative connections for surge protection device (when fitted)

Wiring Colour Code:

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

## ROUTINE MAINTENANCE (Cont'd)

## Technical Data – 17 ACR

(i) Earth polarity	Negative
(ii) Nominal voltage	12V
(iii) Nominal d.c. output (hot, at 14V and 6,000 rev/min.)	36A
(iv) Alternator controlled voltage (measured across the battery terminals with alternator current stabilised below 10A)	13.6-14.4V
(v) Maximum permissible speed	15,000 rev/min.
(vi) Rotor field winding resistance (approx.)	4.2 ohms (17ACR rotors with PINK windings.) 3.2 ohms (17ACR rotors with GREEN windings.)
(vii) Brush spring pressure (measured with brush depressed flush with brushbox moulding)	255 to 368 gf (9 to 13 ozf)
(viii) New brush length:	12 mm. (0.5 ins.)
Renew when worn to:	8 mm. (0.3 ins.)

## Technical Data – 18 ACR

(i) Earth polarity	Negative
(ii) Nominal voltage	12V
(iii) Nominal d.c. output (hot, at 14V at 6,000 rev/min)	45A
(iv) Nominal machine voltage	14.2V (at 20 <sup>0</sup> rated output)
(v) Number of Poles	12
(vi) Maximum permissible speed	15,000 rev/min
(vii) Rotor field winding resistance (approx)	3.2 ohms
(viii) Brush spring pressure (measured with brush depressed flush with brushbox moulding)	255 to 368 gf (9 to 13 ozf)
(ix) New brush length	12 mm (0.5 in)
(x) Renew when worn to:	8 mm (0.3 in)

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## Overhauling the Alternator

## (a) CHECKING THE CHARGING SYSTEM

## (i) Eliminate the Battery

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 as shown in the table overleaf.

CHECKING THE CHARGING SYSTEM (Cont'd)

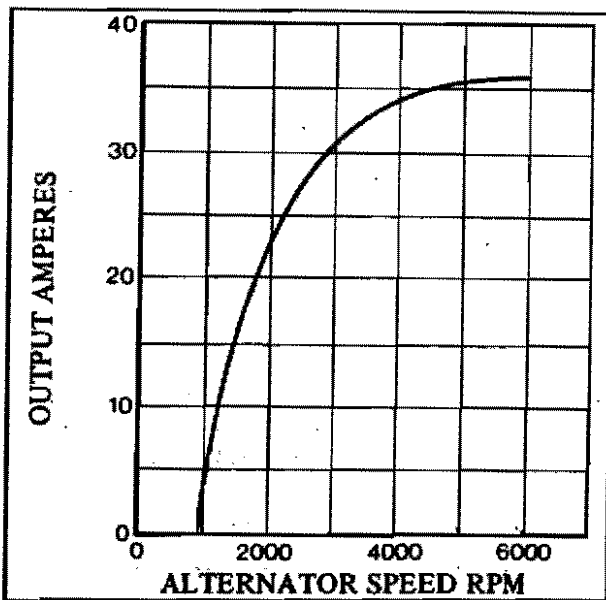


Fig. 36a

Typical 17 ACR Performance Curve  
(Alternator Hot)

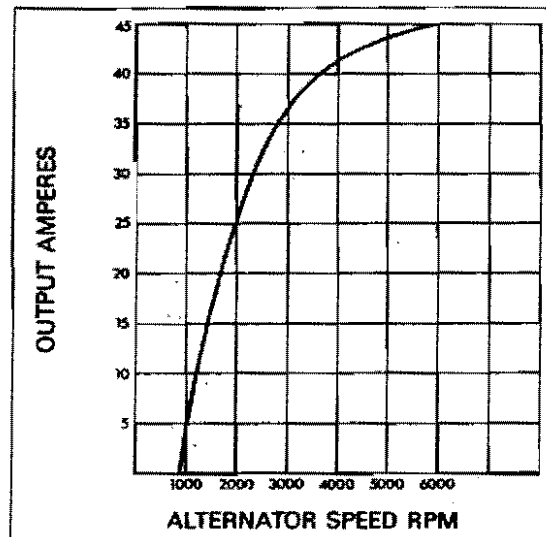


Fig. 36b

Typical 18 ACR Performance Curve  
(Alternator Hot)

State of charge	Specific 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

Electrolyte Temperature Correction

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

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.

(ii) Observe Operation of the Warning Light.

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 para. iv.

If the warning light is illuminated, start the engine and run 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 para. iii).

## CHECKING THE CHARGING SYSTEM (Cont'd)

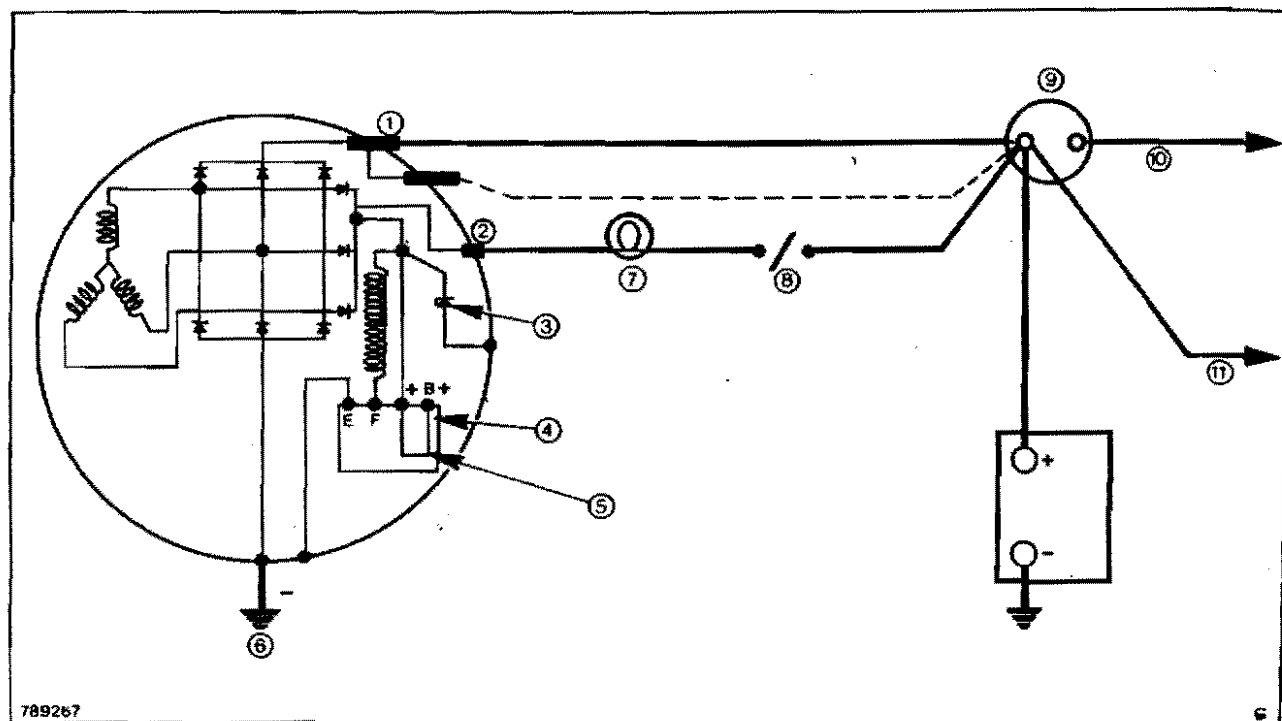


Fig. 37 Machine-sensing system, 17 ACR and 18 ACR alternators (European terminations).

- |   |                           |             |
|---|---------------------------|-------------|
| 1. Main positive terminal                       | 5. Internal B+ Connection | 9. Solenoid |
| 2. IND  | 6. Main negative terminal | 10. Starter |
| 3. Surge protection device<br>(Avalanche diode) | 7. Warning light          | 11. Load    |
| 4. Regulator 8TR                                | 8. Ignition switch        |             |

**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.



**CHECKING THE CHARGING SYSTEM (Cont'd)**

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

**(iii) Check the Driving Belt**

Check whether the driving belt is broken or slipping. With the driving belt depressed by hand at the longest point between pulleys, total deflection of the belt should be approximately 13 mm (0.5 in).

**(iv) Check the Alternator Plug Connections.**

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

Move ignition switch on equivalent control switch to 'ON'.

Remove connector plug from alternator and connect voltmeter between each cable-end in turn and the frame (negative-side of voltmeter to frame). Battery voltage should be registered.

If the test is unsatisfactory, the continuity fault in the external cable circuit(s) must be traced and remedied (refer circuit diagram Fig. 37).

If the test is satisfactory, refit connector plug to the alternator and proceed to next test para. v.

**(v) Check Alternator Charging Current, and Alternator Controlled Voltage at the Battery Terminals.**

NOTE: In addition to the voltmeter used in the previous test (para. iv), unless the installation is fitted with an ammeter, it will be necessary to connect a test-ammeter, 0-60A range, in series with the cable(s) connected to the main output '+' terminal of the alternator. (This can be achieved by connecting the ammeter in series with the brown-coloured 'eyeleted' alternator cable(s) attached to the main input terminal of the starter solenoid. Connect ammeter negative-side to solenoid terminal and positive-side to cable eyelet).

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

Start engine, increase speed (ignore voltmeter at this stage) and observe the ammeter reading.

If ammeter registers zero amps, 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, 13.6-14.4V 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.

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 para. (vi) 'Charging Circuit Volt Drop Testing'. If the volt drop tests are satisfactory, remove the alternator from the vehicle and proceed to 'Bench Testing'.

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## CHECKING THE CHARGING SYSTEM (Cont'd)

### (vi) Charging Circuit Volt Drop Testing

Check for a high resistance fault in the charging system, by carrying out two separate volt drop tests on the insulated-side and earth-side of the charging circuit. The tests must be carried out with all the alternator cables connected. (The connector plug is open-ended to facilitate testing). Switch on the head-lamps or introduce a similar load to the charging system and run the engine at a fairly high speed (simulating normal working speed), and connect the voltmeter as follows:

Insulated-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 0–0.5V.

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

Earth-side volt drop test.

Connect a voltmeter between the alternator frame and the '-' (earth) terminal of the battery. (Voltmeter black lead to alternator and red lead to battery).

The test is satisfactory if the voltmeter registers 0–0.25V.

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

### (b) BENCH TESTING

**NOTE:** The test rig must be capable of varying the alternator speed from zero to 6,000 rev/min. 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 installation, 14/010 (14/0.25 mm.) grade for the 'IND' field circuit cables and 120/012 (120/0.30 mm.) grade for the main terminal(s) and earth 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, similar to the circuit shown in Fig. 37 but using direct connections between the alternator, warning light (12V 2.2W), and the test battery.

Include in the test circuit: a 0–60A moving-coil ammeter in series with the alternator main output '+' cable and connect in parallel across the battery terminals a 0–20V moving-coil voltmeter and a 15 ohm 35A variable load resistor. The warning light should be illuminated, in which case proceed direct to first test para. (i) 'Alternator Output Test with Regulator Inoperative'.

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. Check in the following order: regulator, brushes-and-springs and rotor slip-rings, rotor field-winding continuity.



## CHECKING THE CHARGING SYSTEM (Cont'd)

## Regulator

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.

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. 35).

## FAULT SYSTEMS

Warning Light	Alternator			Probable Fault (Associated Damage)
	Temperature	Noise	Output	
Illuminated at stand-still, extinguished at cut-in speed (1,500 rev/min.) but at higher speeds becomes partially illuminated again and gets progressively brighter	High	Normal	Higher than normal at 6,000 rev/min. Approximately: 38A – 17ACR 50A – 18ACR	Live-side main output diode open-circuit. (May damage rotor field winding and regulator, overheat brush-boxes, and fuse warning light bulb)
Not illuminated between zero and 1,500 rev/min.	High	Excessive	Very low at 6,000 rev/min. Approximately: 10A – Both models	Live-side main output diode short-circuit. (May damage associated 'field' diode).
Illuminated at stand-still, dims appreciably at cut-in speed (1,500 rev/min.) and gets progressively dimmer or may be extinguished at higher speeds.	Normal	Excessive	Poor at low speed. Slightly below normal at 6,000 rev/min. Approximately: 30A – 17ACR 40A – 18ACR	Earth-side main output diode open-circuit
Illuminated at stand-still, dims appreciably at cut-in speed (1,500 rev/min.) and gets progressively dimmer or may be extinguished at higher speeds.	Normal	Normal	Lower than normal at 6,000 rev/min. Approximately: 29A – 17ACR 35A – 18ACR	'Field' diode open-circuit.
Illuminated at Stand-still, dims at cut-in speeds (1,500 rev/min.) and remains dim, but may be extinguished at very high speeds.	Normal	Excessive	Very low at all speeds above cut-in (1,500 rev/min). Approximately: 7A – both models	Earth-side main output diode short-circuit, or stator winding short-circuit to earth.
Illuminated at stand-still dims at cut-in speed (1,500 rev/min.) and remains dim, but may be extinguished at very high speeds.	Normal	Excessive	Very low at 6,000 rev/min. Approximately: 7A – both models	'Field' diode short-circuit.

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## CHECKING THE CHARGING SYSTEM (Cont'd)

### Brushes-and-springs and rotor slip-rings.

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 ins.) 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 ins.).

While the brushbox moulding is removed, check rotor field winding continuity.

### Rotor field winding continuity.

Check the rotor field winding continuity, by connecting a battery-operated ohmmeter or a 12V battery test-lamp between each of the rotor slip-rings. The ohmmeter should register a reading or the test lamp should light.

If the test is unsatisfactory, renew the rotor (refer to 'Dismantling') and then proceed to para. (i) 'Alternator Output Test with Regulator Inoperative'.

### (i) Alternator Output Test with Regulator Inoperative

Make the regulator inoperative, by linking its green lead ('F' terminal) to alternator frame. A model 14TR regulator does not incorporate a green lead (the 'F' terminal being via the regulator case), in which case connect the regulator case in alternator frame.

Run the alternator in the test rig at a slowly-increasing speed. At the cutting-in speed of 1550 r.p.m. max. the warning light should be extinguished.

If the warning light is not extinguished, the suppression capacitor 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 must be dismantled for detailed inspection to determine and rectify the fault. (Proceed to 'Dismantling, Inspection and Electrical Testing of Components').

~~Providing the first half of the test is satisfactory (warning light extinguished), increase alternator speed to 6,000 rev/min. and adjust the variable load resistor until the voltmeter registers 13.6V. The ammeter should register the maximum rated output of the alternator. (Refer TECHNICAL DATA).~~

If this second half of the test is unsatisfactory, the suppression capacitor 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. (Refer 'Dismantling, Inspection and Electrical Testing of Components').

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 symptom table shows how diode failure will influence alternator output test results, and para. c (iii) gives information on testing the diodes.

## CHECKING THE CHARGING SYSTEM (Cont'd)

## (ii) Regulator Test (in situ)

NOTE: This test assumes the alternator output test (para. i) 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.

Run the alternator at 6,000 rev/min, until the ammeter registers less than 10A. If the voltmeter registers 13.6–14.4V, the regulator is working normally. If the voltmeter reading is outside the limits specified, the regulator must be renewed.

## (c) Dismantling, Inspection and Electrical Testing of Components

## (i) Preliminary dismantling.

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 (c) iv 'Further Dismantling'.

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

Note the arrangement of the stator winding connections to the rectifier diode connecting pins, and then using a thermal shunt (see Fig. 44) and a light-weight soldering iron (e.g. 25-watt) unsolder the connections to the rectifier.

Refer to Fig. 35 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 dis-connected from the rectifier.

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

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 as detailed in the following paras. (ii) and (iii).

## (ii) Inspection of brushgear and rotor slip-rings.

## Brushgear

Renew the brush-and-spring assemblies if the overall length of the brushes are worn to, or approaching 8 mm. (0.3 ins.). 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 brushbox 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 255 to 368 gf (9 to 13 ozf).

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## CHECKING THE CHARGING SYSTEM (Cont'd)

### 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.

### (iii) Electrical testing of components.

NOTE: For clarity, illustrations of electrical testing show the components separated from the rest of the alternator.

### Rotor field winding

Check field winding continuity and resistance simultaneously, by connecting either a battery-operated ohmmeter (see Fig. 38) or a 12V battery and moving-coil ammeter (see Fig. 39) between the slip-rings. The ohmmeter should indicate the appropriate resistance given in TECHNICAL DATA, or the ammeter should indicate a current approximate to the figure obtained by dividing the appropriate resistance of the rotor into the battery voltage (12).

Check for satisfactory field winding insulation, by connecting a 110V a.c. 15-watt test lamp (see Fig. 40) between either of the slip-rings and the rotor body. The lamp should not light.

### Stator windings

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. If this is the case, renew the stator assembly without the need for further testing.

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-watts (see Fig. 41). 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. 42). The lamp should not light.

### 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 undergoing is soldered (see Fig. 43). 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.

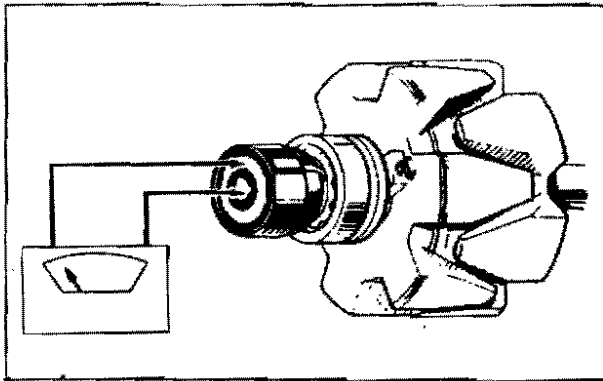


Fig. 38 – Measuring rotor winding resistance with ohmmeter

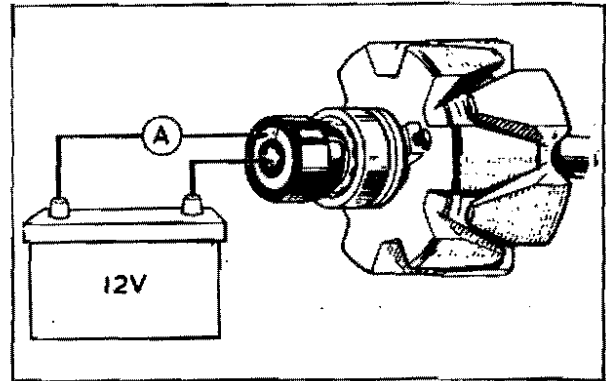


Fig. 39—Measuring rotor winding resistance with battery and ammeter

CHECKING THE CHARGING SYSTEM (Cont'd)

NOTE: During reassembly of the alternator, 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. 44).

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.

Surge protection device (avalanche diode) and suppression capacitor, (when fitted).

Both these components should be proved by disconnecting them in turn during bench testing. If the alternator then performs satisfactorily, the component should be renewed.

(iv) Further dismantling

In reference to preliminary dismantling para. (i), if it is necessary to extend dismantling to enable the bearings or other faulty parts to be renewed, proceed as follows:

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 three major parts.

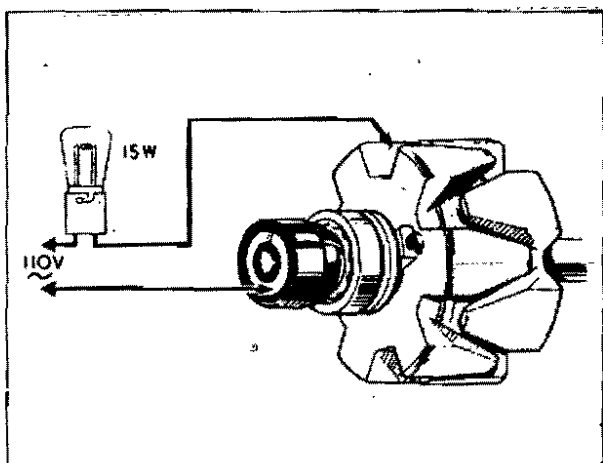


Fig. 40 – Insulation test of rotor winding

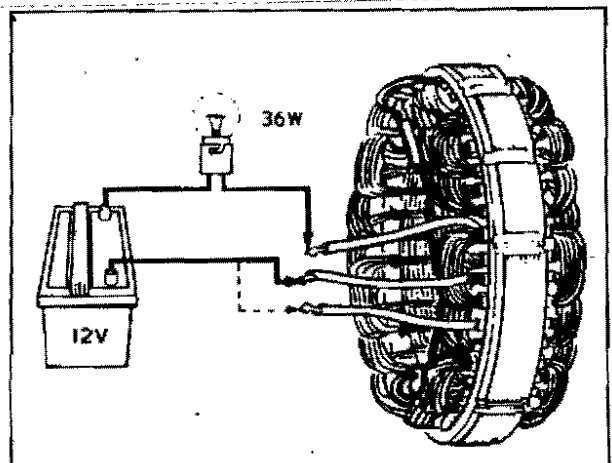


Fig. 41 – Stator winding continuity test

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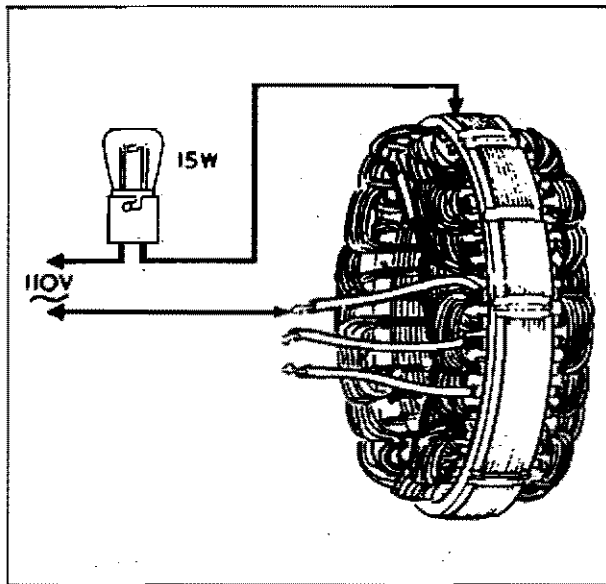


Fig. 42 – Stator winding insulation test

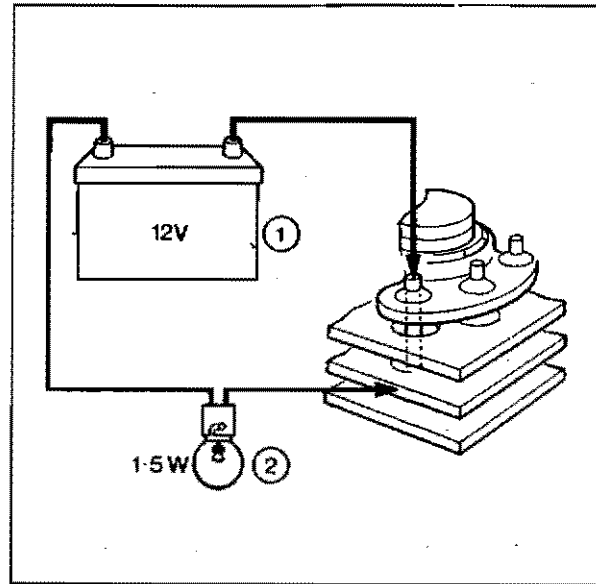


Fig. 43 – Simple test for diodes

## CHECKING THE CHARGING SYSTEM (Cont'd)

Slip-ring end bracket.

Stator laminations-and-windings

Sub-assembly comprising:

Fan and pulley

Drive-end bracket and bearing

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, then press the rotor shaft from the bearing in the bracket. Alternatively, use the open jaws of a vice to support the bracket and carefully drive the rotor shaft from the bearing by a series of light blows applied to the end of the shaft with a hide, plastic, or wooden mallet. (Open the jaws of the vice sufficient only to clear the rotor poles; position the bracket off-set to the centre of the top of the vice to avoid the slip-ring moulding fouling the bottom of the vice, and temporarily fit the shaft nut flush with the end of the shaft to avoid damage to the shaft threads by the mallet).

If it is necessary to renew either the slip-ring moulding assembly or slip-ring end bearing, the slip-ring moulding assembly can be withdrawn from the keyway in the rotor shaft after the field winding connections have been unsoldered. (Use a light-weight soldering iron, e.g. 25-watt, and for re-soldering the connections use only resin-cored solder).

**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.

## CHECKING THE CHARGING SYSTEM (Cont'd)

## Renewing the bearings

After removing the slip-ring moulding from the rotor shaft (refer para. prior to the heading 'Bearing'), the slip-ring end bearing can be removed from the rotor shaft and then either renewed or if otherwise satisfactory re-packed with grease lubricant (refer 'Lubrication of bearings'). Position the two halves of the support plate of hand-operated power press 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.

**NOTE:** When refitting the bearing, ensure the shielded side of the bearing faces the slip-ring moulding.

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.

**NOTE:** When refitting the bearing, ensure correct sequence of assembly of sundry parts associated with the bearing. (See Fig. 35).

## Lubrication of bearings

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 (slip-ring moulding removal is dealt with in the paragraph prior to the heading 'Bearings' and bearing removal is dealt with under the heading 'Renewing the bearings').

**NOTE:** 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).

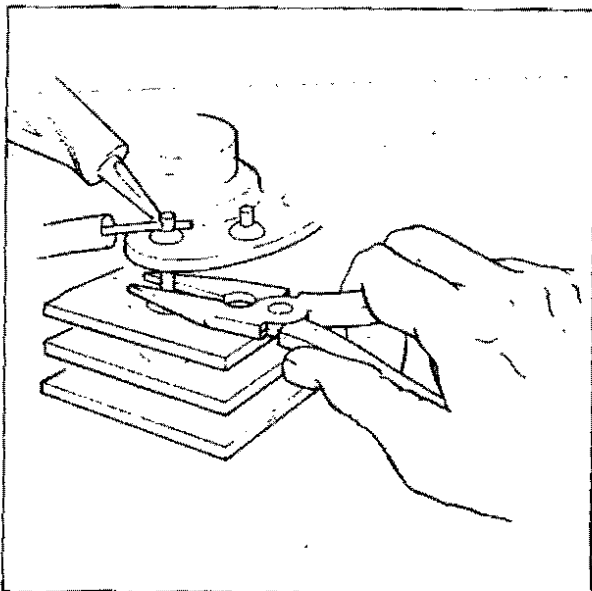


Fig. 44 – Use of thermal shunt when soldering diode connections.

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## CHECKING THE CHARGING SYSTEM (Cont'd)

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.

### (d) Reassembly

Reassembly of the alternator is simply a reversal of the dismantling procedure.

However, it should be noted that the sub-assembly comprising rotor and drive-end bracket, stator assembly and slip-ring end bracket (secured by three through bolts) can be incorrectly assembled in two or three alternative ways which causes misalignment of the alternator fixing lugs of each end bracket.

Assuming the rotor assembly to be already fitted in the drive-end bracket, misalignment of the end brackets previously referred to can be avoided by first fitting the stator assembly correctly in the drive-end bracket. (In preference to first fitting the stator assembly in the slip-ring end bracket).

Fit the stator assembly in the drive-end bracket so that the stator connecting leads are positioned between and in line with 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 (0.64 kgf m or 55 lbf in).

## THE AC 5 ALTERNATOR

### 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 12 volts maximum).
- (j) NEVER use a lever on the stator or rear housing when adjusting the fan belt.
- (k) NOTE the polarity of connections to battery, alternator and voltage regulator. Incorrect connections may result in irreparable damage to semi-conductor devices.



## TYPE ACS ALTERNATOR

The alternator (Fig. 45) is a three phase machine of the revolving field and stationary armature type and is self limiting in current output. Rectification of the output into direct current is provided by means of six silicon diodes contained in the slip ring end shield and connected in a three phase bridge circuit between the stator and output terminals. A second rectifier bridge is formed by using three auxiliary diodes in conjunction with three of the six main diodes and these supply the energy for the alternator field coil which is fed through slip rings and brushes. This arrangement of auxiliary diodes prevents the battery from discharging through the field coil when the alternator is stationary.

The rotor is supported by sealed ball bearings housed in the end shield, which are secured to the stator by through bolts. A moulded brush box containing the two brushes is positioned in a sealed compartment in the end shield. Cooling is carried out by air blow through the alternator, induced by a radial fan at the drive end. The heat sinks in which diodes are fitted are also finned to assist heat dissipation.

A baffle and seal fitted at the slip ring end provides for limited protection against the entry of foreign matter.

The voltage regulator is a fully transistorised unit and contains no moving parts. Being sealed at the time of production, adjustments or repairs are not possible. Should a fault be attributed to the regulator, it must be renewed.

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Fig. 45

## Key to parts

- |                                   |  |
|-----------------------------------|--|
| 1. Brush                          | 20. Pulley nut                                 |
| 2. Gasket                         | 21. Fan  |
| 3. Brush holder                   | 22. Drive end shield swing mounted double hole |
| 4. Lucar blade                    | 23. Bearing spacer                             |
| 5. Field terminal nut and washers | 24. Drive end shield cradle mounted            |
| 6. Retaining screw and washers    | 25. Circlip                                    |
| 7. Insulator                      | 26. Slip rings                                 |
| 8. Grommet                        | 27. Heat sink securing screw                   |
| 9. 'A' lead                       | 28. Diodes and heat sink assembly              |
| 10. 'O' ring                      | 29. Slip ring end shield                       |
| 11. Stator                        | 30. Round slotted nut                          |
| 12. Bearing                       | 31. Insert                                     |
| 13. Rotor                         | 32. Baffle screw                               |
| 14. Woodruff key                  | 33. Baffle                                     |
| 15. Clamp plate                   | 34. Main terminal nut                          |
| 16. Bearing                       | 35. Lucar blade                                |
| 17. Through bolt                  | 36. Shroud                                     |
| 18. Drive end shield              | 37. Cowl                                       |
| 19. Fan spacer                    |  |

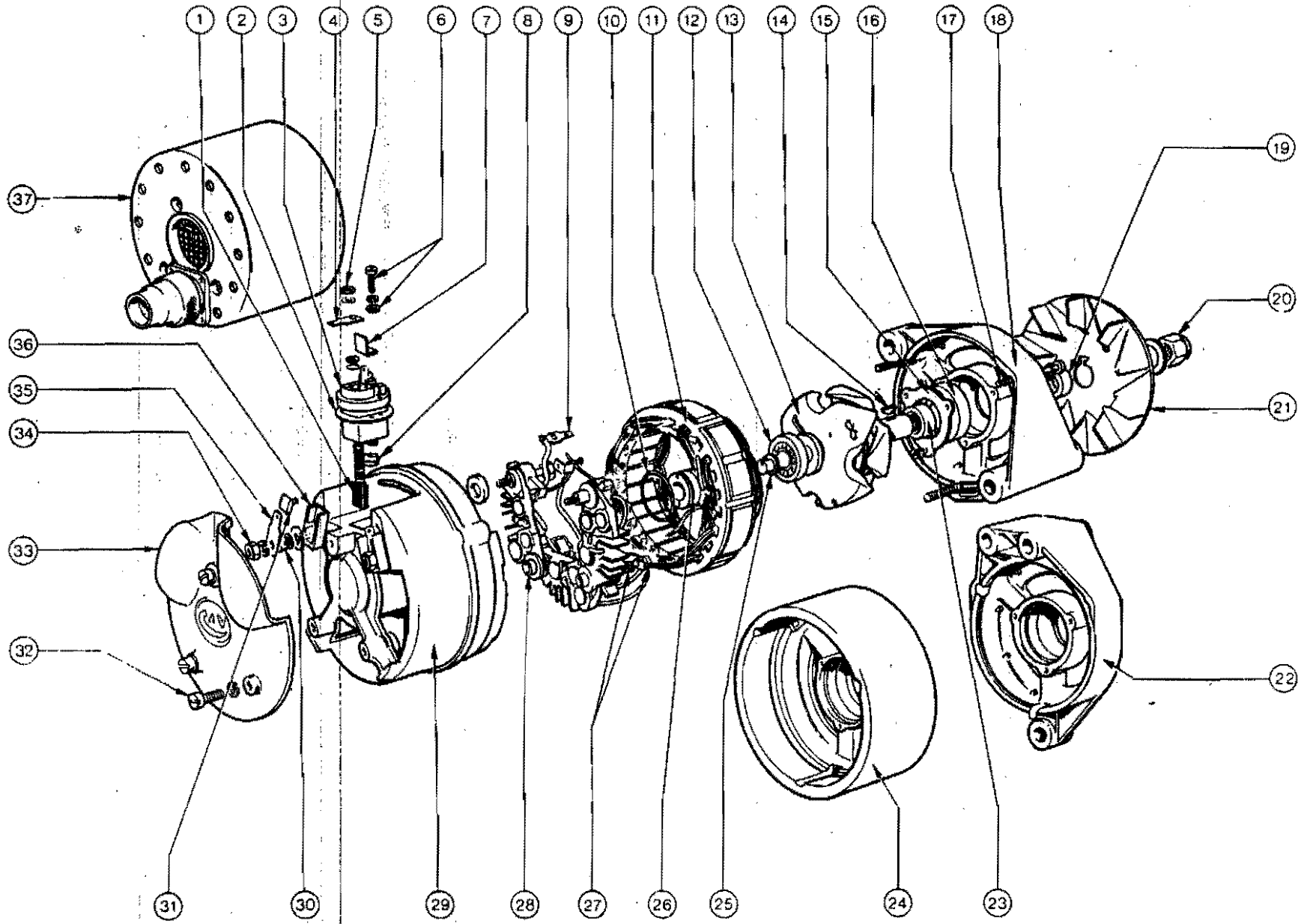
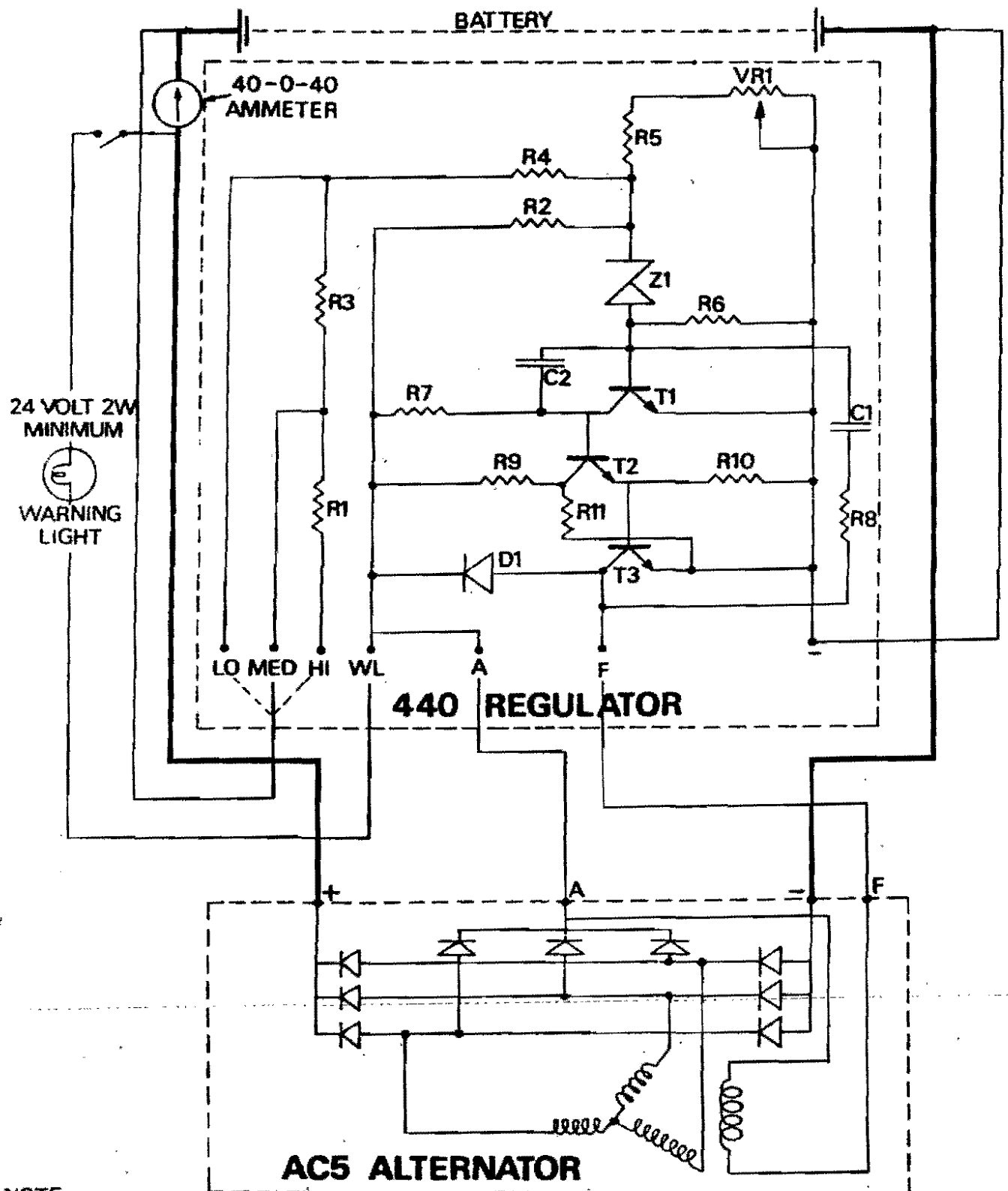


Fig. 45 AC5 Alternator Exploded view



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Fig. 46 Schematic Wiring Diagram of 24 volt AC5 System

## OPERATION

### Operation of the System

Each AC alternator and its associated regulator operates as a system to charge and maintain the battery in a charged condition. Operation is such that a flat battery will be charged in a minimum of time and a good battery will be held in that condition by a trickle charge. The alternator cannot be overloaded since the machine is designed to be self limiting in current output.

The initial field excitation is supplied from the battery through the warning light or equivalent resistance, when the start switch is closed, connected as shown in Fig. 46. The voltage generated from the initial field excitation is rectified by the three auxiliary diodes (in conjunction with three main diodes) and supplements the field current from the battery to rapidly build-up the voltage to the full battery value. At that moment, the potential of point A is equal to that of the alternator positive terminal, consequently the warning light is extinguished and all the field current is now supplied from the alternator terminal A. When the voltage at terminal A rises in excess of battery voltage, the value at the alternator positive terminal will also rise and charging current will be supplied to the battery. Terminal A will not supply any charging current to the battery, but will supply any load connected between P and negative. See Fig. 47.

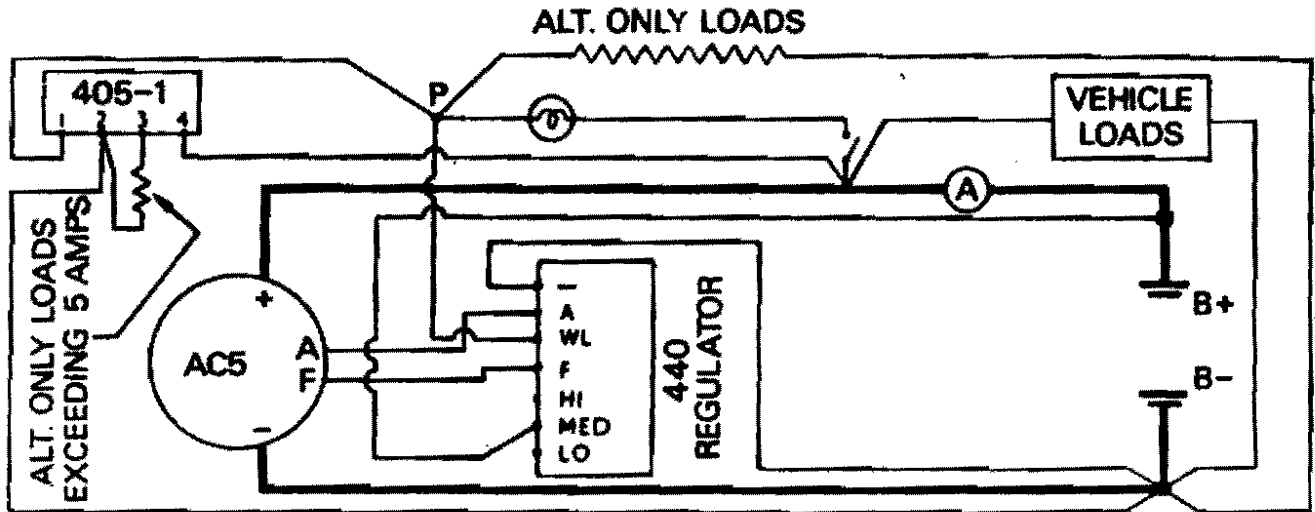
The function of the regulator is to control the alternator output voltage. This is done by rapidly switching on and off the alternator field voltage by means of transistors, while a Zener diode provides the voltage reference.

When the alternator is running, the regulator is supplied by three auxiliary diodes (see Fig. 48) mounted in the alternator end shield. By virtue of the connection through R7, the base circuit of transistor T2 is conducting so that by normal transistor action, current also flows in the collector-emitter of T2 which thus acts as a closed switch and allows the base circuit of T3 to conduct. Again by normal transistor action, T3 acts as a closed switch and allows full voltage to appear across the alternator field. The rising voltage appears across the potential divider consisting of R3, R4, R5 and VR1. According to the setting of the potentiometer VR1 a proportion of this potential is supplied to the Zener diode Z1, a device which only conducts when a certain voltage across it is reached. Therefore the Zener diode conducts when the alternator output voltage rises to a predetermined value and current flows in the base circuit of T1. T1 now acts as a closed switch and diverts the current supplied to the base circuit of T2 which therefore switches off, causing T3 to switch off the field supply.

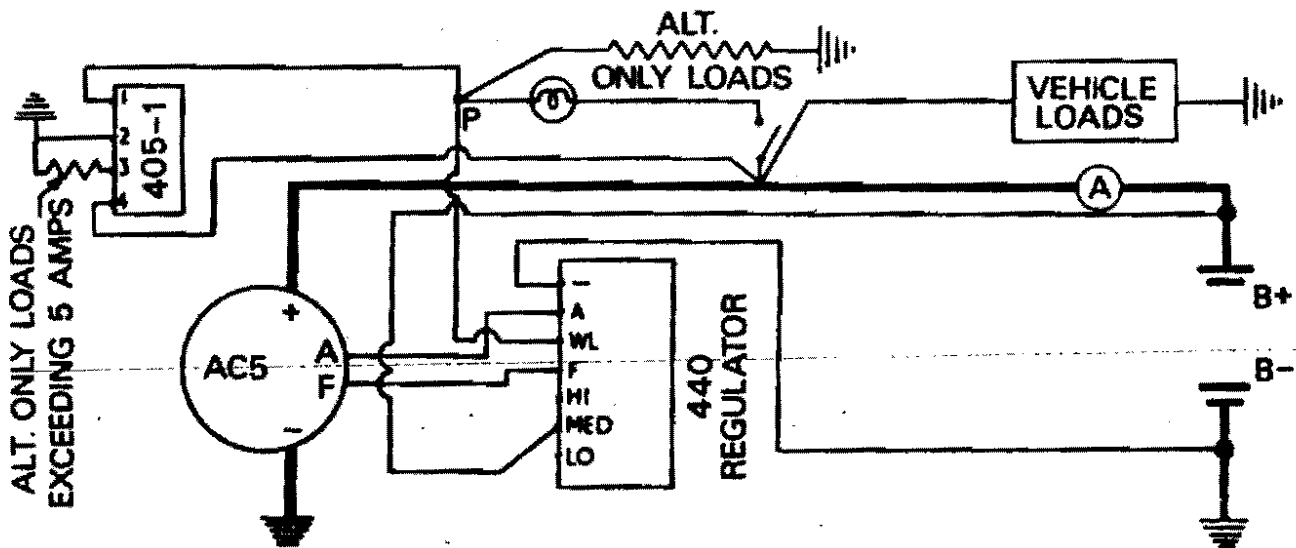
Since the field supply is removed the alternator output voltage falls and this fall is sensed by Z1, which no longer conducts and causes T1 to switch off. Now the base current is supplied to T2 which switches on, thus switching on the power transistor T3. Again full voltage is supplied to the alternator field and the line voltage is restored, initiating the action previously described.

The principle of operation of the 440 regulator requires certain necessary additions. Fast switching of the power transistor T3 is desirable to reduce internal heat generation and this is achieved by positive feedback via capacitor C1 and resistance R8, which allows T1 base to sense any change of state of T3 and thus speed up the change.

Diode D1 is a discharge path for the field current when T3 switches off, preventing generation of high reverse voltage across the transistor. Capacitor C2 between the base and collector of T1 prevents ripple on the rectified output from adversely affecting regulation.



1. INSULATED RETURN



2. NEGATIVE EARTH RETURN

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Fig. 47 Theoretical Circuits for 24 volt Systems

## CIRCUITRY AND CONNECTIONS

The standard alternator is produced as an insulated return machine but it can be installed in a positive earth return or negative earth return system connecting either its positive or negative terminal to earth (vehicle chassis) as appropriate. Typical circuit diagrams are shown in Fig. 47.

### 'ALTERNATOR ONLY' LOADS NOT EXCEEDING 5 AMP. 24 VOLT OR 10 AMP. 12 VOLT

These are loads only in circuit when the alternator is generating. The continuous DC load should not exceed 5 amp. (24 volts) or 10 amp. (12 volt) otherwise the alternator could be prevented from building up to its rated output.

### 'Alternator only' loads exceeding 5 amp. 24 volt or 10 amp 12 volt

When equipment such as heaters, demisters etc., are wired into the system to be operable only when engine is running, a type 405 relay box must be installed in the circuit. These loads must not exceed 15 amp. inductive or 22 amp. resistive.

### 'Sensing' leads

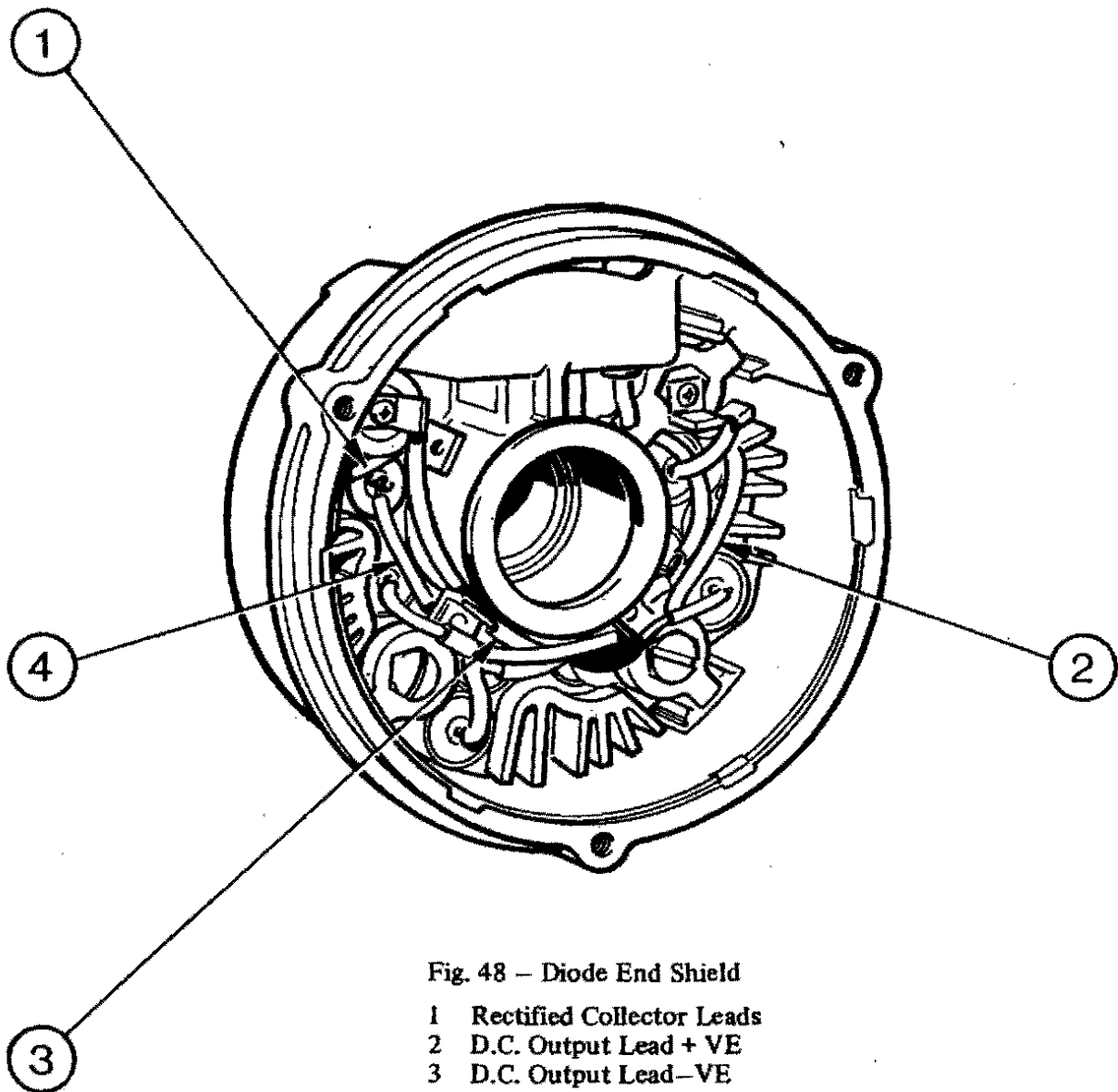
The 'Sensing' leads from the 440 regulator terminals negative (—) and positive (HI, MED or LO whichever is applicable) should be connected as close to the battery as possible. Their combined voltage drop must not exceed 0.25 volt at 2.5 amp. (24 volt system) or 0.3 volt at 3.6 amp. (12 volt system). Connections to the vehicle frame or chassis must not be used for these 'Sensing' circuits. This means that it is necessary to use two wires, both of which return to the battery.

## MAINTENANCE

Normally the charging system will require very little attention but it should be kept free from build-up of dirt and a check made if it fails to keep the battery charged. This may be due to a slipping drive belt.

1. Occasionally inspect the driving belt for wear and correct tension and see that the alternator is properly aligned with respect to the drive. A slack belt will wear rapidly and because of slip may not drive the alternator at the required speed. Too tight a drive belt will impose a severe side thrust on the alternator bearings and shorten their life. Check with the engine hand book for correct belt tension.

## MAINTENANCE (Continued)



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2. — Keep the alternator reasonably clean with a cloth moistened in paraffin or white spirit. Ensure that ventilation slots and air spaces are clear and unobstructed.

3. Remove any dirt accumulated on the regulator housing and ensure that cooling air can pass freely over the casing

## CHECKING OPERATION OF SYSTEM ON THE EQUIPMENT

The AC5 generator system is so designed that a flow of current indicated either by the extinguishing of the warning light or as shown on an ammeter is sufficient evidence that the system is in proper working order

Accordingly, no open circuit voltage, or current output checks should be performed on the vehicle installation UNLESS:—

## CHECKING OPERATION OF SYSTEM ON THE EQUIPMENT (Continued)

- (a) The warning light fails to illuminate when the generator is stationary and the switch is closed, or fails to extinguish when the generator is running.
- (b) No charging current shows on ammeter.
- (c) The battery is flat.
- (d) The battery is 'boiling', indicating loss of voltage control.

In any of the above conditions the procedure indicated in the "Fault Finding" section of this manual should be followed in order to trace the sources of trouble.

Unless a fault occurs the voltage setting will remain constant throughout the life of the equipment and it is normally only necessary to check the function and wiring of the system when first installed on the vehicle. This should be carried out as described in the following paragraphs.

## CHECKING OPERATION OF NEWLY WIRED SYSTEM

All terminal connections should be made as per wiring diagram Fig. 46 observing the following points:-

1. **OBSERVE POLARITY:—CARE MUST BE EXERCISED TO MAKE THE CORRECT CONNECTIONS TO THE REGULATOR. WRONG CONNECTIONS OR SHORT CIRCUITS HOWEVER BRIEF, CAN CAUSE IRREPARABLE DAMAGE. (A clip-on multi-connector plug to prevent reversed connection of the wiring harness to the regulator, and an 'inhibitor' type connector for the field terminals on the brush box are available if required).**
2. **DO NOT USE INSULATION TESTERS ON REGULATOR**
3. **DISCONNECT REGULATOR FROM THE SYSTEM PRIOR TO MAKING INSULATION TESTS ON THE WIRING.**
4. **TESTS FOR EARTH MAY BE MADE USING A 24 VOLT SUPPLY PROVIDING A SERIES RESISTANCE IS USED TO LIMIT THE CURRENT TO 0.5 AMPERE MAXIMUM.**

---

## FAULT FINDING

### Test Equipment Required

1. A British Standard first grade moving coil voltmeter, 0-50 volt range.
2. A British Standard first grade moving coil ammeter, 0-100 amp. range

### Test Procedure

Connect the voltmeter across the battery or regulator negative terminal and one of the three positive terminals marked LO, MED, HI.

Connect the ammeter in the alternator positive line as shown in the wiring diagram Fig. 46.



### FAULT FINDING (Continued)

The system is in correct working order when the following sequence is observed:—

Note: The battery should be in a charged condition.

1. Close the 'Start' switch and observe that the warning light (if fitted) illuminates.
2. Connect a lamp load (about 100 watts) across the battery.
3. Start the engine and allow it to run at a fast idling speed.  
Observe that:—
  - (a) The warning light (if fitted) is extinguished.
  - (b) If no warning light is fitted, the ammeter records a small charging current, dependent on idling speed.
4. Momentarily increase the engine speed to maximum r.p.m. and observe that charging current is about 30 amp. for 24 volt system; and 53 amp. for 12 volt system. (40 amp. for low cutting-in-speed version).
5. With the alternator running at approximately half speed, switch off all the lights. Depending on the connection selected for the positive sensing wire (LO, MED, or HI) the voltage should rise to between 26 and 28 volt on 24 volt systems (13-14 volt on 12 volt system) and then remain constant. At the same time the current reading should drop appreciably.

Should there be a fault in the system this will be apparent by one or more of the following symptoms:—

6. On installations which incorporate a warning lamp the correct functioning of the lamp (lighting upon closing of the 'start' of ignition switch and extinguishing when idling speed is exceeded) is an indication that the system is charging. If no light is observed check the bulb and renew it if it is defective in any way.
7. If the bulb is serviceable and still no light appears, check the regulator by first switching off the 'start' switch and disconnecting the lead from the F terminal on the regulator. Clip this lead to the negative terminal on the regulator and switch on the 'start' switch. If the light now appears the regulator is faulty and must be replaced by a new regulator. (The regulator is a sealed non-repairable unit). If no light appears, then the alternator is faulty and requires workshop attention. Tests as described in Paras. 9 - 12 may be used to locate the alternator fault. Having located the fault, switch off and reconnect the F lead to its correct position on the F terminal.

#### 8. Field Winding

Disconnect the leads from the F and A terminals on the alternator and remove brush gear moulding (see section on dismantling). Check field resistance across the slip rings which should be:—

AC5/12	3.2 ohm )
AC5/24	9.6 ohm ) $\pm 5\%$

Note:— An appreciably lower field resistance could mean a short circuit between the coils; a higher reading advises that the contact surfaces of the slip rings need cleaning. An infinity reading would indicate an open circuit in the field.

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## FAULT FINDING (Continued)

### 9. Brushes

Assuming the field resistance is correct check that the brush length is above the minimum length of 7.94 mm. (0.312 in.) and that they make proper contact with slip rings. Check also that the brushes move freely in their holders, if at all sluggish, lightly polish the brush sides with a smooth file. Remove all traces of dust before refitting the brushes to the holders.

### 10. Slip Rings

The surface of the slip rings should be smooth and uncontaminated by oil or other foreign matter. The surface may be cleaned with a piece of very fine glass paper without fully dismantling the machine.

### 11. Stator Winding

Low output or none at all from the alternator might be due to either a faulty stator or a faulty diode. It is difficult to distinguish between the two faults without dismantling the machine. In these circumstances it is advisable to separate the stator from the rest of the machine and measure the volt drop across each pair of three stator connections as described under 'Checking'.

## DISMANTLING PROCEDURE

### General

1. Unscrew the three screws and detach the baffle or cowl from Slip Ring End (SRE) Shield.
2. Disconnect lead from terminal A of brush box, remove retaining screws, spring and plain washers, and withdraw brush box complete with brushes. Discard gasket.
3. Remove field terminal retaining nuts, crinkle washers, Lucar blades and insulator from terminal posts. Withdraw brushes and field terminal posts from brushbox. Discard sealing washers.
4. Remove pulley nut from Drive End (DE) and withdraw pulley, fan, woodruff key and fan spacer.

Before proceeding further a line should be lightly scribed across both end shields and stator to facilitate alignment on reassembly.

5. Remove the three through bolts and spring washers and withdraw the DE shield complete with rotor. When 'Loctite' grade A has been used to secure the through bolts, local heat should be applied with a heated soldering iron, or a small flame to loosen them. No part should be overheated. If necessary use a hide faced mallet and gently tap the DE shield away from the stator and SRE shield. Do not damage the slip ring when laying DE shield and rotor assembly on the bench.

Note:—The stator is sandwiched between the two endshields, and great care must be exercised at this stage to prevent the full weight of the stator from falling onto the three stator phase leads.

6. Lay the stator and SRE shield assembly carefully on the bench; endshield uppermost.
7. Unsolder the three stator phase leads from the heat sink terminal tags, (DO NOT REMOVE TAGS FROM HEAT SINKS) and separate SRE shield from stator, using a hide faced mallet if necessary.

## DISMANTLING PROCEDURE (Continued)

8. Remove and discard 'O' ring from SRE shield bearing housing, using a sharp pointed probe. Do not damage the 'O' ring groove.
9. Place the DE shield (drive shaft upwards) over a suitable large diameter cylinder so that the rotor is encased within the cylinder, and the cylinder seats squarely against the three end shield webs. (N.B. a discarded 4.0 in. to 4.5 in. starter motor or dynamo yoke is admirable for this operation, but care must be exercised to ensure the end face of the yoke does not cut into the web radii). Support the rotor from underneath and gently press the rotor from the DE shield with a standard fly-press.

Note: It is unnecessary to strip the diode assembly from the SRE shield unless it is established that there is a fault in one or more of the diodes. Accordingly, the diodes should next be subjected to the tests detailed under SLIP RING END SHIELD DIODE TESTS of the Test Section of this manual. If a faulty diode is detected proceed as instructed in Inspection and Repair Section — Diode replacement.

## INSPECTION AND REPAIR

## General

After dismantling, all components which require cleaning should be thoroughly cleaned.

1. Examine all parts generally for cracking, corrosion, serviceability of threads, score marks and excessive wear. The "Nyloc" pulley nut can be used again provided the nylon insert is in reasonable condition.
2. Remove foreign material from rotor shaft and stator, using a clean cloth moistened with white spirit.

**CAUTION:** Spirit should not be allowed to contact leads of stator and must not contaminate the protective coating of the rotor core.

3. Examine stator windings for security and condition. Check stator leads for deterioration of insulation.
4. Check bearings for excessive play and smoothness of operation. Since the bearings are sealed and cannot be lubricated, any evidence of dryness will necessitate renewal. Note: If the SRE bearing requires replacement, it will be necessary to renew the slip-ring as well. (See appropriate section under Bearing Renewal).
5. Examine slip rings for signs of wear and scoring. The slip rings may be skimmed to a minimum diameter of 28.85 mm. (1.136 in.) before replacement is necessary. (See under Bearing Renewal — Slip-Ring End Shield, item 19).
6. Check carbon brushes for wear. New brushes are 15.9 mm. (0.625 in.) long and the minimum length of usable brushes is 0.312 in. (7.9 mm.). Brushes worn below this minimum length should be discarded and new brushes fitted.

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## BEARING RENEWAL

### Drive End

7. Remove the three screws and washers securing the clamp plate and push out the bearing with a suitable drift.

Note:- On early production models a star tolerance ring was fitted in the drive end shield to locate the bearing and the latter was secured by a circlip. The star tolerance ring and circlip must be dispensed with as with excessive drive belt tension service life of the bearing could be greatly reduced. This type of end shield must therefore be replaced by a conventional end shield having a bearing liner and clamp plate.

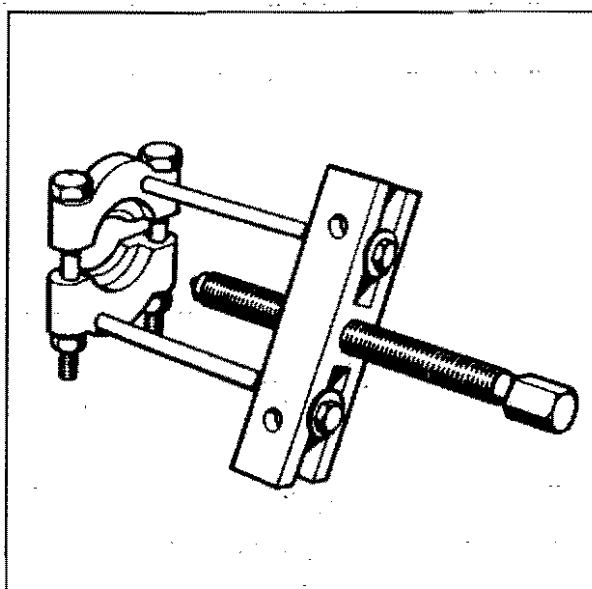


Fig. 49 – Sykes type race puller.

8. Fit a new bearing to the housing by pressing it in, ensuring that the bearing remains perfectly square to the housing.

9. Place clamp plate in position and secure with three screws and washers.

### Slip Ring End

10. Cut the ends of the field leads free from the slip ring terminal posts.

11. Using extractor shown in Fig. 49 withdraw the slip ring assembly. Removal of the slip ring will render it unserviceable and a new one must be fitted.

12. Remove bearing circlip. Adjust the jaws of bearing extractor so that the jaws locate between the outer race and the bearing spacer and withdraw bearing.

13. Examine bearing spacer for cracks and distortion. Clean out groove. Renew spacer if damaged.

14. Detaching the rotor leads from the slip ring assembly imposes mechanical stresses that may weaken the leads and produce the possibility of failure under operating conditions at a later date. It is strongly recommended that the leads are renewed in the following manner:—

## BEARING RENEWAL (Continued)

Cut the leads so that the subsequent joints are staggered as shown in Fig. 50 (A). Trim back the glass-fibre sleeving and lightly twist a new length of Lumex copper wire (21.5 swg for 12 volt alternator; 23.5 swg for 24 volt alternator) to the existing wire and solder together. Snip off excess wire. Apply a liberal coating of shellac and slide a short length of 2 mm. glass-fibre sleeving over the join so that it slides inside the existing sleeve, Fig. 50 (B). Apply a further coating of shellac and slide on a new length of 3 mm. glass-fibre sleeving to abutt the original sleeve. Apply a final coat of shellac to the outside.

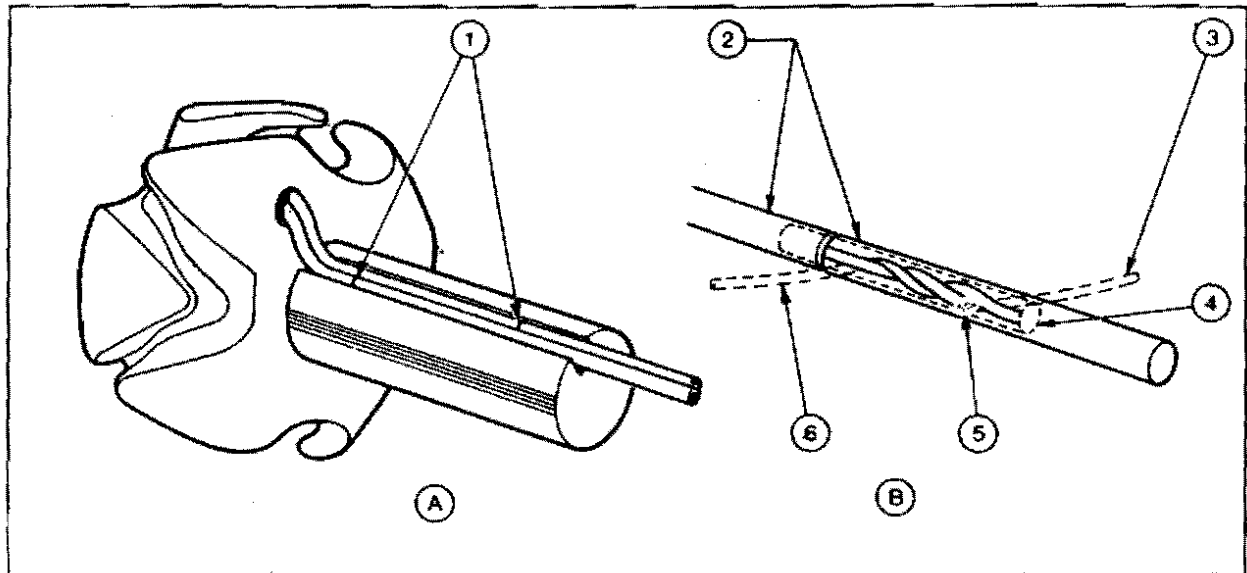


Fig. 50 – Renewing the slip ring connecting leads.

15. Refit the bearing spacer over the rotor shaft so that the moulded groove is in the correct position to contain the field leads from the rotor. Press into position. Press new bearing onto the rotor shaft with a suitable hand press. Refit the circlip, ensuring it is fully seated and a tight fit in its groove. Plug with 'SILCOSET' 151 any gap that appears where the leads enter the spacer between the spacer and the rotor claws. Wipe off any surplus 'SILCOSET' 151.

16. Place the rotor (drive end downwards) in a suitable fixture of a hand press so that the weight is supported on the rotor claws. Pass the two field leads through the bore of a new slip-ring and locate the slip-ring to the shaft with the terminal posts positioned at 90° relative to the shaft lead slot.

17. Place press tool (see Fig. 51) so that the spigot registers in the slip-ring bore with the cut-away portion in line with the field leads. Gently press the slip-ring down until the press tool spigot abutts the rotor shaft. Feed the field leads through cut-away portion of press tool as they appear.

18. Trim off the ends of the glass-fibre sleeve to leave approximately 6.5 mm (0.25 in) projecting beyond the rotor shaft. This will prevent the field leads from shorting onto the shaft during service. Wrap the field leads around the terminal posts of the slip ring, cut to length, and solder in position.

19. Mount the rotor in a suitable lathe, locating the steady on the outer race of the SRE bearing. Lightly skim the slip-rings to ensure that they are concentric with the SRE bearing to within 0.05 mm (0.002 in.). Remove the minimum amount of metal to achieve this degree of concentricity and do not reduce the slip-ring diameter to below 28.85 mm. (1.136 in.). To obtain the required surface finish, it is essential that a highly finished diamond or tungsten carbide tipped cutting tool be used for this operation.

## DIODE REPLACEMENT (SRE SHIELD)

Note: Individual diodes cannot be replaced and a fault in any diode will entail the renewal of the complete associated heat sink.

20. Carefully separate the Ross Courtney tag from the 'A' lead and pull the lead through the rubber grommet in the end shield. Remove and discard grommet.

21. (a) 12 volt machine and marine version

Remove external positive and negative main terminal nuts, spring washers, terminal post retaining nuts, spring and plain washers.

(b) 24 volt machine

Remove external positive and negative main terminal nuts, spring washers, and Lucar blades. Remove round slotted nuts, (using key see Fig. 52) spring and plain washers and nylon terminal shrouds. Later models have a plastic insert fitted to the shroud on the positive terminal.

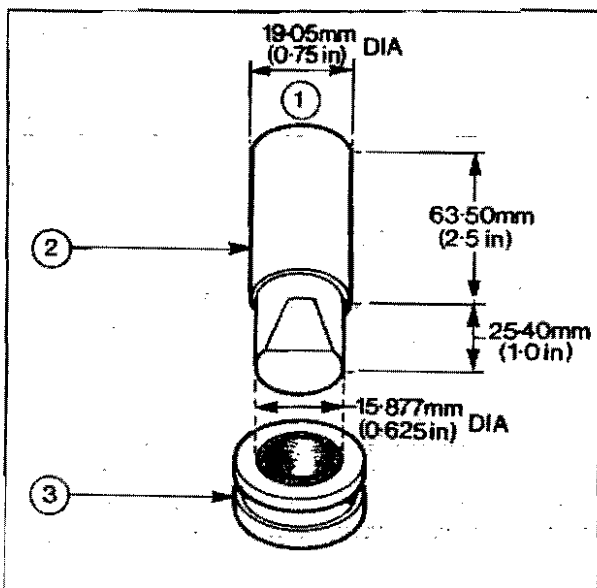


Fig. 51 - Slip Ring Press Tool

1. Mild Steel
2. Slip Ring Press Tool
3. Slip Ring

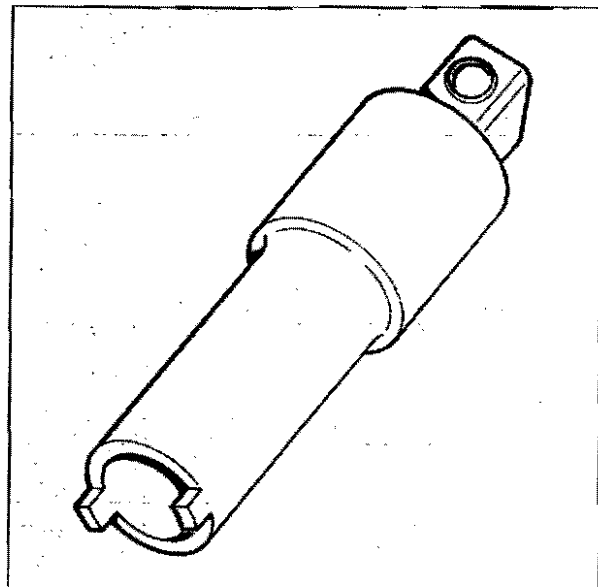


Fig. 52 - Key for Slotted Nut

22. Remove heat sink securing screws (two large cheese headed screws), spring and plain washers from underside of SRE shield. Withdraw complete heat sink assembly.

23. Snip the two copper braids of the faulty heat sink close to the angle terminal tags and unsolder the sleeved lead from the third diode. Remove appropriate nylon retaining washers and withdraw heat sink.

24. Assemble new heat sink (see parts list for identification) ensuring that nylon insulating washers are interposed between adjacent heat sinks. Replace outside nylon retaining washers.

25. Solder the diode braids to the appropriate angle tags (Note: the length of the braids are such that it is impossible to connect them incorrectly).

## DIODE REPLACEMENT (SRE SHIELD) (Continued)

26. Solder sleeved wire to remaining diode.

**WARNING:** Excessive heat can cause immediate and permanent damage to diodes. It is recommended that a pair of long nosed pliers be used to grip the diode shank to act as a thermal shunt and that the operation be carried out as quickly as possible.

27. Apply lamp test as detailed under Test Procedure Table (Page 32r) items 1 to 6, to ascertain that the diodes are functioning correctly.

28. Thread lead A through a new rubber grommet. (Supplied in seal and gasket set). If the lead is cotton braided it is advisable to replace this with a Unipren covered lead, size Unipren 4.

29. Replace heat sink assembly in SRE shield. Secure with the two cheese headed screws, plain and spring washers. Replace grommet and A lead, and re-fit Ross Courtney tag (or banjo tag).

30. Fit new 'O' ring (supplied in seal and gasket set) to groove in internal bore of slip-ring housing.

31. (a) 12 volt machine and marine version

Replace plain and spring washers, main terminal post retaining nuts, spring washers and main terminal nuts.

(b) 24 volt machine

Replace nylon terminal shrouds, plain and spring washers and round slotted nut. (Use key see Fig. 52). Replace Lucar blades, spring washers and terminal nuts.

## MAIN TERMINALS

These have been re-arranged on later 24 volt models to prevent accidental reversal of connections and consequent damage to the alternator. The positive terminal is distinguished by two flats along its threaded length, together with a plastic insert pressed into the insulating shroud. The plastic insert allows a standard Lucar connector with a standard sleeve to be connected to the positive terminal. The same standard Lucar connector is used on the negative terminal but this has an enlarged sleeve which cannot be connected to the positive terminal because of the insert.

The 12 volt models and marine versions are similarly provided with the positive terminal having 2 flats but have special Ross Courtney lugs fitted to the leads. On the positive side the hole in the lug is specially shaped and it will only fit the positive terminal.

To modify earlier models (if required) the positive terminal stud with 2 flats must be fitted in place of the original stud and the various additional parts added.

## CHECKING

Equipment required

1. A British Standard first grade moving coil DC ammeter 0-100 amp. range.
2. A British Standard first grade moving coil DC voltmeter 0-50 volt range.
3. A non-destructive 110 volts Flash Tester or 110 volts Megohm Meter.

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**CHECKING (Continued)**

**Rotor**

1. Using the insulation tester, subject the rotor to an insulation test at 100 volt between each slip-ring and the shaft. The minimum resistance should be 10 megohms.
2. Measure the resistance between the slip-rings which should be 9.6 ohm  $\pm$  0.2 ohm for the 24 volt model and 3.2 ohm  $\pm$  0.1 ohm for the 12 volt model.

**Stator**

1. Subject the stator to an insulation test between any terminal tag and the frame. The minimum resistance should be 10 megohms.
2. Connect the stator leads, two at a time to a 20 ampere DC supply and check that the voltage drop in each case is 8.4 volt for the 24 volt model and 2.2 volt for the 12 volt model.

**Slip Ring End Shield Diode Tests**

Connect a test probe in series with a 48 watt 24 volt lamp on the positive terminal of 24 volt DC supply. Connect another test probe to the negative terminal of the DC supply.

Test No.	Test lead Connection (Positive)	Test lead Connection (Negative)	Diode under test	Serviceable
1	Each heat sink in turn	D+	Positive	Lamp illuminates
2	D+	Each heat sink in turn	Positive	No illumination
3	D-	Each heat sink in turn	Negative	Lamp illuminates
4	Each heat sink in turn	D-	Negative	No illumination
5	Each heat sink in turn	A	Auxiliary	Lamp illuminates
6	A	Each heat sink in turn	Auxiliary	No illumination

The opposite reaction to any of the above tests will establish a faulty diode, and the complete associated heat sink must be renewed.

Note: If any of the diodes have been replaced or if the polyurethane paint (blue) on the diodes is damaged the diodes must be repainted with polyurethane paint.



## ASSEMBLY

Refer to Fig. 45.

Normal workshop practices should be followed taking special care to keep working surfaces and tools clean.

1. Lay the stator on the bench with the three stator phase leads facing upwards.
2. Invert the end shield and locate it over the stator, so that the three wide spaces on the heat sink finning coincide with the three stator phase leads. Carefully lower the slip ring end shield to the stator and align scribe marks. (Ref. paragraph 4 of dismantling procedure). Twist stator phase leads once only around heat sink tags and solder.
3. Fit spacer over the rotor drive shaft and insert drive shaft through the bore of the drive end-shield ballrace.

Note: The original short spacer 9.343 mm. (0.368 in.) was used when the rotor had a dust thrower. The dust thrower is no longer used and a longer spacer 10.721 mm. (0.422 in.) is necessary when a new rotor is fitted. The longer spacer must not be used with the old rotor and vice versa.

4. Support the rotor, slip-rings downwards, between a pair of parallel blocks on a suitable hand-press table (great care must be exercised at this stage not to damage the rotor field leads with the blocks). Gently press the drive end shield into place with a suitable piece of tube pressing on the bearing housing.

5. Assemble the rotor and slip-ring end shield assembly to the drive end ensuring again that the scribed lines are in alignment. Insert the three through bolts with 'Loctite' grade A applied to the threads and tighten them evenly and progressively whilst gently tapping the slip-ring end shield with a hide faced mallet to draw end shields squarely into position. Finally tighten the through bolts to a maximum torque of 5.1 Nm (0.52 kgf m or 45 lbf in).

Note: Alternators manufactured prior to serial number UH 1001 or having three digits in the serial number, must have the through bolts changed as there is a danger of breakage. New through bolts now available (having the same part number) are made of stronger material. To indicate the change scribe a line on the new bolt head at 90° to the screw driver slot before fitting.

6. Refit brushes to brush box making sure that the terminals are fully seated. Thread 'O' sealing rings (supplied in seal and gasket set) over both the terminal posts and assemble insulator to one of the terminals. Fit Lucar blades and crinkle washers to both terminals and secure with terminal nuts. Marine versions have one Lucar blade and one threaded stud

Note: The original brush box moulding was later replaced by a new moulding to prevent accidental reversal of the connections and the locating flange was strengthened. The brush set was also changed to suit. If the new brush set is used with the old moulding a spacing washer is necessary between the Lucar connector and the crinkle washer to ensure that the 'O' ring is compressed.

7. Fit a new gasket (supplied in seal and gasket set) to the brush box moulding and assemble brush gear to the slip ring end shield. Correct positioning is ensured by the locating dowel. Secure with retaining screws, plain and spring washers. Reconnect 'A' lead to terminal post marked 'A', secure with crinkle washer, plain washer and terminal nut.

8. Fit baffle to slip-ring end shield (or cowl, gland and ferrule on marine versions) and secure with screws and spring washers.

9. Fit fan spacer machined slot outwards and aligned with keyway. Fit woodruff key, fan pulley and pulley nut. Tighten pulley nut to a torque of 54.2 Nm (5.53 kgf m or 40 lbf ft).

10. Finally carry out bench tests as follows:-

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## BENCH TESTS

Equipment required.

Test machine capable of speeds up to 10,000 rpm with variable speed drive and the following accessories:-

Battery of 12 or 24 volt to suit system voltage.

Variable load of at least 60 amp maximum capacity.

440 regulator (12 or 24 volt) to suit system voltage (marine version 446).

Non-destructive 110 volt Flash Tester or 110 volt Megohm Meter.

2 Single pole switches.

Bulb 24 Volt 2.0 watt minimum or 12 volt 2.0 watt minimum.

British standard first grade moving coil DC voltmeter 0-50 volt.

British standard first grade moving coil DC ammeter 0-100 amp.

### Procedure

1. Before making any connections, test the alternator for earths with non-destructive flash test (or Megohm Meter) with voltage rating of 110 volt. Connect instrument between D+ and earth, D- and earth and A terminal and earth. Make sure always to keep the one probe on the frame so as not to apply full test voltage between any two terminals on the alternator. If Megohm Meter is used the minimum insulation resistance should be 10 megohms.

2. Mount the alternator to the test machine drive and make all connections to the battery and regulator as wiring diagram Fig. 47. Make sure that the correct warning light bulb in series with a switch is connected in the circuit. Vehicle loads, alternator auxiliary loads and 405 relay need not be included in the circuit. Connect the ammeter in the positive line. The variable load of at least 60 amp maximum capacity with a switch in series should be connected straight across the battery so as to discharge the battery when required by conditions of the following tests.

Note: If a 446 suppression box is used instead of the 440 regulator make connections as shown in the wiring diagram glued inside the box cover and connect the load across the battery as explained above.

3. Close the switch (in series with the warning light) and observe that the bulb illuminates.

4. Start the drive and increase speed until warning light is extinguished which indicates that alternator is charging. This should occur below 1500 rpm.

5. Reduce speed to 1125 rpm (825 rpm for low cutting-in speed version) and measure DC voltage between WL and -ve on the 440 regulator or between WL and B-ve terminal on the 446 box. The voltage should be between 24-28 volts.

6. Connect the voltmeter across B+ and B-. Apply load (see table below) to the battery and increase alternator speed to 3200 rpm (2000 rpm on the low C I S version). Observe the ammeter reading which should be as follows:-

## BENCH TESTS (Continued)

Model	Load applied	Speed	Ammeter reading	Voltage
24 volt	20-30 amp	3200 rpm	28-31 amp @	26-27
12 volt	40-50 amp	3200 rpm	50-55 amp @	13-13.6
12 volt (low c. i. s.)	25-35 amp	2000 rpm	32-35 amp @	13-13.7

Increase speed to 10,000 rpm and again observe ammeter reading which should be as follows:-

Model	Ammeter reading	Voltage
24 volt	30-35 amp @	26-27
12 volt	60-65 amp @	13-14
12 volt (low c. i. s.)	40-45 amp @	13-14

Adjust battery load as necessary. Run at top speed of 10,000 rpm for 1 minute.

8. Decrease speed to 3000 rpm and switch off loads connected across the battery. Depending on the connection selected for the positive sensing wire (LO, MED, HI) the voltage should rise to between 26-28 volt and then remain constant. At the same time the current reading should drop appreciably. This test indicates that the regulator is working correctly. With sensing wire connected to + Med and load adjusted to 15 amp the voltage reading should be  $27.5 \pm 0.25$  volt. With sensing wire connected to + Hi the reading should be 1 volt up, and if connected to + Lo 1 volt down (0.5 volt on 12 volt models).

## TECHNICAL DATA

OUTPUT, Maximum (hot)	24 volt 12 volt (Standard) 12 volt (Low c.i.s. version)	31 amp @ 27.5 volt 55 amp @ 13.5 volt 41 amp @ 13.5 volt
CUTTING-IN SPEED	(Standard 12 and 24 volt) (Low c.i.s. 12 volt)	1125 rpm 825 rpm
MAXIMUM SPEED		10,000 rpm
BRUSH SPRING LOADING		227 gm. (8 oz.)
MINIMUM USABLE BRUSH LENGTH		7.94 mm. (0.312 in.)
SLIP RING MINIMUM DIAMETER		28.85 mm. (1.136 in.)
BELT TENSION		Refer to coolant Section.
MAXIMUM AMBIENT OPERATING TEMPERATURE		70°C (158°F)
COOLING		Built-in fan
RECTIFICATION		Built-in Silicon diodes
REGULATOR		440 (Fully transistorised)
BHP ABSORBED		2.4 bhp @ 3500 rpm.

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## STARTER MOTOR

With self indexing drive and Roller clutch (Type M50)

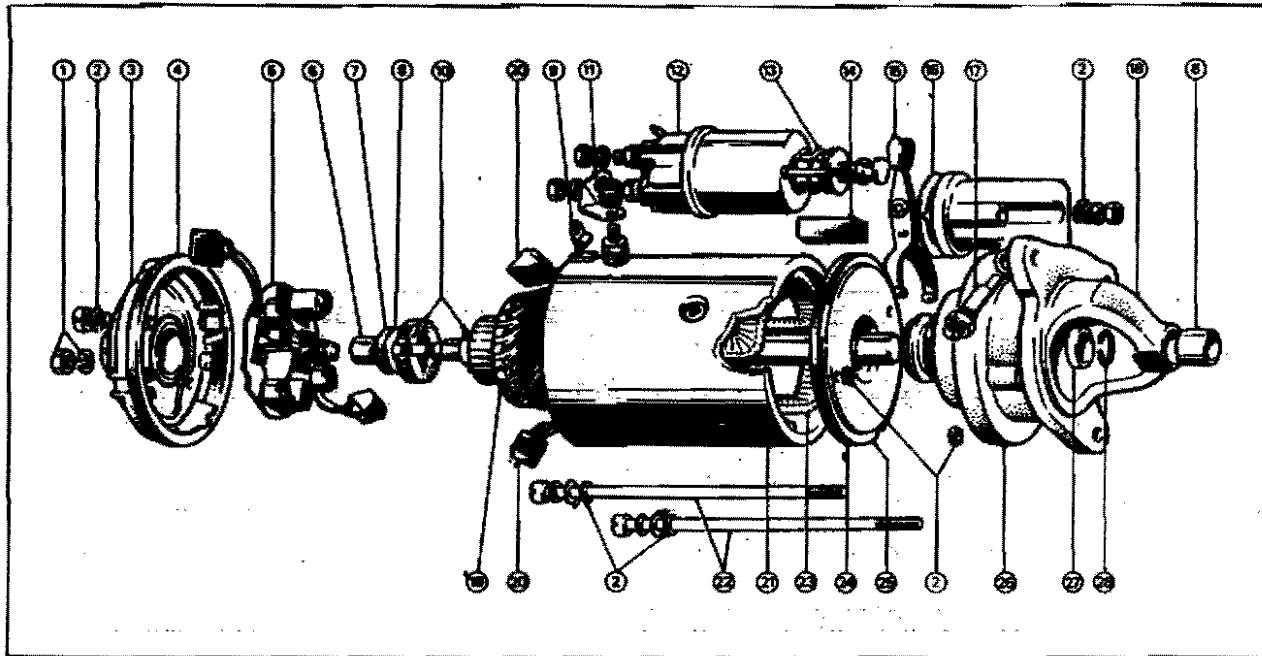


Fig. 53 — Starter, dismantled

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

### Description

The pre-engaged starter (Fig. 53) 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 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. 54, 55 & 56).

STARTER MOTOR (Continued)

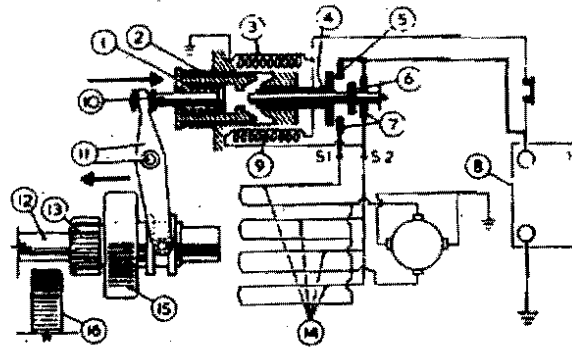


Fig. 54 – Explanation of two-stage switching

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

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

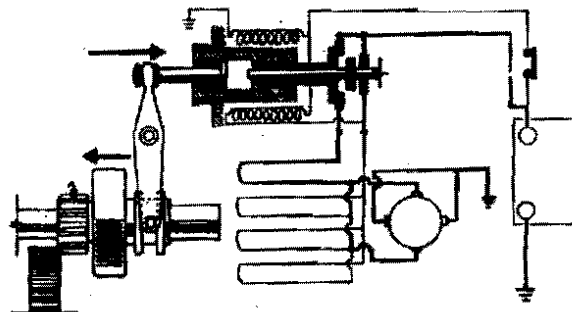


Fig. 55

If tooth-to-tooth abutment occurs, the first set of solenoid contacts close and energise one field coil only, thus giving low power indexing to move the pinion teeth into a meshing position.

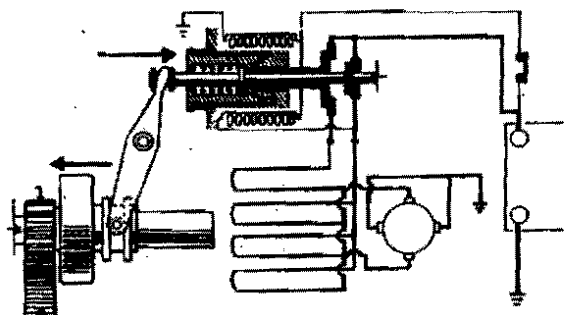


Fig. 56

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## STARTER MOTOR (Continued)

On full drive engagement, the second set of solenoid contacts close giving full cranking power.

If the pinion teeth, on moving forward, can mesh immediately with the gear ring, full drive engagement takes place with the simultaneous closing of both contacts in the final stage.

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 yoke.
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. 53.

### 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.

### 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.
5. Remove the through bolts complete with washers and sealing washers.
6. Remove the two cross-recessed headed screws from the outer face of the commutator end cover (These screws secure the brush gear to the inner face of the end cover).

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.

## STARTER MOTOR (Continued)

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 screw driver, lever up the brush springs so that the brushes can be disengaged from their brushboxes. Remove the brushgear assembly.
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 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 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 110 v.a.c. 15 w test lamp connected between one of the commutator segments and the armature shaft Fig. 57.

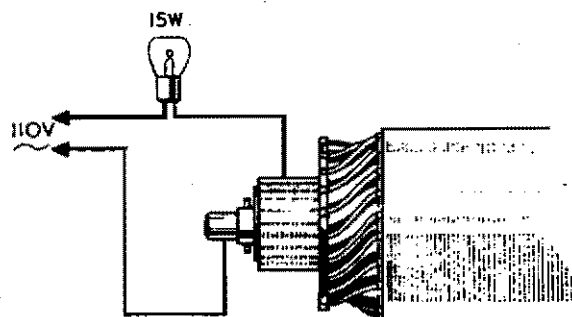


Fig. 57 – Armature insulation test

## STARTER MOTOR (Continued)

If the lamp lights, the insulation is unsatisfactory.

Check the armature for short-circuited 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 BRUSHES

**Insulated brushes (field coil).** Place the yoke assembly on its end, with the brush and terminal arrangement uppermost, Fig. 58. 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 yoke, 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 firmly down over the edge and outside of the yoke. (Fig. 58).

**Earth Brushes (brushgear plate).** Place the hot soldering iron on the rolled over portion of the brush flexible joint. When the solder inside the joint is sufficiently heated, use a screw driver and lever up the rolled over portion enough to enable the worn brush flexible lead to be pulled clean of the joint.

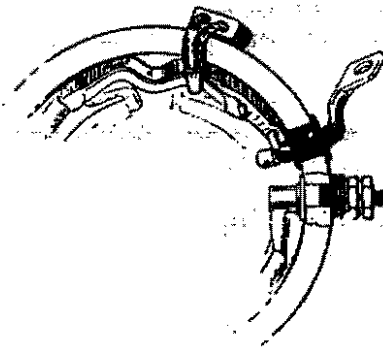


Fig. 58 - Brush and terminal arrangement

## 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. 59). The spring pressure reading should be 1190 gf (42 ozf).

## Checking the brush gear Insulation

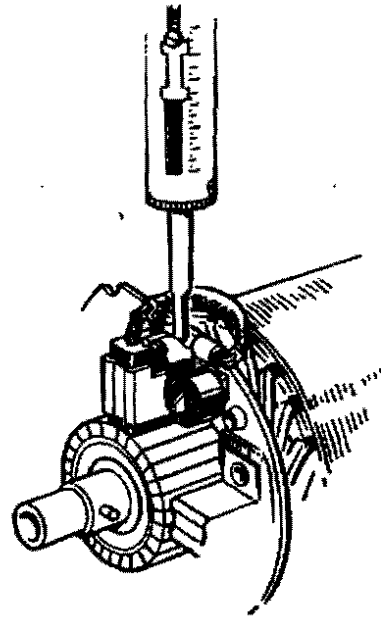
Connect a 110V a.c. 15 watt test lamp between a clean part of the brush gear plate and each of the two insulated brush boxes in turn.

If the lamp lights, the insulation between the brush boxes and the brushgear is unsatisfactory and the brush gear assembly must be renewed.



**CHECKING THE SPRING PRESSURE (Continued)**

Fig. 59 –Checking brush spring pressure

**Checking Field Coil Insulation**

Ensure that both insulated brushes are clear of the yoke and connect a 110 v.a.c. 15 watt test lamp between the eyelet of the flexible link and a clean part of the yoke. If the lamp lights, there is a short circuit between the field coils and the yoke. The field coil assembly must therefore be renewed

**Field Coil Continuity and Inter-winding Insulation.**

Due to the very low resistance of the field coils and the method of interconnecting the conductors, the continuity of the field coils and the presence of a short circuit between windings can only be determined by using special equipment. The field coils should be visually inspected in situ for signs of obvious faults. Check the various joints of the field coil assembly and look for discolouration (due to burning) of the winding insulation tape, which could indicate short-circuited windings. If in doubt, the field coil should be proved by substitution.

**Renewing the Field Coil Assembly**

Before disturbing the original fitting of the field coils, pay particular attention to the following:-

The close-forming of the field coil conductors to the yoke to ensure adequate clearance for the armature.

A minimum clearance of 10.32 mm. (0.406 in.) between the edge of the field coil assembly and the end face of the yoke.

The forming of the conductors around the two through bolt entry points.

The build-up of the insulators and washers associated with the yoke terminal. (Fig. 58).

Use a wheel-operated or power-assisted screw driver to unscrew and refit the pole shoe retaining screws. The fitting operation will be facilitated by using pole shoe expanding equipment and the screws should be progressively tightened to a torque of 27.1 Nm (2.77 kgf m or 20 lbf ft) the yoke terminals lower fixing nuts to 2.71 Nm (0.28 kgf m or 2 lbf ft).

## BEARINGS

The commutator end cover intermediate bracket and drive end fixing bracket are fitted with self lubricating porous bronze bearing bushes. New bushes should be allowed to stand for 24 hours at room temperature completely immersed in clean light engine oil. Alternatively the bush may be immersed in light engine oil at 100°C (212°F) for two hours, and allowed to cool before removal. Bushes must not be reamed after fitting otherwise the self lubricating qualities will be impaired.

Brushes must be replaced when there is excessive side play of the armature shaft. Fouling of the pole-shoes by the armature, or inefficient operation of the starter is likely to occur when the inner diameter of the bushes exceed the following dimensions:-

Commutator-end cover bush 12.82 mm. (0.505 in.)

Intermediate bracket bush 28.62 mm. (1.127 in.)

Drive end fixing bracket bush 17.14 mm. (0.675 in.)

The bush in the commutator end cover can be removed by inserting a 14.30 mm. (0.563 in.) thread tap and then withdrawing the tap complete with the bush.

The bushes in the intermediate bracket and drive end fixing bracket can be removed by using a press, or by supporting the bracket and carefully tapping the bush out with a mandrel.

New bushes should be pressed or carefully driven squarely into position using a shouldered polished mandrel with a bush fitting dimension as follows:-

Commutator-end cover bush 12.712 mm. (0.5005 in.).

Intermediate bracket bush 31.054 mm. (1.1226 in.).

Drive end fixing bracket bush 17.030 mm. (0.6705 in.).

### Roller-Clutch and Drive Operating Mechanism.

The roller clutch is an over-running device which prevents the armature from rotating at excessive speed if the drive is held in engagement, after the engine has started.

A roller clutch drive assembly in good condition provides instantaneous take-up of the drive in one direction while it is free to rotate in the other. The assembly should move freely along the armature shaft splines without roughness or tendency to bind. All moving parts should be smeared liberally with Shell SB2628 (cold climate) Retinax 'A' (hot climate).

## SOLENOID

In addition to the engagement spring inside the plunger and the return spring outside the plunger, the solenoid plunger is also fitted with a lost motion spring (Fig. 60) which provides a measure of lost motion as the drive commences to disengage, ensuring that the solenoid contacts are open before the pinion retracts. This also takes effect if the pinion remains engaged with the flywheel ring gear when the solenoid switch is released.

Before dismantling the solenoid, check for satisfactory closing of the first and second stage contacts associated with terminals S1 and S2. Disconnect terminal S1 and apply a 12 volt battery supply between the solenoid "Lucar" terminal and a clean part of the solenoid body or starter frame. Using a battery operated ohmmeter or battery operated test lamp, connect one lead to the solenoid main (largest) terminal and connect the other lead alternatively to the terminals S1 and S2. If there is a zero reading on the ohmmeter or test lamp lights, it proves that the solenoid contacts are satisfactory.

## SOLENOID (Continued)

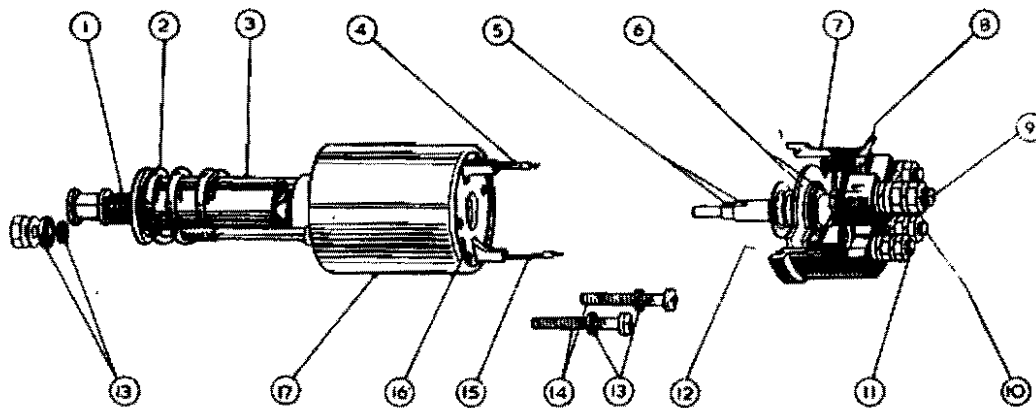


Fig. 60—Solenoid dismantled

- |   |                                |                                 |
|---|--------------------------------|---------------------------------|
| 1 Lost motion spring                                  | 7 Moulded cover                | 12 Sealing ring                 |
| 2 Plunger return spring                               | 8 'Lucar' terminal blade       | 13 Sealing washer(s)            |
| 3 Plunger   | 9 Main input terminal(s)       | 14 Fixing screw (moulded cover) |
| 4 Start of shunt & series windings ('Lucar' terminal) | with copper strap marked 'BAT' | 15 End of series winding (S2)   |
| 5 Brass sleeve & cross pin                            | 10 Terminal S2                 | 16 End of shunt winding         |
| 6 Moving contracts                                    | 11 Terminal S1                 | 17 Solenoid body                |

## Renewing Contacts

After being in service for long periods, the contacts may require renewing. If this is necessary, the major part of the solenoid can be retained and the solenoid repaired by fitting a service replacement contact set comprising terminal and base assembly, refer Fig. 60.

Remove the two screws securing the terminal and base assembly to the solenoid body. Apply a hot soldering iron alternatively to each of the two soldered terminal connections, and wait for the solder to run free. Shake most of the melted solder out of the joints by tapping the solenoid terminal ends sharply down on the bench. Now clamp the solenoid body in a vice and while continually pulling on the moulded cover, apply a soldering iron alternatively to the two soldered connections until terminal and base assembly is free. When remaking soldered connections, avoid dry-soldered joints by ensuring that the parts are clean and adequately heated before applying solder. Tighten the terminal and base assembly fixing screws to a torque of 2.5 Nm (0.25 kgf ft or 1.8 lbf ft).

## To Reassemble

1. Fit intermediate bracket and drive assembly to the armature (Check that the shims have been included between armature core and intermediate bracket).
2. Fit sealing ring to groove in intermediate bracket. Also fit sealing washers to fixing bracket, one at each end, through bolt entry point and one on dowel peg. (Fig. 53).
3. Assemble the armature sub-assembly to the fixing bracket, locating the intermediate bracket with dowel peg in the fixing bracket.
4. Slide the yoke assembly over the armature and locate with the dowel peg protruding through edge of intermediate bracket. At this stage check for sufficient clearance between the armature and field coil conductors, particularly at the through bolt entry points.

## SOLENOID (Continued)

5. Locate partially in their holders the two earth brushes and then the two insulated brushes. The springs should be wedged against the sides of the brushes to hold them temporarily in the lifted position for reassembly purposes.
6. Place the brush gear assembly partially over the commutator (as far as the brush flexibles will allow). Locate the two through bolts in the half-holes of the brush gear plate and screw the bolts a few threads into the fixing bracket to position the brush gear plate in its correct assembly position.
7. Press the brushes on to the commutator and check that the springs are properly located before finally fitting the brush gear assembly to its working position.
8. Position the armature with the brake shoe cross peg in line with the two threaded holes in the brush gear plate.
9. Remove the two through bolts, but do not disturb the position of the brush gear plate.
10. Assemble the fibre washer, steel washer and brake shoe parts into the commutator end cover (refer to Fig. 53 to ensure correct sequence of assembly).
11. Position the brake shoes in the commutator end cover with the cross peg slot in line with the two smallest of the four holes in the cover.
12. Fit sealing ring to the commutator end cover.
13. Locate the dowel peg in the end cover approximately in line with the dowel hole in the end face of the yoke and loosely assemble the end cover on the armature shaft and to the yoke.
14. Fix first the two through bolts and then the two brush gear securing screws, (difficulty in locating the threads of the brush gear securing screws is avoided by fixing the through bolts prior to the brush gear securing screws).
15. Loosely fit the eccentric pivot pin through the drive engagement lever and into the fixing bracket. The pivot pin lock nut should not be tightened at this stage, as the pinion position must be set by adjusting the pivot pin when the starter is fully assembled.
16. Fit the block shaped sealing grommet between the yoke and solenoid mounting portion of the fixing bracket. (Soaping the grommet will facilitate fitting).
17. Fit the solenoid plunger to the drive engagement lever. Fit the solenoid unit (Lucar terminal uppermost) complete with gasket and sealing washers.
18. Connect the solenoid terminals S1 and S2 to the starter flexible link and yoke terminal respectively.

## Pinion Setting

The position of the pinion must be set after reassembling the starter motor.

The amount of adjustment of the eccentric pivot pin for setting the pinion is  $180^{\circ}$ , and the centre of this limit is denoted by an arrow head marking on the fixing bracket. When adjusting the pinion position, first apply a coat of gold size to the threads of the pivot pin, then turn the pivot pin until correct adjustment of the pinion is obtained with the arrow head marking on the end face of the pivot pin within the  $180^{\circ}$  limit of the fixing bracket marking. After adjustment, secure the pinion setting by tightening the pivot pin lock nut to a torque of 21.7 Nm (2.21 kgf m or 16 lbf ft).



## TYPE 'B' STARTER MOTOR:—CO-AXIAL

### GENERAL DESCRIPTION

(C.A.V. type CA45D)

The CA45D type starter motors are 114 mm. (4.5 in.) diameter machines designed to provide maximum efficiency with small dimensions.

The principal features are (a) the special design whereby only the starter pinion and pinion sleeve move axially to engage the engine ring gear (b) two stage engagement of the starter pinion prevents shock loading (c) only when the pinion is fully meshed with the flywheel ring gear is full power applied to the starter motor. The CA45F is similar to the CA45D in performance and physical outline. The "F" design provides mechanical overspeed protection to the starter by means of a centrifugally operated mechanism for releasing the pinion from the flywheel on those occasions when excessive rotational speeds are reached. This obviates the necessity of using rising dynamo voltage to cut-out the starter or the additional under current relay when an AC generator is fitted, as with the CA45D starter.

This device incorporates four equi-spaced radial holes in the pinion sleeve into which four overspeed balls locate. The locking collar has an internal cone which encircles these balls. Additionally there are four steel segments held together and against a recess in the pinion sleeve by a garter type spring. The bore of the solenoid also has an annular recess into which the segments become magnetically latched by the magnetic flux of the solenoid during the starting cycle.

### Installation Notes

When installing a CA45 starter it is necessary to connect a 2ST relay in series with the starter internal solenoid coil. By this means the current through the starter push switch is reduced to that taken by the 2ST relay coil, also the voltage drop in the starter solenoid switch circuit is reduced to a minimum. This relay is also used as part of an electrical overspeed protection device on the CA45D installation.

On starters wired for insulated return the return path for the starter solenoid is made externally by connecting terminal 'R' on the commutator end shield to the terminal marked 'R' at the drive end next to the 'S' terminal. The cable size should be 65/012 minimum.

Typical installation circuits for the CA45 D starter are shown in Figs. 62, 63 & 64. The electrical overspeed protection, where installed, can be left in 'SITU' on the equipment when CA45D is replaced by CA45F.

### OPERATION (See Fig. 67)

In the following text the figures in brackets refer to Fig. 66, unless otherwise stated.

When the starter switch is operated current flows through the solenoid of the overspeed relay and closes the relay contacts. The solenoid (6) is then energised and its hollow plunger (43) moves forward, pushing the pinion (46) towards the engine flywheel teeth. At the same time, the movement of the plunger closes the contacts (7), connecting the battery to the field and armature windings via a heavy duty resistor (40). The resistor reduces the current flow to the windings with the result that the armature rotates at low speed.

This combination of forward and rotary movement partially engages the pinion with the engine flywheel. The pinion, prevented from rotating by the inertia of the flywheel, is then pushed fully into mesh by the action of the helix on the slowly rotating armature shaft. Shortly before the fully engaged position is reached, collar (10), carried on the end of the pinion sleeve, trips a trigger (39) on the solenoid. This causes a second set of contacts (42) to close and short circuit the resistor, applying full battery voltage to the windings. Thus, full starting torque is exerted only when the pinion is completely engaged with the engine flywheel minimising the risk of damage to pinion and flywheel teeth.

TYPE 'B' STARTER MOTOR (CO-AXIAL) (Continued)

When the pinion is engaged it is locked in position by a special locking device consisting of four steel balls (8) located in holes in the pinion sleeve. These balls drop into recesses in the armature shaft when the pinion reaches its fully engaged position, and a spring loaded collar (38) slides over and holds them firmly in position. Hence, the pinion cannot be ejected prematurely but will remain in mesh until the starter button is released, or the overspeed device switches out the starter.

NOTE.—The automatic ejection of the starter by the overspeed device does not occur until extremely high rotation speeds of the starter are reached. This leads to excessive wear of bearings and brushes and would considerably shorten the service life of the starter if this were used on every normal start. It must be stressed that the operator must treat the overspeed device as an emergency measure.

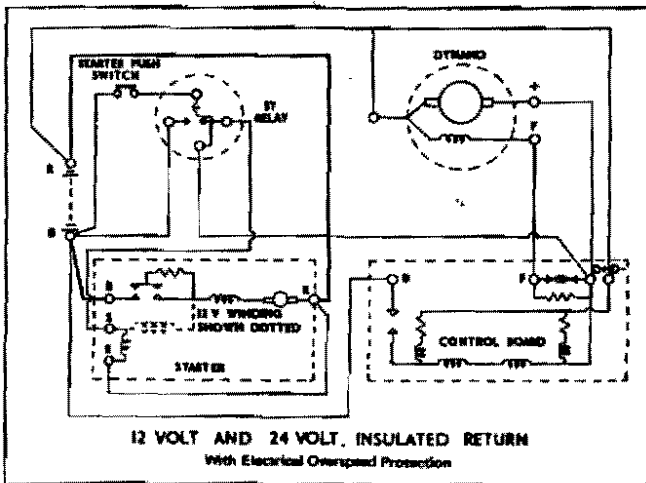


Fig. 62 Typical installation circuit.

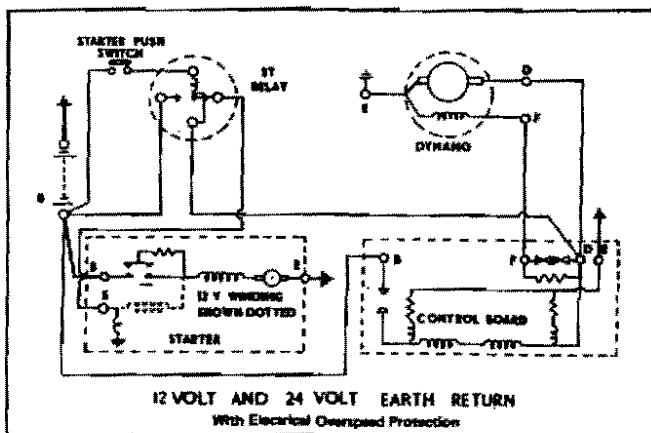


Fig. 63 Typical installation circuit.

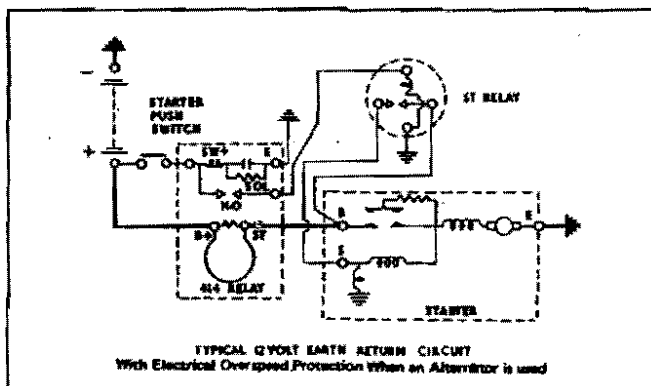


Fig. 64 Typical installation circuit.

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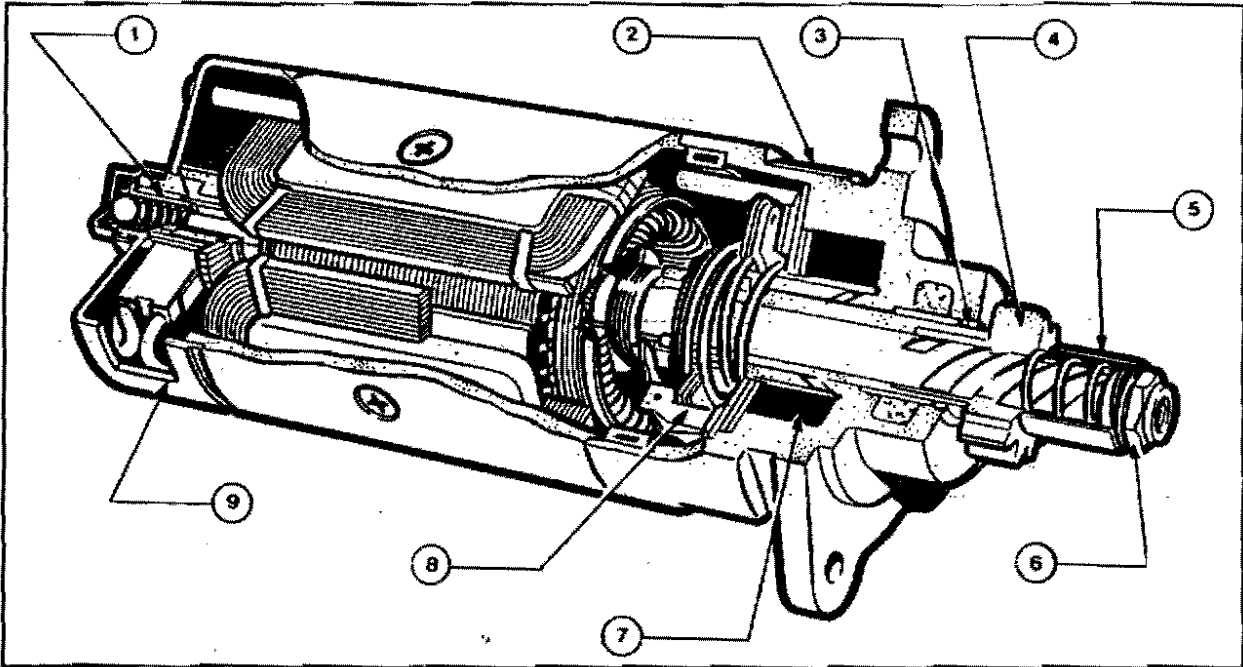


Fig. 65—The Starter Motor—Part Sectioned

- |                     |                   |                     |
|---------------------|-------------------|---------------------|
| 1 Recoil Mechanism  | 4 Pinion Assembly | 7 Solenoid Assembly |
| 2 Housing           | 5 Pinion Spring   | 8 Trigger Mechanism |
| 3 Dust Scraper Ring | 6 Pinion Stop Nut | 9 Cover Band        |

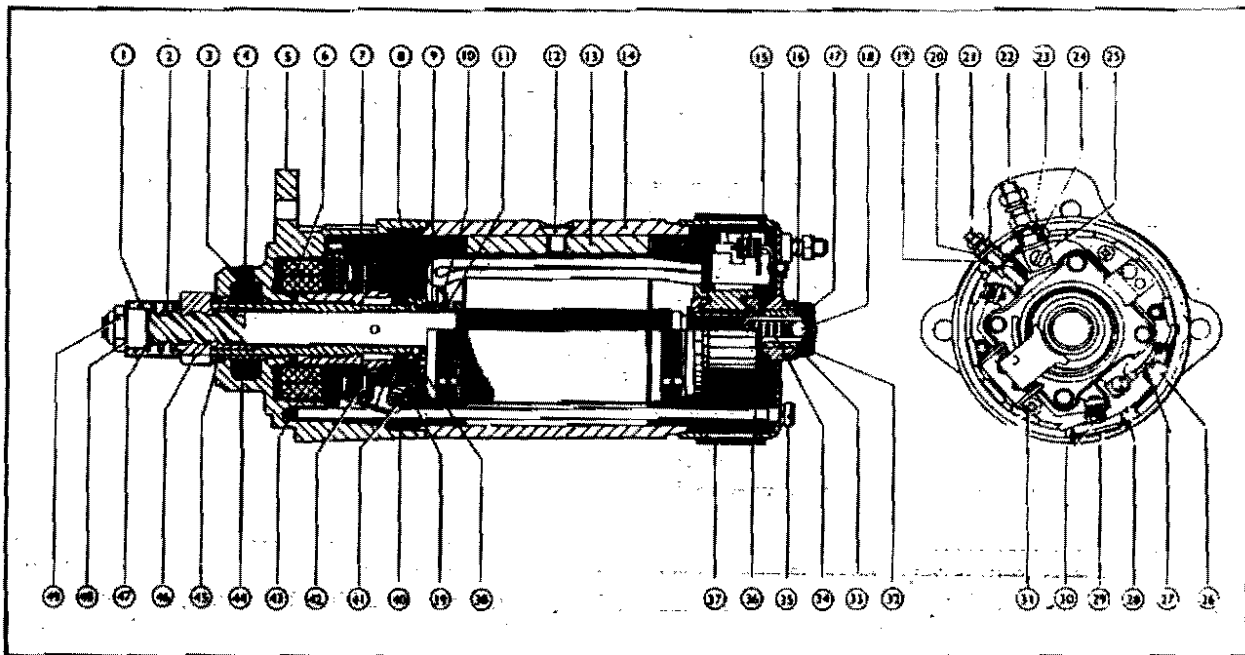
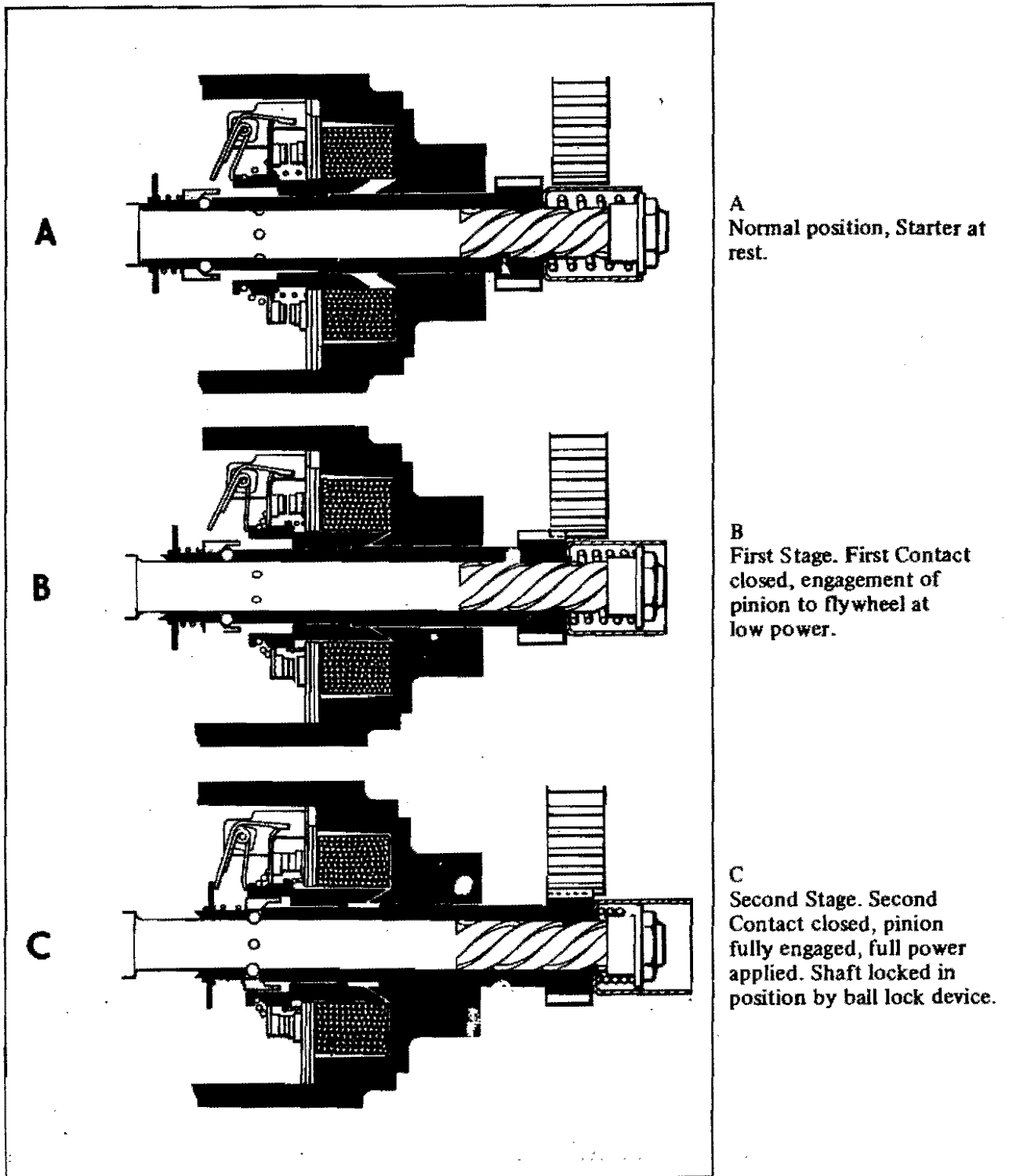


Fig. 66—Sectional View of Starter

- |                        |                          |                           |                      |
|------------------------|--------------------------|---------------------------|----------------------|
| 1 Helix Cover          | 14 Yoke                  | 26 Spacer                 | 38 Lock Collar       |
| 2 Pinion Spring        | 15 Commutator End Shield | 27 Resistor Rivet         | 39 Trigger           |
| 3 Pinion Return Spring | 16 Shim Washers          | 28 Resistor Flexible Lead | 40 Resistor          |
| 4 Lubricator Core Plug | 17 Circlip               | 29 Core Plug              | 41 Trigger Spring    |
| 5 Drive End Shield     | 18 Steel Ball            | 30 Field Terminal Screw   | 42 Second Contact    |
| 6 Solenoid Assembly    | 19 Insulating Bush       | 31 Self Tapping Screws    | 43 Solenoid plunger  |
| 7 First Contact        | 20 Terminal Nut          | 32 End Cap                | 44 Lubricator Wick   |
| 8 Locking Balls        | 21 Solenoid Terminal     | 33 Thrust Washer          | 45 Dust Scraper Ring |
| 9 Lock Collar Spring   | 22 Main Terminal         | 34 Recoil Spring          | 46 Pinion Assembly   |
| 10 Trip Collar         | 23 Terminal Nut          | 35 Through Bolts          | 47 Shim Washer       |
| 11 Circlip             | 24 Insulating Bush       | 36 Shims                  | 48 Thrust Washer     |
| 12 Pole Screw          | 25 Screw                 | 37 Commutator Cover       | 49 Pinion Stop Nut   |



THE STARTER MOTOR



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Fig. 67—Stages of Starter Motor Operation

## OPERATION (Continued)

On rare occasions, the pinion and flywheel may meet tooth to tooth; this will not affect engagement under normal conditions, as the pinion will continue to rotate until the teeth slide into mesh. If the gear teeth are worn and burrs are present rotation of the pinion may be prevented and the pinion may even be held against the flywheel face when the starter button is released. In order to overcome this difficulty, the starter incorporates an armature recoil mechanism comprising a steel ball (18) and recoil spring (34) fitted at the commutator end of the armature shaft.

Whenever the pinion is prevented from rotating, the action of the helix, on the slowly rotating armature shaft will be to force the armature back against the recoil mechanism, compressing the recoil spring; as soon as the starter button is released, the spring thrusts the armature forward. At the same time, rotary motion, opposite to the normal direction of rotation is imparted to the armature by the helix in the stationary pinion.

When the armature reaches the end of its forward movement, its momentum is sufficient to rotate the pinion slightly, freeing it from burrs. The pinion then returns to its disengaged position under the influence of the pinion return spring; its radial position will now be slightly retarded, so that there is little likelihood of the gears meeting tooth to tooth during the next engagement.

## FAULTS IN OPERATION

If the starter does not function, or is sluggish or intermittent in operation, check that the battery is in a satisfactory state of charge, and that all cable connections are clean and tight. A defective starter switch, badly worn starter brushes, or tampering with the overspeed device are possible causes of failure and because the overspeed switch is electrically linked to the generator, burnt generator brushes or commutator can affect the operation of the starter motor.

Difficulty in smooth engagement between starter and engine may be caused by dirt in the helix of the armature shaft preventing free pinion movement. In this case the starter should be removed from the engine and the helix thoroughly cleaned with paraffin and then smeared with a small quantity of a suitable grease such as Regal Starfak (DTD 900/4363), Mobil Aero 348 or Aero Shel. 6B.

## MAINTENANCE

Very little servicing is necessary but in order to ensure maximum life and trouble-free starting, we suggest that the following maintenance procedures be undertaken at regular intervals, the length of which are dependent on operating conditions.

## OVERSPEED RELAY TYPE 2ST

The particular relay fitted to the starting system has been chosen to operate satisfactorily with the starter and generator as fitted to the engine. The relay is not adjustable and cannot be serviced. If the relay is defective in any way it must be replaced by a new "2ST" of identical type symbol. This is vital to the proper functioning of the starter motor.

## BRUSHGEAR

Remove the commutator cover, and ensure that the brushes are free in their holders by lifting the brush springs clear of the brushes and pulling gently on the brush leads. If a brush is inclined to stick, remove it from its holder and clean the brush and the inside of the holder with a clean cloth moistened in carbon tetrachloride. Be sure to replace the brush in its original position, so that the curvature of its contact surface accurately conforms with the commutator periphery.

See that the braided sleeving on the brush leads has not become burnt or charred, thus creating the danger of short circuits.

Brushes must be replaced as soon as a minimum length of 12.7 mm. (0.5 in.) is reached.

Replace the commutator cover, ensuring that the yoke windows are fully covered and that the cover fixing screw is at the bottom of the starter when the starter is mounted on the engine. This is most important, as fuel oil and water may enter the machine if the cover is not correctly positioned.

## LUBRICATION

The drive end bearing is lubricated by a wick contained in a large oil reservoir in the drive endshield. The capacity of this reservoir is such that it requires no attention during routine maintenance but should be refilled when the starter is dismantled at major overhaul periods.

This is done by removing the starter and adding a supply of S.A. E. 20W oil through the oil filler hole in the drive endshield. The filler hole lies beneath a core plug which must be removed to gain access to the filler hole. New plugs only must be fitted and care taken to ensure a positive fit in the filler hole.

An oil impregnated bearing is fitted at the commutator end of the machine and requires no attention during service. Under no circumstances should any attempt be made to grease the bearing as this may adversely affect its self-lubricating properties.

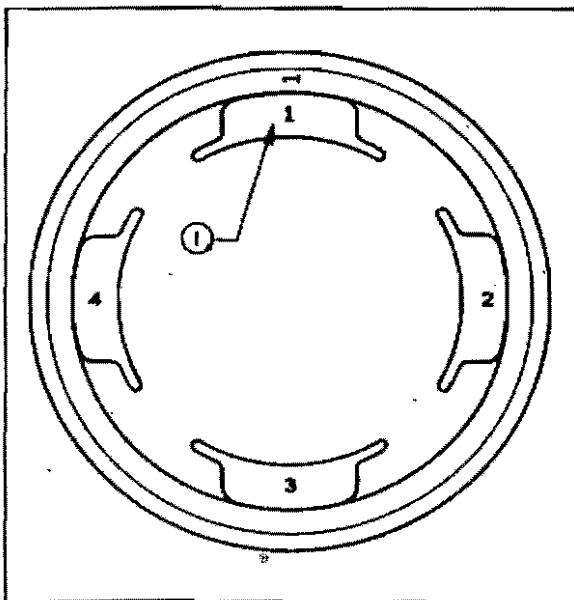


Fig. 68—Position of Poleshoes in Yoke

1 Corresponding Numbers Adjacent

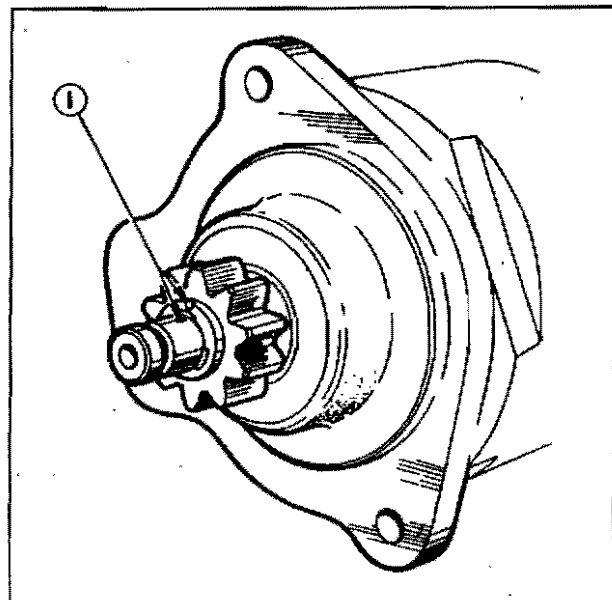


Fig. 69—Pinion and Shaft Indentations

1 Indentations

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## CABLES AND MOUNTING BOLTS

The starter should be examined to ensure that its mounting bolts are securely fastened, and that all cable connections are clean and tight. The cables should also be inspected for fractures particularly at the point where the cable enters the terminal lug. The cable insulation should be free from chafing or deterioration due to oil.

To ensure effective operation of the starter it is recommended that the total voltage drop in the cables, starter switch, relay or any other switch in the circuit does not exceed  $\frac{1}{2}$  volt at 38 amps for the starter solenoid circuit and  $\frac{1}{4}$  volt at 5.3 amps for the relay switch circuit.

### TO DISMANTLE – See Fig. 66

Disconnect the battery, disconnect all motor wiring connections and remove the starter motor from the engine.

1. Remove the two core plugs (29) in the drive endshield (5) with a sharp pointed instrument.
2. Unscrew the two field terminal screws (30) that are exposed when the core plugs are removed.
3. Remove commutator cover (37).
4. Unscrew the brush lead screws, raise the brush springs and remove the brushes from the holders. It should be noted that removal of the brush lead screws also frees the field coil connections.
5. Remove end cap (32). This either has a bayonet type or screw type fixing arrangement and should be removed by pushing inwards and twisting in the opposite direction of starter rotation. When removing the cap, care must be taken not to lose steel ball (18) which is under pressure from spring (34).
6. Withdraw spring (34).
7. Remove circlip (17) and then withdraw thrust washer (33) and shim washers (16).
8. Unscrew and remove the two through-bolts (35).
9. Carefully remove commutator endshield (15) and collect shims (36) from the end of the armature shaft. Keep these shims separately so that if the armature is to be refitted end float adjustment is simplified by refitting the original shims.
10. Tap drive endshield (5) away from yoke (14) with a hide or wooden mallet, and then withdraw endshield complete with armature.
11. Secure the armature in an armature clamp, and, using either a  $\frac{7}{16}$  in. BSF box spanner or socket with the chamfered lead ground away, unscrew the pinion stop nut (49) in the direction of starter rotation. Remove the thrust washer (48), shim washer (47) pinion return spring (2) and helix dust cover (1).
12. Remove core-plug (4) and spring (3) from the drive endshield.
13. Release the ball lock mechanism by pushing the end shield towards the armature. With the lock collar held in this position, unscrew the pinion until the helix disengages. Finally, slide the pinion, together with the drive endshield, off the armature shaft, and collect the four steel balls (8) which may fall through into the inside of the pinion sleeve. Remove the armature from the armature clamp.
14. Using the circlip pliers, remove circlip (11) from the end of the pinion sleeve.

## TO DISMANTLE (Continued)

15. Remove trip collar (10), lock collar spring (9), and lock collar (38).
16. Withdraw pinion assembly (46) from the drive endshield. If any burrs can be seen on the pinion, these should be carefully removed by use of a stone before withdrawing the pinion.
17. Detach the resistor flexible lead (28) from the moving contact plate.
18. Free the resistor (40) from the drive endshield by punching out the securing rivet (27) with a suitable punch. Withdraw the resistor and the two nylon bushes (26).
19. Unscrew main terminal nuts (23) and screw (25). Remove insulating bush (24) and then withdraw main terminal (22) from inside the housing. (Rotating the terminal axially through 180° simplifies this operation).
20. Remove nuts (20) and insulating bush (19) from solenoid terminal (21). Push the terminal well into the drive endshield so that it is clear of its hole.
21. Unscrew self-tapping screws (31) and withdraw solenoid assembly (6).

## INSPECTION AND REPAIR OF COMPONENTS

NOTE.—It is essential to remove all brush dust etc. from components by using dry compressed air before making electrical tests.

## ARMATURE WINDINGS

If the armature windings are suspect, they can be tested for continuity and short circuits by means of a "growler" armature tester; if such a machine is not available, the armature may be tested by substitution.

## SOLENOID ASSEMBLY

Because of the low resistance of the solenoid coils the simplest way to check a suspect solenoid is by substitution. Coils that appear to have overheated should be changed. However, if an accurate, low reading ohmmeter is available, the coils may be checked for internal shorts or open circuits in the following manner. To test coil No. 1 connect the instrument across the red and black leads of the solenoid assembly. The resistance should be within the range 0.50 to 0.55 ohms. To test coil No. 2 connect the ohmmeter between the black lead and the earthed end of the coil where it is soldered to the base of the contact assembly. The resistance should be in the range 0.68 to 0.75 ohms. A low reading will generally indicate a short circuit while no reading will indicate an open circuit.

## TESTING SOLENOID COILS AND CONTACTS

The coils can be checked for short or open circuits by measuring current consumption at nominal voltage. 12 VOLT STARTER SOLENOIDS ONLY are dual wound and consist of a pull-in and a hold-on winding, therefore before testing these, a link should be made between the base of the contact assembly (see Fig. 70), and the terminal lug on EARTH RETURN versions, or between the green lead and terminal lug on insulated RETURN VERSIONS.

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### TESTING SOLENOID COILS AND CONTACTS (Continued)

Examine the contacts and if necessary clean them with white spirit or very fine carborundum paper. The first stage gap should be 2.1 mm. (0.083 in.) with a bottom limit of 1.93 mm. (0.076 in.) and a maximum of 2.5 mm. (0.098 in.). Press down the plunger and check that the second stage contacts make only after the trigger is tripped.

If the contacts are badly burnt, gap excessive or coils appear to have overheated, the solenoid should be replaced as a complete unit.

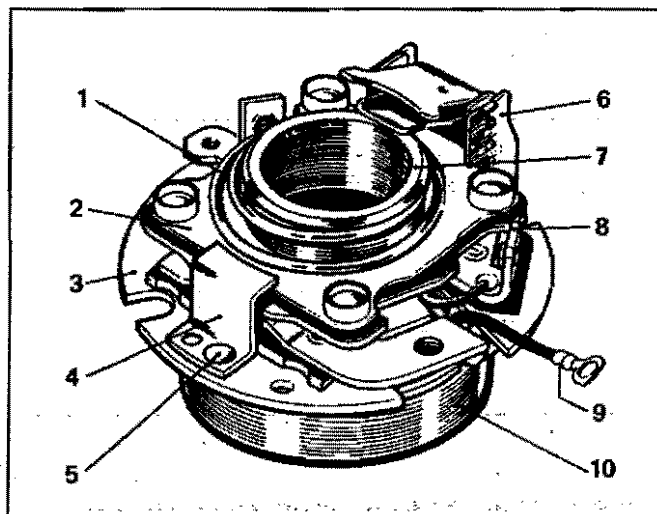


Fig. 70 – Solenoid switch assembly.

- 1 Plunger Spring
- 2 Moving Contact Assembly
- 3 Fixed Contact Assembly
- 4 Contact Stop
- 5 Rivet
- 6 Trigger Assembly
- 7 Plunger
- 8 Fixed Contact Lug
- 9 Terminal Tag
- 10 Solenoid Coil

### SOLENOID TEST DATA

Starter type	With ammeter in supply circuit	Read ammeter
CA4512 Earth Return	Apply 12 volt to black lead and base of fixed contact assembly.	Check current consumption is 39 amp approx. (On oil sealed starters 59 amp approx).
CA4512 Insulated return	Apply 12 volt to black and green leads	as above
CA4524 Earth Return	Apply 24 volt to black lead and base of fixed contact assembly	Check current consumption is 16 amp approx. (On oil sealed starters 19 amp approx).
CA4524 Insulated return	Apply 24 volt to black and green leads	as above

Note: On some starter solenoids the green lead is replaced by a yellow lead.

Fig. 71

**DISMANTLING SOLENOID SWITCH ASSEMBLY (See Fig. 66)**

1. Remove the burred over ends of the rivets (5) also the rivets securing the trigger assembly (6) using a 4.75 mm. (0.187 in.) diameter drill.
2. Carefully punch out the rivets and remove the contact stop (4) and trigger assembly. Examine the trigger assembly for wear on the pivot points, if excessive, fit a new trigger assembly.
3. Withdraw plunger (7) and plunger spring (1) moving contact assembly (2) and inner spring as one assembly.
4. Unsolder the red solenoid lead connected to the fixed contact lug (8) on 12 volt machines, also the bare solenoid lead connected to the fixed contact baseplate on all earth return machines.
5. Remove the fixed contact assembly (3).

**TO REASSEMBLE**

1. Locate the fixed contact assembly (3) on the solenoid coil (10). Ensure the contact plate rivet holes line up with those in the solenoid coil plate.
2. Replace the assembly consisting of the plunger, moving contact and springs. The rectangular shaped extension on one side of the moving contact assembly must face the two rivet holes for the trigger.
3. Push the solenoid plunger fully home. With the plunger held in this position replace the contact stop (4) and trigger assembly (6) rivet in position.
4. Solder the red solenoid lead to the fixed contact lug (8) on all 12 volt machines. On all earth return machines solder the other bare solenoid lead to the fixed contact baseplate, localising the area of solder. Test security of joint with by a sharp tug on the lead.
5. Check the first stage contact gap is within the limits (refer to section headed, "Testing Solenoid Coils and Contacts"). Slight adjustments can be made by bending the brass contact stop (4).

Examine the contacts, and if necessary clean them with white spirit or very fine carborundum paper. The first stage gap should be 2.1 mm. (0.083 in.) with a bottom limit of 1.93 mm. (0.076 in.) and a maximum of 2.5 mm. (0.098 in.). Press down the plunger and check that the second stage contacts make only after the trigger is tripped.

If the contacts are badly burnt and the gap excessive or the solenoid winding is defective, the solenoid assembly must be replaced as a complete unit.

**COMMUTATOR END BEARING**

Ensure that the commutator end bearing is tight in its housing, and check the side play between armature shaft and bearing. If this is excessive, either a replacement commutator endshield and bearing assembly should be fitted, or the bearing should be renewed as follows:—

1. Press the old bearing out of the endshield using special tool No. 5963—240.
2. With the same tool, press the new bearing (after smearing with light oil) into the endshield. After assembly, the bearing should not protrude from either end of the housing; no machining should be attempted. A special plug gauge, 5693—275 is available for checking the bush bore. The end of the gauge marked "NOT GO" should not enter the bush.

NOTE.—The bearing must not be soaked in oil prior to assembly as it is impregnated with a special lubricant by the manufacturers.

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## DRIVE END SHIELD

Check the internal diameter of the drive-end bearing with the special plug gauge 5693-267. If the bearing is worn the drive-end shield **MUST** be replaced as an assembly. Service exchange drive-end shields are available under the appropriate part number.

**IMPORTANT.**—On new and replacement drive-end shields a leatheroid retaining pad is fitted in the oilway. This **MUST** be removed to prevent the bearing being oil starved. Check that the felt pad is free to move under the influence of the spring.

**NOTE.**—Do not fit the lubricator pad spring (3) and core plug (4) at this stage, as pressure on the felt pad will prevent the pinion sleeve from being fitted.

Examine the dust scraper ring (45) and if worn or damaged remove and discard it. Clean out the groove in the endshield and fit a new ring, using special Service Tool 5693-299 to press in the new ring.

## SPRINGS

See that the springs are not damaged and have not lost tension. The tension of the springs when compressed should be as follows:-

Spring	Compressed Length	Tension
Lock Spring	9.53 mm. (0.375 in.)	0.765 to 0.878 kgf (1.69 to 1.94 lbf)
Recoil Spring	33.33 mm. (1.313 in.)	12.0 to 13.39 kgf (26.5 to 29.5 lbf)
Pinion Spring	31.75 mm. (1.250 in.)	3.5 to 3.85 kgf (7.75 to 8.5 lbf)
Pinion Spring (oil sealed starter)	37.3 mm. (1.469 in.)	4.4 to 4.6 kgf (9.81 to 10.19 lbf)

## Commutator

If the commutator surface is dirty or discoloured, it can be cleaned with a very fine grade of glass paper (do not use emery cloth or carborundum paper). In cases where the surface is badly pitted or grooved, the armature should be set up in a lathe and the commutator skimmed. A rough cut should first be made, removing just sufficient copper to clear traces of grooving or pitting, after which a light cut should be taken, using a diamond tool to obtain the desired high quality finish. Finally, remove all traces of swarf using compressed air or hand bellows.

The recess in the commutator is required only for initial manufacture, and can therefore be eliminated when skinning is undertaken. Minimum diameter to which the commutator can be reduced is 39.2 mm. (1.56 in.) and the radius at the junction of the risers and commutator must not exceed 1.0 mm. (0.040 in.). Do not skim the risers.

The commutator must not be undercut otherwise brush dust tracking may occur.

## Field Windings

Before making electrical tests remove all traces of brush dust etc. by blowing with dry compressed air.

The windings can be tested for earths to the yoke using a 100 volt Megger.



### SPRINGS (Continued)

There is no easy way of checking for initial shorts in the coils as their resistance is very low. New coils should be tried if the existing ones are suspect. Unserviceable coils should be renewed as follows:—

1. Unscrew pole screws (12) (Fig. 66) and remove the poleshoes (13) and windings, noting the position of the windings and poleshoes in order to facilitate re-assembly.
2. Fit the new windings into the yoke and replace the poleshoes. Concentricity is achieved by machining the poleshoes and the poleshoes must be replaced in their original positions, otherwise they may foul the armature. As an aid to correct assembly, the poleshoes are numbered, and must be replaced in the positions shown in Fig. 68.
3. Insert and tighten the pole fixing screws (12) using a poleshoe screwdriver. Care must be taken that the poleshoes are correctly aligned in the yoke, otherwise they will not bed down fully and may foul the armature.

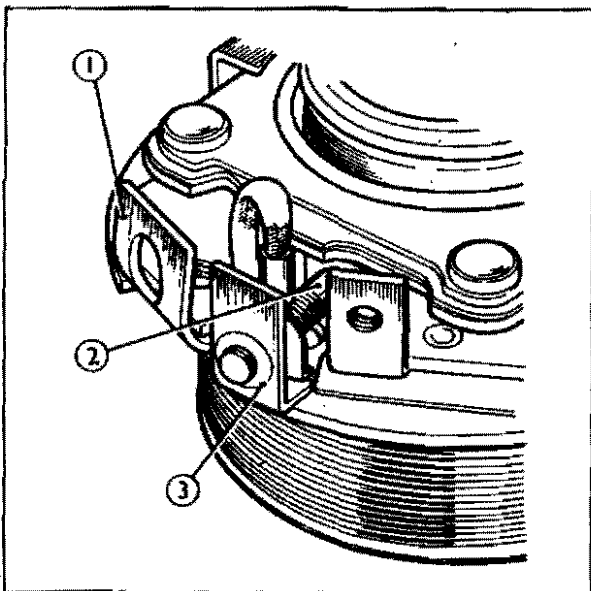


Fig. 72 – Solenoid Terminal and Insulators

- 1 Main Terminal Insulator
- 2 Solenoid Terminal
- 3 Solenoid Terminal Insulator

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### BRUSHES

The brushes should always be renewed at overhaul periods in order to ensure maximum life between overhauls. It is essential that replacement brushes are fitted in complete sets.

Replacement brushes must be well "bedded", i.e. shaped to the commutator periphery. To do this, wrap a strip of fine glass paper around the Commutator and 'bed' the assembled brushes on its surface.

### BRUSH SPRINGS

The brush spring pressure should be within the range 2.7 to 3.4 kgf (6 to 7.5 lbf). To check the pressure remove the brushes from the holder and with a suitable spring balance hooked under the lip of the spring raise the lip to the height of the brush. If the spring pressure is outside limits, fit new brush springs.

## RE-ASSEMBLING THE STARTER

**NOTE:**—The only difference in the assembling procedure between the CA45D and CA45F Starters is fitting the overspeed balls to the pinion sleeve and the four segments with garter spring to the solenoid plunger. All other operations are the same as detailed in the appropriate section of this Workshop Manual.

### Segments

- (a) First check that there are no burrs or sharp edges on the segments. Place the garter spring on a clean flat surface and with the fingers position the four segments inside the spring so that they lie end to end in a circle. The garter spring will fit in the outer groove of the segments and hold them together.
- (b) Place the solenoid switch on the bench, coil end upwards and with the fingers gently push in the garter spring and segment assembly into the bore of the solenoid plunger so that it fits into the recess provided. It will be found easier if one segment is located in the recess first and then the other three can be edged into position.
- (c) Proceed as for the CA45D starter assembly Number 4.

### Overspeed balls

The overspeed balls as well as the locking balls can be inserted into the pinion sleeve holes from inside the bore as detailed in paragraph 13 of the CA45D starter assembly. The blade end of a small screw-driver with a spot of grease will be found useful to feed in the balls.

## THE CA45F 24 VOLT STARTER

This is mechanically the same as the 12 volt version but only has a single wound solenoid winding whereas the 12 volt version has a dual wound winding.

The figures in brackets refer to Fig. 66 unless otherwise stated.

1. Fit the protection collar (special Service Tool No. 6244—6) over the end of the pinion sleeve and insert the pinion assembly into the drive-end shield, ensuring that the dust scraper ring (45) is not damaged in the process.
2. Place the assembly of pinion and endshield on the bench, pinion side downwards, and detach the protection collar from the pinion sleeve.
3. Place the solenoid terminal, solenoid terminal insulator, and main terminal insulator on the solenoid assembly as shown in Fig. 72.
4. Insert the solenoid assembly into the drive endshield and fasten it in position with spring washers and self-tapping screws (31). Drop the anodized metal strip on the inside face of the main terminal insulator.
5. Push the solenoid terminal (21) into its hole, and replace bush (19), spring washer and nut (20).

**NOTE.**—On insulated return models there is an additional solenoid lead, coloured green or yellow, which must be attached to its terminal screw exactly as above. This is the 'R' terminal.

6. Insert main terminal (22) into position from inside the housing, and replace bush (24), rubber ring, insulating washers, plain washers, spring washers and nut (23). Pressing down the plunger gives room to insert the main terminal. Do not tighten until item 7 has been carried out. Add the solenoid terminal tag (9) Fig. 70.

## RE-ASSEMBLING THE STARTER (Continued)

7. Replace spring washer and screw (25) and tighten securely. Now tighten nut (23) to a torque of 6.78 Nm (0.69 kgf m or 5 lbf ft).
8. Fit the lock collar (38) to the pinion sleeve making sure that the 45° chamfer inside the collar is facing towards the solenoid assembly.
9. Replace the spring (9) trip collar (10) and secure in position with circlip (11), dished side downwards. Make sure that the circlip locates in the locking collar groove. Check with gauge 6244-3 for seating squarely.
10. Insert resistor (40) into its recess in the drive endshield, and secure it in position by means of bush and spacer (26) and rivet (27).
11. Connect the resistor lead to the lug on the solenoid assembly by means of washer and screw (28).

NOTE.—On insulated return models there is a link bar between the lug and a corner of the moving contact. The link is secured to the lug by a washer and screw and the other end is attached to a post together with the resistor flexible lead by means of a washer and nut.

12. Insert lock balls (8) and with the CA45F, the four overspeed balls into the pinion sleeve holes from inside the bore, using grease to hold them in position.

NOTE.—12 volt starters have four lock balls and 24 volt six lock balls.

13. Assemble the pinion and endshield assembly to the armature as follows:-
  - (a) Pull the pinion out of the drive endshield until lock collar (39) is pressed back against its spring by the end of solenoid plunger (43). Keep it in this position until otherwise stated.
  - (b) Press lock balls (8) fully into their holes to allow free entry of the armature shaft.
  - (c) Slide the pinion and endshield assembly on the armature shaft, taking care not to displace the lock balls.
  - (d) Engage the pinion with the shaft helix, and then release the pull on the pinion. Screw the pinion on to the shaft and check that the pinion indentation corresponds with the shaft indentation as shown in Fig. 84. If not, the pinion must be unscrewed and engaged in the correct position, otherwise the locking mechanism will not operate.
  - (e) Finally, support the weight of the drive endshield, and rotate the pinion first in one direction and then in the other to ensure that the pinion is free on the shaft and that the locking mechanism functions correctly. The locking mechanism can be released by pulling lock collar (38) back against its spring.

14. Mount the armature in an armature clamp. Assemble the helix dust cover (1) the pinion return spring (2), the shim washer (47), and the thrust washer (48) on to the pinion shaft. Screw a NEW pinion stop nut (49) on to the shaft in the opposite direction of starter rotation. Using a 7/16 in. BSF socket with the chamfered lead ground away, tighten the pinion stop nut to a torque of 54 to 68 Nm (5.53 to 6.92 kgf m or 40 to 50 lbf ft). On oil sealed starters use ONLY Loctite grade 'D' on the nut thread.

15. Assemble the armature and drive endshield assembly to yoke (14), ensuring that the dowel in the end of the yoke locates in the slot in the endshield.

NOTE.—The joint between the yoke and each endshield should be sealed with Wellseal Compound.

## RE-ASSEMBLING THE STARTER (Continued)

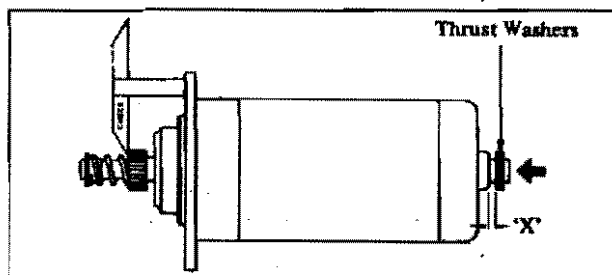


Fig. 73

Adjustment of Armature Endfloat

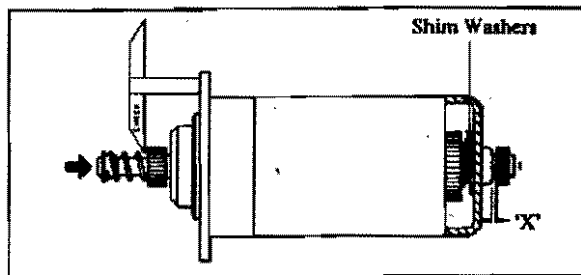


Fig. 74

16. Check that shims (36) have all been removed from the armature shaft, and then replace commutator end shield (15). Fit through bolts (35) and tighten securely, to a torque of 9.5 to 10.2 Nm (0.97 to 1.04 kgf m or 7 to 7.5 lbf ft).
17. Replace thrust washer (33) and circlips (17), but do not fit shims (16).
18. The armature endfloat, and the distance between the pinion and mounting flange, must now be adjusted as follows, using gauge S693-222, S693-222A or S693-222B as appropriate:—
  - (a) Bolt the gauge on to the mounting flange with the arm marked "CHECK" towards the pinion as shown in Fig. 73, then push the armature towards the drive end of the machine until the pinion face just touches the gauge. With the armature held in this position, measure gap 'X' between thrust washers (33) and the commutator end shield, using feeler gauges. Shim washers, having a total thickness equivalent to the measurement taken by the feeler gauges should then be fitted between the thrust washer and circlip. The shim washers must be well greased before use, and are available in two thicknesses 0.20 and 0.10 mm. (0.008 and 0.004 in.). A combination of these sizes giving the closest approximation to the required dimension should be used.
  - (b) When this has been done, push the armature towards the commutator end of the machine as shown in Fig. 74 and again measure gap 'X' which should now be within the limits  $2.03 + 0.50 - 0.00$  mm. (0.079 + 0.02 = 0.00 in.) using Tool No. 6244.4 go no go gauge.

**NOTE.**—If the gap is outside this limit remove the commutator end shield, and fit shim washers (36) on the armature shaft to the value of the excess. For example, if this is 3.04 mm. (0.120 in.) shim washers having a total thickness 0.51 to 1.01 mm. (0.020 to 0.040 in.) should be fitted i.e. four shims each 0.20 mm. (0.008 in.) thick. These shims must be smeared with grease before use.

Replace commutator end shield, thrust washers, shim washers as described in paragraph (a) and the circlip.

- (c) Smear steel ball (18) and spring (34) with grease and insert them in the bore in the armature shaft. Replace end cap (32), twisting it in the direction of starter rotation to lock it in place.

**NOTE.**—If a screwed end cap is originally fitted in place of the bayonet type, the starter motor must be held vertically, commutator end uppermost and the thrust pad attached to the cap with grease. The cap must be tightened to a torque of 9.5 to 13.6 Nm (0.97 to 1.38 kgf m or 7 to 10 lbf ft) and the two thin corners of the hexagon caulked to slots in the bearing collar with a punch.

**RE-ASSEMBLING THE STARTER (Continued)**

- (d) Check that any variation in the relationship of pinion position to check gauge is within the limits of  $+0.076$  to  $-0.050$  mm. ( $+0.003$  to  $-0.002$  in.).

Rectify if necessary by varying the shims as in 18 (b).

19. Fill the reservoir in the drive endshield with oil, and insert spring (3). Replace core plug (4) using special tool 5693-300.
20. Connect the field windings and the free end of the resistor to the solenoid switch lugs by means of screws and washers (30).
21. Fit the brushes and place the brush springs in position. Connect the brush leads and the field winding leads to the brush gear. Check that the brush leads allow free movement of the brushes in their holders.

**TESTING****ENGAGEMENT MECHANISM**

**WARNING.**—Under no circumstances should BOTH main terminals be connected to the supply during these tests, otherwise the pinion will rotate at high speed when pulled forward, causing injury to the operator.

1. With the machine disconnected, pull the pinion forward by hand approximately 1.6 mm. (0.0625 in.) and release. The pinion should return to its original position.
2. Energise the solenoid when cold by applying a battery voltage of 12 volt for 12 volt starters or 24 volt for 24 volt starters. For all tests the battery should be well charged, in good condition and of minimum capacity refer to (Fig. 78). The battery should be connected between the solenoid terminal 'S' and earth terminal for machines designed for earth return systems, and between the solenoid terminal 'S' and the solenoid terminal 'R' for insulated return machines. When the solenoid has been energised, the pinion should move forward for a distance of 6.3 mm. (0.25 in.) minimum.
3. With the solenoid still energised, pull the pinion forward by hand. The locking mechanism should now come into operation locking the pinion in the forward position.
4. Disconnect the supply to the solenoid. The pinion must return to its disengaged position in one sharp movement.
5. Check the recoil spring action by applying compression spring balance to the driving end of the armature shaft. The force required before backward movement of the shaft occurs should be 13.6 to 17.2 kgf (30 to 38 lbf).

**PERFORMANCE TESTS**

For the purpose of these tests, the brushes must be bedded over at least 80% of their contact area.

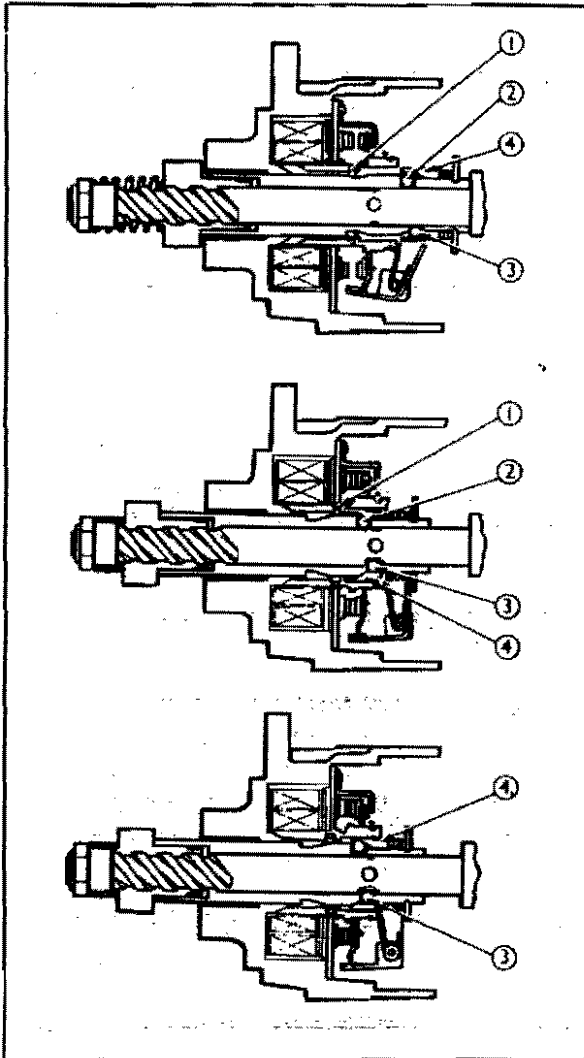
**CAUTION.**—If the starter is allowed to run without engaging a suitable flywheel, the pinion will not be restrained from rotating in the initial stages, and thus will not complete the forward movement necessary to trip the second stage contacts. Under these conditions, the resistor will remain in circuit and may be damaged by overheating. Moreover, prolonged running on first stage contacts may cause grooving of the solenoid trip mechanism. For these reasons, the starter should always be run in conjunction with a flywheel, but if this is not possible, the running period must not exceed five seconds.

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## TEST DATA (Continued)

### Installation Circuitry

The basic wiring circuits for the CA45D starter are applicable to the CA45F. The electrical overspeed protection, where installed, can be left to provide an additional and desirable feature.



**A**  
Normal position at rest. Segment (1) contracted to form a shoulder which carries the pinion forward when the solenoid is energised.

**B**  
Cranking position. Segments (1) expanded by pinion sleeve and held out by solenoid magnetic flux. Overspeed balls (2) not active. Locking balls (3) mating with shaft indents and holding pinion forward. Lock collar (4) pushed forward by its spring and retaining the locking balls.

**C**  
Overspeed condition. Lock collar (4) pushed back by the centrifugal action of the overspeed balls. Locking balls (3) released from the shaft indents. Pinion free to be driven out of engagement by reverse torque of the engine flywheel.

Fig. 79 – Operation of the CA45F starter

### RELAY TEST

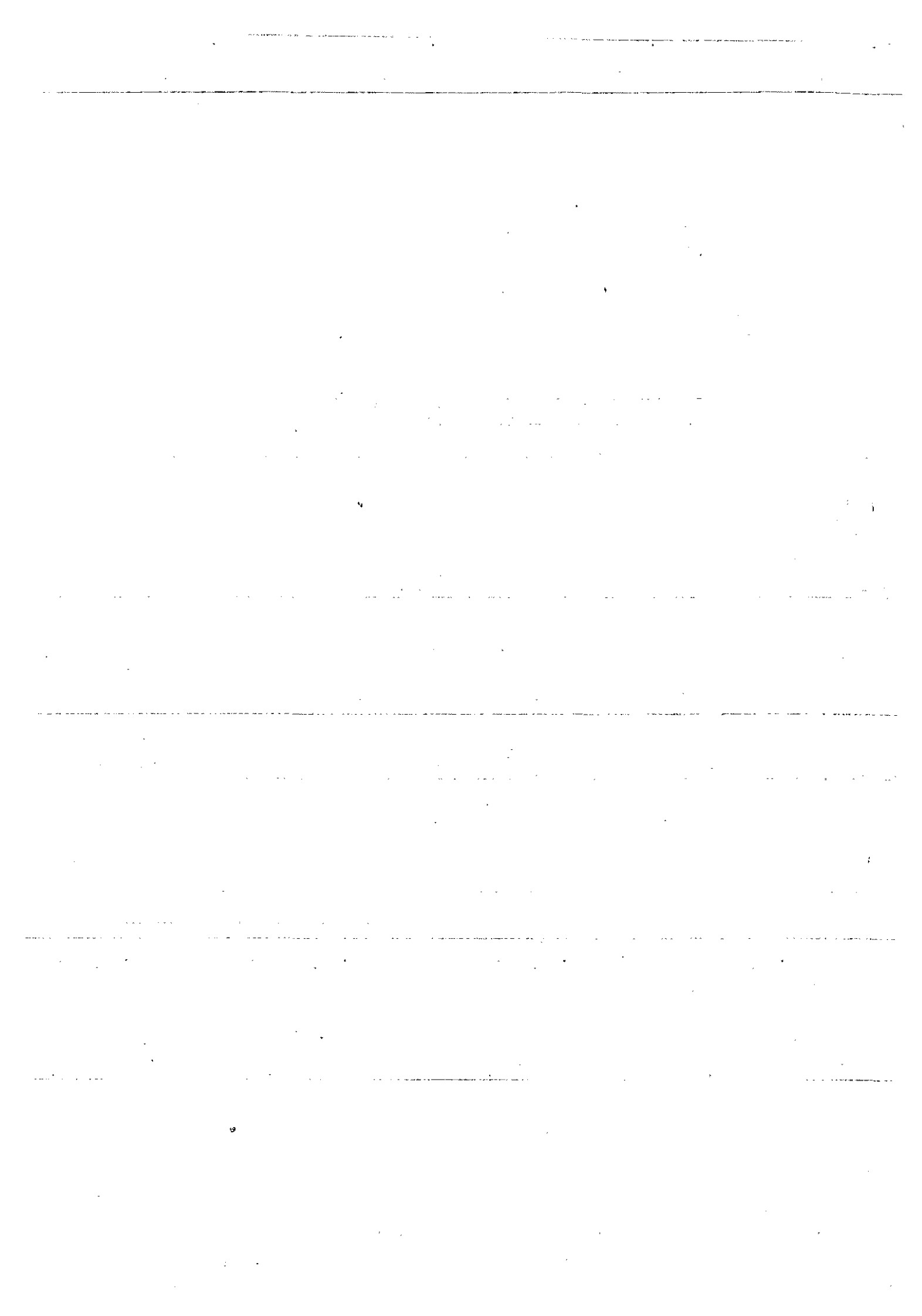
1. Check continuity between B+ and ST terminals and the insulation to frame of all terminals. (see Fig. 62) Check relay contact gaps which should be 1.14 to 1.27 mm. (0.045 to 0.050 in.). When closed the core gap should be 0.38 to 0.51 mm. (0.015 to 0.020 in.).
2. Connect a 1000 ohm, 5 watt variable resistance and milliammeter in series with a 12 volt battery and the relay winding B+ to 5w+ terminal, B- to junction of capacitor positive and the black relay winding start lead. Increase the variable resistance and set the relay by adjusting the armature spring tension so that the contacts open at between 60 to 62 milliamperes.

**RELAY TEST (Continued)**

3. Connect a voltage source not exceeding 8 volt to terminals SW+ and E and observe that the relay momentarily closes. Failure to do this indicates a faulty capacitor, loose or broken connections, or an excessive core gap setting.
4. Connect a 12 volt lamp and battery in series with the relay contacts, SW+ and SOL terminals. Press armature to coil, to close contacts and observe if lamp lights. Failure to light indicates dirty contacts, loose or broken connections.

Check for high resistance in the windings by connecting a resistance meter across the slip rings. The resistance should be 9.4 to 9.8 ohms.

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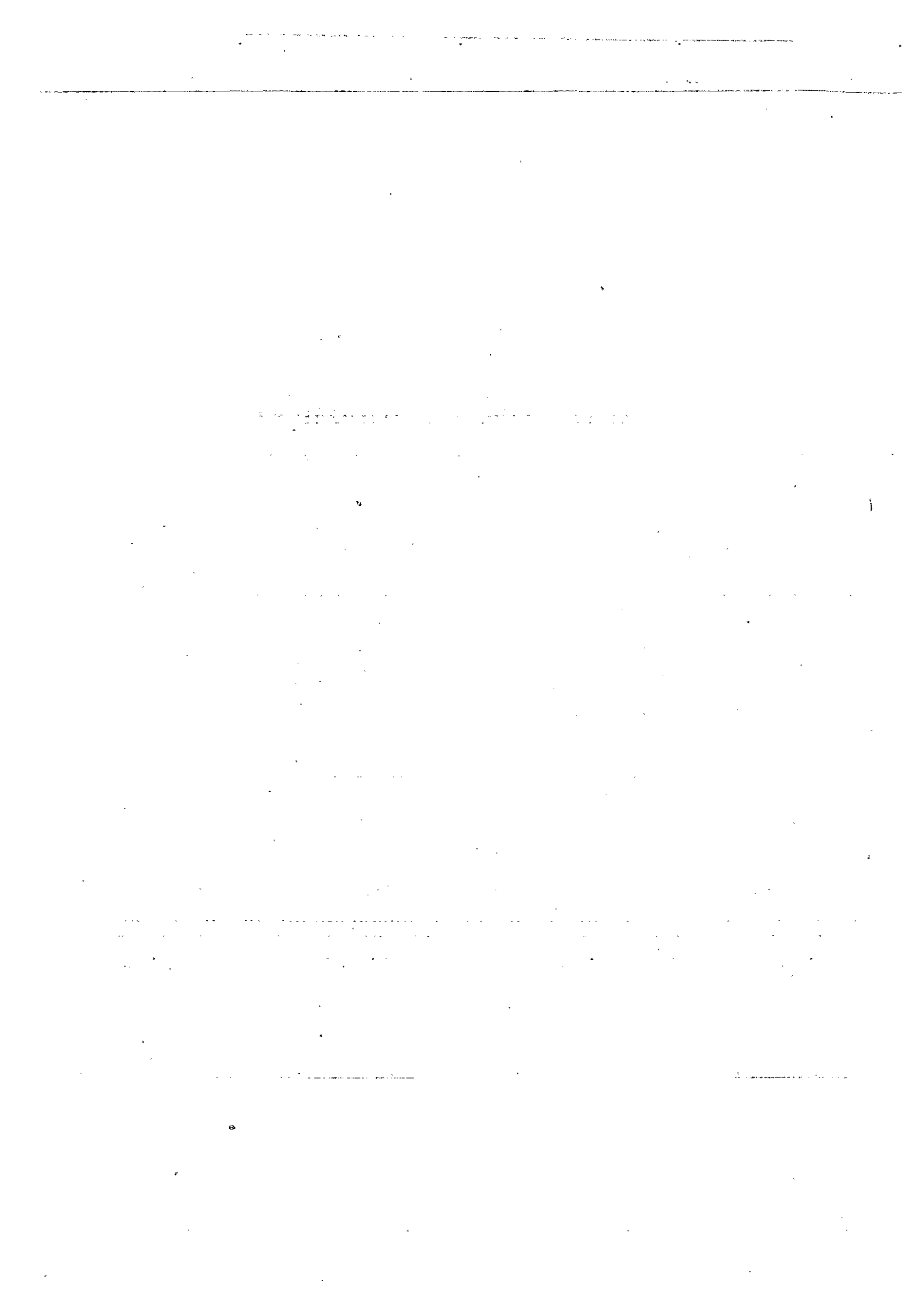


# SECTION 5

## ADDITIONAL EQUIPMENT

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Power Steering Pump . . . . .		8r.
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## THE EXHAUSTER

The exhauster is mounted beneath the fuel injection pump and is bolted to the rear of the timing case. It is gear driven directly off the timing gears and runs at engine speed. Oil is fed from the engine lubricating system through an oil-way in the engine block to the plain bush in the front cover. The oil then passes through the rotor shaft to the rotor and blades and the ball bearing in the rear end cover. The oil is pumped with the air from the exhauster into the timing case.

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

### TO DISMANTLE THE EXHAUSTER

1. Remove the drive gear. Unscrew the gear retaining nut and washer and remove the drive gear. Remove the woodruff key from the rotor shaft, and scribe mating marks on the end covers and body to ensure correct assembly.
2. Unscrew the four nuts at the rear of the unit and carefully remove the rear end cover, taking care not to lose the four coil springs located in drillings in the cover. Remove the gasket from the end cover or body.

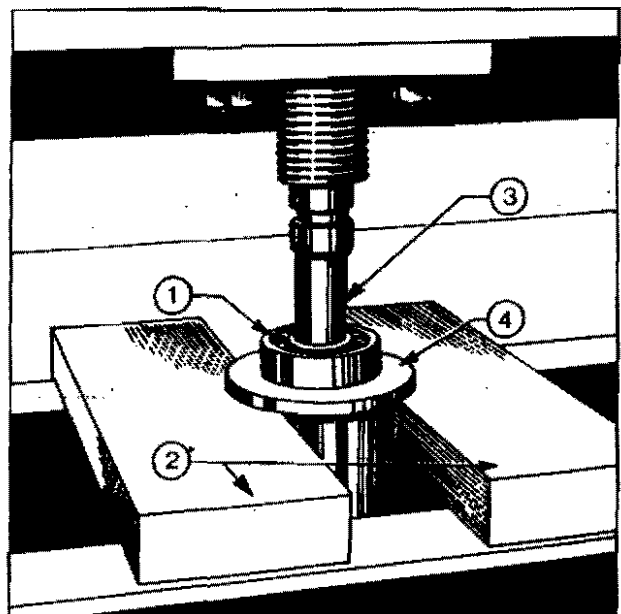
#### Note

If difficulty is encountered in removing the cover, the drive gear retaining nut can be screwed onto the rotor shaft and the nut gently tapped until the cover is released. Do not insert a screwdriver or similar tool between the flange faces as these faces may be scored and cause a leakage.

3. Withdraw the rotor assembly and remove the blades. The ball bearing and the sealing plate can be pulled off using a suitable press (Fig. 1).

Fig. 1

1. Ball bearing
2. Support blocks
3. Ram
4. Sealing plate





### TO ASSEMBLE THE EXHAUSTER

1. Fit a new oil seal in the front end cover using Tool No. CT.6068 and fit a new gasket either to the cover or pump body.
2. Replace the bearing and sealing plate assembly on the rotor shaft, the sealing plate having its dowel pointing away from the rotor. The ball bearing can be pressed into position.
3. Replace the rotor assembly and front sealing plate in the body, making sure that the blades are correctly located. Fit a new gasket to the body or end cover.
4. Replace the four coil springs in their drillings in the end covers. Hold the exhaustor body with the exhaust port at the six o'clock position. Looking from the drive gear end of the rotor shaft, rotate the sealing plate until the dowel is at the two o'clock position. Replace the front cover and gasket ensuring that the sealing plate dowel locates in the coil spring, and the front plate dowel locates in the exhaustor body correctly.

Align the dowel in the rear sealing plate with the dowel in the front sealing plate and replace the rear cover and gasket. Ensure that the dowel locates in the coil spring and bearing fits in the end cover correctly. Ensure all mating marks align correctly.

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1. Timing case
2. Banjo union

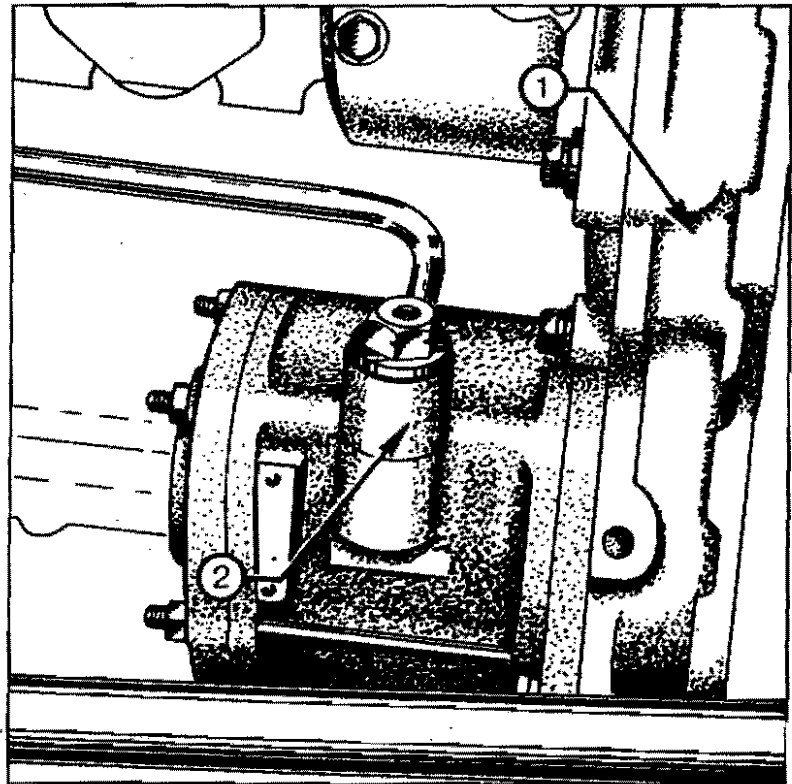


Fig. 3

5. Replace the end cover retaining nuts and washers and tighten them a little at a time in sequence. The sealing of the gaskets depends on having all these nuts tightened evenly.

6. Replace woodruff key and drive gear. Tighten the retaining nut to 34 to 40.7 Nm (3.46 to 4.15 kgf m or 25 to 30 lbf ft).

#### **TO REMOVE THE EXHAUSTER**

1. Disconnect the take-off pipe and remove the retaining nut and the two bolts. Withdraw the exhauster assembly and gasket.

#### **TO REPLACE THE EXHAUSTER**

1. Refit the exhauster assembly ensuring that the drive gear mates with the timing gears. Replace the retaining bolts and nut, and ensure a new gasket is fitted. Tighten to a torque of 23 to 30 Nm (2.35 to 3.04 kgf m or 17 to 22 lbf ft).

Note—An exploded view of the exhauster is shown in Fig. 2.

## AIR COMPRESSOR

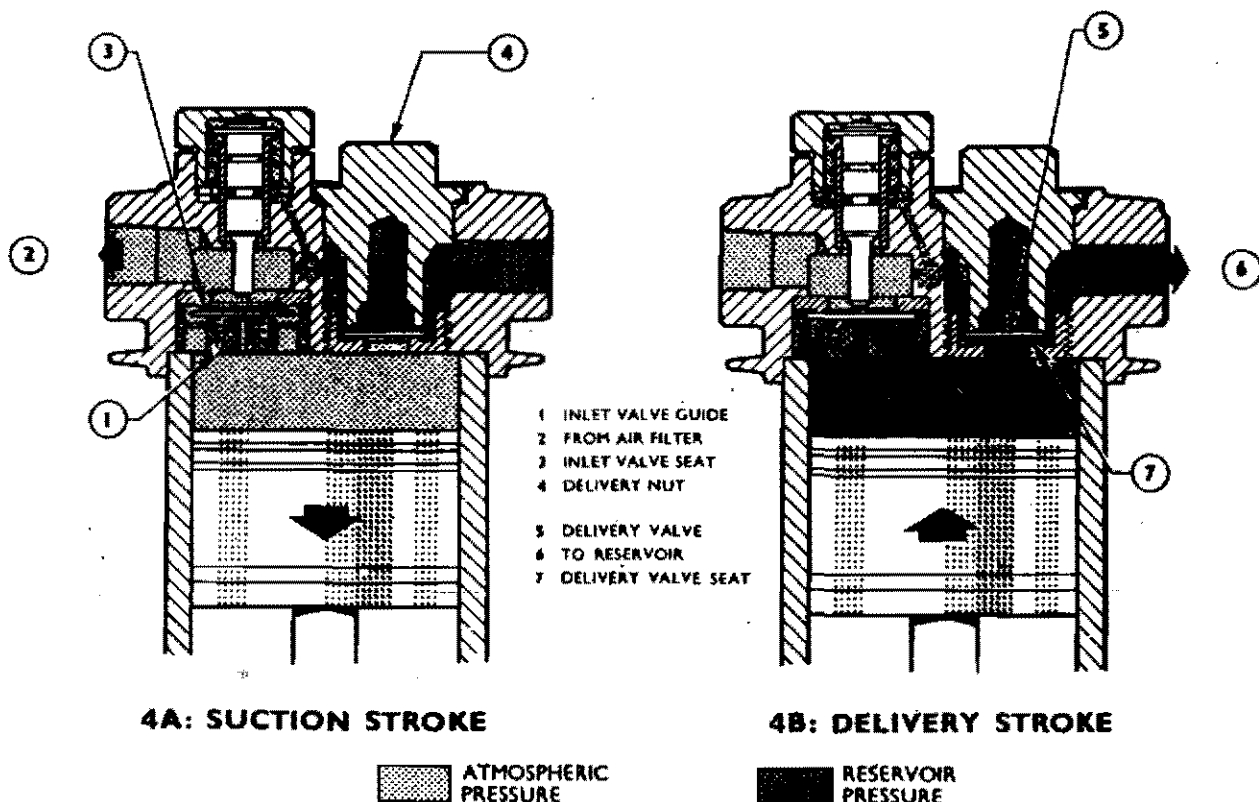
The air compressor is a single cylinder air cooled unit. It is mounted beneath the fuel injection pump and is bolted to the rear of the timing case. The compressor is gear driven directly off the timing gears and runs at engine speed. Oil is fed from the engine lubrication system, through an oil-way in the block to the bush in the front of the crankcase, it then passes through drillings in the crankshaft to the connecting rod bearing and the rear cover bush. The piston and bore are splash lubricated by oil thrown off the crankshaft. The oil drains back from the compressor into the sump via the timing case.

The crankshaft runs in steel backed white metal bushes and end-float is controlled by thrust washers located between the crankshaft and the front of the crankcase and end cover.

The cylinder head, which is detachable, contains the inlet and delivery valve assemblies. The inlet valve is a hardened and lapped steel disc, lightly sprung against a replaceable valve seat. The delivery valve comprises a square-shaped valve disc held on to a replaceable valve seat by a spring located in the delivery valve cap.

### OPERATION (Reservoir pressure below 6.89 bar (7.03 kgf/cm<sup>2</sup> or 100 lbf/in<sup>2</sup>))

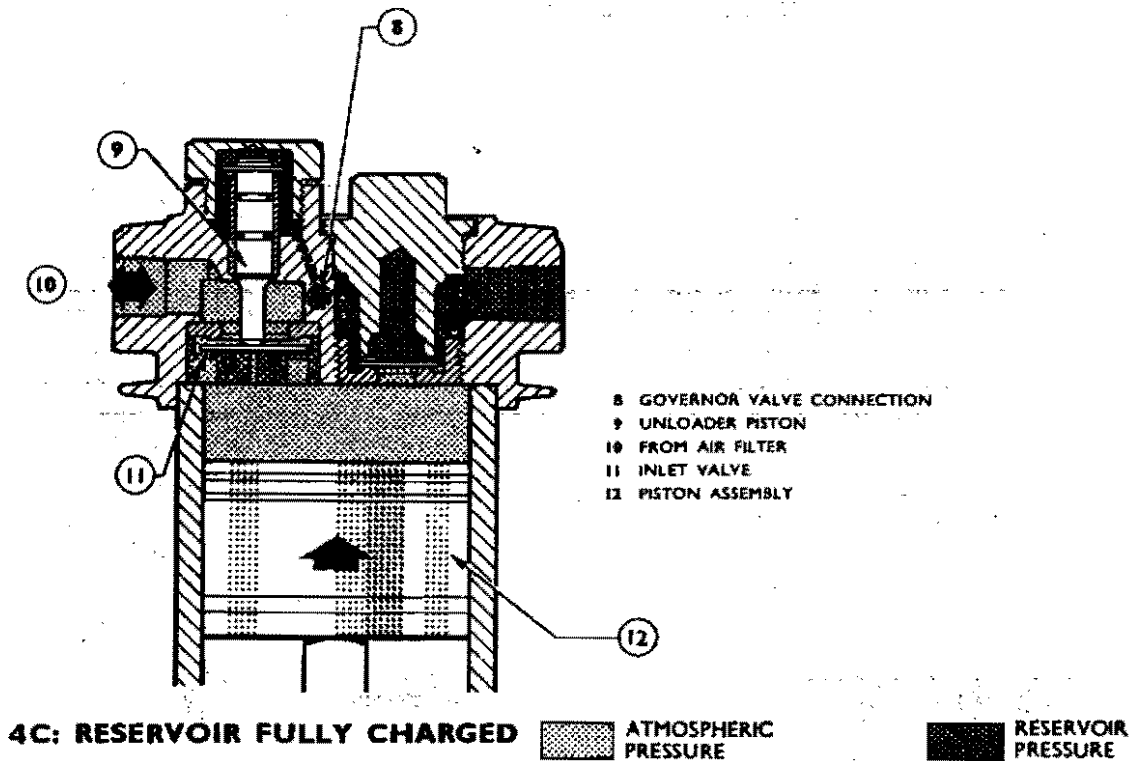
During the downstroke (suction) of the piston, a partial vacuum is created in the cylinder, overcoming the inlet valve spring tension, thus unseating the inlet valve and allowing air to be drawn into the cylinder (see Fig. 4A). When the piston commences its upward stroke (compression) the inlet valve closes under the action of the valve spring and air pressure under the valve. As the piston continues its upward stroke the air above the piston is compressed further until the pressure overcomes the delivery valve spring, forcing the delivery valve to open. Compressed air is then discharged through the air line to the air reservoir (see Fig. 4B). On the following downward stroke the delivery valve reseats, preventing the compressed air from returning into the cylinder, and the inlet valve opens. The cycle is then repeated.



## OPERATION (Reservoir fully charged)

As soon as the air pressure in the reservoir reaches the setting of the governor valve, compressed air passes through the governor valve to the unloader chamber situated in the compressor cylinder head.

Air pressure operates the unloader piston moving it downwards to unseat the compressor inlet valve. Hence, air will pass to atmosphere during each upward stroke (see Fig. 4C). When air pressure in the reservoir falls below the governor setting the governor valve releases the air pressure above the unloader piston. The unloader spring lifts the unloader piston and the inlet valve spring then returns the inlet valve to its seat, so that further air can be compressed.



## TO REMOVE THE COMPRESSOR

1. Disconnect the air pipes at the compressor cylinder head, to the governor valve, the reservoir and the alcohol evaporator where fitted.
2. Remove the power steering pump and coupling, where power steering is fitted, from the rear of the compressor and place to one side. Do not disconnect the pipes from the pump to the power cylinder.
3. Remove the two bolts and the nut retaining the compressor to the rear of the timing case.
4. Remove the drive gear and retaining nut and washer.



### TO REPLACE THE COMPRESSOR

1. Replace the drive gear and tighten the nut to a torque of 34 to 40.7 Nm (3.46 to 4.15 kgf m or 25 to 30 lbf ft).
2. Refit the compressor to the rear of the timing case meshing the drive gear with the timing gears. Replace the retaining bolts and nuts, and ensure a new gasket is fitted.
3. Replace the power steering pump and coupling (where fitted) and replace the retaining nuts and bolts.
4. Reconnect the air pipes to the compressor cylinder head.

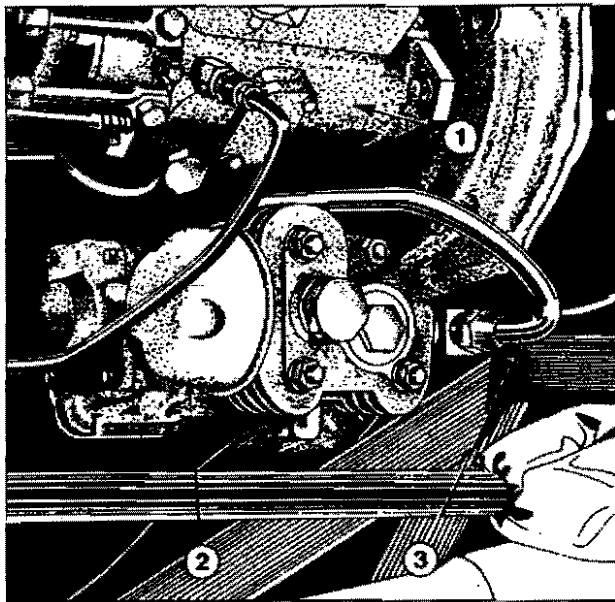


Fig. 5

1. Injection pump
2. Air filter
3. Outlet pipe

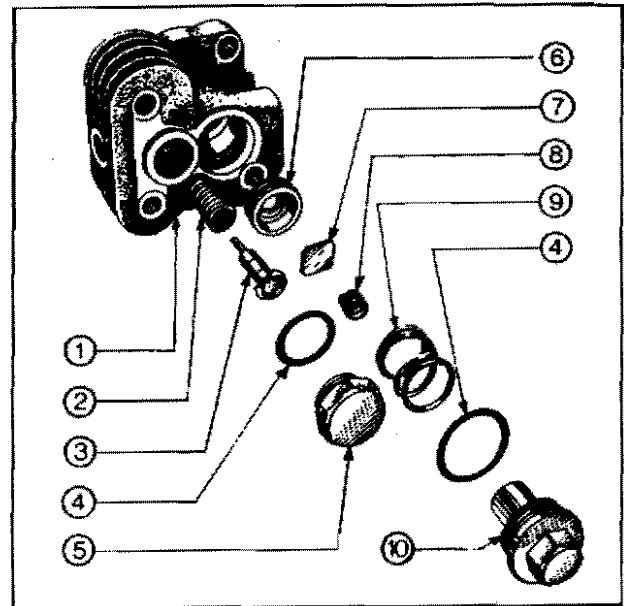


Fig. 6

1. Cylinder head
2. Return spring
3. Unloader piston
4. Washer
5. Unloader valve unit
6. Delivery valve seat
7. Delivery valve
8. Valve spring
9. Delivery valve seat retaining spring
10. Delivery valve nut

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## TO DISMANTLE THE COMPRESSOR

1. Suitably mark the cylinder head, cylinder and the crankshaft end cover in relation to the compressor crankcase to ensure correct reassembly.
2. Remove the cylinder head assembly. Lightly clamp the compressor in a vice and remove the four nuts, spring washers and flat washers securing the cylinder head to the cylinder. Lift the cylinder head assembly from the four studs.
3. Dismantle the cylinder head assembly (see Fig. 6) as follows:—
  - (a) Using a pair of soft jaws clamp the cylinder head assembly in a vice.
  - (b) Remove the delivery valve nut, copper washer and withdraw the valve spring and valve seat retaining spring. Lift out the delivery valve and unscrew the valve seat from its location.
  - (c) Remove the unloader valve nut, copper washer and withdraw the unloader piston, sealing ring and the return spring.
  - (d) Invert the cylinder head assembly and withdraw the inlet valve guide (see Fig. 7), using a simple extractor made from two  $\frac{1}{4}$  UNF bolts 25 mm (1.0 in) long, and a metal plate as shown in Fig. 8.
  - (e) Remove the inlet valve, valve spring and the valve seat.

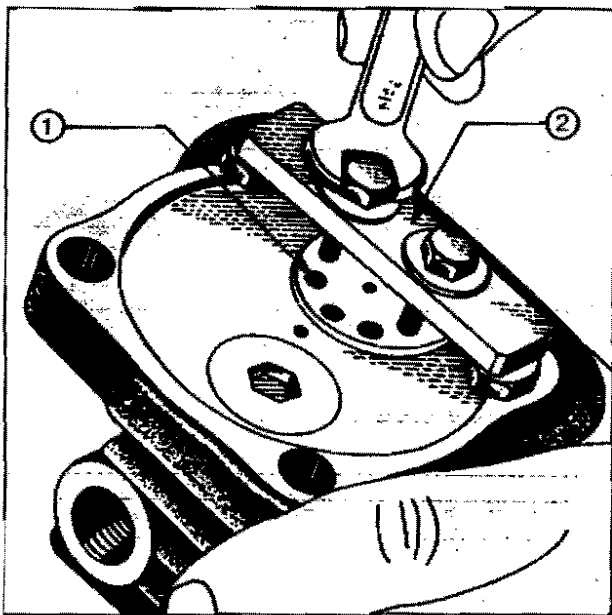


Fig. 7

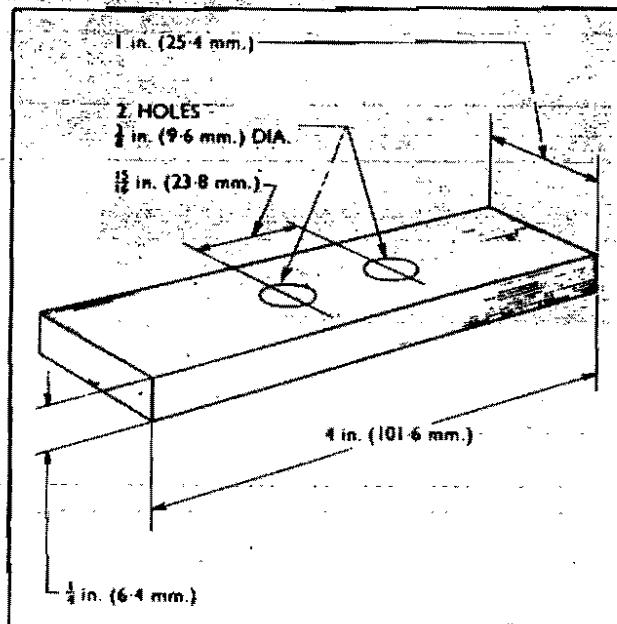


Fig. 8

1. Inlet valve guide
2. Extractor

## TO DISMANTLE THE COMPRESSOR (continued)

4. Remove the compressor bottom cover, unscrew the four bolts and remove the spring washers, cover and cork gasket.

5. Withdraw the piston and connecting rod assembly.

(a) Support the compressor in the inverted position and mark the connecting rod in relation to the crankcase for reassembly purposes. Turn the crankshaft to B.D.C.

(b) Bend back the locking strip from the two connecting rod bolts.

(c) Remove the two bolts and push the piston up the bore until it can be removed from the top of the cylinder. Remove the connecting rod cap and reassemble it to the connecting rod when the piston and connecting rod assembly has been removed. Suitably mark the bearing liners for reassembly purposes.

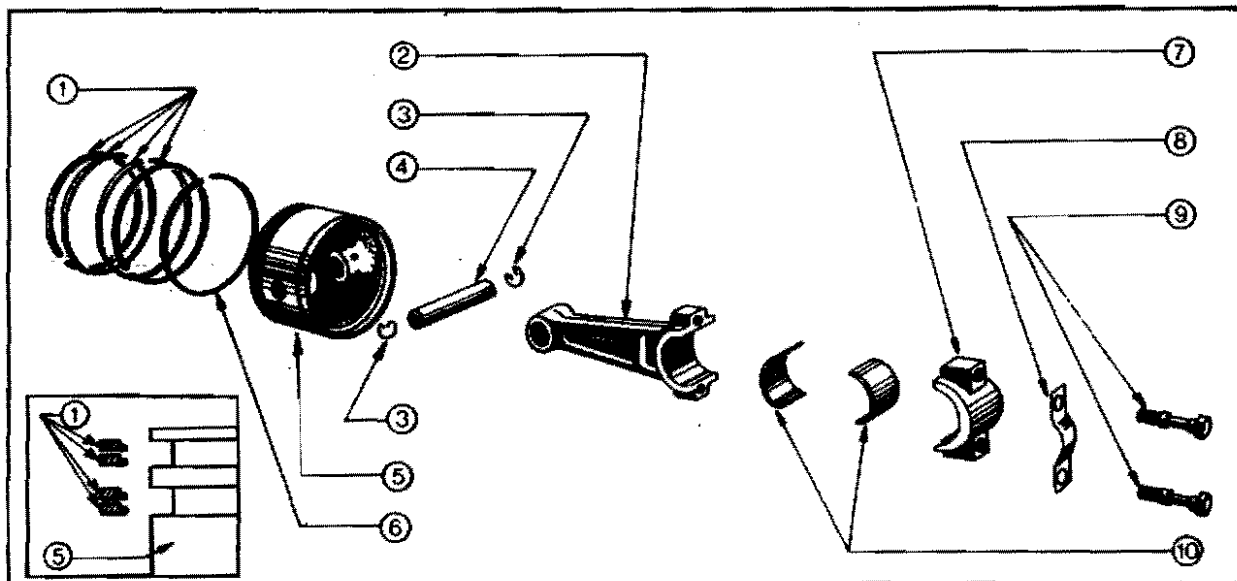


Fig. 9

- |                      |                         |
|----------------------|-------------------------|
| 1. Compression rings | 6. Oil control ring     |
| 2. Connecting rod    | 7. Connecting rod cap   |
| 3. Circlip           | 8. Locking strip        |
| 4. Piston pin        | 9. Connecting rod bolts |
| 5. Piston            | 10. Bearing liners      |

6. Remove the piston from the connecting rod assembly (see Fig. 9).

(a) Remove the five piston rings. Turn the rings so that the ring gaps are aligned and push three feeler strips 0.5 mm (0.020 in) thick, not more than 12 mm (0.5 in) wide through the gap between the rings and the piston. Work two of these strips sideways until the three strips are equally spaced around the piston. The rings can then be worked off the piston.

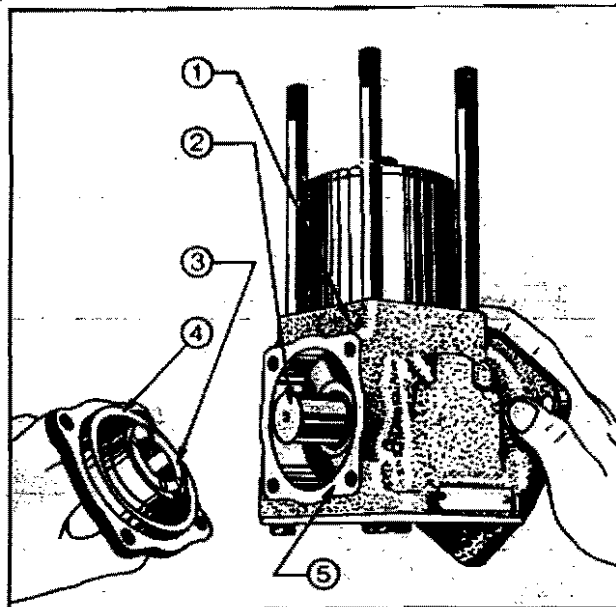
(b) Mark the inside of the piston in relation to the connecting rod, for reassembly purposes. Remove the two piston pin retaining circlips and press the pin out of the piston. It may assist, if the piston is warmed slightly by immersing in hot water or oil. Separate the piston from the connecting rod.

## TO DISMANTLE THE COMPRESSOR (continued)

7. Remove the cylinder by pulling upwards and at the same time twisting, to facilitate removal. Detach the gasket.
8. Remove the rear cover. Unscrew the four retaining nuts and detach the cover, gasket and thrust washer.
9. Withdraw the crankshaft from the crankcase and remove the thrust washer from the crankshaft.

Fig. 10

1. Crankcase
2. Crankshaft
3. Thrust washer
4. Rear cover
5. Gasket



## TO REASSEMBLE THE COMPRESSOR

1. Fit the crankshaft. Lubricate all bearing surfaces and relocate the thrust washer on the crankshaft. Position the crankshaft in the crankcase, ensuring that the lug on the thrust washer locates in the slot in the crankcase.
2. Replace the rear end cover and gasket, ensuring that the lug on the second thrust washer locates in the slot in the end cover. Replace the spring washers and bolts and tighten to 6.8 to 9.5 Nm (0.69 to 0.97 kgf m or 5 to 7 lbf ft) and check that the crankshaft is free to rotate and does not bind at any point.
3. Check each piston ring gap. Place each ring in turn into the cylinder and centralise if necessary with the piston. Check the ring gap (see Fig. 11), with those given in the Specification.
4. Position the cylinder. Locate the gasket on the cylinder and position in the crankcase, taking note of the marks made prior to dismantling.
5. Refit the piston rings to the piston. Check that the piston ring grooves are clean and replace the five rings, oil control ring first, in their respective grooves. The compression rings are marked "Top" and are stepped. Space the ring gaps at 120°.

6. Reassemble the piston to the connecting rod. Fit a circlip in position in the piston pin boss. Locate the connecting rod small end between the piston pin bosses in the piston taking note of the marks made prior to dismantling. Slide the piston pin through the piston bosses and connecting rod small end until it abuts the circlip. If necessary warm the piston slightly to facilitate fitting the piston pin. Fit the second circlip.

7. Fit the piston and connecting rod assembly to the cylinder bore. Lubricate the piston assembly and the cylinder bore with engine oil. Position the piston and connecting rod assembly into the cylinder taking note of the marks made prior to dismantling. Compress the piston rings, using a ring squeezer (bore dia. 66.7 mm or 2.625 in) and tap the piston down the cylinder bore with the crankshaft in the B.D.C. position. Locate the bearing liners in the connecting rod and the connecting rod cap and fit the cap to the connecting rod with the cast mating marks (see Fig. 12) together. Fit the connecting rod locking strip and bolts and tighten the bolts to a torque of 5.1 to 5.4 Nm (0.52 to 0.55 kgf m or 45 to 48 lbf ft). Rotate crankshaft and ensure it does not bind at any point.

8. Replace the bottom cover. Position the cork gasket, lubricate the big end bearing and the small end bush. Replace the cover, spring washers and bolts. Tighten the bolts to 6.8 to 9.5 Nm (0.69 to 0.97 kgf m or 5 to 7 lbf ft).

9. Reassemble the cylinder head.

(a) Insert the inlet valve seat so that the raised seating is away from the unloader valve guide.

(b) Assemble the inlet valve spring and valve to the inlet valve guides and hold the valve in the depressed position as the guide is installed into the cylinder head. This can be done by inserting a thin rod through the bore or the unloader valve guide. Check that the valve is free after the inlet valve guide is fully located.

NOTE.—It is important that the inlet valve guide does not protrude above the machined face of the cylinder head.

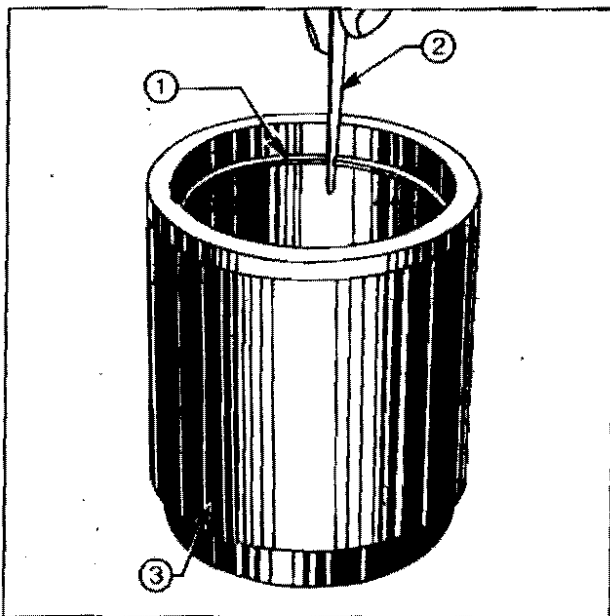


Fig. 11

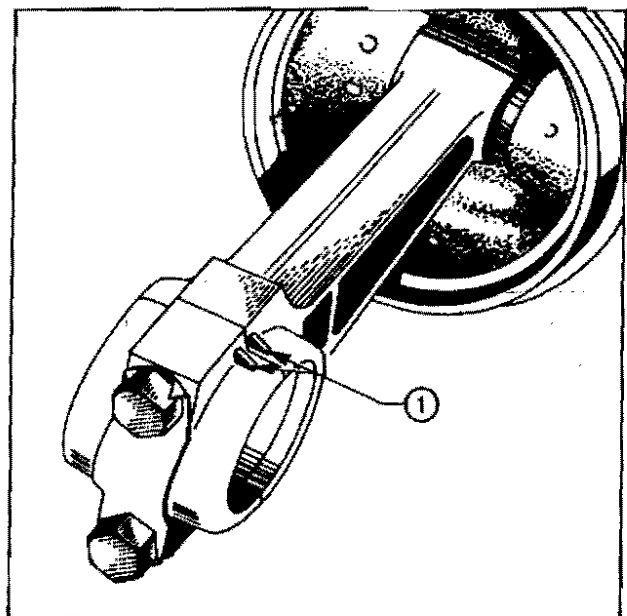


Fig. 12

1. Piston ring parallel with top face
2. Check gap with feeler gauge
3. Cylinder

1. Cast mating marks

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## TO REASSEMBLE THE COMPRESSOR (continued)

(c) Install a new sealing ring in the groove in the unloader piston. Replace the circlip and position the spring on the unloader piston. Replace the unloader valve assembly into the cylinder head and screw in the unloader valve nut with the copper washer in position.

(d) Screw the delivery valve seat in position and replace the delivery valve and the delivery valve seat retaining spring in the cylinder head. Locate the valve retaining spring in the delivery valve nut. Use a new copper washer and refit the nut (see Fig. 6).

10. Fit the cylinder head. Install the cylinder head so that the intake port connection faces away from the drive side. Use a new cylinder head gasket, fit the head to the cylinder, replace the flat washers, spring washers and nuts. Tighten the nuts progressively to 20.3 to 23 Nm (2.07 to 2.35 kgf m or 15 to 17 lbf ft) torque.

## SPECIFICATIONS

### Air Compressor

Type	Single Cylinder, Air-cooled
Bore	66.67 mm (2.625 in)
Stroke	41.28 mm (1.625 in)
Capacity	0.17 cu m (6 cu ft) at 1250 r.p.m.
Thrust Washer thickness	23.37 to 24.38 mm (0.920 to 0.960 in)

### Piston

No. of Rings	Aluminium Alloy
Piston Ring Gap	Two pairs compression, one oil control
	0.08 to 0.18 mm (0.003 to 0.007 in)

### Tightening Torques

	Nm	kgfm	lbf ft	lbf in
Cylinder Head	20.3 to 23	2.07 to 2.35	15 to 17	—
Big End Bearing	5.1 to 5.4	0.52 to 0.55	—	45 to 48
Rear End Cover	6.8 to 9.5	0.69 to 0.97	5 to 7	—
Bottom Cover	6.8 to 9.5	0.69 to 0.97	5 to 7	—
Compressor to Block, rear	23 to 30	2.35 to 3.04	17 to 22	—
Compressor to Pump	30 to 36.6	3.04 to 3.73	22 to 27	—

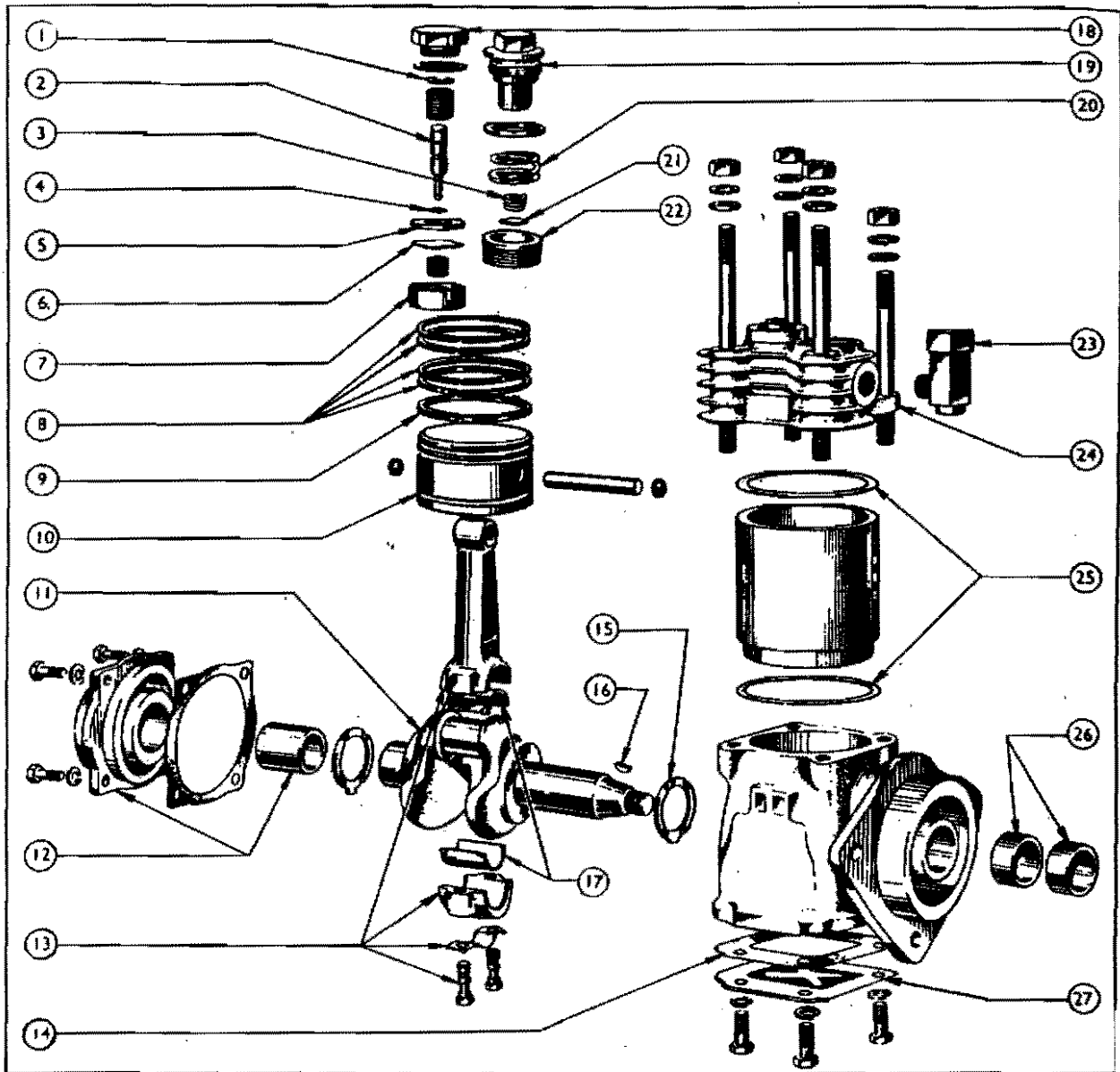


Fig. 13

- |                             |  |
|-----------------------------|--|
| 1. Circlip                  | 15. Thrust washer                        |
| 2. Unloader piston          | 16. Key                                  |
| 3. Valve spring             | 17. Bearing liners                       |
| 4. Sealing ring             | 18. Unloader valve nut                   |
| 5. Inlet valve seat         | 19. Delivery valve nut                   |
| 6. Inlet valve              | 20. Delivery valve seat retaining spring |
| 7. Inlet valve guide        | 21. Delivery valve                       |
| 8. Compression rings        | 22. Delivery valve seat                  |
| 9. Oil control ring         | 23. Elbow                                |
| 10. Piston                  | 24. Cylinder head                        |
| 11. Crankshaft              | 25. Gaskets                              |
| 12. Rear cover assembly     | 26. Crankcase bushes                     |
| 13. Connecting rod assembly | 27. Bottom cover                         |
| 14. Gasket                  |  |

# POWER STEERING PUMP

The hydraulic pump is mounted on the rear of the exhaustor or the compressor (air hydraulic). A special exhaustor or compressor is necessary, fitted with a longer crankshaft, slotted to accommodate the pump drive coupling.

The oil reservoir is mounted directly on top of the pump with no external connections between the reservoir and the pump. A spring loaded filter assembly is fitted, which will by-pass the oil, should the element become clogged (see Fig. 19).

## THE PUMP CONTROL VALVE

To maintain a uniform degree of power assistance, irrespective of engine speed, a combined flow control and pressure relief valve is incorporated in the pump assembly. The valve is retained by the hexagon headed cap, (see Fig. 20). Do not alter the position of the ball in the smaller end of the control valve, as its depth sets the maximum pump pressure.

Pump Control Valve Action (see Fig. 15).

As flow commences, a pressure drop will occur across the orifice A. The higher pressure tends to move the valve inwards against the lower pressure applied through orifice B, together with the force exerted by the valve spring D. This pressure difference increases with flow until the valve has moved to uncover the by-pass hole C. A continued increase in flow will result in further valve movement with increased by-pass. Thus, a maximum flow is maintained depending on the rate of the valve spring.

The delivery pressure is also applied to the pilot relief valve through orifice B. When this is sufficient to lift the ball from its seat, oil will flow from the spring chamber. Due to the action of orifice B, an additional pressure drop occurs in the spring chamber, resulting in the valve moving to the by-pass position. As the delivery pressure drops, the pilot relief valve closes and the main valve resumes its flow control action.

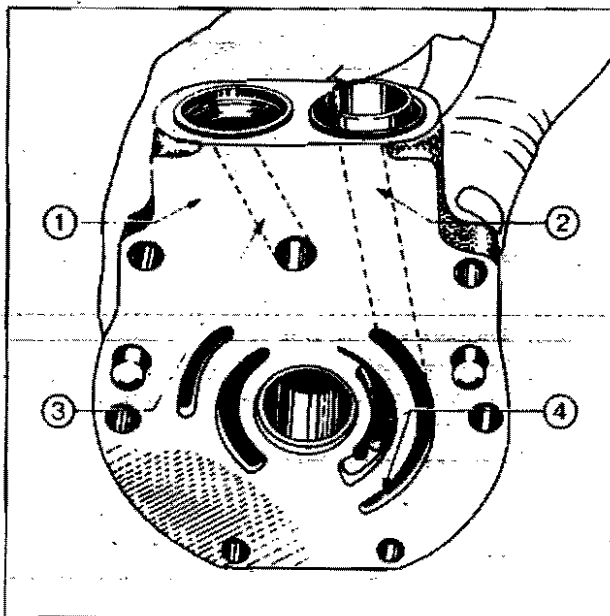


Fig. 14

1. Pump cover
2. Supply from reservoir
3. Overspill
4. Inlet ports

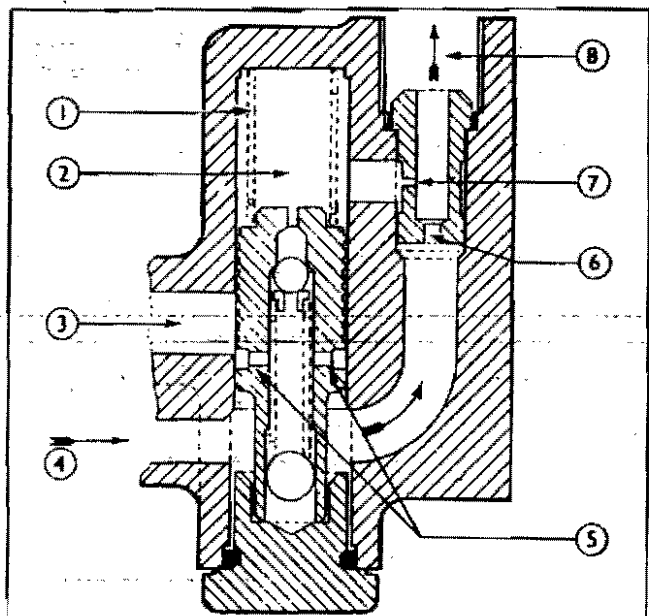


Fig. 15

- |                     |                           |
|---------------------|---------------------------|
| 1. Valve spring 'D' | 5. Pilot relief spill 'E' |
| 2. Spring chamber   | 6. Orifice 'A'            |
| 3. By-pass hole 'C' | 7. Orifice 'B'            |
| 4. From pump        | 8. To power cylinder      |



## ROUTINE SERVICING

### At Weekly Intervals

Check the reservoir oil level. Always clean the top of the reservoir and the filler cap, before removing. If necessary, add oil until the level is just above the top of the filter element. Use S.A.E. 10 hydraulic oil. Do not use detergent or multigrade engine oils.

### Every 1,200 Hours

At 1200 hour intervals, renew the filter element. Unscrew the bolt retaining the reservoir cover and remove the cover assembly, the spring, the retaining washer and the old filter element. Install the new element, the washer and the spring. Check the condition of the cover gasket and refit the cover assembly. Fit the retaining bolt and the sealing washer and tighten the bolt. Prime and bleed the system.

## TO REMOVE THE PUMP AND RESERVOIR ASSEMBLY

1. Position a suitable container below the pump to catch the oil, then disconnect the two pipes.
2. Remove the four nuts, securing the pump to the exhauster or compressor and lift away. At this stage, the shaft coupling assembly may drop down and care should be taken to retrieve it.

## TO DISMANTLE THE PUMP ASSEMBLY

1. Blank off the reservoir stub and the pump delivery. Thoroughly clean the exterior of the pump, preferably using de-greasing equipment and an air line.
2. Remove the bolt and the sealing washers from the centre of the reservoir cover. Lift out the element spring, the retaining washer and the filter element.
3. Unscrew the union stud in the centre of the reservoir and remove the lower filter support, the reinforcing plate and the reservoir tank.
4. Remove the six cap screws holding the pump cover to the body and tap the cover off its locating dowels, vertically, to prevent the internal parts falling out.
5. Remove the two "O" rings from the pump body, the circular gaskets from the recesses in the top of the pump cover and the adaptor from the pump inlet. Note that the venturi flow director and the orifice tube are pressed into the inlet and the outlet passages respectively and should not be removed.
6. Remove the four socket head screws and lockwashers retaining the mounting plate to the pump body and remove the plate and the gasket.

NOTE.—Handle the internal parts with great care, as the working surfaces are precision finished.

7. Wash all the parts in a suitable solvent, dry and lightly oil, for storage or reassembly.

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## TO REASSEMBLE THE PUMP ASSEMBLY

1. Inspect the pump body and the cover, for worn bushes or damage. If necessary, renew either part.
2. Fit a new carrier shaft oil seal, flat face first, using Tool No. CP. 7102 and the 575 handle. Drive the seal fully home but ensure that it is not squashed.
3. Insert the cam lock peg in the pump body. Inspect the cam ring for wear or damage and renew if necessary.
4. Fit the cam ring to the pump body, ensuring that the lock peg is located in the cam ring slot and that the cam ring is seated at the bottom of the pocket.

NOTE.—If the cam ring or the carrier and the rollers are worn or damaged, the components must be renewed as an assembly. This is essential, as the parts are individually matched, to give the required end clearances.

5. Grease the oil seal and insert the carrier shaft from the cam ring side of the body, ensuring that the seal lips are not damaged.
6. Fit the carrier drive pin to the groove in the shaft and retain with grease, if necessary.
7. Inspect the carrier and fit to the shaft. When viewed from the cover end, the shaft rotates anti-clockwise. The carrier must be installed so that the flank inclined at the greater angle is leading (see Fig. 16).
8. Inspect the rollers and renew, if any damage is apparent, particularly on the ends.
9. Place a straight edge across the cam ring, with the "O" ring removed. Check the clearance on the ends of the carrier and the rollers (see Fig. 17). If this clearance exceeds 0.002 in. (0.05 mm.), the cam ring, the carrier and the rollers must be renewed. Install the carrier and the rollers and fit a new snap ring to the carrier shaft.

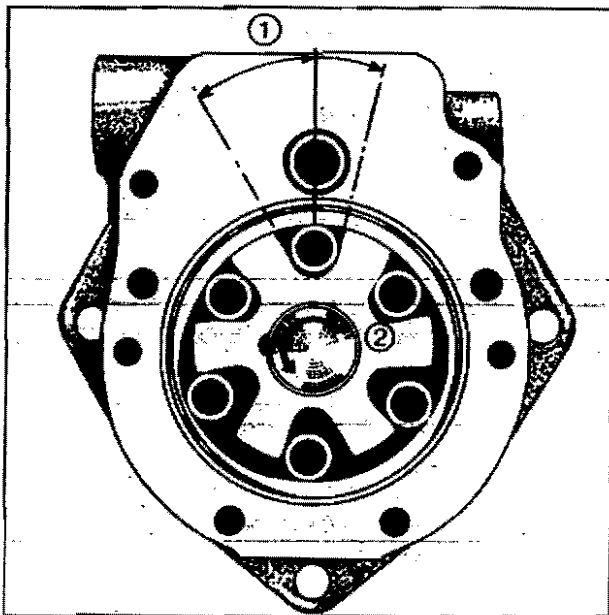


Fig. 16

1. Greater angle in leading position
2. Direction of rotation

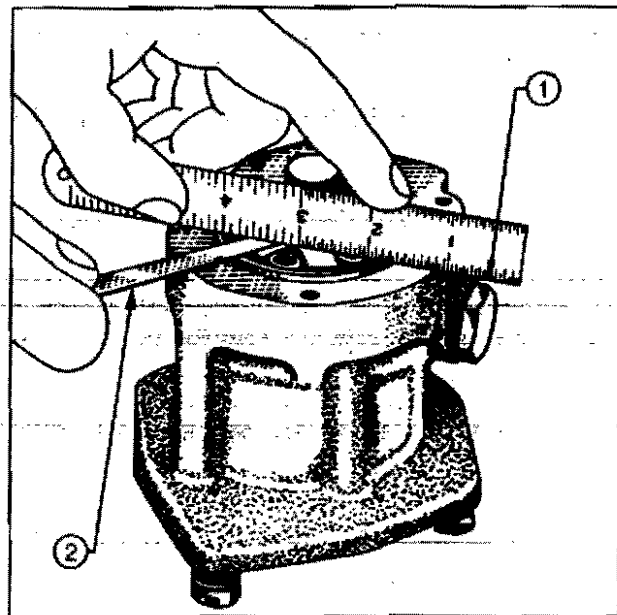


Fig. 17

1. Straight edge
2. Feeler blade (0.05 mm (0.002 in.) maximum)

## TO REASSEMBLE THE PUMP ASSEMBLY (continued)

10. Check the control valve spring; when subject to a load of 4.1 to 4.6 kgf (8 to 9 lbf), the length of the spring should be 0.82 in (20.8 mm). If this condition cannot be obtained, fit a new spring.

11. Insert the valve spring in the bore, followed by the valve. Enter the larger end of the valve into the body first (see Fig. 18). It is essential that the valve is correctly fitted or the system will not function.

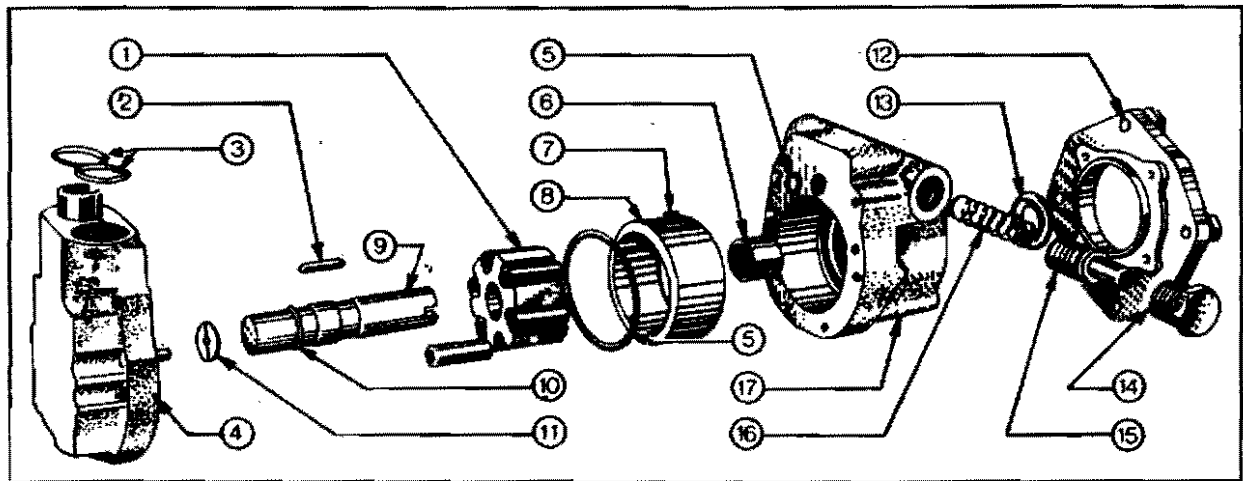


Fig. 18

- |                        |                   |                  |
|------------------------|-------------------|------------------|
| 1. Carrier and rollers | 7. Cam lock peg   | 13. Seal         |
| 2. Drive pin           | 8. Cam ring       | 14. Valve cap    |
| 3. Gaskets             | 9. Shaft          | 15. Valve        |
| 4. Pump cover          | 10. Snap ring     | 16. Valve spring |
| 5. "O" ring            | 11. Thrust washer | 17. Pump body    |
| 6. Bush                | 12. End plate     |                  |

12. Fit a new "O" ring to the valve cap and tighten to a torque of 40.7 to 47.5 Nm (4.15 to 4.84 kgf m or 30 to 35 lbf ft).

13. Place new "O" rings on the body joint face. The smaller ring seals the spill port, while the larger, seals the end of the cam ring. Note that the pump cover locates on the end of the cam ring and a small gap will exist, between the pump cover and the body, after assembly.

14. Fit the thrust washer to the bearing bore of the pump cover.

15. Assemble the pump cover to the body and secure with the six cap screws and the lockwashers. Tighten the screws evenly to a torque of 19 to 21.7 Nm (1.93 to 2.21 kgf m or 14 to 16 lbf ft) and check the shaft for free rotation. There should be slight resistance due to the oil seal but no tight spots or roughness. End-float should be perceptible, indicating that the thrust washer is not tight on the end of the shaft.

16. Assemble the gasket and the mounting plate to the pump body, securing with the four socket head screws and the lockwashers. Tighten to a torque of 19 to 21.7 Nm (1.93 to 2.21 kgf m or 14 to 16 lbf ft).

17. Replace the circular gaskets in the recesses in the top of the pump cover and insert the adaptor in the pump inlet port.

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**TO REASSEMBLE THE PUMP ASSEMBLY (continued)**

18. Replace the reservoir tank, the reinforcement plate and the lower filter support. Secure with the mounting stud and tighten to a torque of 40.7 to 47.5 Nm (4.15 to 4.84 kgf m or 30 to 35 lbf ft).

19. Fit the filter element, the retaining washer and the element spring. Check the condition of the cover gasket and refit the cover assembly. Fit the retaining bolt and the sealing washers and tighten the bolt (see Fig. 19).

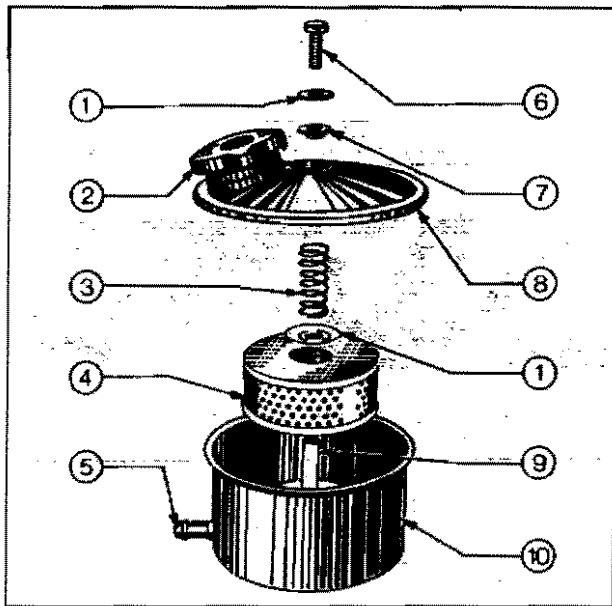


Fig. 19

- |                               |                    |
|-------------------------------|--------------------|
| 1. Washer                     | 6. Retaining bolt  |
| 2. Filler cap                 | 7. Sealing washer  |
| 3. Element spring             | 8. Reservoir cover |
| 4. Filter element             | 9. Mounting stud   |
| 5. Return from power cylinder | 10. Reservoir tank |

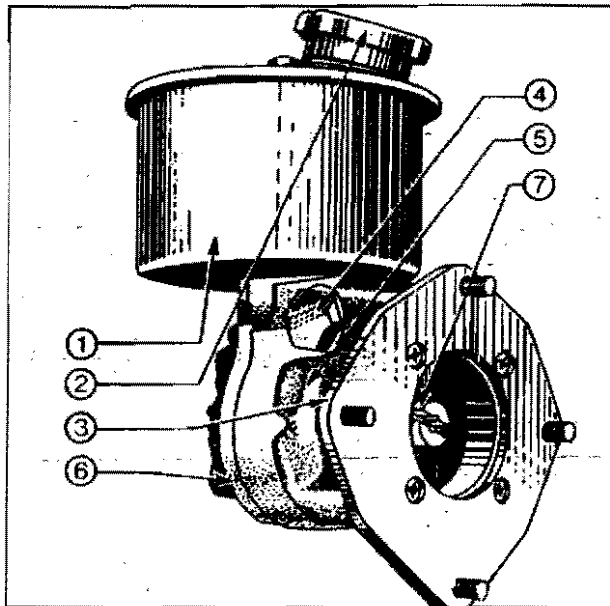


Fig. 20

- |                      |               |
|----------------------|---------------|
| 1. Reservoir tank    | 5. Pump body  |
| 2. Filler cap        | 6. Pump cover |
| 3. Mounting flange   | 7. Oil seal   |
| 4. Control valve cap |               |

**To Replace**

1. Install the drive coupling and the pump assembly. Ensure that the drive coupling is correctly located in the slots in the shafts and fit the lock washers and the retaining nuts. Tighten the retaining nuts.
2. Connect the low pressure return hose from the cooling coil to the reservoir stub.
3. Connect the high pressure hose to the pump outlet.
4. Prime and bleed the system.

# SPECIFICATIONS

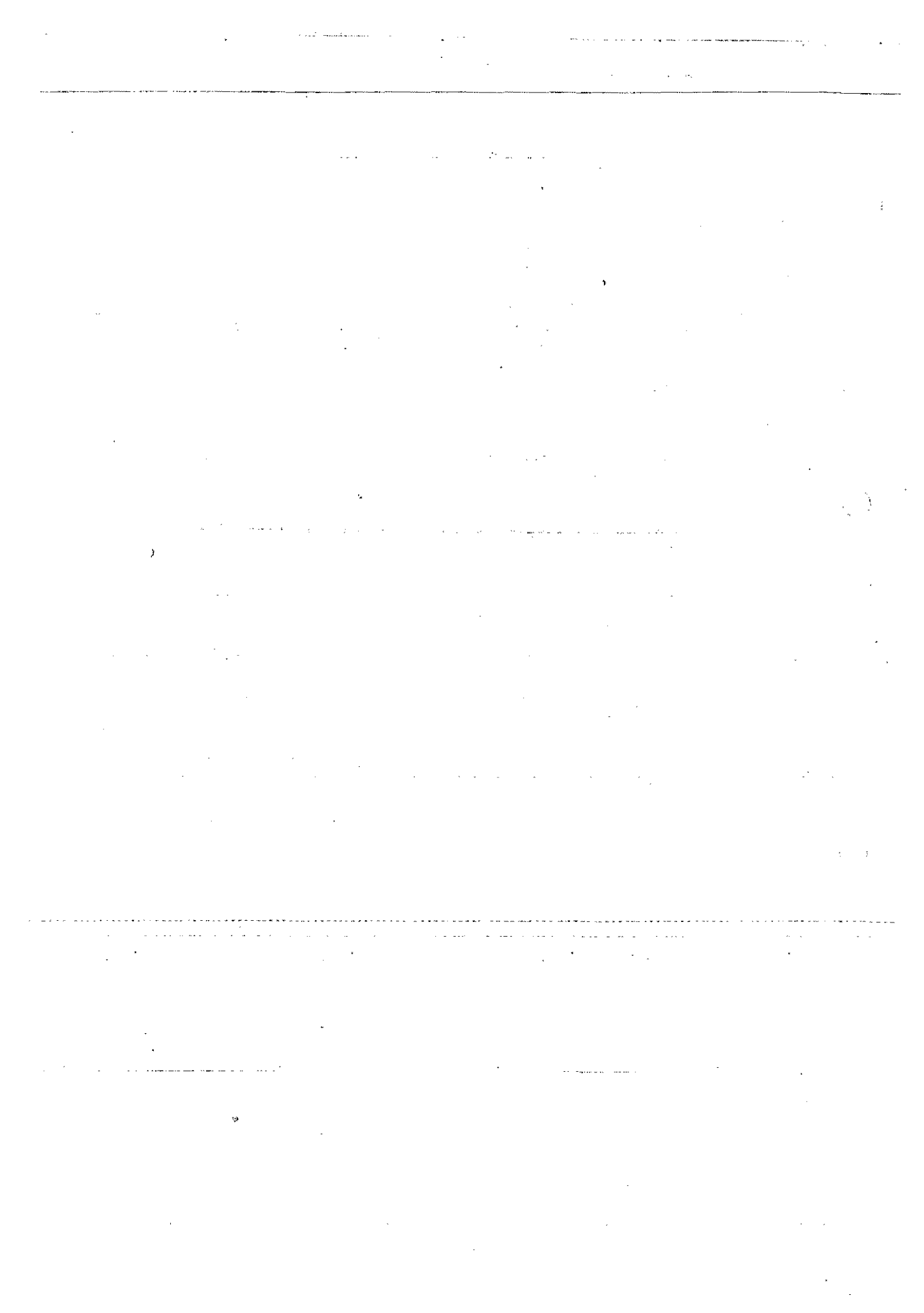
## POWER STEERING PUMP

Hobourn Eaton, 29.2 mm (1.15 in), Roller Vane type. Rotation in the same direction as the crankshaft. Directly driven at crankshaft speed.

Flow Rate		bar	Pressure		Pump speed r.p.m.
litre/min	gal/min		kgf/cm <sup>2</sup>	lbf/in <sup>2</sup>	
8.41	1.85	27.58	28.13	400	500
12.50	2.75	"	"	"	1000
14.32	3.15	"	"	"	2000
16.37	3.60	"	"	"	2500

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# SECTION 6

## SERVICE TOOLS

### CONTENTS

Engine .....	1r
Cooling System .....	3r
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Fuel System—D.P.A. ....	5r
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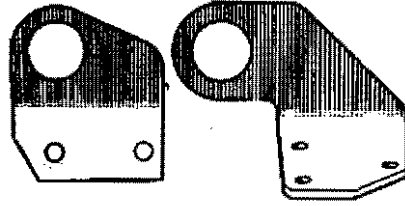
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## SERVICE TOOLS

### ENGINE

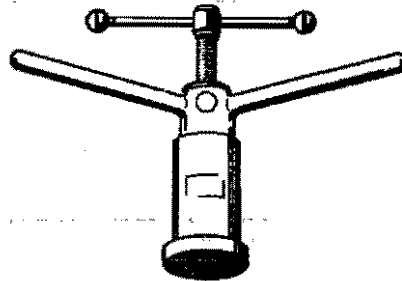
#### CT6003 Engine Lifting Bracket

These brackets bolt to the cylinder head with four high tensile bolts supplied as part of the set. One bracket fits on to a special pad on the front nearside edge of the cylinder head, the other fits on to the secondary fuel filter mounting pad.



#### CT6069A Crankshaft Gear Replacer

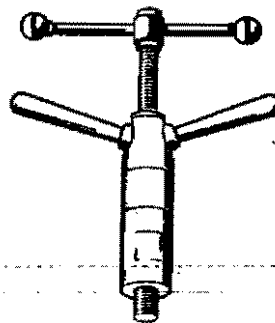
This tool is placed over the end of the crankshaft, with the gear positioned on the reduced diameter. The centre screw is screwed into the starter dog hole to locate the tool. The gear is screwed home using the cast handles, taking care to align the key on the crankshaft with the keyway in the gear and the body of the tool.



#### CT6073 Valve Guide Remover and Replacer

Screw puller rod CT6073-1A/e into the centre screw of the main tool CT6073. CT6073-1A/a slides up the puller rod so that the recessed end locates in the main tool. Pass the assembly through the valve guide from the valve seat side so that the conical end of CT6073-1A/a centralises in the end of the guide. Fit the spacer CT6073-1A/b over the free length of the puller rod and screw on the nut (d). Extract the guide by screwing in the cast handle on the main tool.

When replacing, repeat the above procedure but pass the new guide over the rod. The relevant stop adaptor from C6073-3 passes over the guide and is held by the nut and pulled into position with the main tool until the stop abutts the valve seat.



#### CT6073-1A Valve Guide Remover and Replacer Adaptor

For details of use, refer to CT6073.



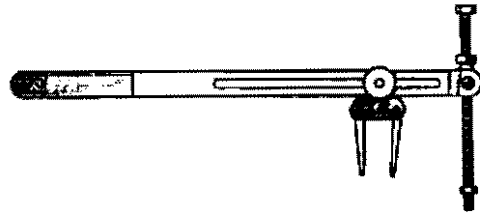


**C6073—3 Valve Guide Remover and Replacer Adaptors**

For details of use, refer to CT6073.

**6118A Valve Spring Compressor Main Tool**

The adaptor CT6118—3A screws into one of the rocker shaft bolt holes and the post of the main tool C6118A screws into the adaptor to give a rigid mounting. The height of the arm is adjusted by screwing the two adjusting nuts up or down the post. The two legs, which fit onto the valve spring retainer, slide along the arm and are retained in position by a knurled locknut. The valve spring is then compressed by pulling the arm down.



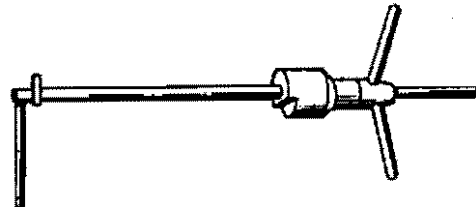
**CT6118—3A Valve Spring Compressor Adaptor**

For details of use, refer to C118A.



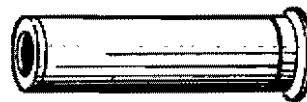
**CT6119A Camshaft Bearing Remover and Replacer Main Tool**

The cast body of the main tool has its internal diameter opened out to 2.340-2.360 in. (5.944/5.994 cm.) to a depth of 1½ in. (3.8 cm.).



**C6119—2 Camshaft Bearing Remover and Replacer Adaptors**

This tool is used with CT6119A Main Tool. Full instructions for use are included with the main tool.



**CT6124 Camshaft Gear Holding Wrench**

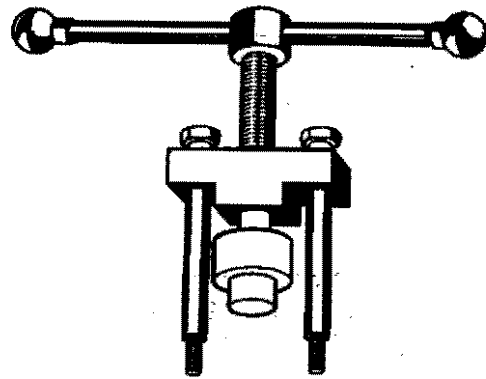
The pins on this wrench locate into holes in the camshaft gear and with the fibre pad on the arm abutting the crankshaft the gear centre bolt can be slackened or tightened without any stress on the rest of the gear train.



OCTOBER 1972

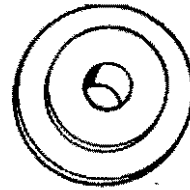
### C6131 Crankshaft Gear Remover

The legs of this puller screw into tapped holes in the crankshaft gear. The pad on the centre screw locates in the hole in the end of the crankshaft to centralise the puller. The gear can then be removed without the necessity of removing the timing gear case.



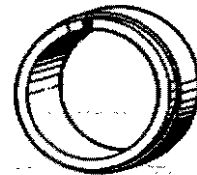
### C6132 Crankshaft Front Oil Seal Remover and Replacer

The larger diameter side of this tool abutts the outer face of the seal, enabling it to be removed without risk of distorting the front cover. For replacements, the smaller diameter side of the tool locates in the seal, the collar abutting the front face, thus avoiding damaging the seal.



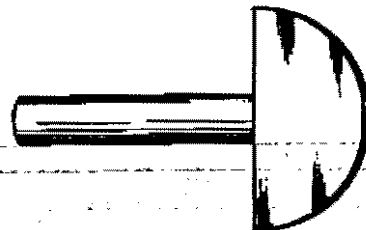
### C6133 Timing Cover Centraliser

The inside diameter of this tool is an accurate fit on the crankshaft. The plain section of the outside diameter locates on the accurately moulded section of the front cover oil seal, in front of the seal lip. This holds the seal in its correct relation to the crankshaft whilst the front cover is bolted into position.



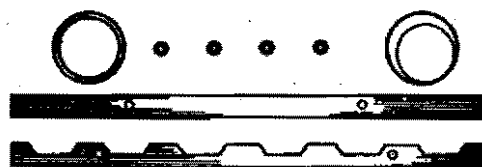
### C6134 Crankshaft Rear Oil Seal Replacer

The rear oil seal requires accurate fitting and this tool gives an even fit quickly and easily.



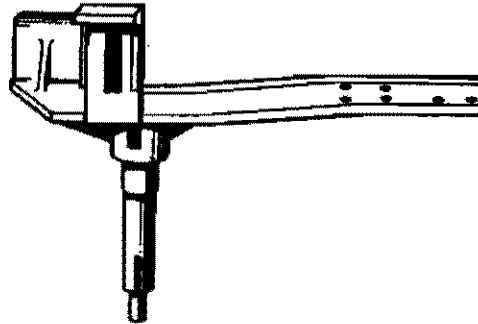
### C6136 Cylinder Liner Remover and Replacer

Used in conjunction with a press, this tool enables all liners to be removed and replaced, automatically giving the correct liner protrusion. The rubbing strips are to protect the head face.



**CT6138 Engine Mounting Bracket**

To take the additional weight of 6 cyl. engines, a new hardened high tensile steel shaft has been incorporated in the existing CT6006 Bracket. The bracket can be returned to V. L. Churchill and Co., Ltd. to be reconditioned and have the new shaft fitted. **UNDER NO CIRCUMSTANCES MUST A 6 CYL. ENGINE BE MOUNTED ON A CT6006 BRACKET.** To provide identification, the modified bracket is painted RED, and a new retaining wing nut with a different thread is used.

**C6139 Main Bearing Liner Remover and Replacer**

This tool fits into the main bearing oilway with the main bearing caps removed. When the crankshaft is rotated, the head of the tool pushes the bearing liner out of the block. The bearing can be replaced in the same manner.

**6600 Flywheel Remover Main Tool****C6600-1 Flywheel Remover Adaptor**

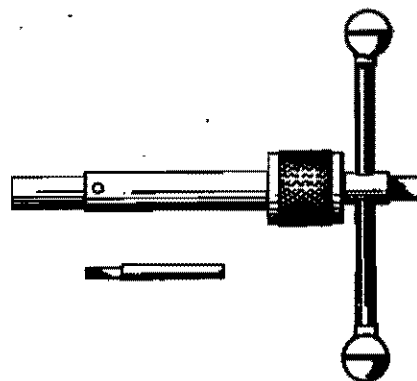
This tool mounts on the head of a jack to allow the engine flywheel to be removed and replaced with the engine in situ.

**38U3 Piston Ring Compressor**

This is a ring of spring steel into which the piston, complete with a set of rings, is placed. The ring is contracted with a key-operated ratchet to compress the piston rings. A lever on the side of the tool releases the ratchet to open it. The range of adjustment makes this tool suitable for all the pistons in the 2700 range.

**316X Valve Seat Cutter Handle**

This tool is used, together with 316-12, 317-TT-26, FMC 317-27, FMC 317-29 and 317-TT-30, to cut the valve seats in the 2700 range, diesel engines cylinder heads.

**316-12 Valve Seat Cutter Pilot**

This tool is used, together with 316X, 317-TT-26, FMC 317-27, FMC 317-29 and 317-TT-30.

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**34-TT-26 Valve Seat Cutter-Exhaust**

**FMC 317-27 Valve Seat Narrowing Cutter-Exhaust**



**FMC 317-29 Valve Seat Narrowing Cutter-Inlet**

**317-TT-30 Valve Seat Cutter-Inlet**

These cutters are the full set for diesel engines of the 2700 range.

**BA 20 Cylinder Head Spot Face Tool**

Enables new type cylinder head bolts with integral washers to be used with earlier type cylinder heads.

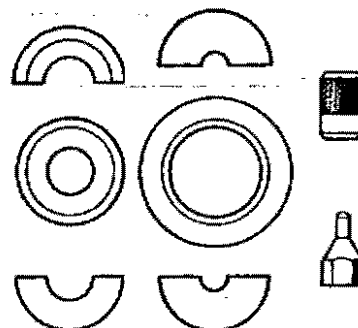
**COOLING SYSTEM**

**C8000-3 Water Pump Overhaul Kit**

Use details /a and /b only in conjunction with C8009 and 370 base or C4000.

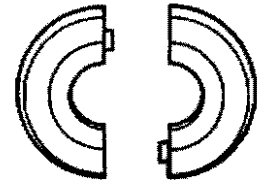
**C8009 Water Pump Overhaul Kit**

Used to overhaul water pumps fitted to diesel engines in the Ford 'D' Series range. Full instructions for use are included with the kit.



## FUEL SYSTEM MINIMEC

**CT6085-1A Pump Camshaft Bearing and Replacer**  
Used with CT9056, 370 base and slave ring.



**CT9001A Fuel Pump Cleaning Pipe (4 Cyl.)**

Used with a calibrating machine, this tool consists of four flexible pipes, one end of each fitting onto the delivery outlets. The other end is connected to a common pipe which directs the fuel to the bed of the calibrating machine when flushing the pump under gravity flow feed.

**CT9002A Pump Cleaning Pipe (6 Cyl.)**

For details of use, refer to CT9001A.

**CT9005 Pump Dismantling Tray**

This is a steel tray, divided into sections to enable all the pump components to be kept clean and tidy when dismantling the pump.

**CT9009 Nozzle Nut Socket**

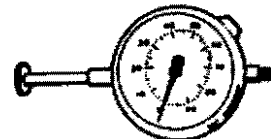
This specially shaped socket is used to remove and replace injector nozzle nuts, having a 1/2 in. square drive in one end, to accommodate a torque wrench when replacing.

**CT9014 Fuel Injector Cleaning Kit**

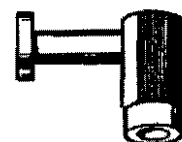
This consists of a "tool roll" containing pricker wires, brush etc., for injector cleaning.

**CT9017 Camshaft End Float Gauge and Anvil Main Tool**

The dial indicator, extension and anvil are assembled and clamped to the adaptor body CT9017/1a with the knurled screw provided. The complete assembly being screwed onto the end of the pump camshaft.



**CT9017-1 Camshaft End Float Gauge Adaptor**  
For details of use, refer to CT9017.



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#### **CT9022 Delivery Valve Guide Remover**

A small collet tool which is entered into the delivery valve guide, the centre pin is then pulled up which expands the collet and pulls the delivery valve guide out.

#### **CT9023 Pump Spill Pipe**

Fitted to each delivery outlet in turn, this tool provides an accurate indication of when spill cut off occurs.

#### **CT9024 Nozzle Reverse Flush Adaptor**

The nozzle is inserted between the two parts of the adaptor and is flushed out in the reverse direction to the normal fuel flow.

#### **CT9044 Injector Pipe Union Nut Wrench**

This tool is a slotted ring wrench 5/8 in. A.F.

#### **CT9050 Injection Pump Bearing Cup Remover**

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 into position. The spindle, collet and bearing are then driven out of the pump body.

#### **CT9051 Injector Pump Bearing Cup Replacer**

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 abutts the pump body, the cup is then pulled into position with the nut.



#### **CT9054 Delivery Valve Holder Socket**

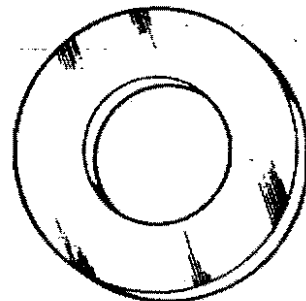
This is an internally splined socket to fit the delivery valve holder for removal and replacement.

#### **CT9055 Tee Wrench**

A 5/16 in. A.F. wrench with many applications on the minimec pump.

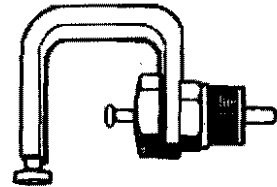
#### **CT9056 Slave Ring**

This tool enables adaptors CT6085 and CT6085-1A to be used, together with the 370 base, on a press.



**CT9076A Plunger Head Clearance Gauge**

This consists of a slave adaptor, push rod and a mounting 'U' bracket. Remove the delivery valve and screw in the slave adaptor. Mount the 'U' bracket on the slave adaptor and lock in position with the lock nut. Mount the dial gauge CT9017 together with its extension and anvil on the 'U' bracket and lightly nip in place with the knurled screw provided.

**C9077 Minimec Timing Tool**

This tool is in the form of a bolt with a spring loaded pin passing through the centre. The tool screws into the pump mounting flange. The pump camshaft is turned until the timing indentation on the gear lines up with the centre pin, which then clicks into the indentation.

**C9078 Gear Holding Wrench**

The pins on this wrench locate into holes in the pump gear. The arm of the tool can then be held whilst the centre nut is tightened or slackened.

**C9079 Protector for Injector Seal**

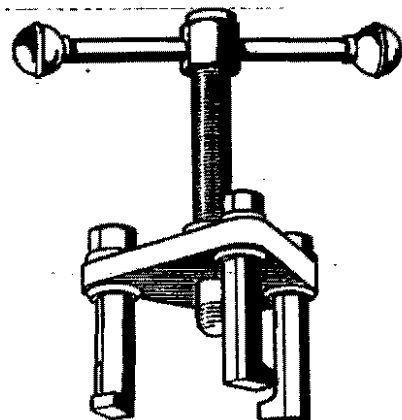
This tool enables the injector fuel seal to be replaced without the risk of damage.

**C9080 Dust Caps and Plugs**

This consists of a set of metal dust caps and plugs to fit the various sizes of inlet and outlet connections on the fuel pumps. This prevents the ingress of foreign matter into the pump, whilst it is not on the vehicle and connected to the fuel lines.

**C9081 Injection Pump and Camshaft Gear Remover**

This is a three legged puller, the legs of which have been designed to locate in the "windows" in the gears. The centre screw abutts the end of the shaft onto which the gear is mounted, thus enabling the gear to be removed.

**C9082 Minimec Expansion Plug Replacer**

## FUEL SYSTEM--DPA

### CA51 Cap for Shut-Off Spindle

This tool is a protection cap used to prevent damage to the shut-off spindle 'O' ring, when this is being replaced.

### CA52 Cap for Auto Advance Plug

This tool serves a similar function to CA51.

### CA53 Cap for Head Locating Fitting

This tool serves a similar function to CA51.

### CA54A Assembly Cap for Head Locating Fitting

This tool serves a similar function to CA51.

### CA58 Box Spanner for Transfer Pump Rotor

This tool is used for removing and replacing the transfer pump rotor, and is used with CA67.

### CA60 Assembly Rod

This is a small probe, useful for assembling various parts of the D.P.A. pump.

### CA62A Assembly Base

This is a plate onto which the pump is mounted and is in turn clamped in a vice to give a rigid mounting.

### CA65 Automatic Advance Gauge

This gauge is used to check the automatic advance on the pump whilst it is running on a calibrating machine.

### CA65-1 Automatic Advance Gauge Adaptor

### CA66A Torque Spanner Socket

This tool is used for removing and replacing the cam ring advance ball stud in the cam ring.

### CA67 Drive Shaft Screw Assembly Tool

This is used for holding the drive hub whilst tightening the hub securing screws when using CA69 and CA58.

### CA69 Torque Adaptor

A key for removing and replacing the drive hub retaining screws.



**CA72A Oil Seal Guide**

This tool enables both oil seals to be replaced in the pump housing.

**CA75 Cap for Throttle Shaft**

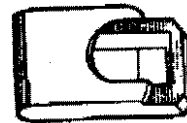
This tool is used when assembling the throttle shaft to the control cover.

**CA76 Cap for Damper Assembly**

This tool serves a similar function to CA51.

**CA111 Wrench for Damper Assembly**

This is a 'U' shaped wrench which allows easy access to the damper assembly for applying the correct torque.

**CA112 Drive Plate Holding Wrench**

A splined wrench for holding the drive plate whilst removing or replacing the drive plate screws.

**CA113 Transfer Pressure Adjuster**

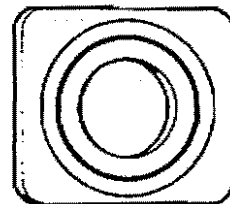
This tool consists of a 'banjo union' bolt, through the centre of which a 'T' key having a hexagonal end passes. Used with a 'banjo' connection this tool enables the transfer pressure to be adjusted whilst the pump is running on a calibrating machine.

**GENERAL TOOLS****200A Engine Stand**

Using the appropriate mounting bracket, the various engines, gearboxes etc. can be mounted on this stand to facilitate dismantling and assembly.

**370 Base**

This tool fits on the bed of most workshop presses to take the various split adaptors etc. from the hand presses.

**512 Piston Pull Scale**

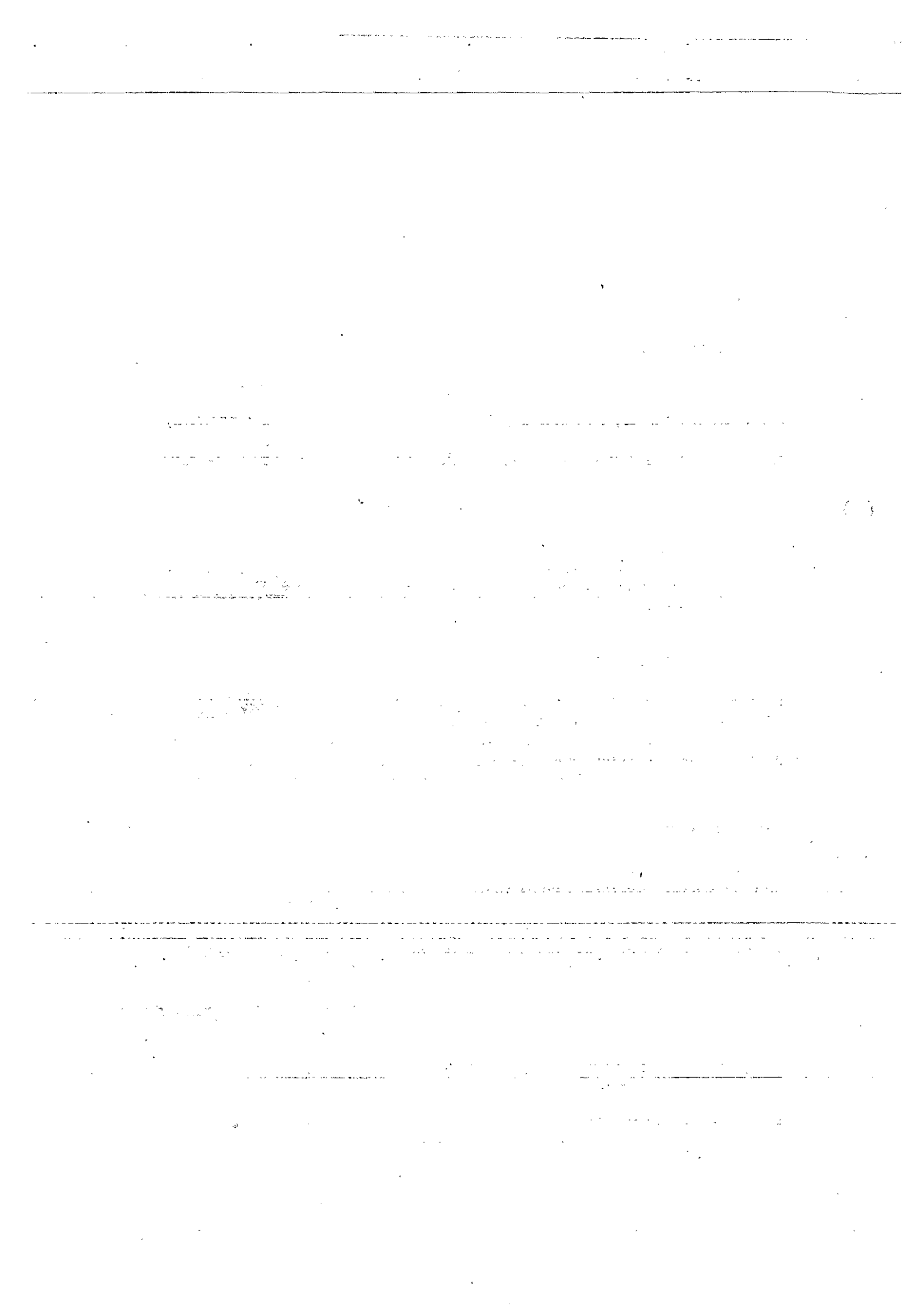
This tool is a light spring balance, with provision for a feeler blade to be attached.

**550 Oil Seal Driver Handle**

This tool has a spigot at one end, onto which the various oil seal replacers etc., will fit.

**575 Light Universal Handle**

This tool is a lighter version of 550.



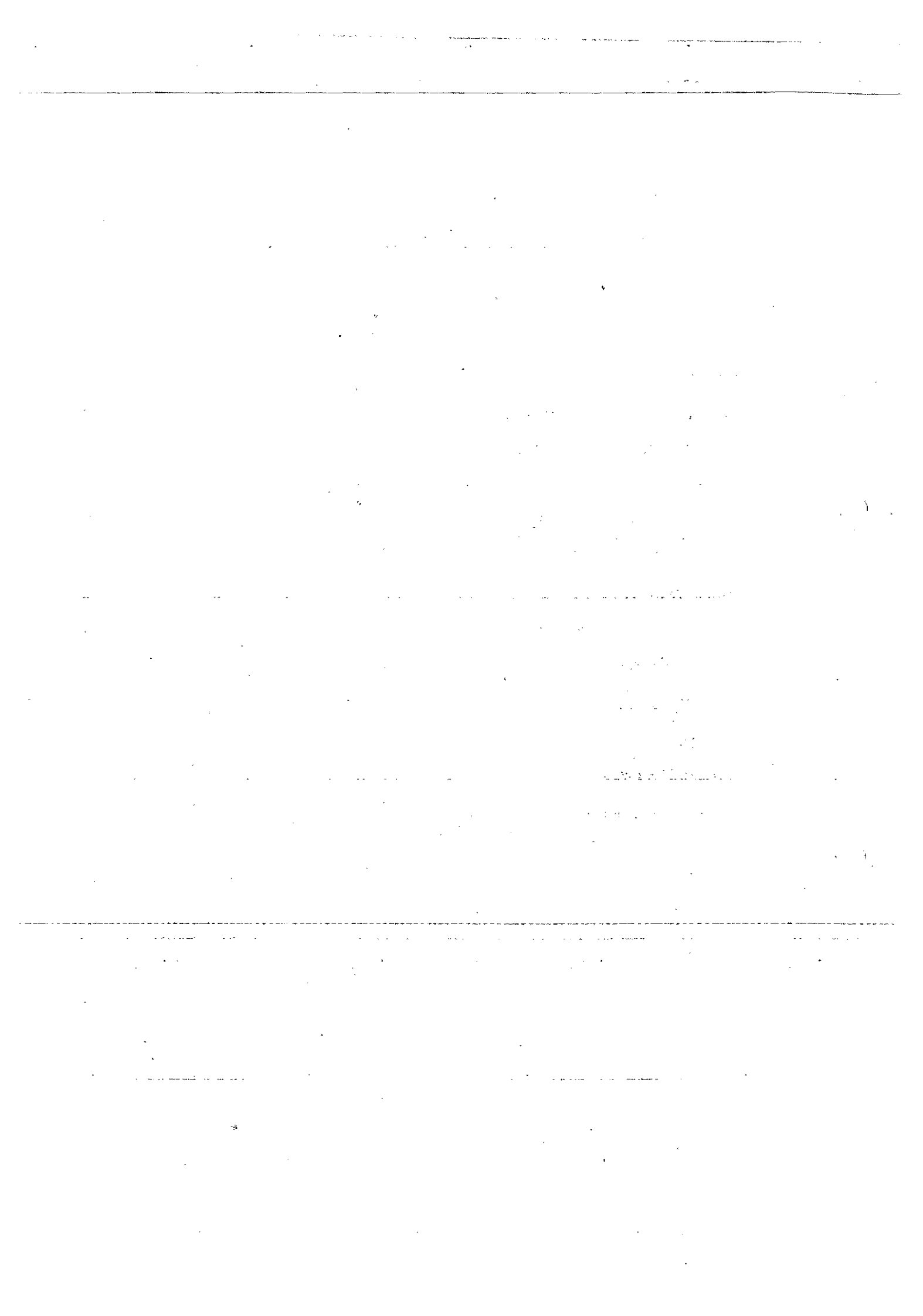
# SECTION 7

## COMBINE HARVESTER ENGINES

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# COMBINE HARVESTER ENGINES

## INTRODUCTION

This section has been added to the Service Manual and replaces the annual issue of a special Combine Harvester booklet.

Special features of the combine engines in service since 1969 are dealt with in this section.

Reference should also be made to Section 3 Fuel System for more detailed information regarding maintenance and overhaul of the fuel system.

The differences between the engines for industrial and general purpose use and those specified for Combine Harvester are confined mainly to the fuel system.

### Features of the Combine Harvester Engine

1. Close governing with special fuelling and injectors to satisfy combine requirements.
2. Shallow oil pans to keep the overall height of the engine to a minimum

### Fuel Equipment

Two sources of fuel equipment are available, CAV/SIMMS and BOSCH.

The correct injection pump fitted to an engine can only be identified externally by the manufacturers specification number, to be found on a plate affixed to the injection pump.

The letter 'W' stamped on the plate indicates that the governor assembly has been modified from a 2 weight to 4 weight in service and the additional weights should not be removed.

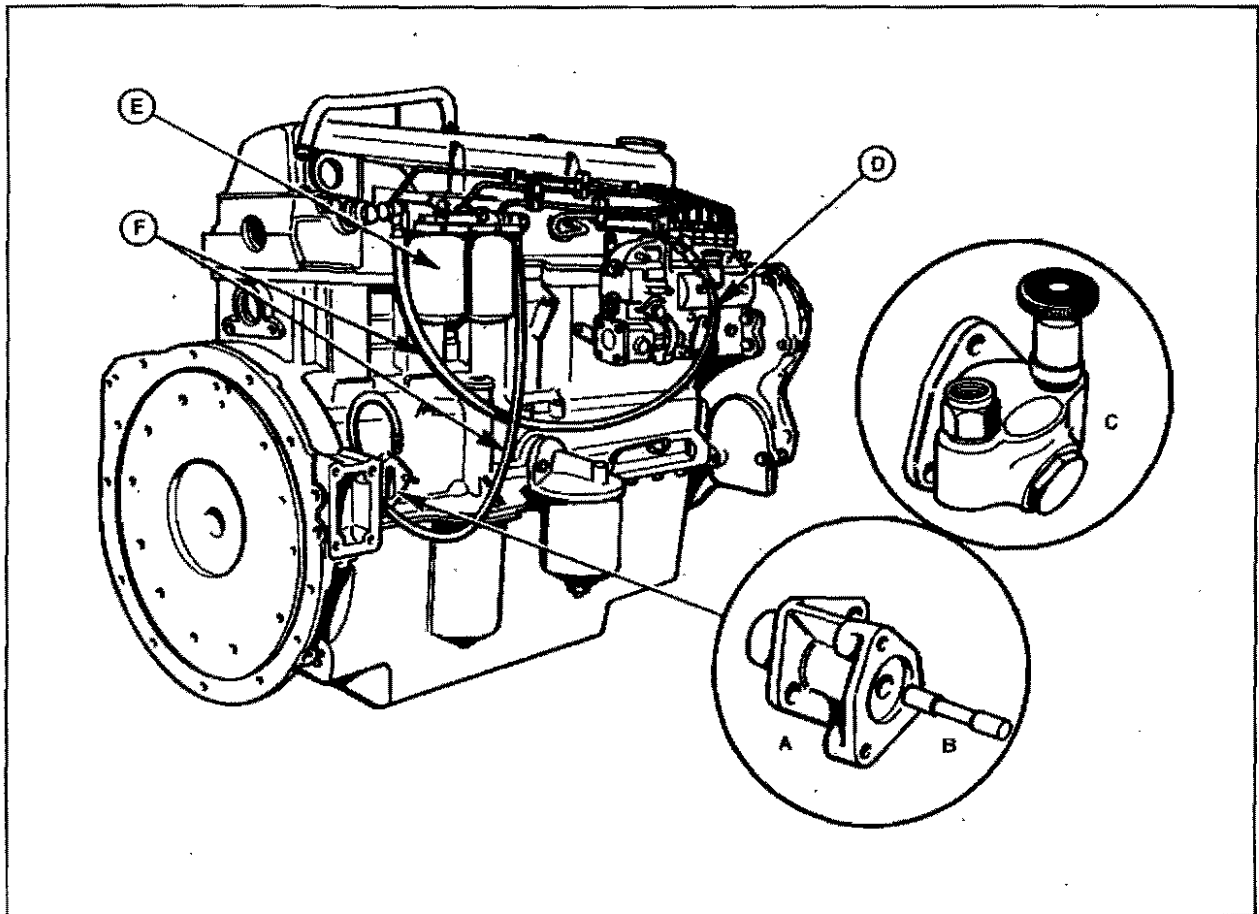
The following table lists the injection pumps for Combine Harvester engines together with the injector nozzles to be used.

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Engine Model	Injection Pump		Injector Nozzle and Holder Assy		Spill timing	Nozzle Opening Pressure	
	Ford Part No.	Supplies No.	Ford Part No.	Supplies No.			
2701E	2701E-9A543-H	P4899/1	713F-9K546-AA	5209006	22°	205 ±	2.5 ATS
	693F-9A543-AAA	P5079	713F-9K546-AAB	5209008	22°	205 ±	2.5 ATS
2703E	2703E-9A543-E	P4816	713F-9K546-AAA	5209006	22°	205 ±	2.5 ATS
	2703E-9A543-H	P5012/B	713F-9K546-AAB	5209008	22°	205 ±	2.5 ATS
	693F-9A543-BAA	P5080/A	713F-9K546-AAB	5209008	22°	205 ±	2.5 ATS
2704E	2704E-9A543-AE	P5012/C	713F-9K546-AAB	5209008	22°	205 ±	2.5 ATS
	693F-9A543-CAA	P5080	713F-9K546-AAB	5209008	22°	205 ±	2.5 ATS
2701C	703F-9A543-AJA	P5084/1A	713F-9K546-AAB	5209008	23°	205 ±	2.5 ATS
	703F-9A543-AJB	P5084/2A	713F-9K546-AAB	5209008	23°	205 ±	2.5 ATS
2712E	723F-9A543-AAA	P5084/2B	713F-9K546-KAA	5209003	23°	205 ±	2.5 ATS
	723F-9A543-AAB	P5084/3B	713F-9K546-KAA	5209003	23°	205 ±	2.5 ATS
	743F-9A543-AAA	PES4A850210 RS2378	713F-9K546-KAA	5209003	23°	205 ±	2.5 ATS
2703C 2713E	703F-9A543-BEA	P5085/B	713F-9K546-AAB	5209008	23°	205 ±	2.5 ATS
	703F-9A543-BEB	P5085/2B	713F-9K546-AAB	5209008	23°	205 ±	2.5 ATS
	703F-9A543-BEC	P5085/3B	713F-9K546-AAB	5209008	23°	205 ±	2.5 ATS
	743F-9A543-BAA	PES6A850210 RS2379Z	713F-9K546-KAA	5209003	23°	205 ±	2.5 ATS
2704C 2715E	703F-9A543-CJA	P5085/C	713F-9K546-AAB	5209008	23°	205 ±	2.5 ATS
	703F-9A543-CJB	P5085/2C	713F-9K546-AAB	5209008	23°	205 ±	2.5 ATS
	703F-9A543-CJC	P5085/3C	713F-9K546-AAB	5209008	23°	205 ±	2.5 ATS
	743F-9A543-CAA	PES6A850210 RS 2379			23°	205 ±	2.5 ATS
2715E CLAAS ONLY	693F-9A543-CBA	PES6A85C410 1/C RV8880	713F-9K546-KAA	5209003	23°	205 ±	2.5 ATS
	713F-9A543-CAA	P5186	713F-9K546-AAB	5209008	23°	205 ±	2.5 ATS
2704BT	713F-9A543-CAB	P5186/1	713F-9K546-AAB	5209008	23°	205 ±	2.5 ATS
	713F-9A543-CAC	P5186/2	713F-9K546-AAB	5209008	23°	205 ±	2.5 ATS
	693F-9A543-GAA	P5078	713F-9K546-AAB	5209008	23°	205 ±	2.5 ATS
2704BT	693F-9A543-GAB	P5078/1	713F-9K546-AAB	5209008	23°	205 ±	2.5 ATS
	693F-9K543-GAC	P5078/2	713F-9K546-AAB	5209008	23°	205 ±	2.5 ATS
	723F-9K543-GAA	P5229	713F-9K546-AAB	5209008	23°	205 ±	2.5 ATS
					23°	205 ±	2.5 ATS

## BOSCH FUEL EQUIPMENT – CLAAS

Fig. 1 illustrates an engine fitted with Bosch equipment, specified for Claas Combines only. This equipment was only introduced on 6 cylinder engines from 4.11.69, engine Serial Number S723593.



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Fig. 1 Bosch Fuel Equipment—Claas

- \* (A) 2701E – 9416-A (Finis Code No. 1411370)
- \* (B) 733F – 9K341-A (Finis Code No. 6018119)
- \* (C) 713F – 9350-ABA (Finis Code No. 1536780)
- † (D) Injection Pump
- † (E) Fuel Filters
- † (F) Fuel Lines

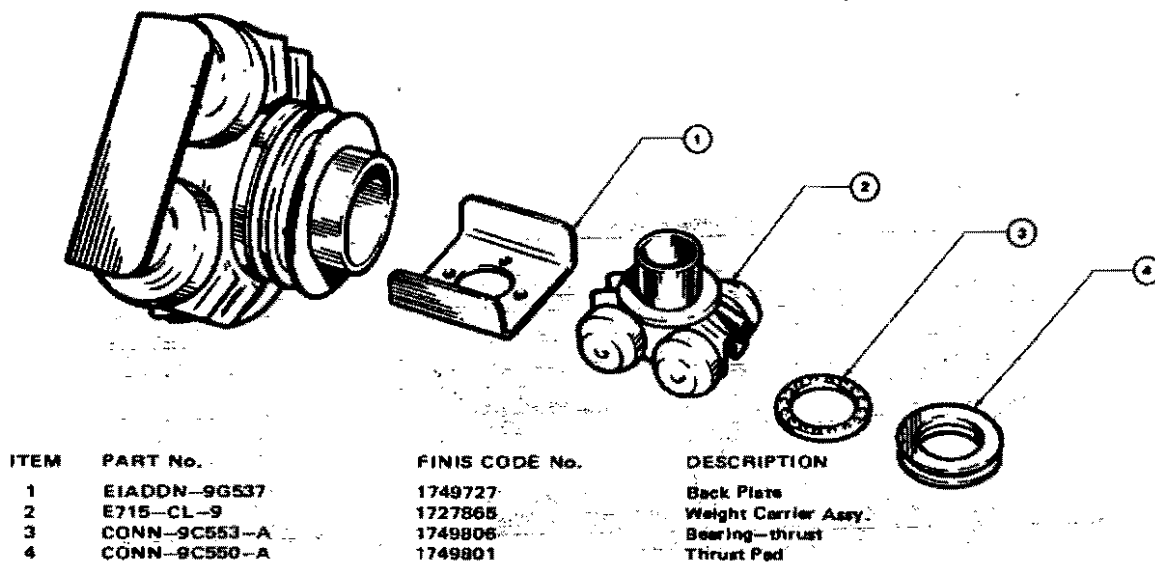
\* F.M.C. supply      † Bosch supply

Service for all Bosch equipment is the responsibility of the Claas Service Organisation.

## INTERNAL IDENTIFICATION OF SIMMS INJECTION PUMPS

In order to ensure the correct identification of service parts fitted to the close governing pumps, the items that need clarification are illustrated on Fig. 2

### IDENTIFICATION OF 'GE' GOVERNOR



### IDENTIFICATION OF 'GX' GOVERNOR

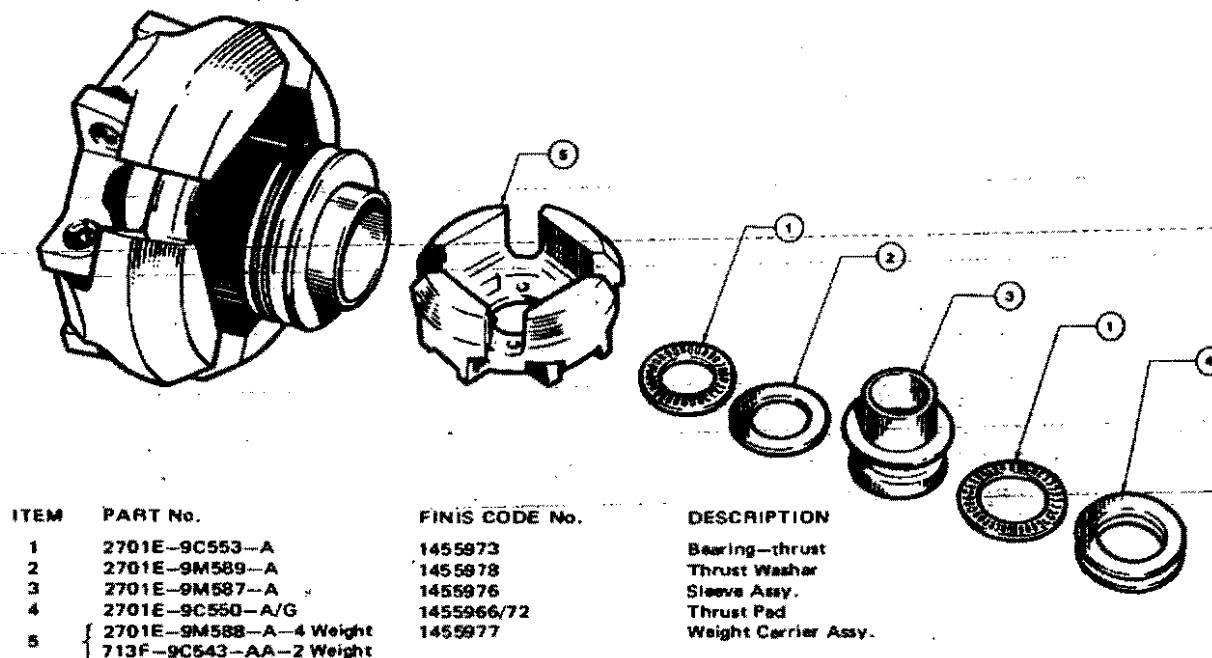


Fig. 2



INTERNAL IDENTIFICATION OF CAV/SIMMS INJECTION PUMPS

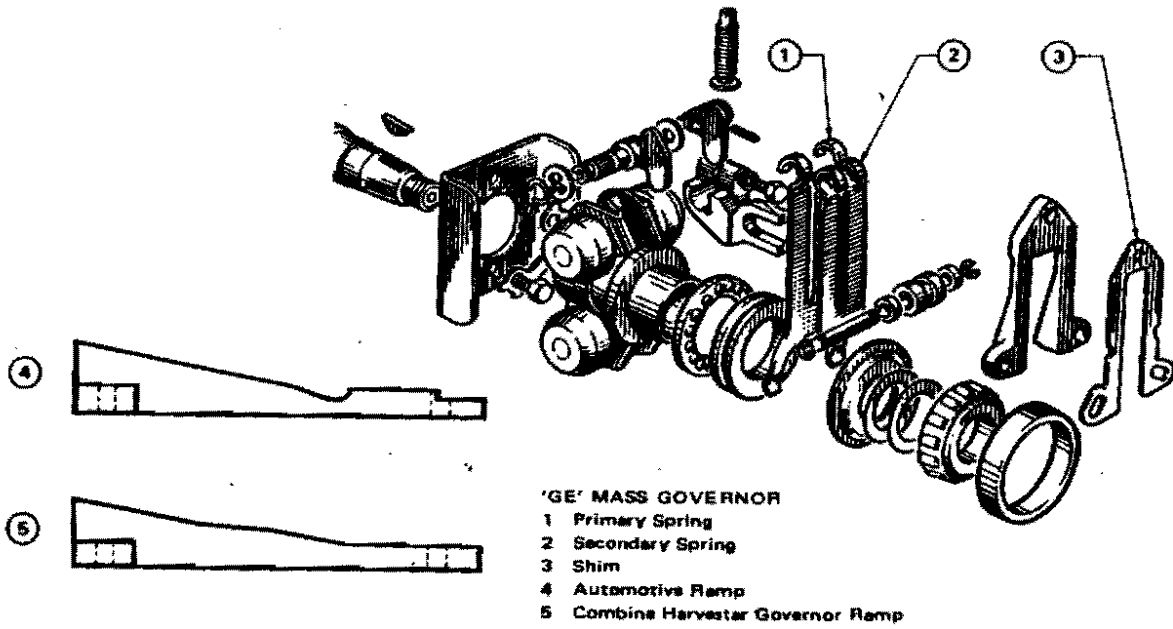


Fig. 3

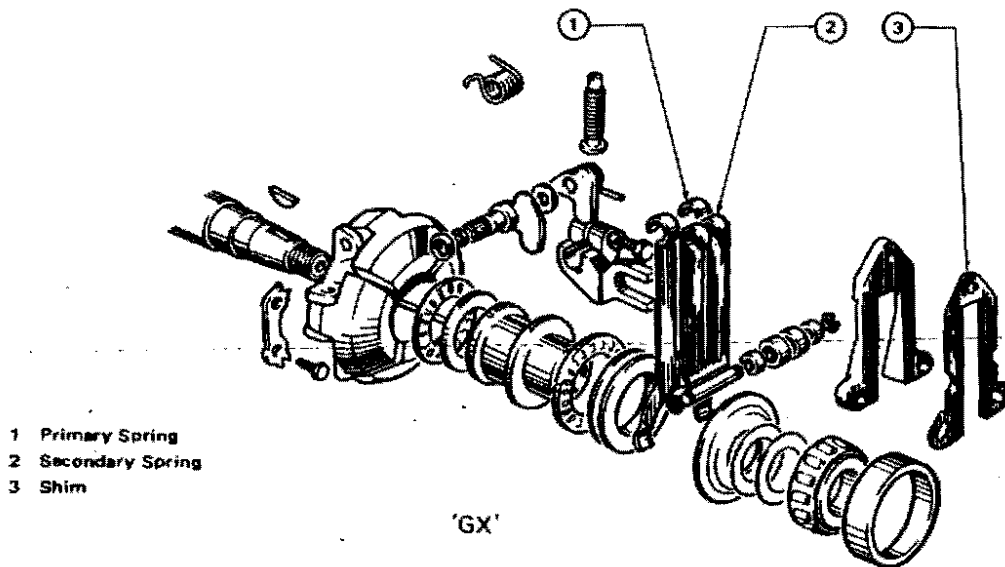


Fig. 4

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INTERNAL IDENTIFICATION OF CAV/SIMMS INJECTION PUMPS—Continued

PUMP PART No.		Spring Colour Code		PUMP PART No.		Spring Colour Code	
FORD	SUPPLIER	Green	Yellow	FORD	SUPPLIER	Green	Yellow
2701E-9A543-H	P4899/A	X		703F-9A543-BEB	P5085/2B		X
693F-9A543-AAA	P5079	X		703F-9A543-BEC	P5085/3B		X
2703F-9A543-E	P4816		X	713F-9A543-CAA	P5816		X
2703E-9A543-H	P5012/B	X		713F-9A543-CAB	P5186/1		X
693F-9A543-BAA	P5080/A	X		713F-9A543-CAC	P5186/2		X
2704E-9A543-AE	P5012/C	X		703F-9A543-CJA	P5085/C		X
693F-9A543-CAA	P5080	X		703F-9A543-CJB	P5085/2C		X
703F-9A543-AJA	P5084/1A		X	703F-9A543-CJC	P5085/3C		X
703F-9A543-AJB	P5084/2A		X	693F-9A543-GAA	P5078	X	
723F-9A543-AAA	P5084/2B		X	693F-9A543-GAB	P5078/1	X	
723F-9A543-AAB	P5084/3B		X	693F-9A543-GAC	P5078/2	X	
703F-9A543-BEA	P5085/B		X	723F-9A543-GAA	P5229	X	

GOVERNOR PRIMARY AND SECONDARY SPRINGS

Green Paint Spot

Part No.	Finis Code No.
2701E-9C555-A	1767536
2701E-9K522-A	1767523

PRIMARY  
SECONDARY

Yellow Paint Spot

Part No.	Finis Code No.
2701E-9C555-B	1793882
2701E-9C555-B	1793876

It is important the correct colour coded springs are used with the injection pump as specified.

GOVERNOR RAMP

The correct governor ramp for the Combine range of injection pumps (with the exception of the Bosch pump) is 2701E-9K535-C (Finis Code No. 1455963) See Fig. 3 for the correct identification of this ramp.

**RAMP HEIGHT**

The ramp height distance 'X' in Fig. 5 should be checked against the relevant injection pump number shown in Table 'B'.

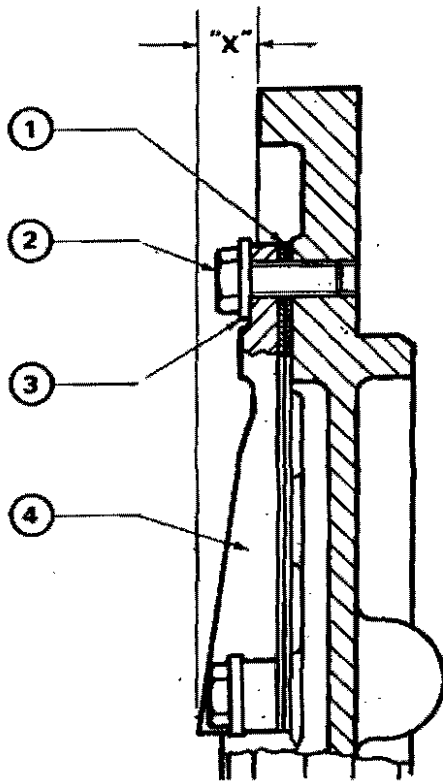


Fig. 5

TABLE 'B'	
Pump Part No.	Height in 'mm' Distance 'X'
P4816	7.2 — 7.5
P4899	7.9 — 8.2
P5012	7.9 — 8.2
P5078	8.1 — 8.4
P5079	7.9 — 8.2
P5080	7.9 — 8.2
P5084	8.3 — 8.5
P5085	8.3 — 8.5
P5186	8.6 — 8.9
P5229	8.1 — 8.4

1. Ramp Shims
2. Ramp Screw
3. Lockwasher
4. Ramp

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## THRUST PAD DIMENSIONS 'GE' AND 'GX' GOVERNORS

The 'Y' dimension shown in Fig. 6 is taken from the face of the governor housing to the face of the thrust pad for 'GE' and 'GX' governors. The correct dimension can be obtained by using a graded thrust pad shown in Fig. 7.

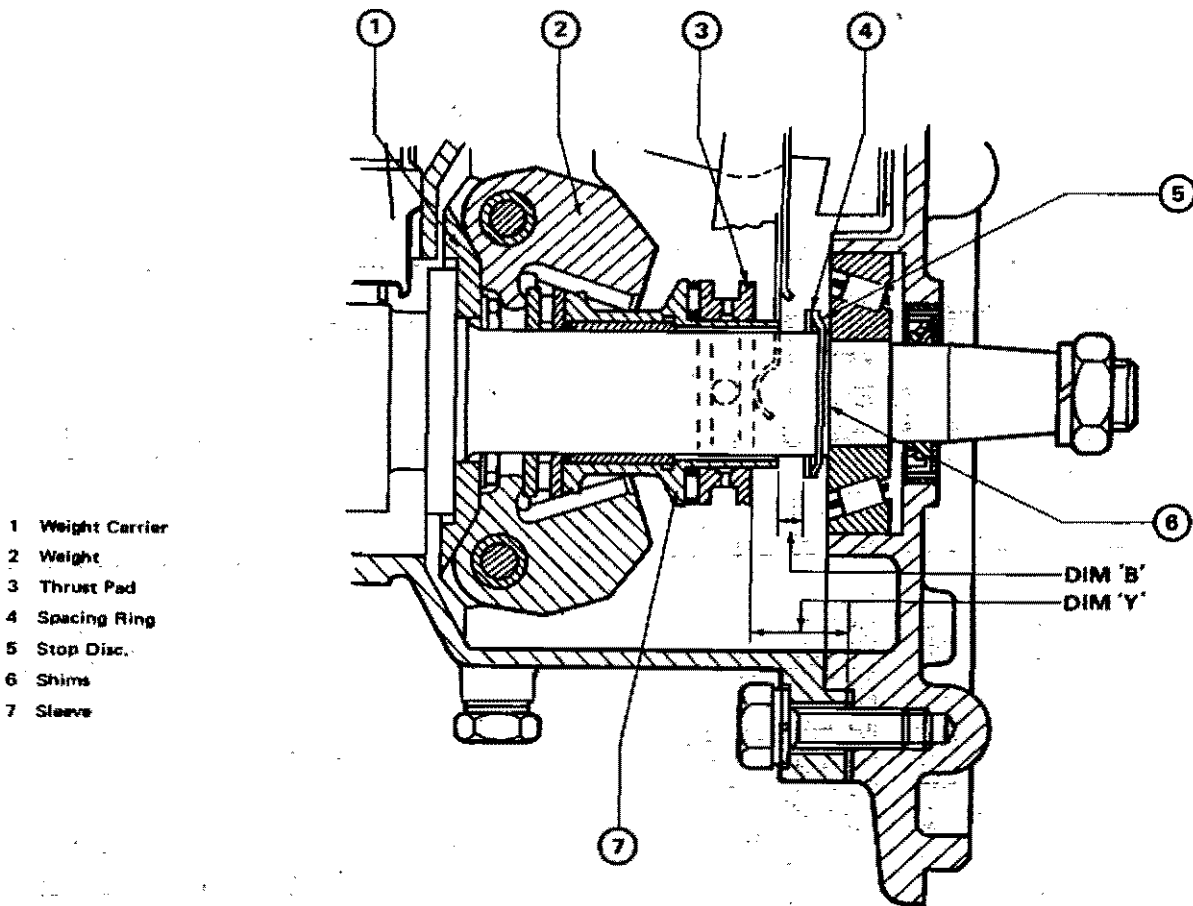


Fig. 6

Pump Part No.	'Y' Dimension	'B' Dimension
P4816	19.8 – 20.3 mm	
P4899	19.9 – 20.6 mm	5.9 – 6.2 mm
P5012	19.9 – 20.6 mm	5.9 – 6.2 mm
P5078	19.9 – 20.6 mm	5.9 – 6.2 mm
P5079	19.9 – 20.6 mm	5.9 – 6.2 mm
P5080	19.9 – 20.6 mm	5.9 – 6.2 mm
P5084	19.9 – 20.6 mm	5.9 – 6.2 mm
P5085	19.9 – 20.6 mm	5.9 – 6.2 mm
P5186	19.9 – 20.6 mm	5.9 – 6.2 mm
P5229	19.9 – 20.6 mm	5.9 – 6.2 mm

The 'B' dimension shown in Fig. 6 for the 'GX' governor is adjusted by fitting the appropriate thickness spacing ring Part Number EIADDN-993202-A, 0.102 mm (.004 in) thick (Finis Code No. 1714558) or EIADDN-993202-B, 0.203 mm (.008 in) thick (Finis Code No. 1714561).

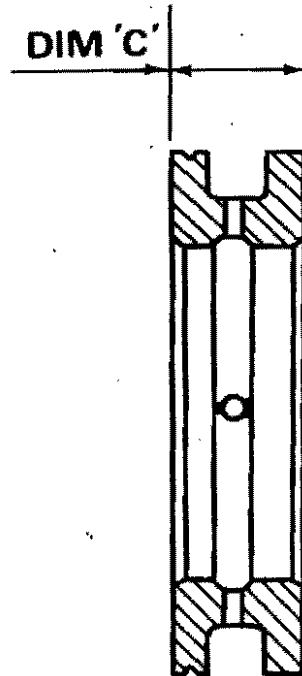


Fig. 7 Graded Thrust Pad

FORD PART No.	FINIS CODE No.	SIMMS PART No.	MARK NO.	DIM. 'C'
2701E-9C550-A	1455966	503333	1	8.6 mm 8.5 mm
2701E-9C550-B	1455967	503334	2	9.1 mm 9.0 mm
2701E-9C550-C	1455968	503335	3	9.6 mm 9.5 mm
2701E-9C550-D	1455969	503336	4	10.1 mm 10.0 mm
2701E-9C550-E	1455970	503337	5	10.6 mm 10.5 mm
2701E-9C550-F	1455971	503338	6	11.1 mm 11.0 mm
2701E-9C550-G	1455972	503339	7	11.6 mm 11.5 mm

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CALIBRATION OF FUEL INJECTION PUMP

Pump Assembly Ford Part No. Engine Capacity	Suppliers Part No.	CAV Injector BDN 12SD 12 Delivery in cc. for 200 shots at RPM	Idling Speed Pump	Pump Speed RPM	
				Control Rod Starts to move	No Delivery
2701E-9A543-H 3964 cc (242 cu.in)	P4899/1	12.0 - 12.2 800 RPM	500	1010 - 1020	1180 MAX
693F-9A543-AAA 3964 cc (242 cu. in)	P5079	12.3 - 12.5 1000 RPM	525	1160 - 1170	1215 - 1245
703F-9A543-AJA 4150 cc (254 cu. in.)	P5084/1A PB	11.5 - 11.7 1000 RPM	600	1160 - 1170	1220 - 1250
703F-9A543-AJB 4150 cc (254 cu. in.)	P5084/2A PB	11.5 - 11.7 1000 RPM	600	1160 - 1170	1220 - 1250
723F-9A543-AAA 4150 cc (254 cu. in)	P5084/2B PB	12.9 - 13.1 1000 RPM	500	1150 - 1160	1240 - 1250
723F-9A543-AAB	P5084/3B	12.9 - 13.1	500	1150 - 1160	1240 - 1250
743F-9A543-AAA 4150 cc (254 cu. in.)	PES4A85D210 PB RS2378	11.3 - 12.5 1000 RPM	550	1185 - 1195	-
2703E-9A543-E 5416 cc (330 cu. in.)	P4816	11.2 - 11.4 800 RPM	500	1010 - 1020	1120 - 1140
2703E-9A543-H 5416 cc (330 cu. in.)	P5012/B	11.2 - 11.4 800 RPM	500	1010 - 1020	1060 - 1080
693F-9A543-BAA 5416 cc (330 cu. in.)	P5080/A	9.9 - 10.1 1000 RPM	525	1160 - 1170	1215 - 1245
2704E-9A543-AE 5950 cc (363 cu. in.)	P5012/C	12.0 - 12.2 800 RPM	500	1010 - 1020	1060 - 1080
703F-9A543-BEA 5950 cc (363 cu. in.)	P5085/B PB	10.2 - 10.4 1000 RPM	600	1160 - 1170	1220 - 1250
703F-9A543-BEB 5950 cc (363 cu. in.)	P5085/2B PB	10.2 - 10.4 1000 RPM	600	1160 - 1170	1220 - 1250
703 F-9A543-BEC 5950 cc (363 cu. in.)	P5085/3B PB	10.2 - 10.4 1000 RPM	600	1160 - 1170	1220 - 1250
743F-9A543-BAA 5950 cc (363 cu. in.)	PES6A85D210 PB RS23782	9.2 - 10.4 1000 RPM	550	1180 - 1190	-
693F-9A543-CAA 5950 cc (363 cu. in.)	P5080	12.3 - 12.5 1000 RPM	525	1160 - 1170	1215 - 1245
693F-9A543-CBA 6220 cc (380 cu. in.)	PES6A85C4101/C RV8880	12.1 - 12.3 1100 RPM	550	1123 - 1133	-
703F-9A543-CJA 6220 cc (380 cu. in.)	P5085/C PB	11.5 - 11.7 1000 RPM	600	1160 - 1170	1220 - 1250
703F-9A543-CJB 6220 cc (380 cu. in.)	P5085/2C PB	11.5 - 11.7 1000 RPM	600	1160 - 1170	1220 - 1250
703F-9A543-CJC 6220 cc (380 cu. in.)	P5085/3C PB	11.5 - 11.7 1000 RPM	600	1160 - 1170	1220 - 1250
743F-9A543-CAA 6220 cc (380 cu. in.)	PES6A85D210 PB RS2379	10.6 - 11.8 1000 RPM	550	1185 - 1195	-
713F-9A543-CAA 6220 cc (380 cu. in.)	P5186 PB	13.6 - 13.8 1200 RPM	550	1245 - 1255	1325 - 1425
713F-9A543-CAB 6220 cc (380 cu. in.)	P5186/1 PB	13.6 - 13.8 1200 RPM	550	1245 - 1255	1325 - 1425
713F-9A543-CAC 6220 cc (380 cu. in.)	P5186/2 PB	13.6 - 13.8 1200 RPM	550	1245 - 1255	1325 - 1425
693F-9A543-GAA 5950 cc (363 cu. in.)	P5078	15.3 - 15.7 1100 RPM	600	1160 - 1170	1250 - 1270
693F-9A543-GAB 5950 cc (363 cu. in.)	P5078/1	15.3 - 15.7 1100 RPM	600	1160 - 1170	1250 - 1270
693F-9A543-GAC 5950 cc (363 cu. in.)	P5078/2	15.3 - 15.7 1100 RPM	600	1160 - 1170	1250 - 1270
723F-9A543-GAA 5950 cc (363 cu. in.)	P5229	Refer to Service Letter No. 5 1973 for test- ing Procedure	600	1140 - 1170	1240 - 1250

## ENGINE FEATURES

## EXTERNAL

There are two distinct forms of crankcase breathing systems fitted to Claas and Clayton Combines.

- (a) Phase I as fitted to 2700E Range engines (Fig. 8).
- (b) Phase II as fitted to 2700C/2710E Range engines (Fig. 9A and 9B).

## PHASE I CRANKCASE BREATHING SYSTEM

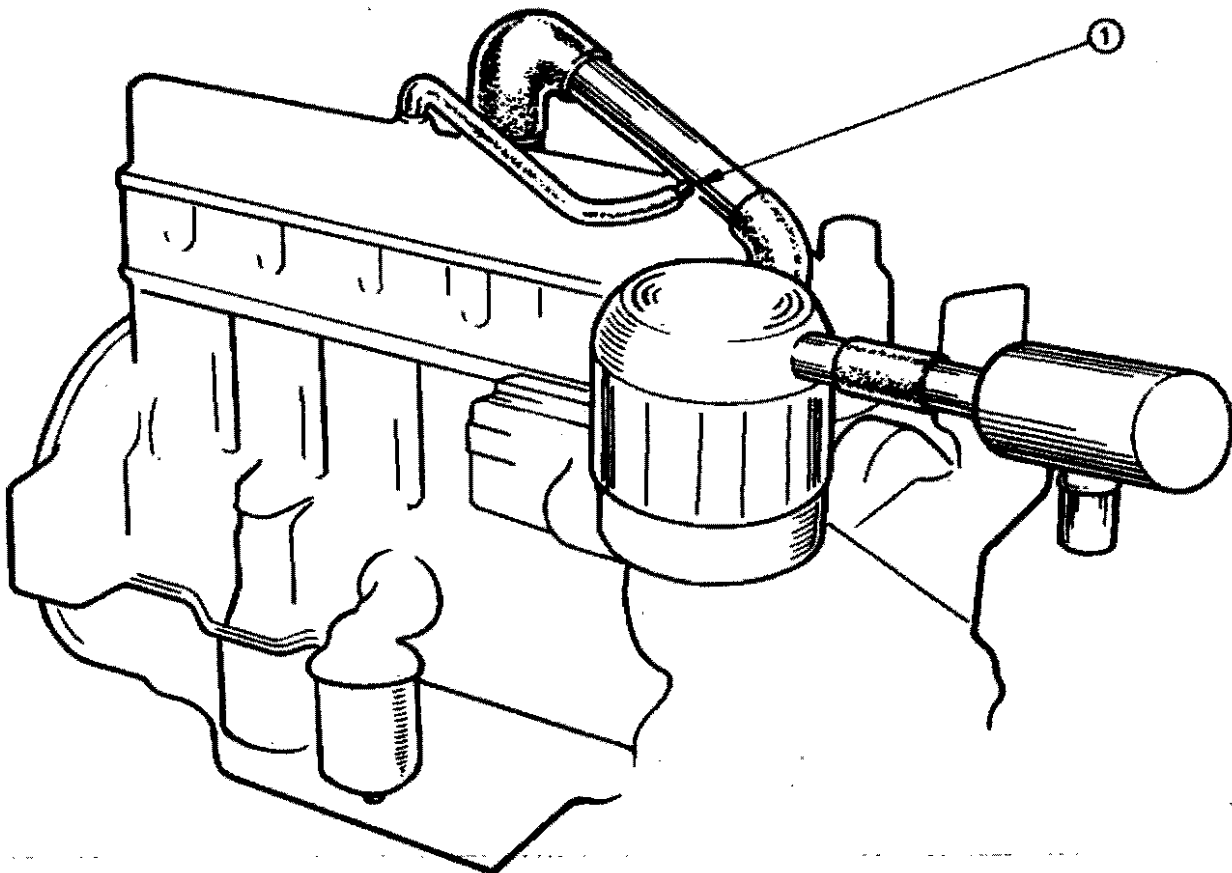


Fig. 8 Typical Breathing System  
1 Hole in wall of air trunk tube

- (a) At first sight, this appears to be a normal automotive system but in fact, this is not the case.

A non-vented filler cap is fitted to the oil pan on the Combine engines and the crankcase pressure is regulated by restricting the size of the hole between the air trunk pipe and the air cleaner hose to:-

- 6.0 mm (.234 in) on the 5945 cc (363 cu. in.) engine
- 6.5 mm (.250 in) on the 3964 cc (242 cu. in.) engine
- 7.0 mm (.281 in) on the 5408 cc (330 cu. in.) engine

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ENGINE FEATURES—Continued

PHASE II BREATHING SYSTEM

(b) The illustrations Figs. 9A, 9B and 10 show the revised crankcase breathing system for the Phase II engine.

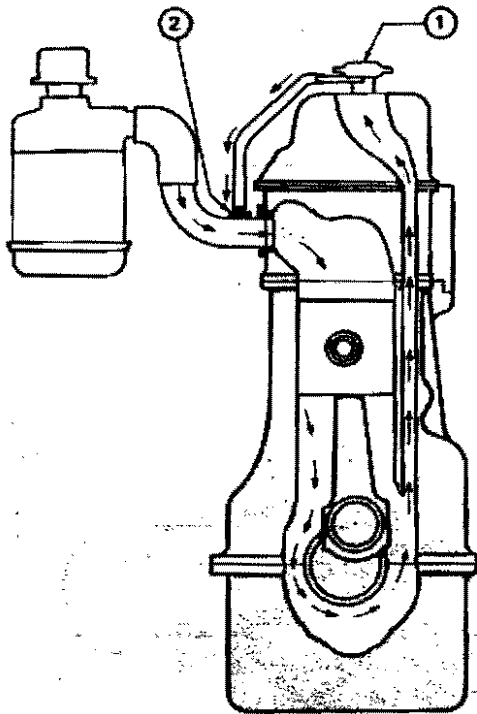


Fig. 9A Latest type

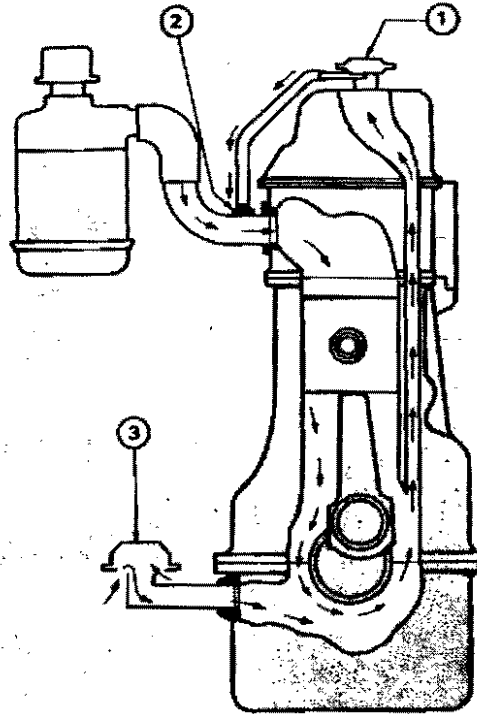


Fig. 9B Previous type

- (1) Emission control valve
- (2) Fumes pass into inlet manifold
- (3) Vented side oil filler cap

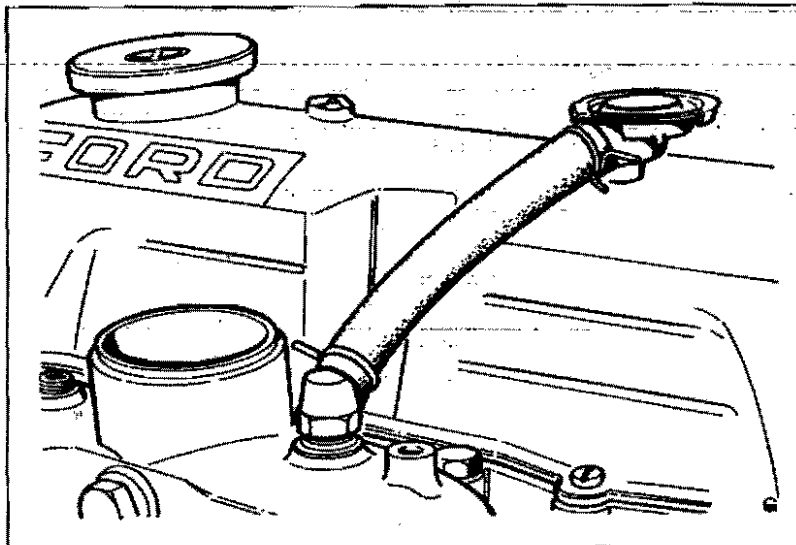


Fig. 10



**FUEL FILTERS**

The single bowl filter was fitted to early production Combine engines. Later production engines were fitted with double bowl filters. The following information will assist in identifying filter/s and replacement element/s.

**SIMMS—SINGLE BOWL FILTER**

Filter Assembly	Part No. 2701E-9155-K	(Finis Code No. 1445341)
Element	Part No. 2701E-9150-B	(Finis Code No. 1423477)

**C.A.V.—SINGLE BOWL FILTER**

Filter Assembly	Part No. 2701E-9155-B	(Finis Code No. 1789434)
Element	Part No. 2704E-9150	(Finis Code No. 1700328)

**SIMMS—DOUBLE BOWL FILTER**

Filter Assembly	Part No. 723F-9155-AAA	(Finis Code No. 1539407)
Element	Part No. 2701E-9150-B	(Finis Code No. 1423477)

**C.A.V.—DOUBLE BOWL FILTER**

* Filter Assembly	Part No. 2701E-9155-D	(Finis Code No. 1402246)
Element	Part No. 2704E-9150	(Finis Code No. 1700328)
Filter Assembly	Part No. 713F-9155-AAA	(Finis Code No. 1537178)
Element	Part No. 2704E-9150	(Finis Code No. 1700328)

\* When using SIMMS Injection Equipment, No. 4 connection must be plugged with (1) 377496-S43 Plug and (1) 378441-ES Washer.

For details of Bosch Filter refer to Claas Service Organisation.

**AIR CLEANERS**

For service details of the Air Cleaners and Breathing Connections on Claas/Ford and Clayson/New Holland Combines, refer to the respective Combine manufacturers.

**FLEXIBLE FUEL PIPE**

On Clayson/New Holland Combines, the pipe used between the lift pump and fuel filters has been increased in length. To ensure that the latest level pipe is fitted the overall length of the flexible tube and connections should be measured. This measurement should read 33.02 cm (13.02 in.) minimum.

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## INHIBITING PROCEDURE

The inhibitor described below is available under the brand name of 'Motorstor' and may be obtained from the following sources:-

European requirements are available direct from:

Daubert Internationaal B.V.  
Bergeweg 33  
Sittard  
Netherlands.

U.K. orders should be directed to the U.K. Sales Manager:

Mr. P. Holland  
P.O. Box 3  
Holmes Chapel  
Cheshire.  
Tel: Holmes Chapel 34531

All other orders should be directed to:

Daubert Chemical Company  
709 Enterprise Drive  
Oak Brook  
Illinois 60521  
U.S.A.

When engines and/or equipment are to be stored for any length of time the following procedure should be adopted.

## INHIBITING ENGINES

DIESEL	Fuel tanks, Fuel lines, Fuel filters, Injection Pump and Injectors.
PETROL	Fuel tank, Fuel lines, Fuel filters and Carburettors.
METHOD	Inject into the fuel tank 30 cc (1 fluid ounce) of 'Motorstor' for each gallon (4.55 litres) of fuel plus 30 cc for each 15 gallons (68 litres) of remaining void volume.
OIL PANS.	Drain engine oil and refill oil pan to the full mark on the dipstick with oil of the correct specification. Inject 66 cc (2 fluid ounces) of 'Motorstor' into the oil pan for each gallon (4.55 litres) of oil.
VALVE GEAR TRAIN	Inject 15 to 30 cc ( $\frac{1}{2}$ - 1 fluid ounce) of 'Motorstor' through the filler cap in the rocker cover or remove and spray 'Motorstor' on to the valve gear.

When the above operations are complete, run the engine for approximately 20 seconds at a fast idle (1,000 RPM) to circulate the inhibited fuel and oil throughout the system.

## CYLINDER BORES

### DIESEL

Inject approximately 10 cc (1/3 fluid ounce) of 'Motorstor' for each cylinder into the inlet manifold and crank the engine slowly for approximately 12 revolutions.

Note:— Do not crank engine excessively as 'Motorstor' is a volatile compound and could fire within the cylinders.

### PETROL

Remove all spark plugs and spray approximately 10 cc (1/3 fluid ounce) of 'Motorstor' into each cylinder.

Rotate engine for approximately 12 revolutions and replace the spark plugs.

### WATER GALLERIES AND WATER PUMP

Drain the cooling system.

Remove hose connection nearest to the water pump body and spray in 15 to 30 cc (½ to 1 fluid ounce) of 'Motorstor'.

### EXHAUST SYSTEM

Spray sufficient 'Motorstor' into the exhaust manifold and pipework to fill the system with vapour—seal the exhaust outlet.

Where engine is fitted to equipment, remove the exhaust pipe at the manifold connection; inhibit manifold and pipe work. re-connect pipe work and seal exhaust outlet.

### GEARBOXES AND DRIVE AXLES

Inject through the oil filler hole 60 cc (2 fluid ounce) of 'Motorstor' for each gallon (4.55 litres) of lubricating oil capacity.

### SPECIAL NOTES

'Motorstor' is a volatile compound and will evaporate unless on completion of inhibiting, all vents, filler caps, etc., are sealed with tape or grommets.

Inhibited equipment is ready for immediate use; it is not necessary to drain off the inhibitor prior to re-commissioning the machinery.

