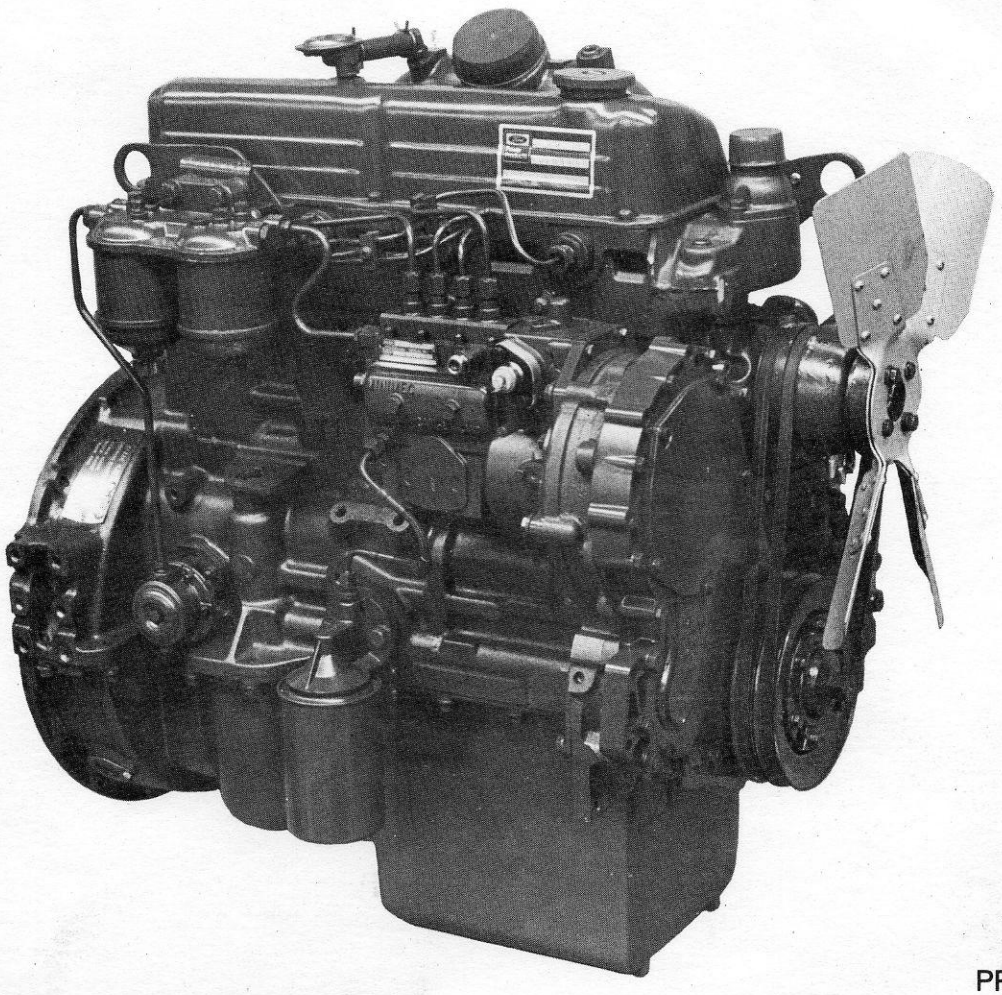
Ford

Power Products

DIESEL ENGINES

ESD-442
ESD-659
ESD-660T
ESD-662

SERVICE MANUAL



PPO 194-243
November, 1983

Introduction

This Service Manual provides the service technician with information for the proper servicing of the Dover Industrial Engine.

In general, this manual covers the servicing of the engine and associated standard equipment. In many cases, engines are supplied with accessories and equipment that are unique to the application. If service information is ever required on such unique accessories or equipment it is suggested that the Industrial Engine Operations of Ford Motor Company be contacted. The proper information will either be forwarded or the Service Technician will be advised where it can be obtained.

The information in this manual is grouped in sections according to the type of work being performed. The various sections are indicated in the index. In addition, each section is subdivided to include topics such as diagnosis and testing, cleaning and inspection, overhaul, removal and installation procedures, disassembly and assembly procedures, and service specifications.

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

Pistons and valves are numbered from the front or timing cover end of the engine commencing at Number 1.

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Note: The recommendations and suggestions contained in this publication are made to assist the distributor in improving his distributorship parts and/or service department operations. These recommendations and suggestions do not supersede or override the provisions of the Warranty and Policy Manual and in any cases where there may be a conflict, the provisions of the Warranty and Policy Manual shall govern.

IMPORTANT SAFETY NOTICE

Appropriate service methods and proper repair procedures are essential for the safe, reliable operation of all motor vehicles as well as the personal safety of the individual doing the work. This Shop Manual provides general directions for accomplishing service and repair work with tested, effective techniques. Following them will help assure reliability.

There are numerous variations in procedures, techniques, tools and parts for servicing vehicles, as well as in the skill of the individual doing the work. This Manual cannot possibly anticipate all such variations and provide advice or cautions as to each. Accordingly, anyone who departs from the instructions provided in the Manual must first establish that he compromises neither his personal safety nor the vehicle integrity by his choice of methods, tools or parts.

NOTES, CAUTIONS, AND WARNINGS

As you read through the procedures, you will come across NOTES, CAUTIONS, and WARNINGS. Each one is there for a specific purpose. NOTES give you added information that will help you to complete a particular procedure. CAUTIONS are given to prevent you from making an error that could damage the vehicle. WARNINGS remind you to be especially careful in those areas where carelessness can cause personal injury. The following list contains some general WARNINGS that you should follow when you work on a vehicle.

- Always wear safety glasses for eye protection.
- Use safety stands whenever a procedure requires you to be under the vehicle.
- Be sure that the ignition switch is always in the OFF position, unless otherwise required by the procedure.
- Set the parking brake when working on the vehicle. If you have an automatic transmission, set it in PARK unless instructed otherwise for a specific operation. If you have a manual transmission, it should be in REVERSE (engine OFF) or NEUTRAL (engine ON) unless instructed otherwise for a specific operation. Place wood blocks (4" x 4" or larger) to the front and rear surfaces of the tires to provide further restraint from inadvertent vehicle movement.
- Operate the engine only in a well-ventilated area to avoid the danger of carbon monoxide.
- Keep yourself and your clothing away from moving parts, when the engine is running, especially the fan and belts.
- To prevent serious burns, avoid contact with hot metal parts such as the radiator, exhaust manifold, tail pipe, catalytic converter and muffler.
- Do not smoke while working on the vehicle.
- To avoid injury, always remove rings, watches, loose hanging jewelry, and loose clothing before beginning to work on a vehicle. Tie long hair securely behind the head.
- Keep hands and other objects clear of the radiator fan blades. Electric cooling fans can start to operate at any time by an increase in underhood temperatures, even though the ignition is in the OFF position. Therefore, care should be taken to ensure that the electric cooling fan is completely disconnected when working under the hood.

PART I - Basic Engine

COMPONENT INDEX

IDENTIFICATION

An Identification Decal (Fig. 1) is affixed to the rocker cover of the engine. The decal contains the engine serial number which identifies the unit from all others. Next is the engine displacement which determines the engine specifications, then the model number and S.O. or special options which determines the parts or components required on the unit. Use all the numbers when seeking information or ordering replacement parts for your unit.

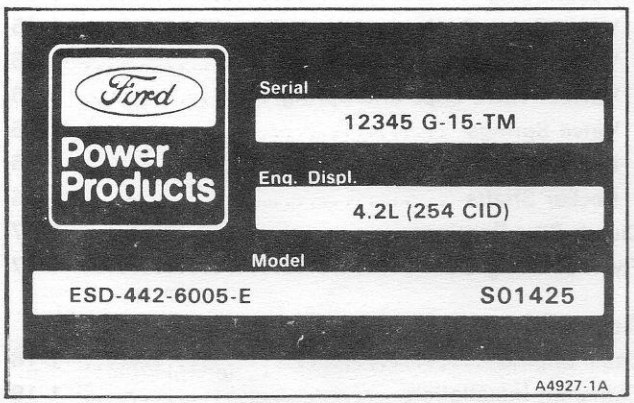


Fig. 1 - Identification Decal

Engine Identification

Identification of the cylinder block, and therefore of the basic engine type can be make by reference to the rised machined pad on the top edge of the cylinder block. As shown in Fig. 2 the identification points are on the fuel injection pump side of the engine.

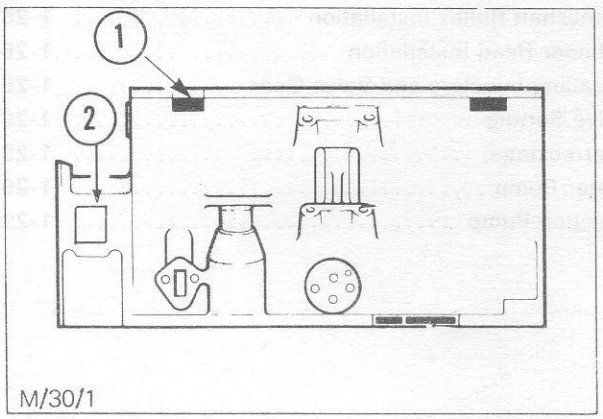


Fig. 2 - Cylinder Block Identification Codes

1. Engine Capacity
2. Engine Build Data Plate and Engine Build Date

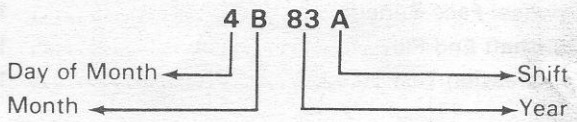
Engine Capacity

Code	Engine Capacity & Type
255	4.2 Litre (254 Cu. In.)
365NA	5.9 Litre (362 Cu. In.)
380NA	6,2 Litre (380 Cu. In.)
365TC	6,0 Litre (363 Cu. In.)

Note: NA - Naturally Aspirated
TC - Turbocharged

Engine Build Date

The engine build date is stamped in the right upper corner of the engine build data plate (Fig. 3).



A - Jan.	E - May	I - Sept.
B - Feb.	F - June	J - Oct.
C - March	G - July	K - Nov.
D - April	H - Aug.	L - Dec.

Orignial Engine Build Data Plate

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

Four possible combinations of sizes may be encountered, and these are identified by the color of the plate and the dimensions on the plate (Fig. 3 A, B, C and D).

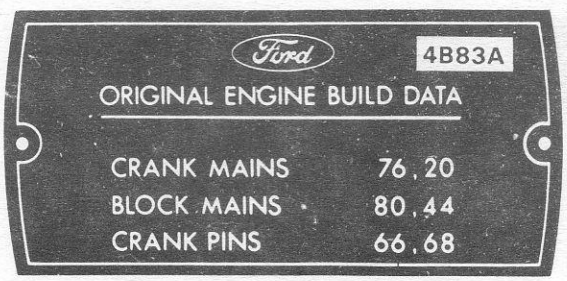


Fig. 3 A - Green

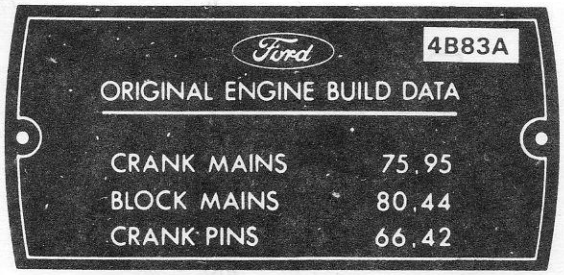


Fig. 3 B - Blue

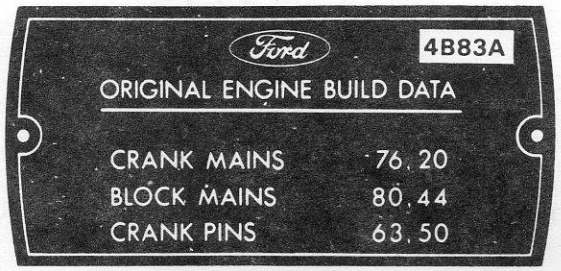


Fig. 3 C - Black

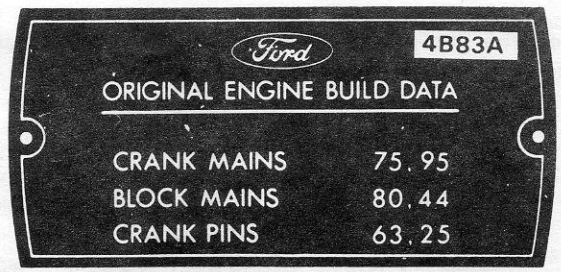


Fig. 3 D - Orange

Service Engines

Service engines are fitted with a service cylinder data plate, giving dimensions in millimeters of crank main bearing diameter, crank rod bearing diameter, block main bearing diameter, and block cam bearing diameter (Fig. 4).

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

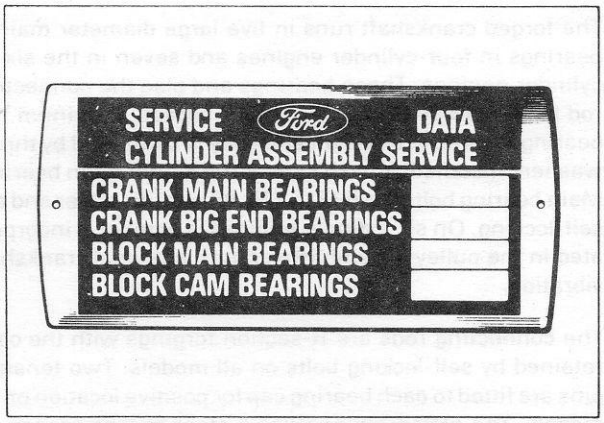


Fig. 4 - Service Cylinder Data Plate

DESCRIPTION

General

The Dover range of Ford Industrial Engines includes the following Models:

ESD-442	4 Cyl.	4.2 Liter (254 CID)
ESD-659	6 Cyl.	5.9 Liter (362 CID)
ESD-660T	6 Cyl.	6.0 Liter (363 CID) Turbo
ESD-662	6 Cyl.	6.2 Liter (380 CID)

Refer to Part 8, the Specifications section of this manual, for the bore, stroke and other details.

The engines are 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 bushings support the camshaft.

The four-cylinder engine has four bearings and the six cylinder engine has six. The front bearing is bronze while the remainder are white metal.

A helical gear, machined integral with the camshaft drives the oil pump. An eccentric for the fuel 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 removable 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 six-cylinder engines. These bearings and also the connecting rod bearings have removable steel-backed aluminum tin bearing inserts. Crankshaft end-play is controlled by thrust washers installed at each side of the center main bearing. Main bearing bolts are 5/8 in. (15.88 mm) diameter and are self-locking. On six-cylinder engines, a damper is incorporated in the pulley assembly to control torsional crankshaft vibration.

The connecting rods are H-section forgings with the caps retained by self-locking bolts on all models. Two tension pins are fitted to each bearing cap for positive location on all models. The piston pin end has a steel-backed bronze bushing.

Aluminum alloy solid skirt pistons with the combustion chamber machined in the piston crowns are used. The pistons of the naturally aspirated engine have two compression and one oil ring. In the turbocharged engine each piston has three compression and one oil control ring. The piston pins are full floating and are held in position by snap rings installed in grooves at each end of the piston pin bore.

The cylinder bores of the turbocharged engine have dry type, pre-sized, slip fit, hard faced cylinder liners. All other models have the piston in contact with the cylinder block. The cylinder block is cast iron and does not incorporate a tappet chamber. Push rods and drain holes are machined in the block.

The oil pans are aluminum castings and are located by dowels on the six-cylinder engines to ensure positive alignment of the rear face.

The fuel injection pump is an in-line type with a separate pumping element for each engine cylinder; it contains a mechanical governor to ensure that the selected engine speed remains constant despite variations in the driven load.

There is a provision for various combinations of power take-offs from the front and rear of the timing gear cover.

The aluminum alloy pan is cast integral with the lower half of the flywheel housing, and incorporates a dipstick housing.

The illustrations in Fig. 5 show the crankcase breathing systems.

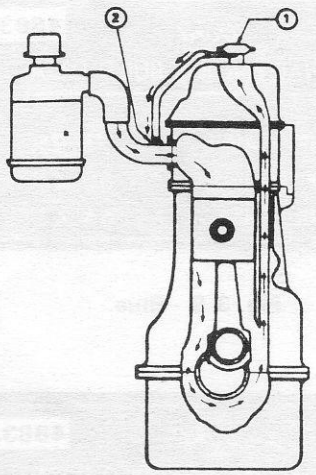


Fig. 5
1. Emission Control Valve
2. Fumes Pass Into Inlet Manifold

DIAGNOSIS AND TESTING

Camshaft Lobe Lift

Check the lift of each lobe in consecutive order and make a note of the readings:

1. Remove valve rocker arm cover.
2. If only one camshaft lobe is to be checked, loosen the valve rocker arm adjusting screw. Slide the rocker arm assembly serving the camshaft lobe to be checked to one side. Secure it in this position. Repeat this procedure on other lobes to be checked. Indicator is in the push rod socket and in the same plane as the push rod movement.
3. Make sure the push rod is in the valve lifter socket. Install a dial indicator so that the actuating point of the indicator is in the push rod socket and in the same plane as the push rod movement (Fig. 6).
4. Connect an auxiliary starter switch in the starting circuit. Crank the engine with the stop control in the "Stop" position. Bump the crankshaft over until the tappet or lifter is on the base circle of the camshaft lobe. At this point, the push rod will be in its lowest position.
5. Zero the dial indicator. Continue to rotate the crankshaft slowly until the push rod is in the fully raised position.
6. Compare the total lift recorded on the indicator with specifications.

7. To check the accuracy of the original indicator reading, continue to rotate the crankshaft until the indicator reads zero. **If the lift on any lobe is below specified wear limits, the camshaft and the valve lifters operating on the worn lobe(s) must be replaced.**
8. Remove the dial indicator and auxiliary starter switch.
9. Install and adjust the rocker arms as detailed under Removal and Installation.
10. Install the valve rocker arm cover.

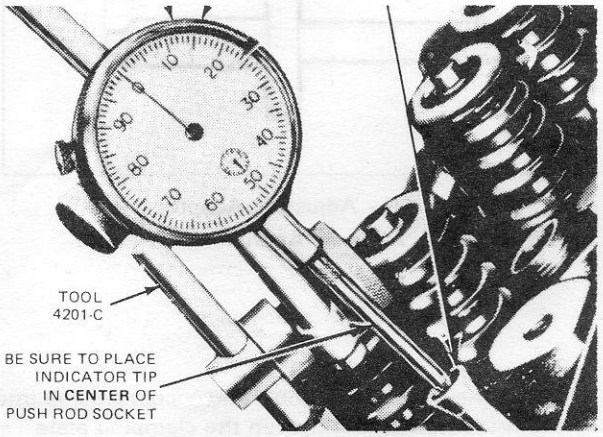


Fig. 6 - Testing Camshaft Lobe Lift - Typical

Crankshaft End Play

1. Force the crankshaft toward the rear of the engine.
2. Install a dial indicator so that the contact point rests against the crankshaft flange and the indicator axis is parallel to the crankshaft axis (Fig. 7).
3. Zero the dial indicator. Push the crankshaft forward and note the reading on the dial.
4. If the end play exceeds the wear limit, replace the thrust washers. If the end play is less than the minimum limit, inspect the thrust bearing faces for scratches, burrs, nicks, or dirt.

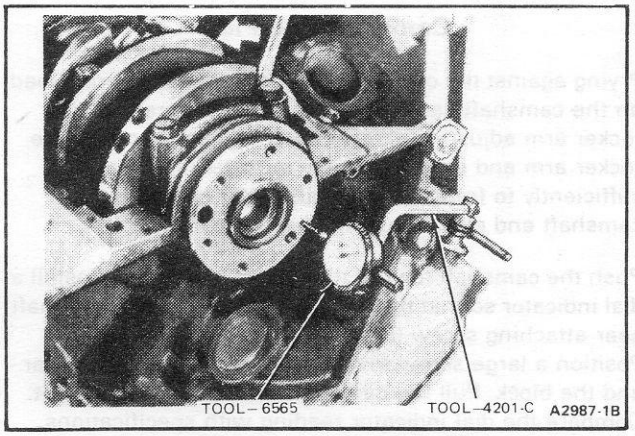


Fig. 7 - Checking Crankshaft End Play - Typical

Flywheel Face Runout

Using a dial gauge and magnetic base check that the flywheel run out is within the specified limits when measured at 140 mm (5,50 in.) radius (Fig. 8).

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

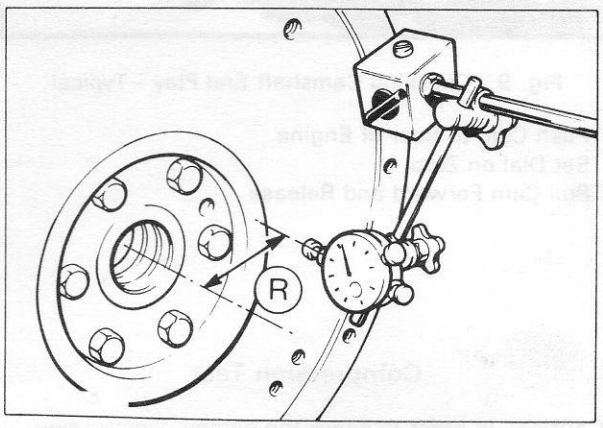


Fig. 8 - Checking Flywheel Run-Out
R = 140 mm (5,50 in.)

Camshaft End Play

Prying against the camshaft gear with the valve train load on the camshaft can damage the gear. Therefore, the rocker arm adjusting screws must be backed off, or the rocker arm and shaft assembly must be loosened sufficiently to free the camshaft. After checking the camshaft end play, adjust the valve clearance.

Push the camshaft toward the rear of the engine. Install a dial indicator so that the indicator point is on the camshaft gear attaching screw (Fig. 9). Zero the dial indicator. Position a large screwdriver between the camshaft gear and the block. Pull the camshaft forward and release it. Compare the dial indicator reading with specifications.

If the end play is excessive, check the plate for correct installation before it is removed. If the plate is correctly installed, replace the thrust plate.

Remove the dial indicator.

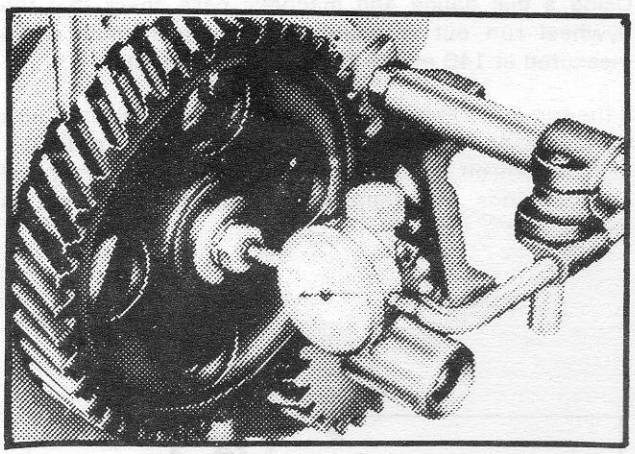


Fig. 9 - Checking Camshaft End Play - Typical

1. Push Cam to Rear of Engine
2. Set Dial on Zero
3. Pull Cam Forward and Release

Compression Test

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

1. If the engine will start, run it and allow it to reach normal operating temperture. Be sure the battery is up to specification.
2. Stop the engine and remove all the injectors as detailed in Part 3.
3. Select a suitable cooper sealing washer for the adaptor. Adjust the adaptor so that the overall length of the assembly (from clamping plate to end of adaptor) is approximately the same as the injector body (Fig. 10).

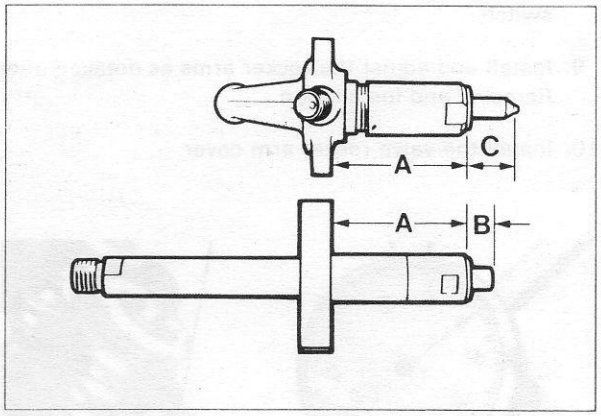


Fig. 10 - Adjusting Adaptor
Dimension "A" to be Approximately Equal

4. Install the adaptor assembly and copper washer into the first cylinder and tighten the clamping plate securely. Connect the pressure gauge assembly to the adaptor.
5. Secure the engine stop control lever on the injection pump in the "no delivery" position.
6. Crank the engine by the starter, and continue to "crank" until the pressure gauge is indicating a steady pressure. Note the pressure obtained.
7. Repeat the operation for the remaining cylinders.
8. Compare the pressure readings obtained from each cylinder with those specified. If the pressure variation is outside the specified limits, or if all cylinder pressures are low, engine damage or wear is indicated.

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

9. Remove and dismantle the test equipment.
10. Check the injector seats to ensure that they are clean and free from any carbon deposits.
11. Install the injectors and bleed the system as detailed in Part 3 and install the valve cover.
12. Start the engine and allow it to run for a short period. Check for oil or fuel leaks. Rectify any leakage as necessary.

DISASSEMBLY

Basic Engine

1. If so equipped, disconnect and remove the turbocharger oil feed pipe and oil return pipe. Detach pipe connecting injection pump boost control and inlet manifold.
2. On the turbocharged industrial engine, loosen clamps securing hose between turbocharger and air inlet pipe, unscrew attaching bolts and remove the pipe.
3. Remove nuts attaching turbocharger to support plate and detach the exhaust outlet elbow. Discard gasket(s).

   Remove turbocharger support plate and bracket from cylinder block. Remove nuts attaching turbocharger to exhaust manifold and detach the turbocharger. Protect turbocharger from ingress of dirt and foreign bodies.
4. Remove inlet manifold and discard all gaskets.
5. Remove exhaust manifold and discard gaskets.
6. Remove starter motor.
7. Lift engine with a suitable hoist, using the cylinder head lifting brackets and mount the engine on the stand.
8. Remove dipstick and, in the case of a high level dipstick, remove the dipstick tube from the oil pan. Unscrew and discard the oil filter.
9. Remove low pressure fuel pipes connecting fuel lift pump, fuel filters and injection pump.
10. Remove fuel lift pump and (if so equipped) the pre-filter unit.
11. Remove fuel filters complete with mounting bracket.
12. Loosen or remove the high pressure fuel pipe clamps as necessary to enable the large oil seal nuts to be backed off.
13. Unscrew the nuts from the injectors and the injection pump and remove the high pressure fuel pipes.
14. Install plugs/caps to all injection equipment apertures, including pipe ends.
15. Remove oil feed pipe between oil filter head and injection pump. Remove filter head from cylinder block and discard gasket. Remove oil pressure sender unit.
16. Detach the lead connecting injection pump automatic excess fuel solenoid to temperature sensitive switch on the thermostat housing.
17. Unscrew the three retaining bolts and remove the injection pump.
18. Remove fan mounting bolts, fan and belt. On "Low Loss" Fan Drive System, also remove the bearing retainer outer plate which is retained by the fan attaching bolts.

    Note: On single belt drives, the pulley can be removed at the same time.
19. Remove water hose(s).
20. Remove water pump attaching bolts/nuts and remove pump from engine. Discard the gasket.
21. Remove alternator. Remove the water pump extension tube (if so equipped) together with the engine mounting bracket or spacers, as applicable.
22. Remove thermostat housing and lift out the thermostat(s).
23. Remove oil pan drain plug(s) and drain off the engine oil into a suitable receptacle.
24. Remove the rocker cover.
25. Loosen each rocker shaft pedestal retaining bolt approximately one turn at a time until all are loose, then remove them.
26. Tie the two end rockers in position to keep the complete assembly together, then lift off rocker shaft assembly complete.
27. Remove push rods in sequence and mark them to ensure that they are replaced in their original positions when assembling them later. Do not dislodge the valve stem caps.

Removing Injectors

28. Remove banjo bolts from leak-off line, then unscrew bolt and remove leak-off line from cylinder head.
29. Unscrew two retaining bolts and remove each injector. Discard "O" ring. Remove copper sealing washers from recesses in cylinder head and discard them (Fig. 11).

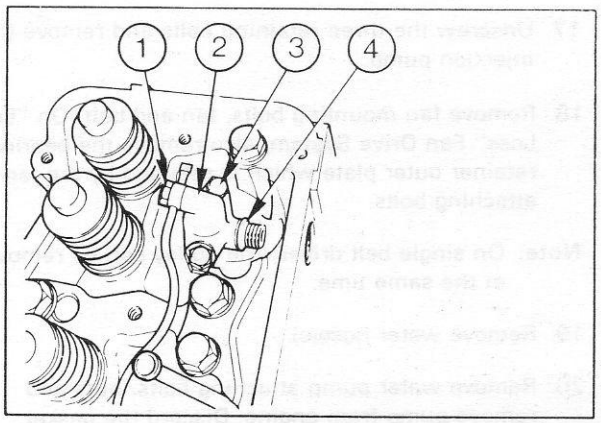


Fig. 11 - Removing Injectors

1. Leak-Off Pipe Banjo Bolt
2. Injector
3. Injector Retaining Bolt
4. "O" Ring

Removing Cylinder Head

30. Loosen each cylinder head bolt a little at a time in the reverse order to the tightening sequence shown in Fig. 12, then remove all bolts.

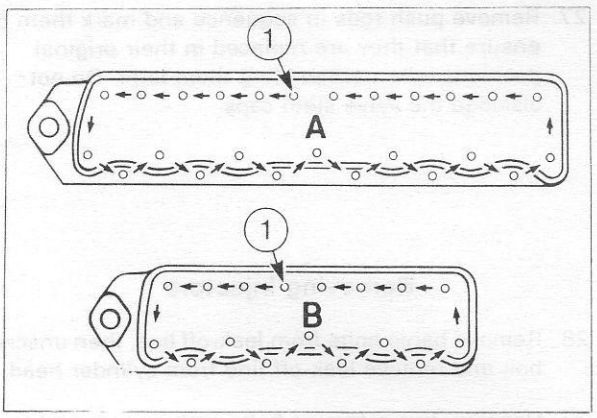


Fig. 12 - Cylinder Head Bolts Tightening Sequence

A. 6 Cylinder Engines
B. 4 Cylinder Engines
1. Start here when tightening. Reverse sequence to loosen.

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

Removing Flywheel

32. Remove the flywheel retaining bolts and, using two suitable bolts in the threaded holes as pullers, tighten the bolts evenly one turn at a time and withdraw the flywheel off the crankshaft (Fig. 13).

Warning: Be sure that the flywheel is adequately supported during removal.

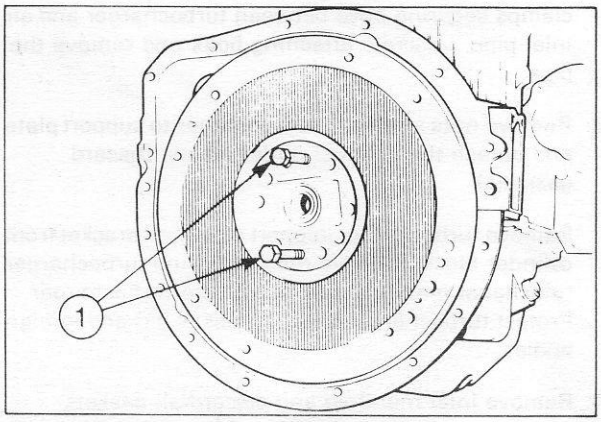


Fig. 13 - Removing Flywheel

1. Flywheel Withdrawal Bolts

Removing Oil Pump

33. Be sure the oil pan has been completely drained of engine oil and invert the engine on the stand.

34. Remove the bolts and nuts and carefully separate the oil pan from the cylinder block.

    ESD-442, 659, 662 and 663T engines not fitted with high inclination oil pans.

35. Bend up the lock tabs securing the oil pick-up pipe union nut to the oil pump, and unscrew the union (Fig. 14). Remove the pick up pipe support bracket bolt from the main bearing cap and withdraw the pick up pipe from the pump. Remove the bolts securing the pump to the cylinder block and carefully withdraw the pump.

    Oil pump overhaul is detailed in Part 2, "Lubrication System".

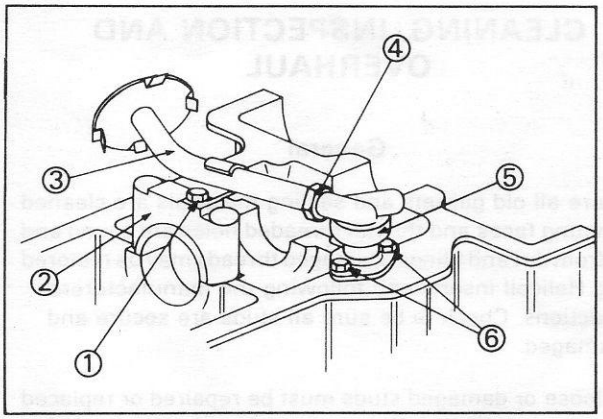


Fig. 14 - Oil Pump Removal/Replacement - Engines Not Fitted With High Inclination Oil Pans

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

Engines fitted with high inclination oil pans (Fig. 15).

36. a. Remove all bolt and lockwashers retaining the pump and pipes then remove the pump from the block.

    b. Remove the screens by turning through 90° to release.

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

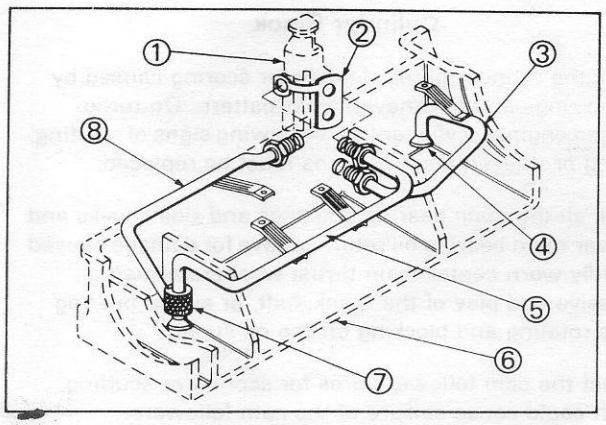


Fig. 15 - Oil Pump and Piping for High Inclination Oil Pans

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

Removing Timing Gears, Housing and Crankshaft Pulley

37. Remove the crankshaft pulley retaining bolt, and remove the crankshaft pulley, using a suitable puller if necessary (Fig. 16).

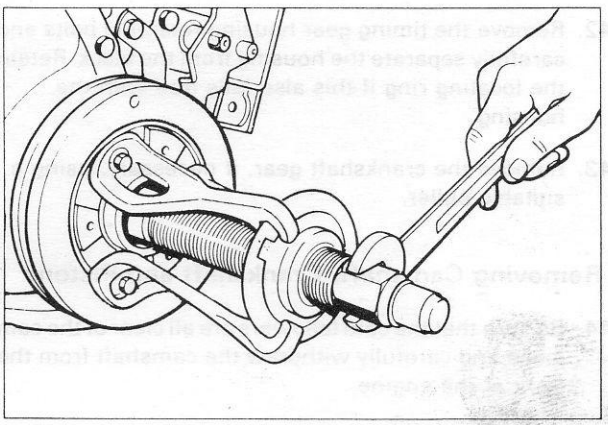


Fig. 16 - Removing Crankshaft Pulley

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

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

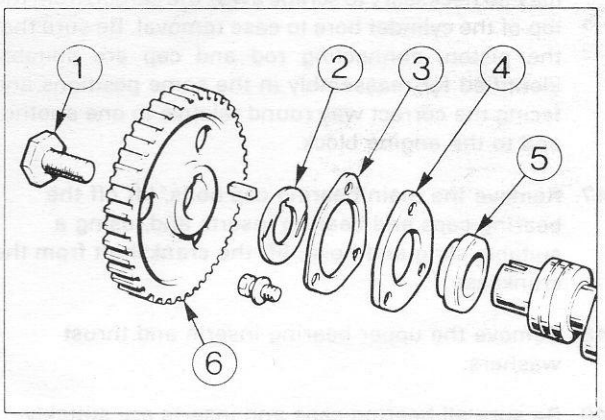


Fig. 17 - Camshaft Gear Assembly

1. Gear Retaining Bolt
2. Thrust Washer
3. Retaining Plate
4. Thrust Plate
5. Thrust Collar
6. Camshaft Gear

40. Lock the camshaft gear to stop it turning and remove gear retaining bolt (Fig. 17). Using a suitable puller remove the camshaft gear. Remove the thrust washer.
41. Remove the three bolts securing the camshaft gear lockplate and thrust plate to the front of the engine, remove the two plates and the camshaft thrust collar (Fig. 17).
42. Remove the timing gear housing retaining bolts and carefully separate the housing from the block. Retain the locating ring if this also falls free with the housing.
43. Remove the crankshaft gear, if necessary, using a suitable puller.

Removing Camshaft, Crankshaft and Pistons

44. Be sure that the cam followers are all clear of the cam lobes and carefully withdraw the camshaft from the front of the engine.

Caution: Take great care to be sure that the camshaft lobes do not damage the camshaft bearings as the shaft is withdrawn.

45. Lift out the cam followers and retain in numerical sequence for reassembly in the same positions.
46. Taking each piston and connecting rod assembly in turn remove the connecting rod cap bolts or nuts and remove the bearing cap. Disengage the connecting rod from the crank pin and using a suitable soft drift (wooden hammer shaft) tap the piston and rod assembly out through the top of the cylinder bore. It may be necessary to scrape away the carbon from the top of the cylinder bore to ease removal. Be sure that the piston, connecting rod and cap are suitably identified for reassembly in the same positions and facing the correct way round relative to one another and to the engine block.
47. Remove the main bearing cap bolts, lift off the bearing caps and bearing inserts and, using a suitable sling and hoist, lift the crankshaft from the crankcase.
48. Remove the upper bearing inserts and thrust washers.
49. Be sure all bearing caps and inserts are suitably identified for reassembly in their original positions.

CLEANING, INSPECTION AND OVERHAUL

General

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

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

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

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

Oil Pan

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

A new drain plug insert or an oversize filler/tube adaptor may be installed, if necessary.

Cylinder Block

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

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

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

Check the camshaft bearings for scoring or excessive wear.

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

To install new bearings see "Camshaft Bearing Replacement".

Using an internal micrometer, measure and record the diameter of each cylinder bore at the following three points, both in line with, and at 90° to, the crankshaft axis (Fig. 18).

A. Cylinder Block Face

1. Immediately below the highest point reached by the piston top ring.
2. 80 mm (3,15 in.) from the top of the cylinder block face.
3. 200 mm (7,90 in.) from the top of the cylinder block face.

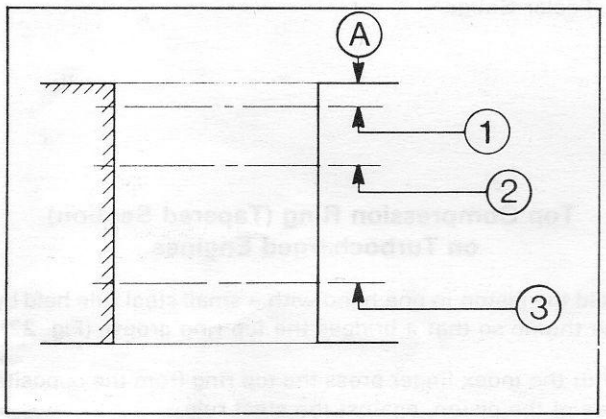


Fig. 18 - Cylinder Bore Wear Measuring Locations (See Text)

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

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

Pistons and Connecting Rods

Remove the piston rings.

Remove all carbon deposits from the ring grooves.

Remove the piston pin retainer and warm the piston in hot water. Push out the piston pin and separate the piston from the connecting rod (Fig. 19). Keep each piston with its respective connecting rod.

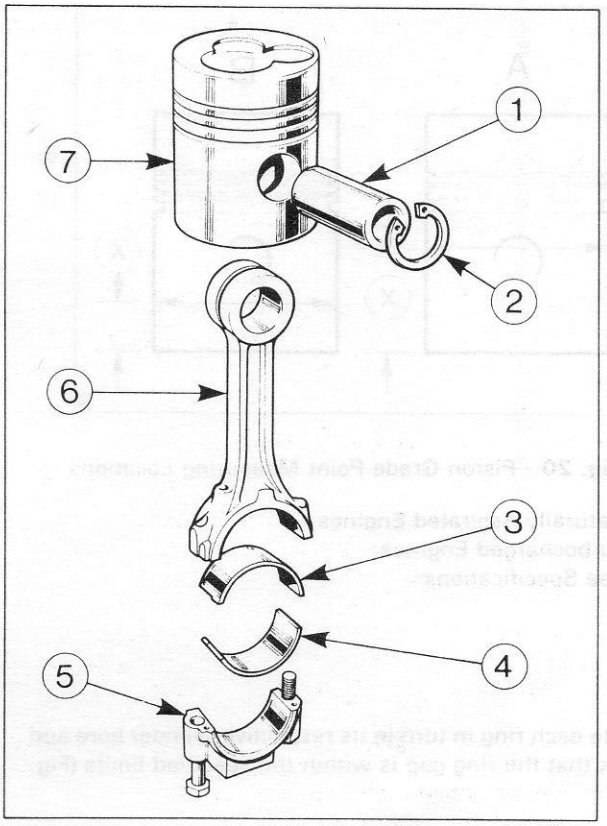


Fig. 19 - Piston and Connecting Rod Assembly

1. Piston Pin
2. Retainer
3. Upper Bearing Insert
4. Lower Bearing Insert
5. Bearing Cap
6. Connecting Rod
7. Piston

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

Measure the diameter of the piston at 90° to the piston pin at the piston grade point (Fig. 20) and refer to "Specifications".

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

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

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

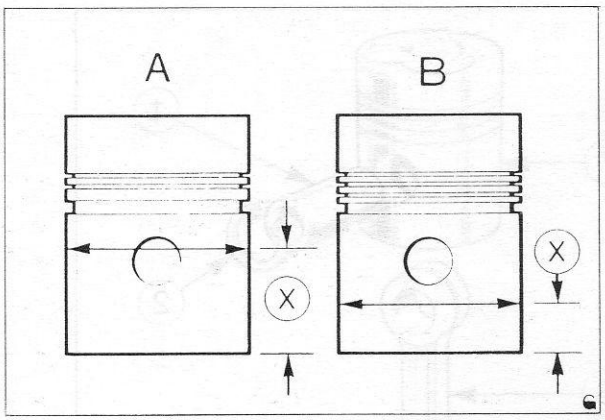


Fig. 20 - Piston Grade Point Measuring Locations

A. Naturally Aspirated Engines
B. Turbocharged Engines
X. See Specifications

Locate each ring in turn in its respective cylinder bore and check that the ring gap is within the specified limits (Fig. 21).

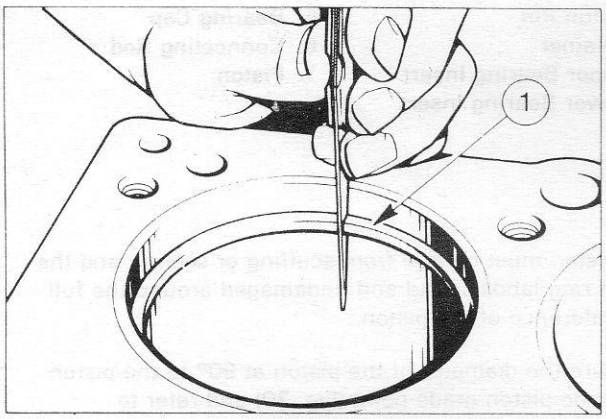


Fig. 21 - Checking Piston Ring Gap in Cylinder Bore

1. Piston Ring

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

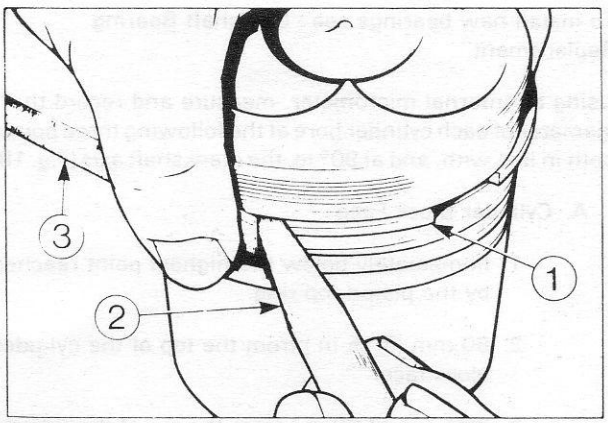


Fig. 22 - Taper Ring to Groove Clearance Check - Turbocharged Engines

1. Top Compression Ring
2. Feeler Gauge
3. Steel Rule

Top Compression Ring (Tapered Section) on Turbocharged Engines.

Hold the piston in one hand with a small steel rule held by the thumb so that it bridges the top ring groove (Fig. 22).

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

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

All Other Rings (Including Oil Control)

Hold the ring in the approximate installed position and measure the clearance between the ring and the groove at three equi-distant points around the piston (Fig. 23).

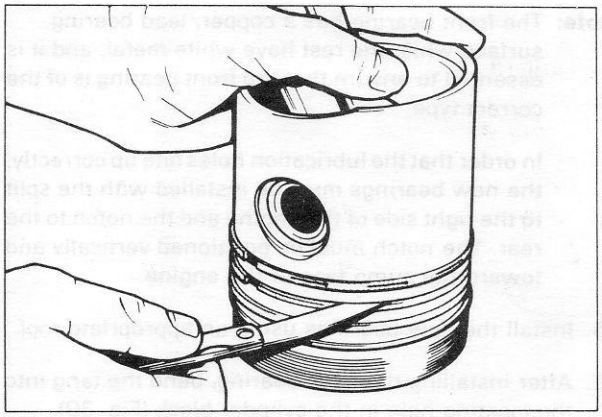


Fig. 23 - Checking Piston Ring to Groove Clearance

Measure the piston pin bore at two points in both sides at approximately 45° to the vertical plane using a suitable dial gauge (Fig. 24).

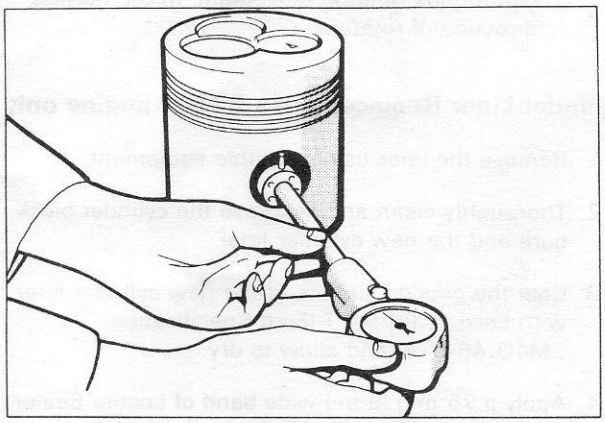


Fig. 24 - Measuring Piston Pin Bore

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

Check to be sure the connecting rod is undamaged and that the side cheeks are not damaged or scored. If the engine has suffered a major failure the rods must be checked for twist or bend.

Measure the piston pin bore using a suitable dial gauge (Fig. 25). If the bore is not within the specified limits a new connecting rod must be installed.

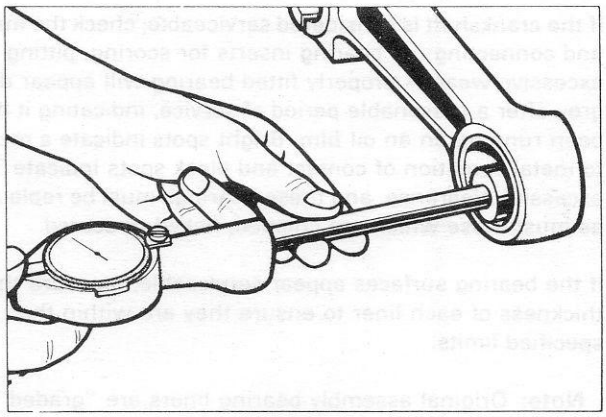


Fig. 25 - Measuring Connecting Rod Bushing Diameter

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

Crankshaft and Bearings

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

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

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

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

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

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

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

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

Note: Original assembly bearing liners are "graded", see Specifications.

Camshaft Bearing Renewal

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

1. Remove the timing gear housing locating ring (if not already removed) (Fig. 30).

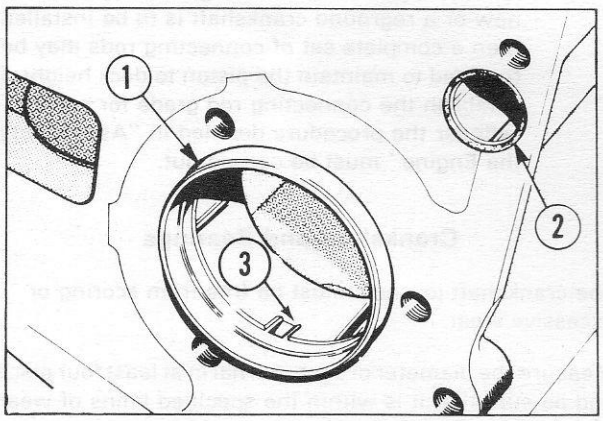


Fig. 30 - Cylinder Block Front Face

1. Timing Gear Housing Locating Ring
2. Oil Gallery Seal "O" Ring
3. Camshaft Front Bearing Tang

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

3. Bend up the tang on the camshaft front bearing (Fig. 30).

4. Remove the camshaft bearing bushing using an appropriate tool.

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

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

5. Install the new bearings using an appropriate tool.

6. After installing the front bearing, bend the tang into the locating hole in the cylinder block (Fig. 30).

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

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

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

Cylinder Liner Replacement - 2726T engine only

1. Remove the liner using suitable equipment.

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

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

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

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

6. Press the liner in until the liner is fully home and the replacer plate is flush against the cylinder block face.

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

7. Remove the press and check the liner protrusion.

Cylinder Head

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

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

Using a Valve Spring Compressor depress each valve spring in turn and remove the keys, retainers, springs, seats, seals and valves. Retain each assembly in a numbered sequence for reassembly to the same position in the head.

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

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

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

Check the cylinder head-to-block face for flatness. If outside the specified limits the head may be planed to restore flatness.

Note: Planing will require valve seat rework to enable counterbore recutting. This is essential to maintain valve seat to head face relationships.

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

Resurfacing

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

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

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

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

Valve Guide Replacement

Using Valve Guide Installer/Remover Tool (10885) or a suitable press, remove the valve guide(s). Check the cylinder head bore for scoring or tearing. Carefully stone out any damage, removing only the burred material.

Using the special tool or a bench press, insert the new guide (internally chamfered end facing outwards) to the specified protrusion (Fig. 26).

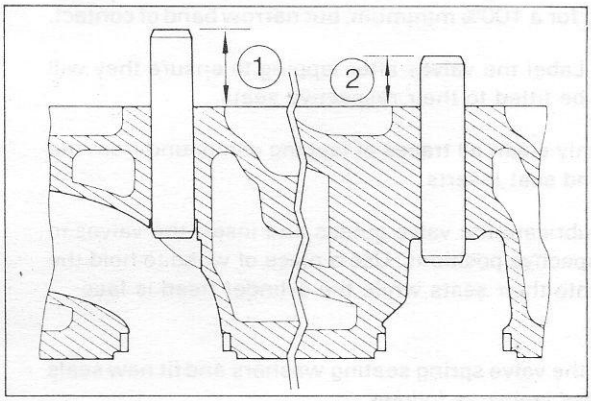


Fig. 26 - Valve Guide Protrusion

1. Exhaust 2. Inlet

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

Valve Seat Insert Replacement

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

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

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

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

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

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

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

Valves, Valve Caps and Springs

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

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

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

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

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

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

Inlet Valves of Naturally Aspirated engines install spring loaded type seals only to these valves. Install the seals with the Seal Installer (Fig. 27).

Caution: Failure to install the seals correctly can cause high oil consumption and severe carboning of the inlet ports.

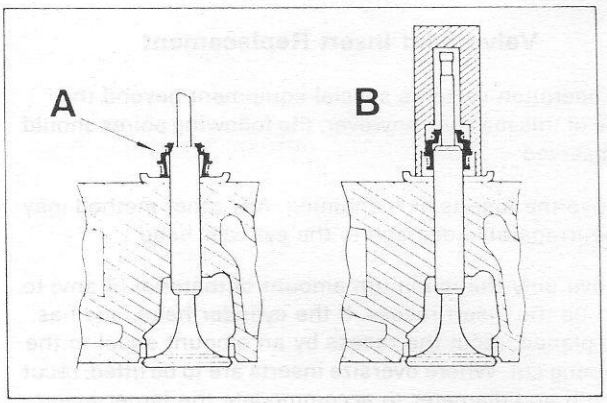


Fig. 27 - Fitting Inlet Valve Stem Seals on Naturally Aspirated Engines

A. Incorrectly installed causing enlarged sealing edge
B. Correctly installed using Tool No. 10881

All other valves install plastic umbrella type seals.

Position the valve springs and retainers, compress the springs and install the keys.

Note: Exhaust valve springs are longer than inlet springs before installing. Both inlet and exhaust valve springs may be installed either way up.

Lightly lubricate and install the valve stem caps.

Caution: If an inlet valve seal of a naturally aspirated engine is removed for any reason - temporary or otherwise, it loses its oil controlling capability. Always install a new seal and destroy the old.

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

Push Rods

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

Rocker Shaft - (Fig. 28)

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

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

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

Examine the shaft supports for cracks.

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

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

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

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

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

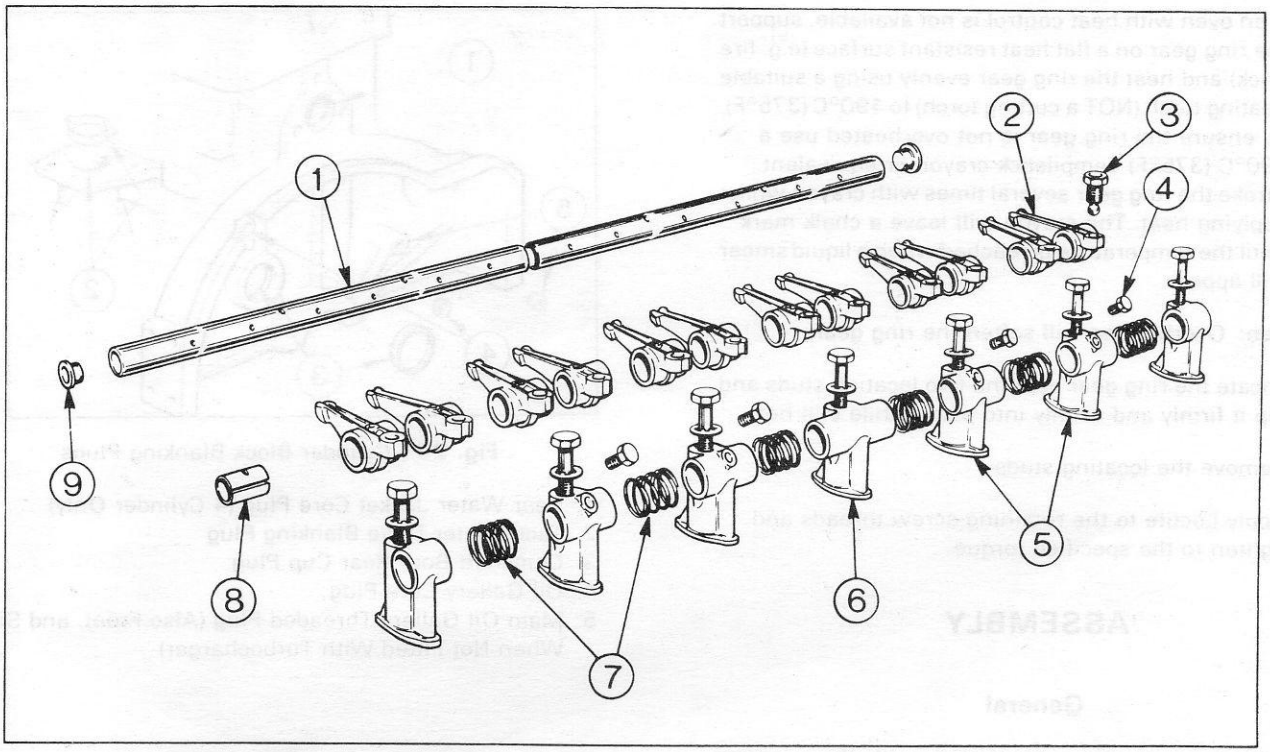


Fig. 28 - Rocker Shaft Assembly Exploded - 6 cylinder Engines

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

Clutch Pilot Bearing

Remove the bearing. Drive the new bearing into position, using a hardwood block and a mallet.

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

Flywheel Ring Gear

1. Remove the six countersunk screws retaining the ring gear to the flywheel.
2. If an oven with heat control is available, heat the flywheel and ring gear to 190°C (375°F) and remove the ring gear using a hammer and a blunt nosed chisel.
3. If an oven with heat control is not available support the flywheel in a sturdy vice taking great care not to damage the flywheel face, and cut through the ring gear between two of the teeth and in line with one of the retaining screw holes using a sharp hacksaw. Cut into the ring gear as far as possible taking care not to cut into the flywheel.
4. Take a sharp chisel and heavy hammer and drive the chisel into the cut from the outer (toothed) edge again taking care not damage the ring gear register. The ring gear should snap across the line of the cut and will spring apart.
5. Clean the flywheel. Lightly stone off any burrs but do not clean the ring gear register with emery cloth or similar materials as this could upset the interference fit of the ring gear.
6. Screw locating studs into two diametrically opposite retaining bolt holes in the flywheel.
7. If an oven with heat control is available, heat the ring gear to 190°C (375°F).

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

Caution: Overheating will soften the ring gear.

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

10. Remove the locating studs.

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

ASSEMBLY

General

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

Use only the specified sealers where indicated.

Basic Engine Assembly

1. Mount the block on the stand.

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

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

4. On the oil gallery core plug (rear), the tachometer drive blanking plug and the cylinder block rear water jacket core plug (4 cylinder engines only) apply specified sealer around the plug bore and drive the plug firmly home (Fig. 29).

Caution: Do Not allow the sealer to contact the camshaft rear bearing.

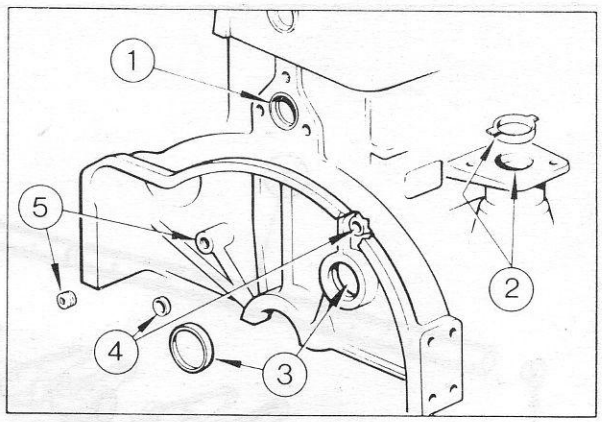


Fig. 29 - Cylinder Block Blanking Plugs

1. Rear Water Jacket Core Plug (4 Cylinder Only)
2. Tachometer Drive Blanking Plug
3. Camshaft Bore Rear Cup Plug
4. Oil Gallery Core Plug
5. Main Oil Gallery Threaded Plug (Also Front, and Side When Not Fitted With Turbocharger)

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

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

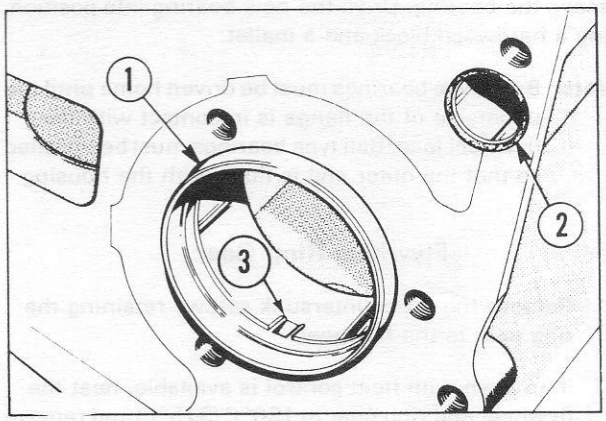


Fig. 30 - Cylinder Block Front Face

1. Timing Gear Housing Location Ring
2. Oil Gallery Seal "O" Ring
3. Camshaft Front Bearing Tang

7. Place the timing gear housing locating ring into the counterbore in the camshaft front bearing housing, and tap it firmly against the stop using a soft faced mallet (Fig. 30).

8. Invert the engine to bring the crank case oil pan face up.

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

Camshaft Installation

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

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

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

Crankshaft Gear Installation

12. Install the crankshaft gear key into the crankshaft, stepped end toward the front end of the crankshaft.

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

Crankshaft Installation

14. Install the graphited fiber rope type seal into the groove in the rear main bearing cap and the cylinder block. DO NOT use any sealer or adhesive. Tap the seal fully home into the respective groves using Seal Installer 10886 as shown in Fig. 31.

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

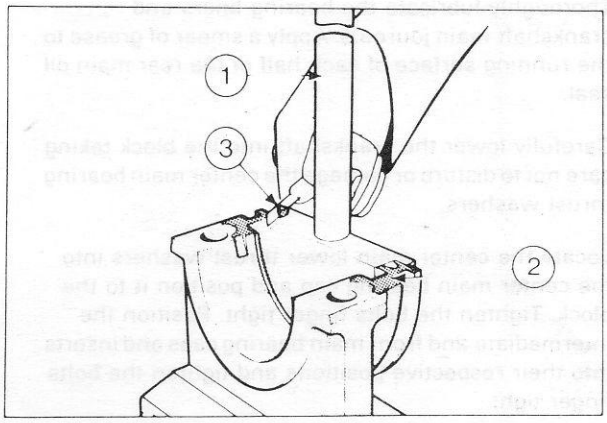


Fig. 31 - Installing Crankshaft Rear Oil Seal - (Main Bearing Cap Shown)

1. Installer
2. Seal
3. Trim Seal

15. Ensure the main bearing housings and caps are perfrctly clean and dry and install the main bearing inserts into their respective positions, with the locating tangs engaged in the slots.

Note: The bearings with oil holes and a continuous oil groove fit into the block, those without oil holes fit into the caps. The center and rear main bearing cap inserts only, have a continuous oil groove.

16. Install the center main bearing upper thrust washers into position ensuring that the tangs are located in the anchor slots (Fig. 32).

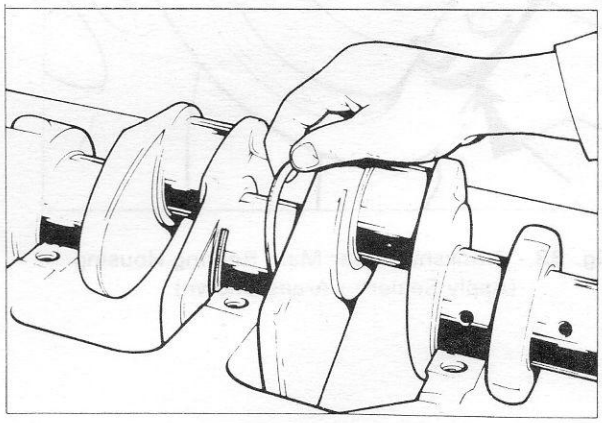


Fig. 32 - Installing Center Main Bearing Upper Thrust Washers

17. Thoroughly lubricate the bearing liners and crankshaft main journals. Apply a smear of grease to the running surface of each half of the rear main oil seal.

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

19. Locate the center main lower thrust washers into the center main bearing cap and position it to the block. Tighten the bolts finger tight. Position the intermediate and front main bearing caps and inserts into their respective positions and tighten the bolts finger tight.

20. Pry the crankshaft backwards and forwards axially to ensure the center main bearing cap is centralized and tighten the bolts to the specified first stage torque. Check crankshaft rotation.

21. Ensure that the rear main bearing cap and block mating faces are clean and dry, and apply sealer to the cylinder block at the areas shown in Fig. 33.

Caution: This sealer hardens on contact with metal and the joint must not therefore be left in a dismantled condition any longer than is absolutely necessary.

It is essential that the sealer is applied with a fine tipped nozzle to the areas shown.

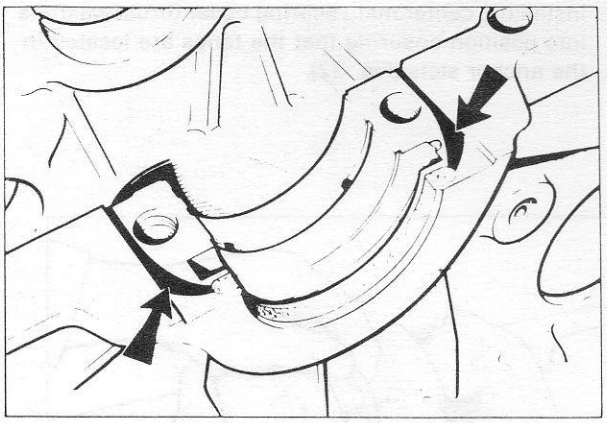


Fig. 33 - Crankshaft Rear Main Bearing Housing (Apply Sealer in Areas Shown)

22. Install the rear main bearing cap and tighten the bolts to the specified first stage torque.

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

24. Check the crankshaft end play. Pry the crankshaft forward to take up end play in one direction, and insert feeler blades between the crankshaft thrust washer and the crankshaft to check that the end play is within the specified limits (Fig. 34).

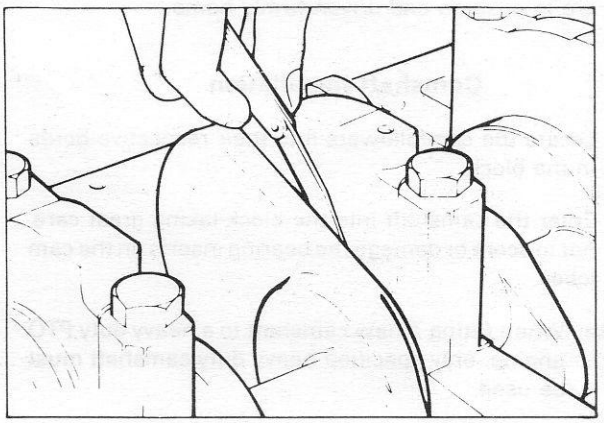


Fig. 34 - Measuring Crankshaft End-Play

25. Install oversize thrust washers if the end play is excessive and recheck as before.

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

Timing Gear Housing Installation

27. Locate a new "O" seal ring into the counterbore at the end of the oil gallery on the front face of the block and position the timing gear housing (using a new gasket) over the locating ring (Fig. 35).

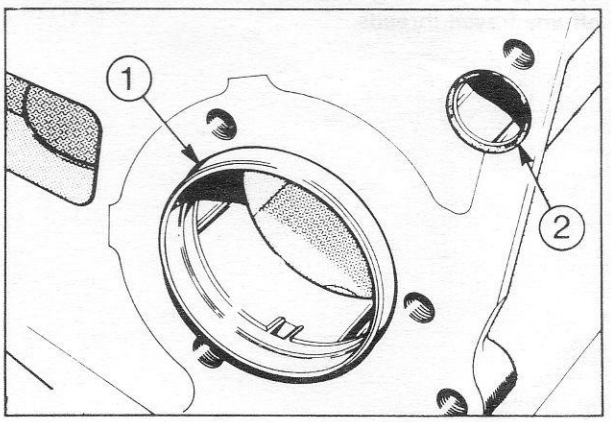


Fig. 35 - Cylinder Block Front Face

1. Timing Gear Housing Locating Ring
2. Oil Gallery Seal "O" Ring

28. Install the camshaft thrust collar, shouldered face outermost, the thrust plate (well lubricated), and the retaining plate. Install the bolts but do not tighten (Fig. 36).

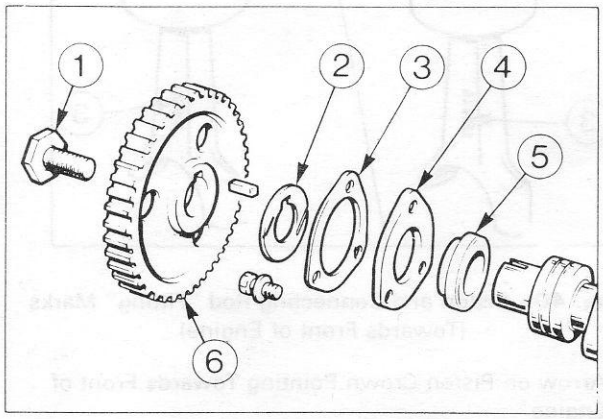


Fig. 36 0 Camshaft Gear Assembly

1. Gear Retaining Bolt
2. Thrust Washer
3. Retaining Plate
4. Thrust Plate
5. Thrust Collar
6. Camshaft Gear

29. Smug the camshaft thrust plate bolts to secure the housing in position then tighten all the bolts in the sequence shown to the specified torque (Fig. 37).

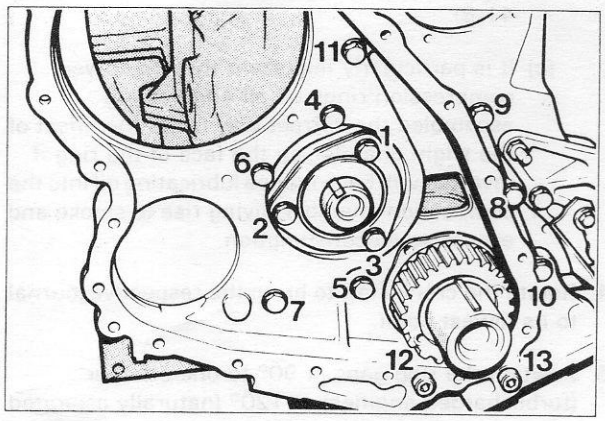


Fig. 37 - Timing Gear Housing Bolt Tightening Sequence

30. Install the thrust washer, grooved face in, and the camshaft key to the camshaft.

Camshaft Gear Installation

31. Rotate the crankshaft and camshaft to bring both shafts in correct relationship to one another so that the timing marks on both gears will line up with one another when the camshaft gear is installed. Install the camshaft gear on to the camshaft ensuring that the keyway and the timing marks are correctly aligned (Fig. 38). DO NOT hammer the gear on to the shaft. If the gear is too tight to fit easily, heat the gear to 82°C (180°F) before fitting it onto the shaft.

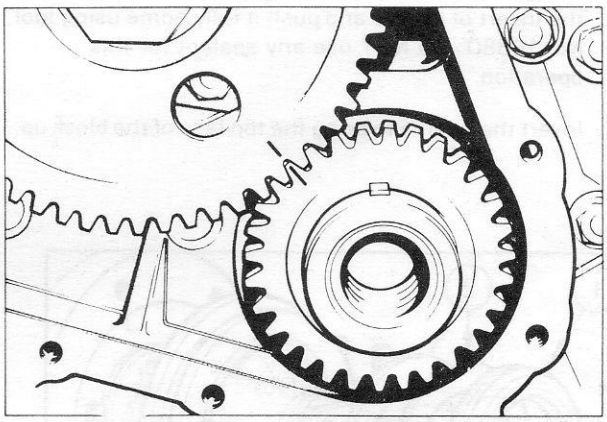


Fig. 38 - Camshaft and Crankshaft Gear Timing Marks in Alignment

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

Note: If a heavy duty PTO camshaft is fitted, the special long gear retaining bolt must be used. The long bolt must not be used with standard duty camshafts - probe the depth of the hole with a piece of stiff wire to establish the type of camshaft installed.

33. Check the camshaft end play using a dial gauge and magnetic base. If the end play is excessive the thrust collar and thrust washer must be replaced.

Front Cover Installation

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

35. Place the front cover onto the housing using the Housing Aligner/Seal Installer (10880) to position the cover assembly over the crankshaft.

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

37. Tighten the bolts gradually and evenly to the specified torque.

38. Remove the Housing Aligner/Seal Installer Tool.

Front Seal Installation

39. After the timing housing cover has been installed and the Aligner Tool No. 10880 removed, check the crankshaft pulley hub outer diameter at the point where it runs in the front oil seal. If the seal is in contact with a highly polished ring, remove one or both spacers (one spacer only on the 4 cylinder engine) before installing the oil seal (Fig. 39). This will enable the seal to run on an unpolished part of the pulley hub. Failure to do this could result in an overheated seal and subsequent oil leakage.

40. Locate the oil seal, lipped edge inwards as shown in the insert of Fig. 39 and push it fully home using tool No. 10880. DO NOT use any sealant for this operation.

41. Invert the engine to bring the top face of the block up.

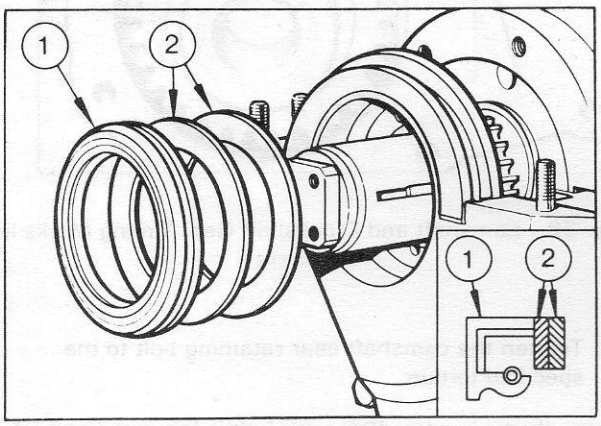


Fig. 39 - Assembling Crankshaft Pulley Oil Seal Into Timing Gear Housing Cover

1. Oil Seal
2. Spacers

Piston and Connecting Rod Assembly and Installation

If the original crankshaft is being used, then the original connecting rods, if serviceable, or new rods of the same grade length can be used in reassembly. If a new or reground crankshaft is being used it may be necessary to fit different grade rods in order to maintain the piston protrusion within the specified limits.

42. Assemble each piston to its respective connecting rod. Heat the piston in hot water, locate the connecting rod into the piston ensuring that the arrow or notch on the piston crown and "F" or "Front" mark on the connecting rod are facing the same way (Fig. 40) and insert the piston pin into the piston and through the connecting rod. Install the two retainers.

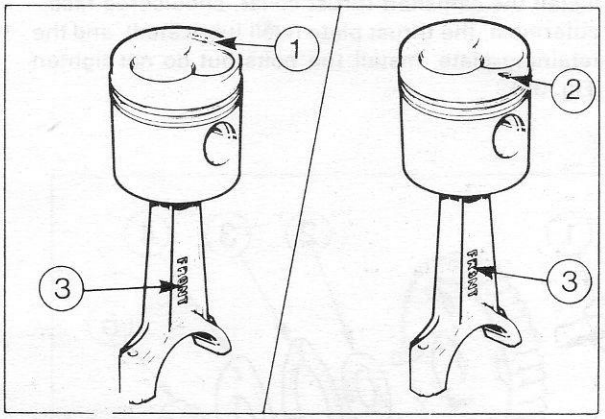


Fig. 40 - Piston and Connecting Rod "Fitting" Marks (Towards Front of Engine)

1. Arrow on Piston Crown Pointing Towards Front of Engine
2. Cut Out in Piston Crown
3. "FRONT" on Connecting Rod Web

43. Assemble the piston rings into their respective grooves on the piston ensuring that the "TOP" marked face is up.

Note: **(a)** Turbocharged engines have one tapered upper compression ring, two lower chamfered compression rings and one oil control ring (Fig. 41-A).

(b) All naturally aspirated engines have one plain compression ring, one lower chamfered compression ring and one oil control ring (Fig. 41-B).

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

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

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

46. Use a soft wooden drift and tap the assembly into the bore, taking care that the lower end of the connecting rod does not touch the crankshaft.

47. Working from the bottom of the engine, place the upper half of the connecting rod bearing insert into the connecting rod, and draw the rod into place over the crankshaft journal. Thoroughly lubricate the journal with new engine oil.

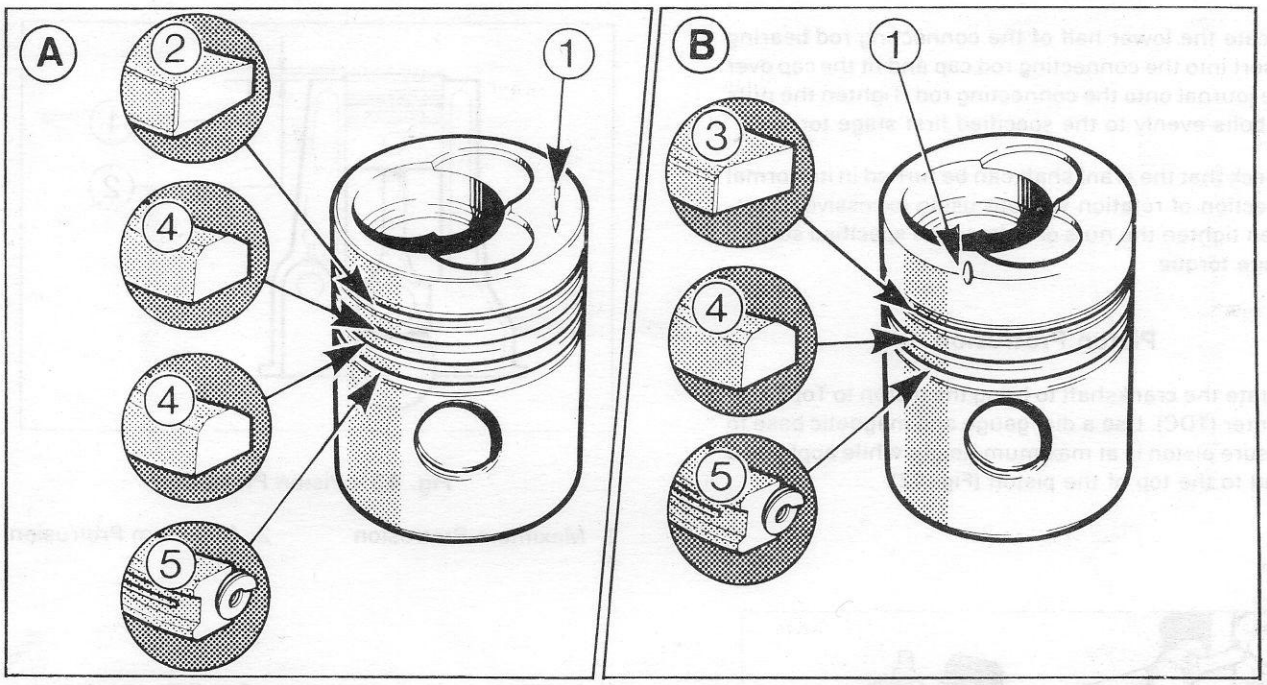


Fig. 41 - Piston/Ring Assemblies

A. Turbocharged Engines
B. Naturally Aspirated Engines
1. "FRONT" Mark on Piston
2. Top Taper Compression Ring
3. Top Plain Compression Ring
4. Lower Compression Ring(s)
5. Oil Control Ring

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

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

Piston Protrusion

50. Rotate the crankshaft to bring the piston to Top Dead Center (TDC). Use a dial gauge and magnetic base to ensure piston is at maximum height while applying a load to the top of the piston (Fig. 42).

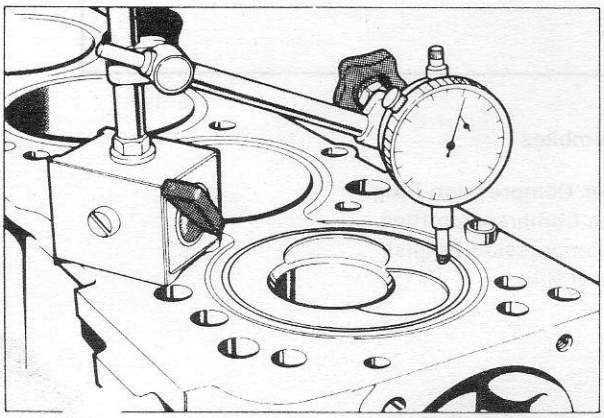


Fig. 42 - Measuring Piston Protrusion

51. Measure and record the protursion of the piston above the face of the block in at least three places and note the maximum and minimum protrusion (Fig. 43). Calculate the average of the three readings. If the figure is within the specified limits for piston protrusion the existing connecting rod length is satisfactory. If, however, the piston protrusion is outside the limits with the grade of rod fitted, it will be necessary to remove the piston and rod assembly and install a longer or shorter grade of rod as required. Refer to specifications, for rod grades.

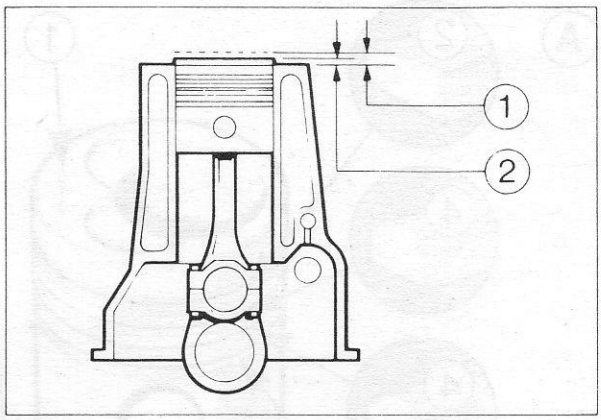


Fig. 43 - Piston Protrusion

1. Maximum Protrusion 2. Minimum Protrusion

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

Oil Pump Installation

Engines not fitted with high inclination oil pans.

53. Check to ensure that the oil pump is well lubricated and the shaft rotates freely. Lubricate the drive gear.

54. Locate the pump assembly into the cylinder block and tighten the retaining bolts to the specified torque (Fig. 44).

55. Install a new union nut lock tab washer to the pick-up pipe orifice, if not already installed.

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

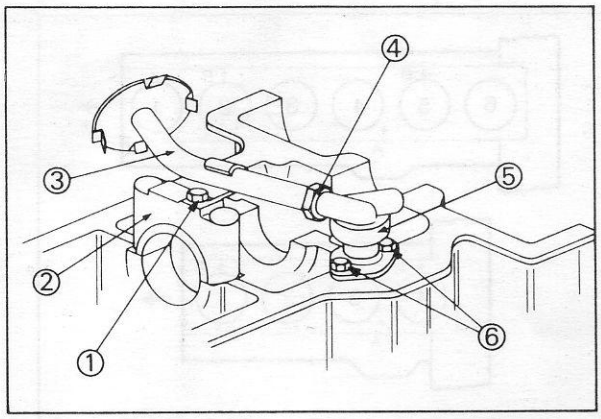


Fig. 44 - Oil Pump Removal/Replacement - Engines Not Fitted With High Inclination Oil Pans

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

Engines fitted with high inclination oil pans.

Locate a new union locking plate on the pump and insert the pipes into their correct locations but do not tighten or lock the unions until the pump is secured to the engine and the pipes correctly aligned (Fig. 45).

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

Install pick up screen.

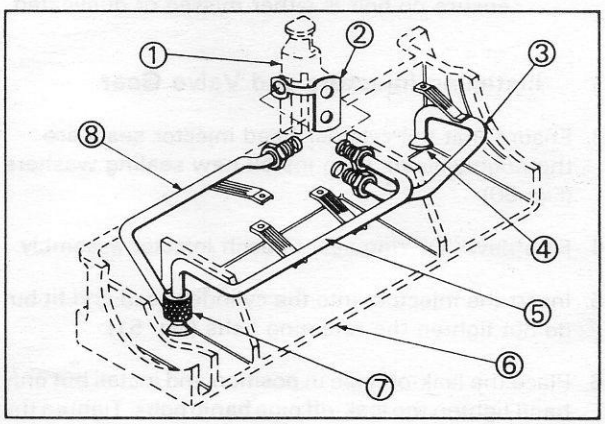


Fig. 45 - Oil Pump and Piping for High Inclination Oil Pans

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

Oil Pan Installation

Note: Before installing the oil pan, ensure that the four studs are in position (Fig. 46).

Caution: The specified sealer dries relatively quickly and should not be allowed to form a skin during an assembly sequence. Once started, the procedure should be progressed through to torque tightening without any idle period.

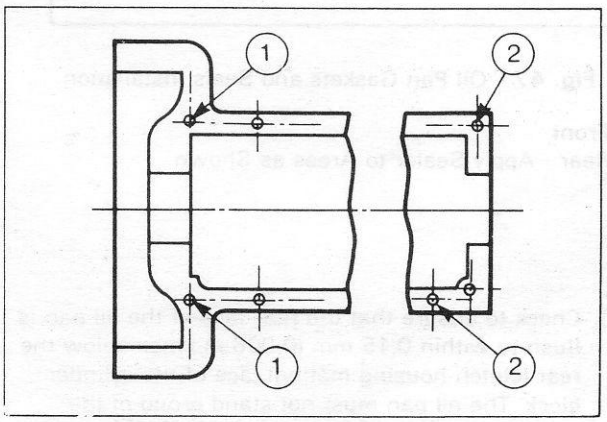


Fig. 46 - Oil Pan Studs

1. Studs For All Engines

57. Position the rear seal, dry, onto the rear main bearing cap then apply a small spot of specified sealer into and from each foot as shown in Fig. 47.

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

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

59. Fit the front seal in position with the feet over the gaskets, then apply a spot of sealer to the joints where the front and rear seals adjoin the gaskets (Fig. 47).

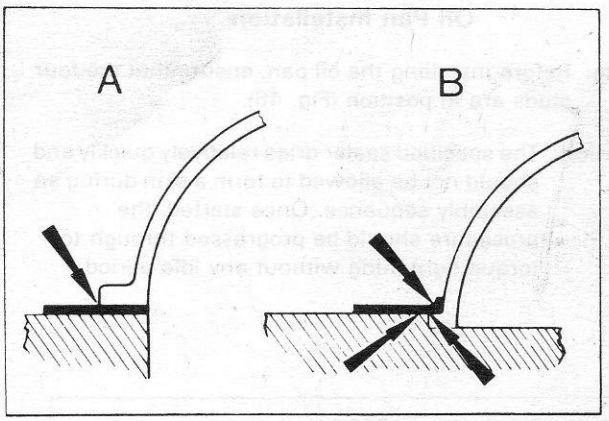


Fig. 47 - Oil Pan Gaskets and Seals Installation

A. Front
B. Rear - Apply Sealer to Areas as Shown

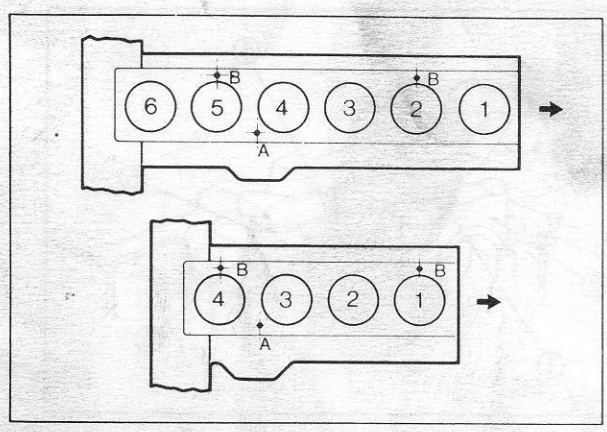


Fig. 48 - Cylinder Head/Gasket Locating Dowels

A. Dowel in Water Gallery
B. Dowels in Head Bolt Holes

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

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

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

Crankshaft Pulley Installation

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

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

Cylinder Head Installation

65. Rotate the engine on the stand to bring the head surface up.

66. Ensure the block and head surface faces are clean and dry.

67. Check to ensure the locating dowels are fitted into the counterbores of the two head bolt threads and the water circulating passage at the position shown in Fig. 48.

68. Position a new gasket over the locating dowels on to the block.

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

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

71. Tighten the cylinder head bolts by increments, in the sequence shown in Fig. 49 to the specified torque.

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

Caution: Mark each bolt head as tightening proceeds to ensure no bolt is either missed or duplicated.

Installing Injectors and Valve Gear

73. Ensure that the cylinder head injector seats are thoroughly clean, then install new sealing washers (Fig. 50).

74. Fit a new "O" ring seal to each injector assembly.

75. Insert the injectors into the cylinder head and fit but do not tighten the retaining bolts (Fig. 51).

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

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

78. Install the pushrods and valve caps into the same positions as when removed, position the rocker shaft assembly, locating the adjuster ball ends into the push rod cups, and gradually and evenly tighten the retaining bolts to the specified torque (Fig. 52).

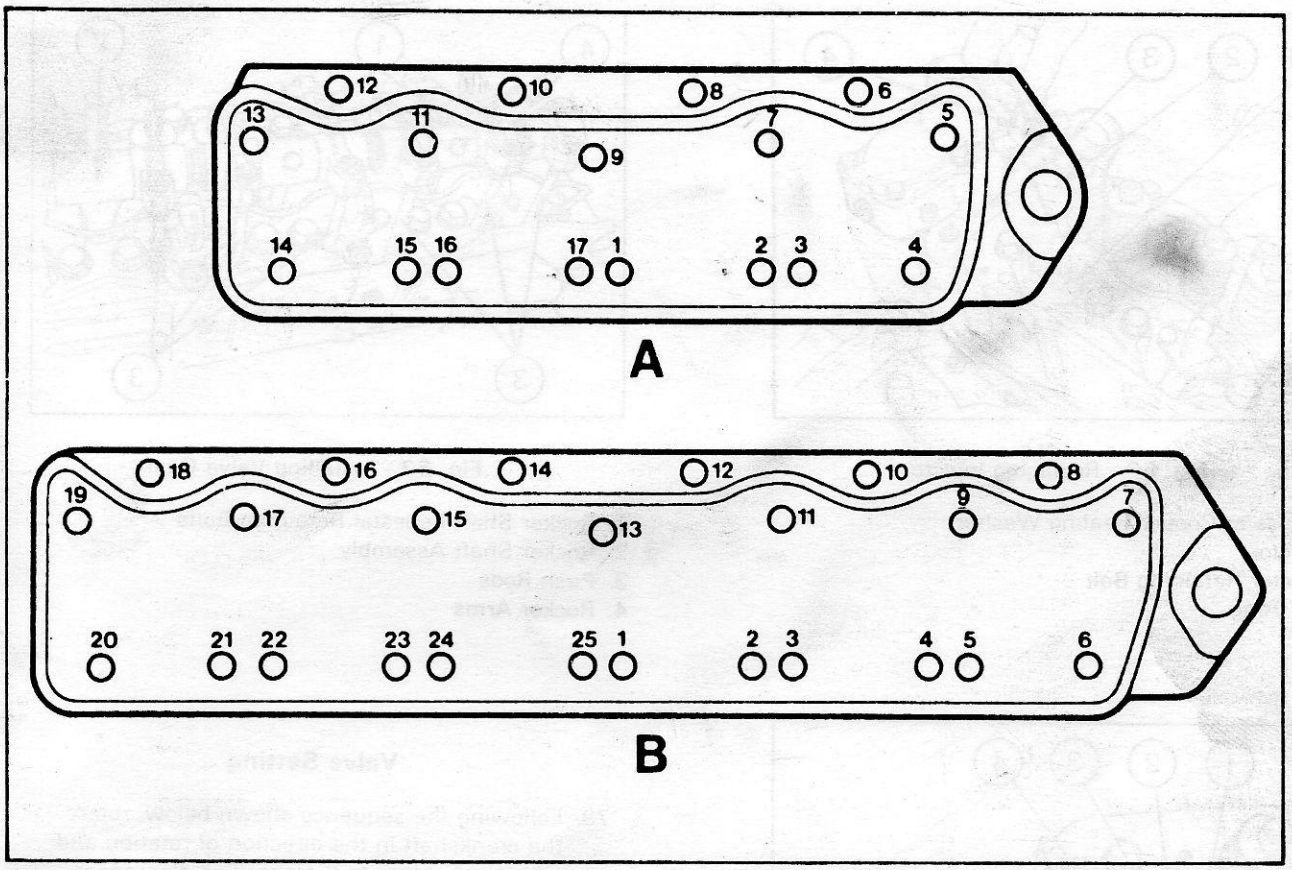


Fig. 49 - Cylinder Head Bolt Tightening Sequence

A. 4 Cylinder Engines

B. 6 Cylinder Engines

55
90
90°

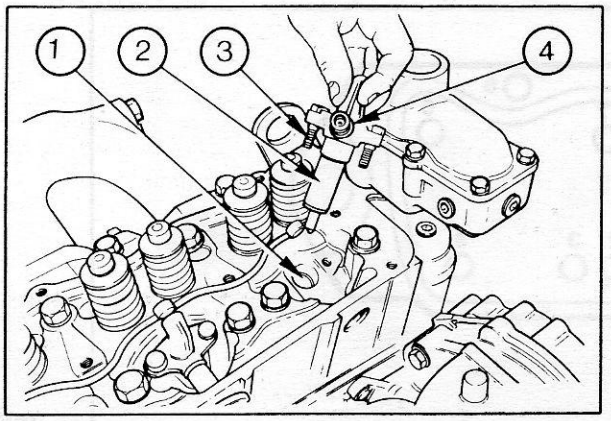


Fig. 50 - Replacing Injectors

1. Recess or Copper Sealing Washer
2. Injector
3. Injector Retaining Bolt
4. "O" Ring

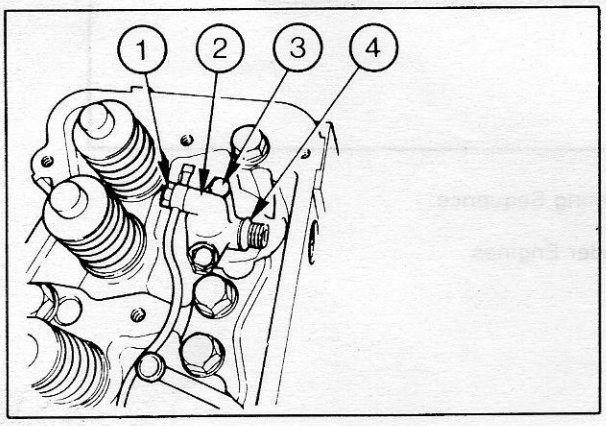


Fig. 51 - Replacing Injectors

1. Leak-Off Pipe Banjo Bolt
2. Injector
3. Injector Retaining Bolt
4. "O" Ring

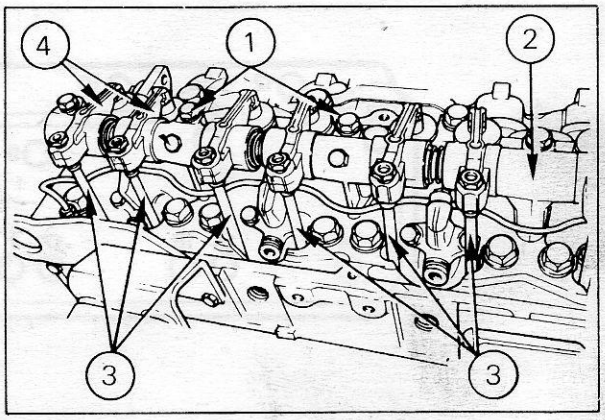


Fig. 52 - Installing Valve Gear

1. Rocker Shaft Pedestal Retaining Bolts
2. Rocker Shaft Assembly
3. Push Rods
4. Rocker Arms

Valve Setting

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

4 Cylinder Engines

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

6 Cylinder Engines

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

To adjust the valve clearance, insert the correct thickness feeler gauge between the rocker pad and the valve cap. Turn the adjusting screw with a wrench or socket until the correct clearance is obtained. This is when the feeler gauge is just gripped between the rocker pad and the valve cap but can be moved with a slight pull (Fig. 53).

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

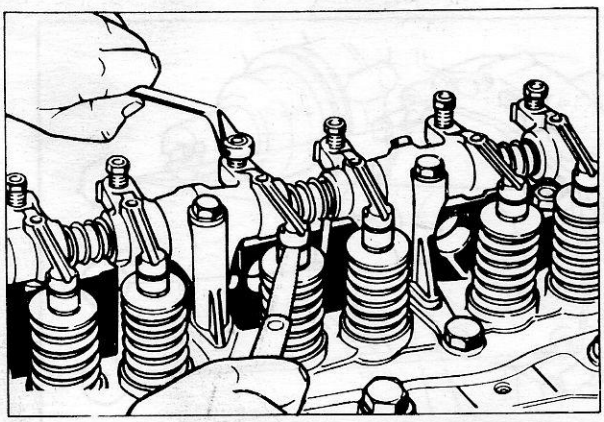


Fig. 53 - Adjusting Valve Clearance

Thermostats

80. Test the thermostat(s) if necessary, as described in Part 8 then fit housing, thermostat(s) and cover, as appropriate, with new gaskets. If removed, replace or fit a new temperature sensitive switch.

Water Pump

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

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

Injection Pump

82. Remove the timing access cover from the flywheel housing and turn the engine in the normal direction of rotation until the specified number of degrees before TDC on No. 1 cylinder is indicated against the timing mark on the edge of the opening (Fig. 54). No. 1 cylinder must be on the compression stroke.

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

General Purpose

83. New pumps only. Install the ring gear and plate into position, but do not fully tighten the screws (Fig. 55). Drain any oil from the fuel gallery of the new pump.

84. Remove the plug from the timing socket on the injection pump mounting flange (Fig. 56).

85. Rotate the pump drive hub until the timing hole is in centered in the opening, then screw the timing tool (10965) into position. Rotate drive gear slightly as necessary to engage the plunger in the drive gear hub hole.

86. Remove the adjustment cover plate on the front of the timing cover (Fig. 57).

87. Install a new "O" ring to the pump mounting flange and install the pump carefully, tightening the bolts to the specified torque.

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

88. Tighten the drive gear retaining screws to the specified torque and check that the correct flywheel marking is still indicated. Replace the timing cover adjustment plate and the flywheel timing access cover and tighten the retaining screws. Remove the timing tool (10965) and replace the plug.

Class "A" (Close Regulating) Governed Injection Pumps

89. Remove plug from injection pump mounting flange. Rotate the pump drive gear until the hole in the gear is centered in the hole in the flange, then screw the timing tool (10964) into position (Fig. 58). Rotate the drive gear slightly, as necessary, to engage the timing tool plunger in the hole.

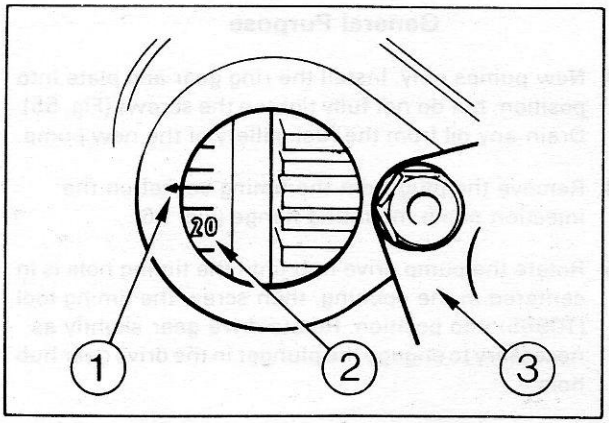


Fig. 54 - Engine Timing

1. Timing Mark on Housing
2. Timing Scale on Flywheel
3. Timing Access Cover

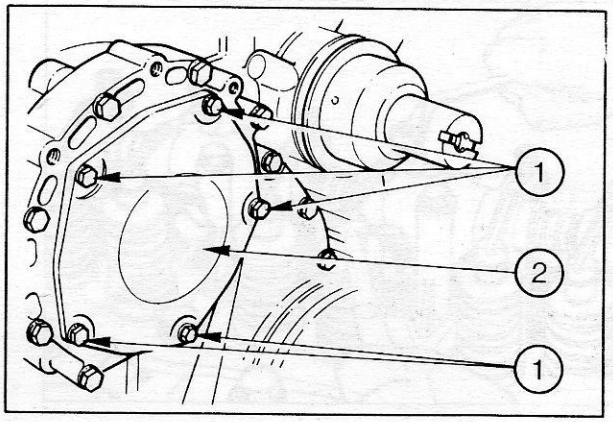


Fig. 57 - Removing Injection Pump Timing Aperature Cover Plate

1. Securing Bolts
2. Cover Plate

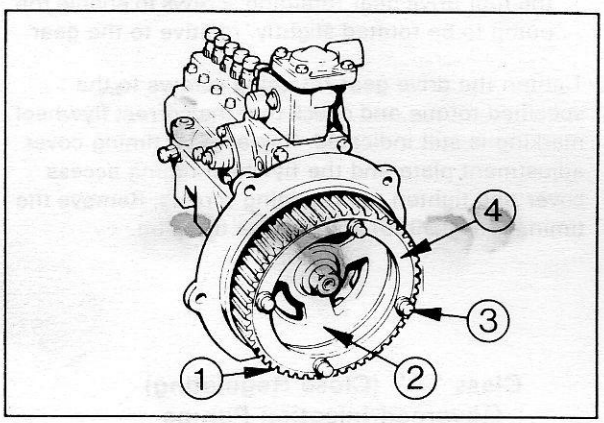


Fig. 55 - Injection Pump Drive Gear

1. Ring Gear
2. Drive Hub
3. Retaining Screws
4. Retaining Plate

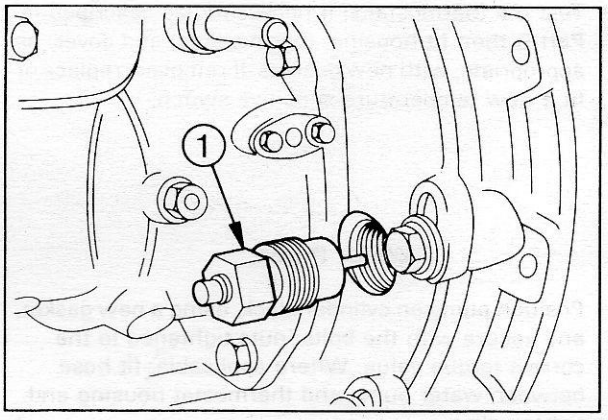


Fig. 58 - Injection Pump Timing - Class "A" and Combine Harvester Governed Pumps

1. Timing Tool

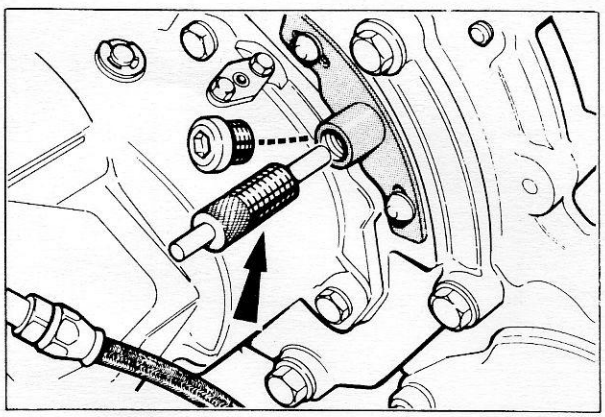


Fig. 56 - Injection Pump Timing

1. Timing Bush Plug
2. Timing Tool

90. Install a new "O" ring to the pump mounting flange and install the pump carefully; tighten the bolts and nut to the specified torque.

91. Check that the correct flywheel marking is still indicated, then replace the fly wheel timing access cover. Remove the injection pump timing tool and replace the plug.

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

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

94. Remove all plugs/caps from high pressure lines, injectors and injection pump.
95. Connect the high pressure fuel lines to the injection pump but do not fully tighten nuts at this stage.
96. Unscrew large oil seal nut fully (Fig. 59).
97. Connect high pressure feed line and tighten nut to the specified torque value.
98. Tighten large oil seal nuts.
99. Tighten high pressure fuel line nuts at the injection pump to the specified torque value.
100. Replace any high pressure line clamps (Fig. 60).
101. Carry out the leak-off pipe pressure test described in Part 3.
102. Replace rocker cover, using a new gasket.
103. Replace the fuel filters complete with mounting bracket.
104. Replace fuel lift pump and (where fitted) the pre-filter unit.
105. Replace the low pressure fuel line connecting fuel lift pump, fuel filters and injection pump.

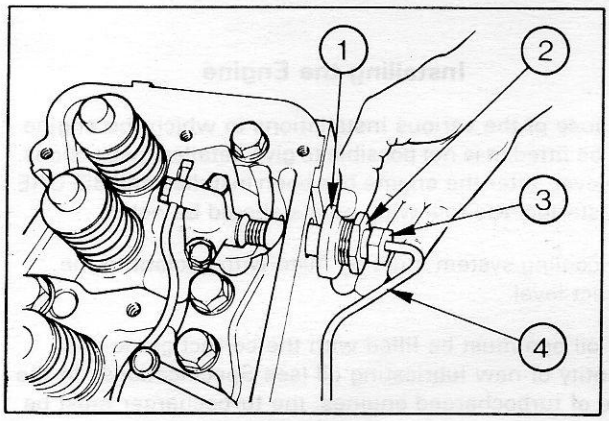


Fig. 59 - Replacing High Pressure Fuel Pipes

1. Oil Seal
2. Oil Seal Nut
3. High Pressure Pipe Gland Nut
4. High Pressure Pipe

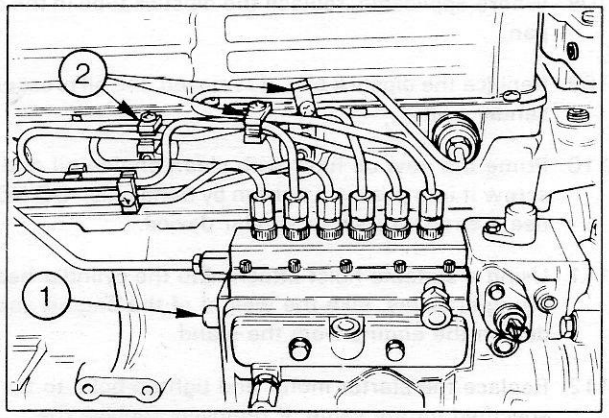


Fig. 60 - Replacing Injection Pump

1. Idling Damper Adjustment Cover
2. High Pressure Fuel Line Clamps

106. If a new injection pump with automotive or General Purpose governing has been fitted, remove the oil filler plug and insert the specified quantity of clean engine oil. Install and tighten the plug.
107. Where an injection pump with Class "A" (Close regulating) governing has been installed, remove the level and filler plugs and top off with clean engine oil as required (Fig. 61).

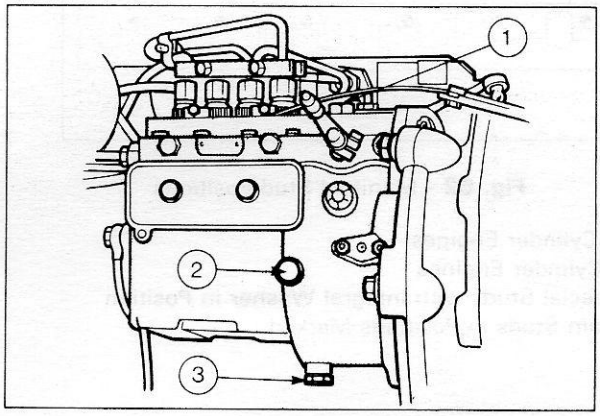


Fig. 61 - Injection Pump Oil Plugs (Class "A" Close Regulating Governing Only)

1. Filler Plug
2. Level Plug
3. Drain Plug

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

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

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

111. Using a suitable hoist attached to the cylinder head lifting brackets, take the weight of the engine and detach the engine from the stand.

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

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

Note: It is imperative that the special shouldered studs, in the positions shown are fully tightened or they may prevent the manifolds fitting flush to the cylinder head (Fig. 62).

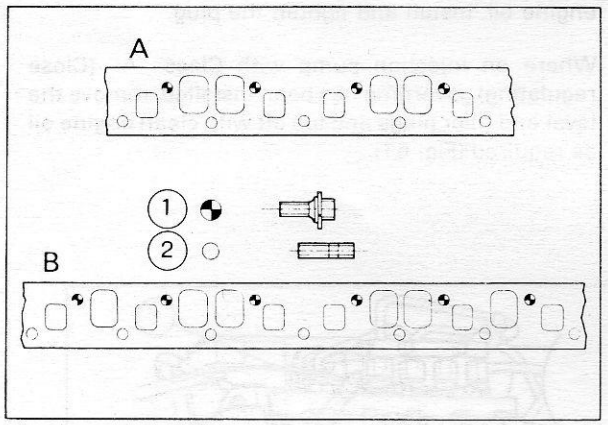


Fig. 62 - Manifold Stud Positions

A. 4 Cylinder Engines
B. 6 Cylinder Engines
1. Special Studs with Integral Washer in Position
2. Plain Studs in Positions Marked

114. Assemble the manifold gasket over the studs.

Note: On turbocharged engines the gasket has eyelets. The full flange of the eyelet must be against the cylinder head.

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

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

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

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

118. Replace the turbocharger oil feed and return lines.

Installing the Engine

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

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

The oil pan must be filled with the correct grade and quantity of new lubricating oil (see Specifications). In the case of turbocharged engines, the turbocharger must be primed with engine oil and the recommended start-up procedure followed.

Injection pumps must contain the specified amount of engine oil (see Secifications).

The fuel system must contain sufficient fuel of the correct type and be bled to remove all air. See Part 3.

The battery must contain the correct amount of electrolyte and be adequately charged.

PART 2 - Lubrication System

CONTENTS

GENERAL DESCRIPTION

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

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

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

All engines have the oil pump mounted on the base of the cylinder block, the drive being taken from a gear on the camshaft.

The oil pump draws oil through a pick-up screen(s) and pumps it through the full flow, type oil filter into the main oil gallery. The filtered oil is then directed at full pressure to the following:

Crankshaft main and connecting rod journals.

Camshaft bearing bushings.

Turbocharger bearings (if so equipped) via an external pipe.

Fuel injection pump, via a line from the oil filter mounting block.

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

An oil filter adaptor is available to enable an oil cooler to be connected if required. This adaptor is fitted between the filter head and cylinder block and contains a pressure relief valve.

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

The engine may be refilled with oil via the rocker cover mounted filler cap or through the low level filler, mounted on the oil pan.

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

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

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

OIL PAN REPAIRS

If a drain plug insert has become dislodged a new 3/4 in. - 24NS2 insert (service part) must be fitted using a "Helicoil" inserting tool of the prewind type (Fig. 1) in the following manner:

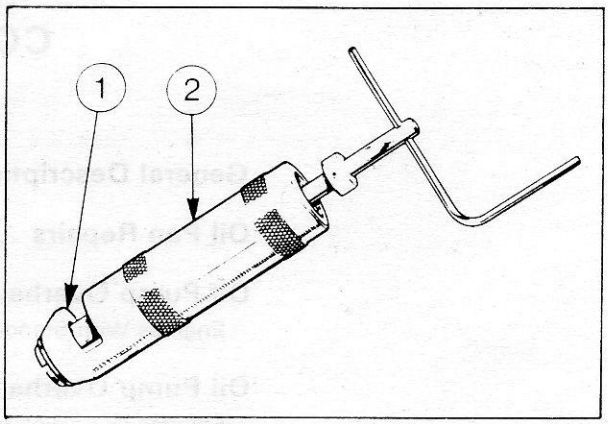


Fig. 1 - Helicoil Inserting Tool

1. Chamber
2. Tool Body

1. Withdraw the handle from the tool body until the mandrel is clear of the chamber.
2. Locate the insert in the chamber with the tang towards the nozzle.
3. Push the handle into the tool body to engage the slot in the mandrel with the tang.
4. Rotate the handle clockwise gently pushing the handle until the insert engages with the nozzle. Continue rotating the handle until the insert starts to appear from the end of the nozzle.
5. Place the tool squarely over the drain plug hole and without applying any end pressure, wind the insert into the oil pan until the insert is 1,6 to 2,4 mm (0,063 to 0,095 in.) below the face of the boss (Fig. 2).
6. Break the tang off using a pull and push action with a pair of long nosed pliers.
7. Stake the oil pan thread at the start of the insert to prevent the insert unwinding.

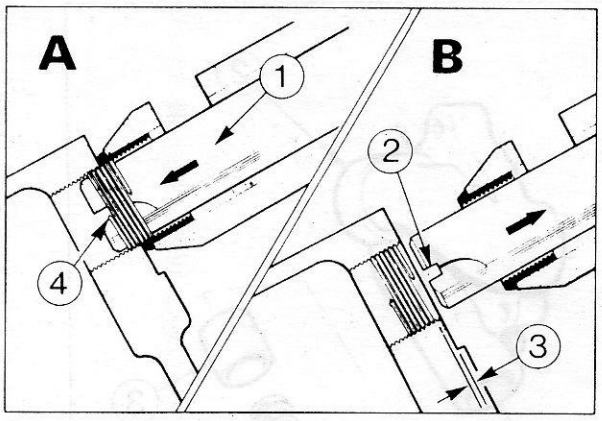


Fig. 2 - Installing Oil Pan Insert

A. Winding in Insert
B. Insert Installed
1. Mandrel
2. Slot
3. Install Insert Below Face
4. Tang

Oil Pump Servicing

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

OIL PUMP OVERHAUL - (STANDARD OIL PAN)

Either one of the two types of pump may be installed, "Holbourn Eaton" or "Whitehead". Complete pumps are interchangeable, individual components are not. When obtaining spare parts the pumps may be identified from the assembly part number cast into the main body of the pump.

Dismantling (Fig. 3)

1. Support the pump in a soft jawed vice, drive gear end downward.
2. Loosen and carefully remove the pressure relief valve cap and remove the spring and plunger.
3. Remove the bolts securing the cover plate and the pick up tube union lock tab.
4. Carefully remove the cover plate from the pump body, if necessary, by tapping with a soft faced mallet.

Caution: DO NOT use levers or screwdrivers to pry off the cover plate, as irreparable damage could be done to the mating faces. Holborn Eaton pumps have two hollow dowels locating the cover plate to the pump body.

5. Mark the outer rotor to ensure reassembly the same way round and remove it from the pump body.
6. Clean and dry the rotors, the cover plate and the pump body interior and check for scoring or excessive wear. If the pump body and cover plate are scored, the pump should be replaced. If the rotors are only scored or worn these can be replaced separately as a matched pair.
7. Place a straight edge across the pump face and measure the clearance to the face of the inner rotor (rotor end play) (Fig. 4). Refit the outer rotor and measure the clearance between the outer rotor and the pump body, and between the rotor lobes (Fig. 5). If the clearances are not within the specified limits the rotors should be replaced.

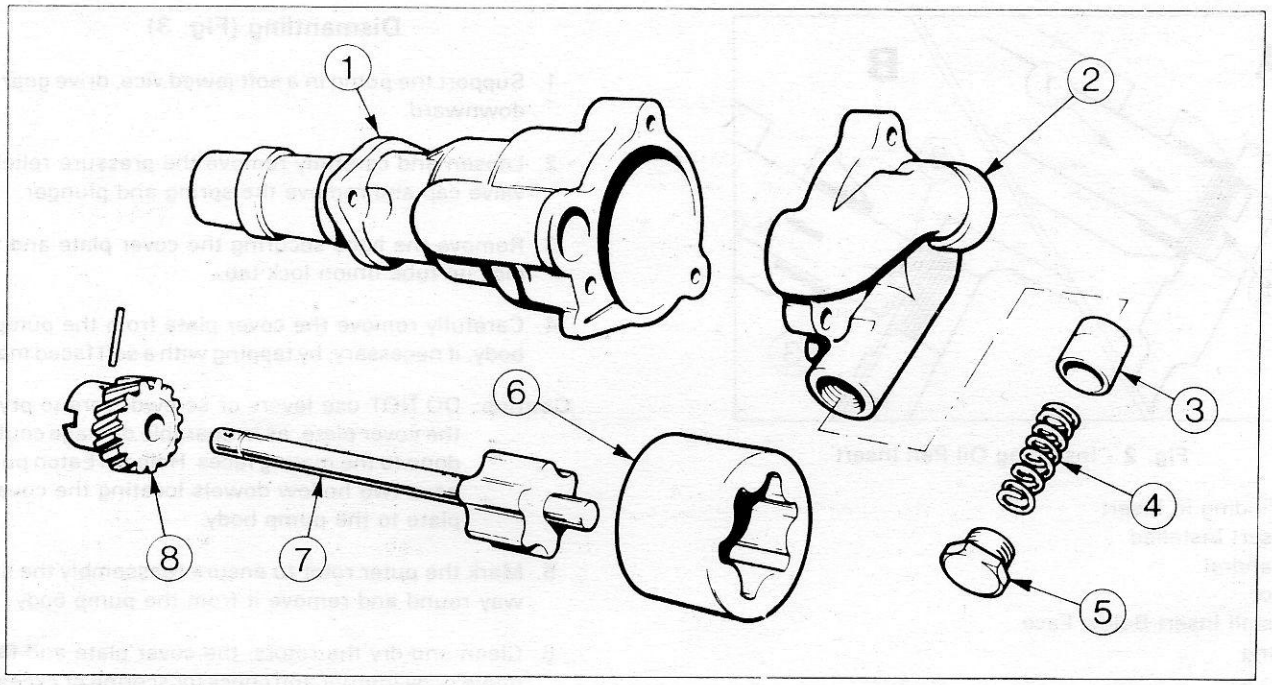


Fig. 3 - Oil Pump Used on 2722, 2723, 2725 and 2726T Engines Not Fitted With High Inclination Oil Pans

1. Pump Body
2. Cover
3. Pressure Relief Valve Plunger
4. Pressure Relief Valve Spring
5. Valve Cap
6. Outer Rotor
7. Inner Rotor and Shaft
8. Drive Gear

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

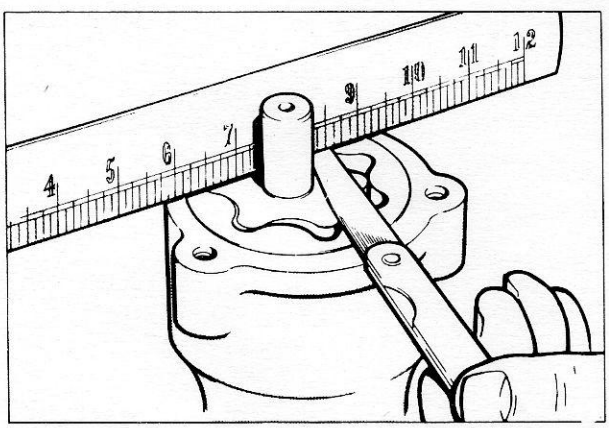


Fig. 4 - Measuring Pump Rotor End Play

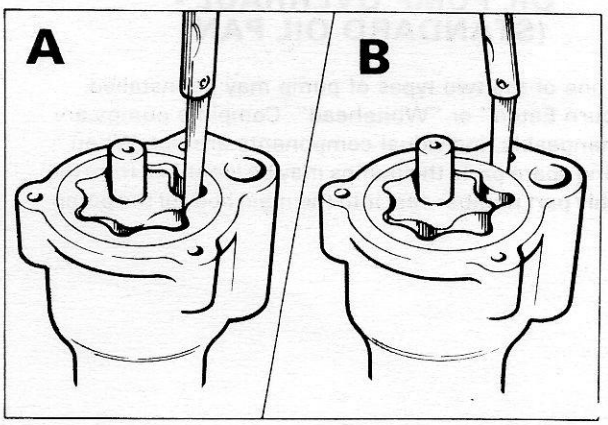


Fig. 5 - Measuring Rotor Lobe/Body Clearance

A. Checking Inner to Outer Rotor Clearance
B. Checking Outer Rotor to Pump Body Clearance

Cleaning and Inspection

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

Note: Bearings are not available separately for in service replacement.

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

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

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

Reassembly

1. Install the inner rotor and shaft assembly into the pump body.
2. Press the gear onto the shaft until a clearance of 0.13 to 0,38 mm (0,005 to 0,015 in.) is obtained between the gear and the pump body, with the rotor flush with the end plate face (Fig. 6).

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

3. Drill and ream a hole 4,94 to 4,98 mm (0,194 to 0,196 in.) through the shaft and gear, drive in the retaining pin and peen both ends to secure.
4. Install the outer rotor, ensuring that it is the correct way round.
5. On Motofides pumps (no locating dowels) apply a very light smear of Loctite 510 to the pump body to cover plate mating face. DO NOT allow the sealer to contact the pump rotor either when being applied or when the cover bolts are tightened.
6. Install the cover plate and bolts, install a new union nut lock plate to the bolt adjacent to the inlet orifice and tighten the bolts to the specified torque.
7. Install the pressure relief valve plunger and spring, apply one spot of the specified thread lock sealant to the valve cap threads and tighten to the specified torque.
8. The pump must rotate freely.

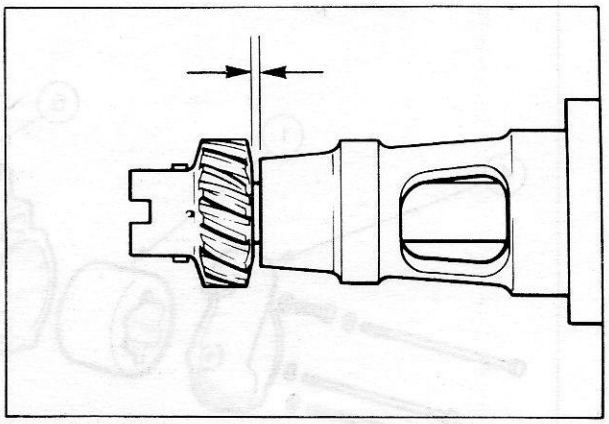


Fig. 6 - Gear to Pump Body Clearance

9. Replace the pump and oil pan as described in Part 1.

OIL PUMP OVERHAUL - (WITH HIGH INCLINATION OIL PANS)

Disassembly and Checking

1. Remove the four retaining bolts and remove the end plate (Fig. 7).
2. Check the oil pump for wear. Place a straight edge across the face of the pump housing and check the clearance between the straight edge and both parts of rotor. If this exceeds the clearance specified, the pump housing can be lapped to bring the clearance within tolerance.
3. Inner to outer rotor clearance and outer rotor to pump housing clearance should be measured with a feeler gauge, (Fig. 8); if these exceed the clearances specified, the inner and outer rotor should be replaced.
4. Remove the inner and outer scavenge rotors, and remove the woodruff key from the shaft.
5. Remove the lower pump body and the oil pressure relief plunger and spring.
6. The same checks for wear should be carried out on the delivery rotors as on the scavenge rotors. See operation 3. Should the clearance exceed the specified tolerance install a new shaft and inner and outer rotors.
7. If it is necessary to renew the delivery rotors and shaft or gear, remove the outer rotor. Drive out the retaining pin retaining the gear to the drive shaft and pull off the gear. The inner rotor and shaft can now be removed from the upper housing.

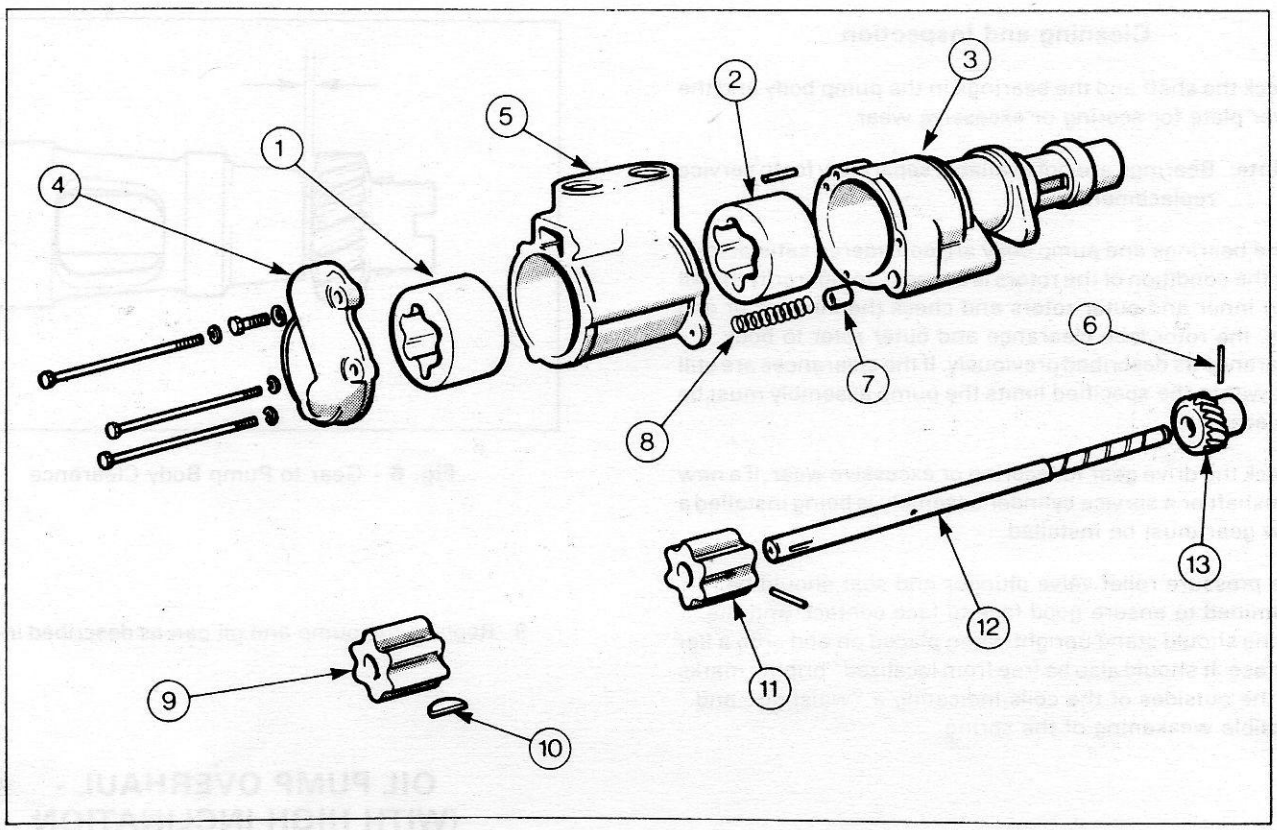


Fig. 7 - Oil Pump With High Inclination Oil Pan

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

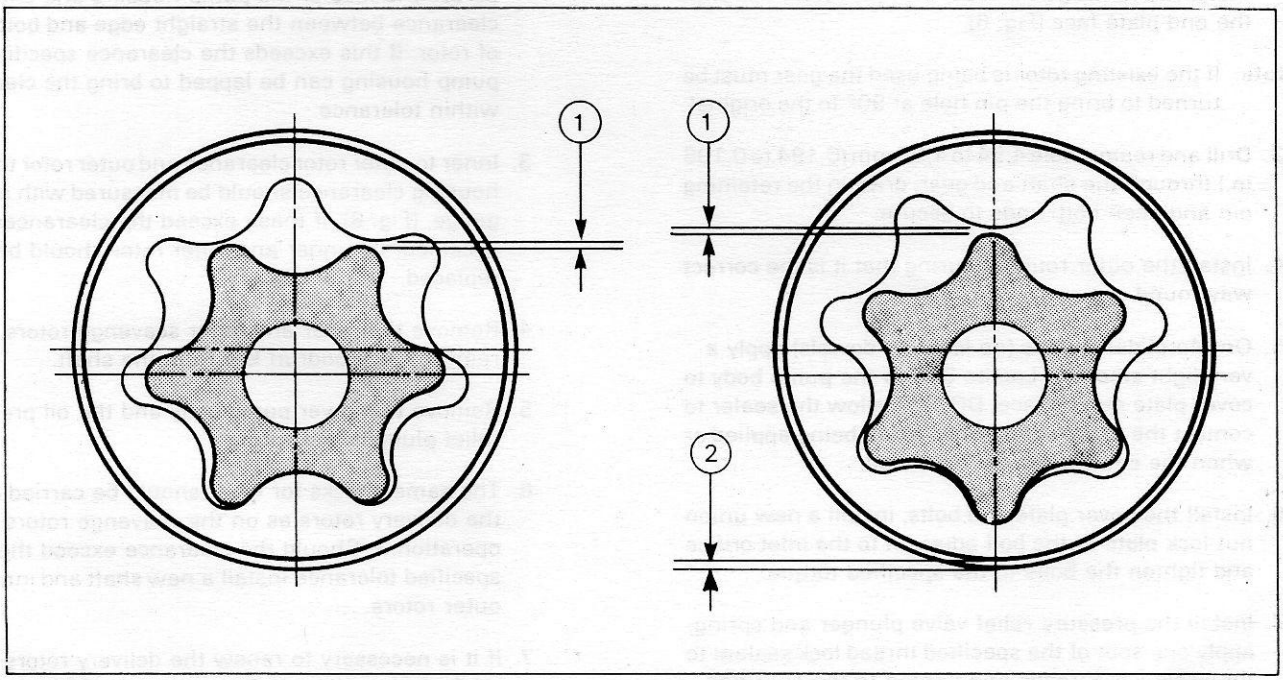


Fig. 8 - Measuring Rotor Clearance - With High Inclination Oil Pans

1. Inner to Outer Rotor
2. Outer Rotor to Pump Housing

Assembly

1. If the pump has been completely dismantled, slide the new drive shaft and main inner rotor into the upper housing.
2. Press the gear onto the drive shaft end until there is a clearance of 0,178 to 0,305 (0,007 to 0,012 in.) between the gear and pump housing (Fig. 6).
3. Supporting the shaft at the rotor end, drill and ream 3,175 mm (0,125 in.) diameter hole diametrically through the gear hub and shaft 13,72 mm (0,540 in.) from the slotted end.
4. Install the gear retaining pin and peen the ends over securely to prevent it becoming loose in service.
5. Replace the outer rotor, chamfered end first, and insert the oil pressure relief plunger and spring in the upper pump housing.
6. Slide the lower pump housing onto the shaft and install the woodruff key in the shaft.
7. Replace inner rotor and outer rotor, chamfered end first, into the lower pump housing.
8. Position the end plate and secure with the four bolts and lockwashers, ensuring that each is in its correct location, and then tighten to the specified torque value.
9. The pump rotor must revolve freely.

OIL FILTER ELEMENT RENEWAL

1. Unscrew the oil filter element and allow the oil to drain into a suitable container. Discard the element.
2. Fill a new filter element with clean engine oil of the specified grade, then screw the element onto the filter head until it contacts the "O" ring seal. Turn the element a further 1/16 to a 1/4 turn BY HAND ONLY.
3. On turbocharged engines, prime the turbocharger as described in Part 3.
4. Check the engine oil level and top off as necessary with engine oil to specification.
5. Start the engine and check for oil leakage.

PART 3 - Fuel System

CONTENTS

GENERAL DESCRIPTION

The principle working components of the fuel system are the lift pump, injection pump and injectors. Together with the tank and filters these items make up the basic system which provides direct injection of fuel into the engine cylinders.

The fuel lift pump is mounted on the right hand, rear end of the cylinder block and is operated by an eccentric on the engine camshaft. Its function is to draw fuel from the tank and provide a constant supply to the injection pump.

The injection pump is an integrated assembly of pumping and governing units mounted on the rear of the timing gear housing and driven by the timing gears.

In the pumping section of the injection pump, spring loaded, fuel fed pumping plungers are operated by an internal camshaft. Each plunger delivers fuel to its respective injector at high pressure and in the correct engine firing order. To vary the quantity of fuel delivered in accordance with specific throttle demand or condition, the plungers are collectively linked to the governing section via a "control rod".

The governing section receives a signal of engine speed from the camshaft mounted flyweights. This "signal" combines with other signal inputs of starting, stopping and power demand (throttle setting) to position the plunger control rod. The flyweight type governor provides automatic idle speed control and restricts maximum engine speed to a pre-set limit.

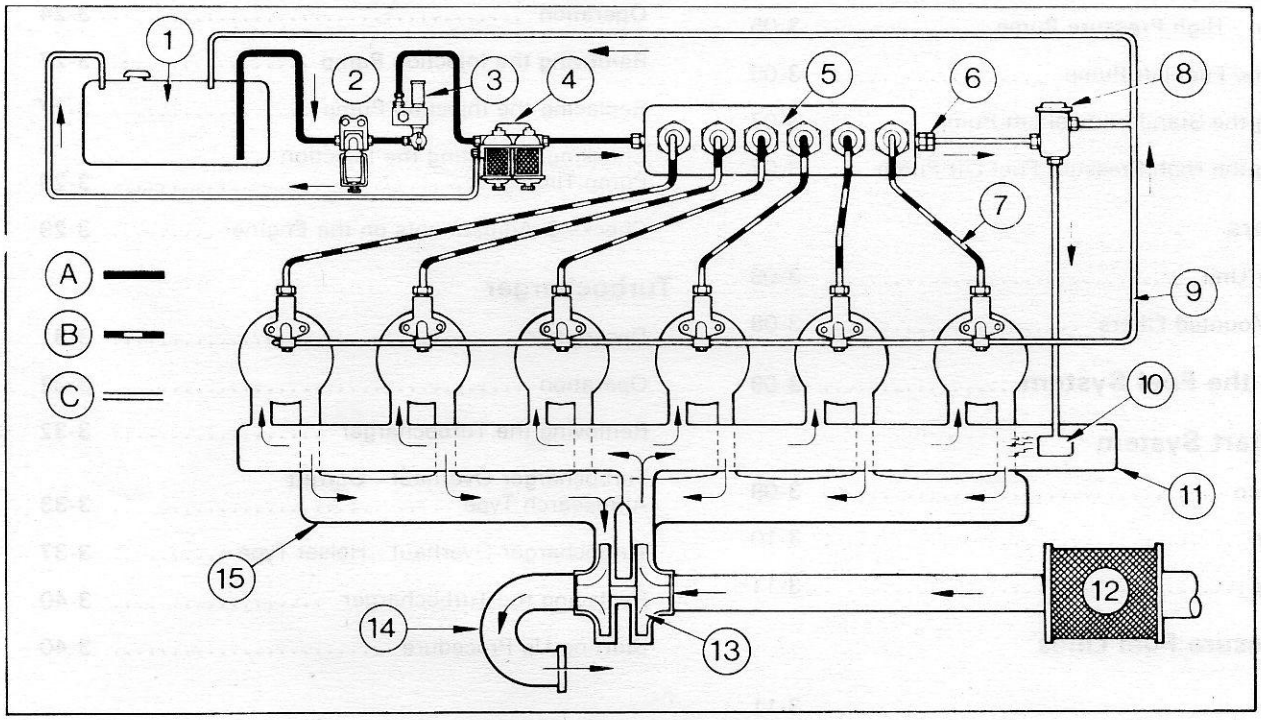


Fig. 1 - Typical Fuel System Schematic (Turbocharged Engine Shown)

A. Low Pressure Fuel Path
B. High Pressure Fuel Path
C. Leak-Off Fuel Return to Tank and Thermostart Feed Paths

1. Tank
2. Water Separator Filter (If So Equipped)
3. Lift Pump and (If So Equipped) Pre-Filter Unit
4. Engine Mounted Filters and Pressure Relief Valve Assembly
5. Injection Pump
6. Fuel Gallery Air Bleed
7. High Pressure Delivery Lines to Injectors
8. Thermostart Reservoir
9. Leak-Off Pipe to Tank
10. Thermostart Element(s)
11. Intake Manifold
12. Air Cleaner
13. Turbocharger
14. Exhaust Elbow/Exhaust Pipe
15. Exhaust Manifold

On turbocharged engines the boosted intake manifold pressure results in higher volumetric efficiency and increased engine power output. A "boost control" on the injection pump of these engines is fitted to prevent excessive overfueling during acceleration.

The fuel injectors act as spring loaded on/off valves, providing a high degree of atomization while open. A calculated, self lubricating internal leakage is allowed to return to the tank via a "leak-off" line.

Stopping the engine is achieved principally by moving the pump plungers into a "non-delivery" condition. This is achieved by means of a stop lever which moves the plunger control rod to the required position.

To enhance engine starting performance, the injection pump is capable of operating briefly in an overfueling condition. This device places the pump plungers in an "excess fuel" position.

General purpose governed injection pumps have an integral automatic excess fuel facility which is temperature sensitive. All other injection pumps have a manually operated excess fuel device but an automatic device is available as an option.

For extreme cold weather conditions a thermostart system may be fitted as an option (mandatory on turbocharged engines).

This system pre-heats the air to the combustion chambers by igniting a small flow of low pressure fuel in the air intake manifold.

FUEL LIFT PUMP

Operation of Standard Pump - Fig. 2

The eccentric on the camshaft operates the fuel pump rocker arm and link and pulls the diaphragm inwards against the pressure of the return spring. This creates a partial vacuum in the pump chamber, causing the inlet valve to open and draw fuel into the diaphragm chamber.

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

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

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

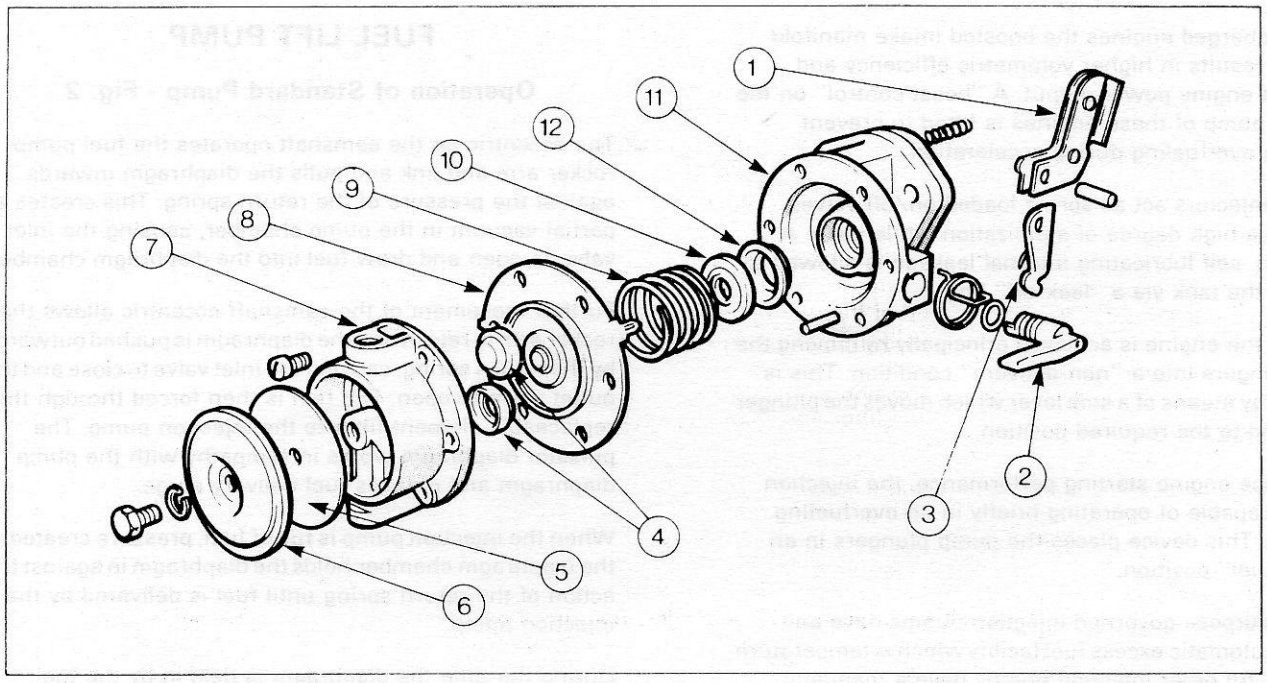


Fig. 2 - Exploded View of Standard Pump

1. Rocker Arm
2. Priming Lever
3. Rocker Arm Link
4. Valves
5. Pulsator Diaphragm
6. Cover
7. Outer Body
8. Pump Diaphragm
9. Return Spring
10. Oil Seal Retainer
11. Inner Body
12. Oil Seal

Operation of High Pressure Pump - Figs. 3 and 4

The fuel lift pump is mounted to an adaptor at the rear of the engine block.

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

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

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

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

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

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

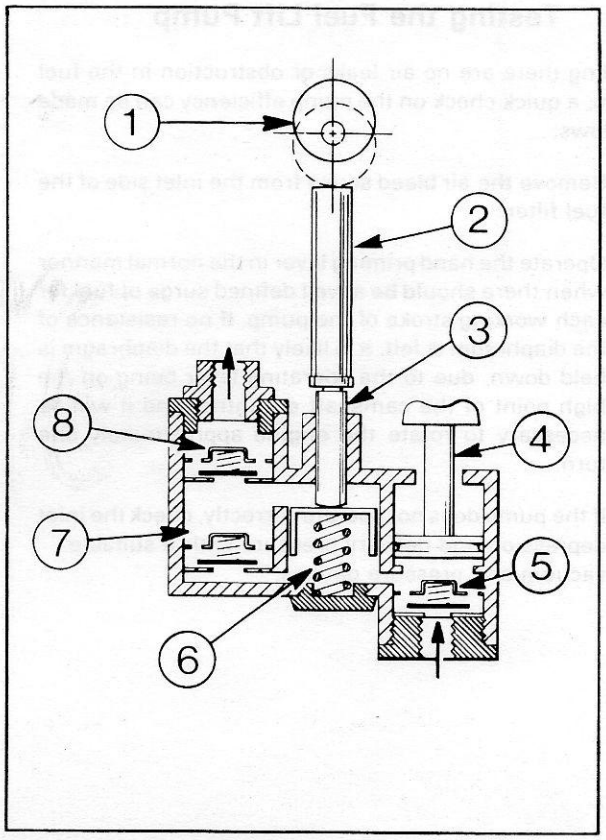


Fig. 3 - High Pressure Pump Shown in Diagramatic Form

1. Camshaft Eccentric
2. Adaptor Rod
3. Plunger Rod
4. Priming Pump
5. Inlet Valve
6. Plunger Return Spring
7. Transfer Valve
8. Outlet Valve (AC Delco Pumps Only)

Testing the Fuel Lift Pump

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

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

   If the pump does not operate correctly, check the inlet depression and delivery pressure with a suitable vacuum and pressure gauges.

Suction Test

1. Operate the lift pump head primer to fill the injection pump fuel gallery.
2. Disconnect the fuel inlet line from the pump and connect the vacuum gauge to the pump inlet union.
3. Start the engine and allow to run at idling speed. The vacuum readings should be at least 21,59 cm (8,5 in.) of mercury.
4. Stop the engine and check the leak-down time for the specific pumps as follows:

   Standard Pump - 0,0177 bar (0,25 lb/in²) in 25 minutes.

   High Pressure Pump - 0,207 bar (3 lb/in²) 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.

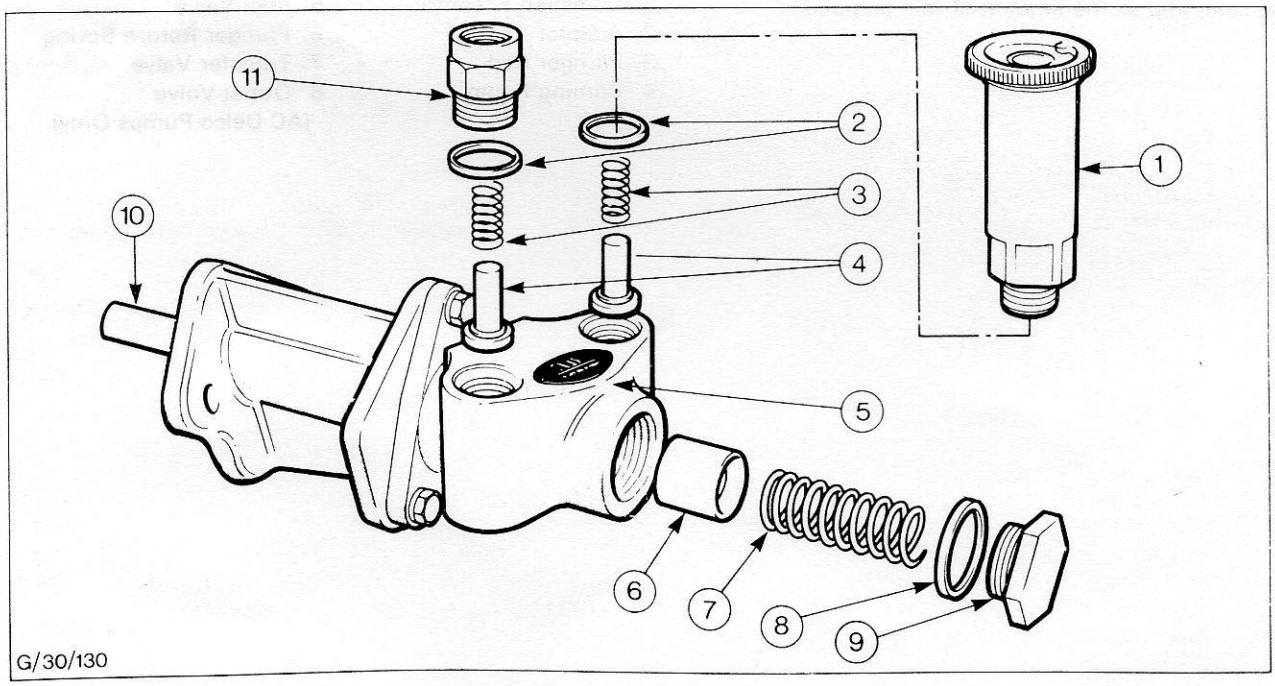


Fig. 4 - Exploded View of High Pressure Pump

1. Primer Plunger Assembly
2. Seal
3. Spring
4. Valve
5. Body
6. Plunger Sleeve
7. Spring
8. Seal
9. Plug
10. Plunger Rod
11. Connector

Pressure Test

1. Operate the lift pump hand primer to fill the injection pump gallery.
2. Disconnect the fuel outlet line 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 (5 to 8 lb/in²) standard pump

   1,03 to 1,24 bar (15 to 18 lb/in²) high pressure pump

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

4. Remove the gauge, connect the fuel line and bleed the fuel system.

Servicing the Standard Fuel Lift Pump - Fig. 2

1. Disconnect the fuel inlet and outlet lines from the lift pump. Where applicable, remove banjo bolt and detach pre-filter unit.
2. Remove the two attaching nuts and remove the lift pump from the cylinder block. Discard gasket.
3. Unscrew the bolt securing the pump cover plate and remove the cover plate and pulsator diaphragm.
4. Mark the positions of the two halves of the pump adjacent to the small tab on the pump diaphragm. Remove the six securing screws and separate the two halves of the pump.
5. If necessary, punch back the staking and remove the two valves from the outer body.
6. Drive out the pin securing the priming lever and withdraw the lever and spring. The priming lever shaft has a flat at its end which locates behind a lug on the diaphragm spring seat.
7. Push the pump diaphragm down against the return spring pressure and disengage the pull rod from the operating link.
8. If necessary, carefully punch back the staking locating the rocker arm pivot pin, tap out the pin and remove the rocker arm and link. Take care not to lose the small spring fitted between the rocker arm and the housing.
9. Thoroughly clean all parts with kerosene or test oil.
10. Insert the inlet and outlet valves, ensuring that they are in their correct positions. The inlet valve is the lower one and is assembled to the outer body with the spring nearest to the pump diaphragm. The outlet valve fits the other way round. Secure each valve by staking the body at four points.
11. Assemble the rocker arm, link and pin to the inner body, locating the return spring between the rocker arm and the housing. Stake the housing at either end of the pivot pin to ensure that it is securely retained.
12. Locate the return spring on the pump diaphragm spring seat and assemble the diaphragm to the inner body with the lug on the spring seat adjacent to the priming lever bore and the small tab next to the mark on the body. Engage the link with the pull rod.
13. Compress the pump diaphragm and return spring and insert the priming lever shaft, with the "O" sealing ring in the outer groove, into the inner body so that the flat is located behind the spring seat lug. Locate the priming lever retaining pin, which locates in a groove in the shaft and drive home.
14. Locate the two halves of the pump body together in the marked positions, insert the six screws until fingertight. Operate the rocker arm a few times to centralize the diaphragm and tighten the screws, holding the rocker lefer fully down.
15. Replace the pump cover plate and pulsator diaphragm and secure with a screw and lock-washer. Tighten to the specified torque value.
16. Locate a new gasket on the cylinder block mounting studs, place the lift pump in position and install with the two nuts and washers. Tighten nuts to the specified torque value.
17. Where applicable, install the pre-filter unit to the pump with the banjo bolt and washers and tighten bolt to the specified torque value.
18. Connect the fuel inlet and outlet lines and bleed the system - see under "Bleeding the Fuel System".

Servicing the High Pressure Fuel Lift Pump - Fig. 4

1. Disconnect the fuel inlet and outlet lines from the lift pump. Where applicable, remove banjo bolt and detach the pre-filter unit.

2. Remove the three attaching bolts and detach the lift pump from the adaptor. Discard gasket.
3. Unscrew and remove the fuel inlet and outlet adaptors with their washers.
4. Unscrew the priming plunger assembly.
5. Withdraw the valve springs and valves.
6. Unscrew the plug, remove the sealing washer and withdraw the spring, plunger sleeve and rod.
7. Thoroughly clean the pump body and all parts with kerosene or test oil.
8. Examine the valves and ensure correct seating in the housing. If satisfactory, refit valves together with springs.
9. Screw in the priming plunger assembly, using new sealing washers.
10. Replace inlet and outlet adaptors using new sealing washers.
11. Examine plunger rod and plunger sleeve for damage or excessive wear, then, if serviceable, insert them into pump body and check that they move easily. Replace spring and secure with plug fitted with new sealing washer.
12. Ensure that the pump mounting face is clean, fit a new gasket and secure the pump to the adaptor housing with the three bolts and washers. Tighten bolts to the specified torque value.
13. Where applicable, secure pre-filter unit to the pump with banjo bolt and washers. tighten bolt to specified torque value.
14. Connect fuel inlet and outlet lines.
15. Bleed the system as detailed under "Bleeding the Fuel System".

FUEL FILTERS

Pre-Filter Unit

This filter is attached to the lift pump by a banjo-bolt and receives fuel directly from the tank. The element comprises a fine mesh cage enclosed in a transparent glass bowl and retained by a thumb screw tensioned "stirrup" (Fig. 5).

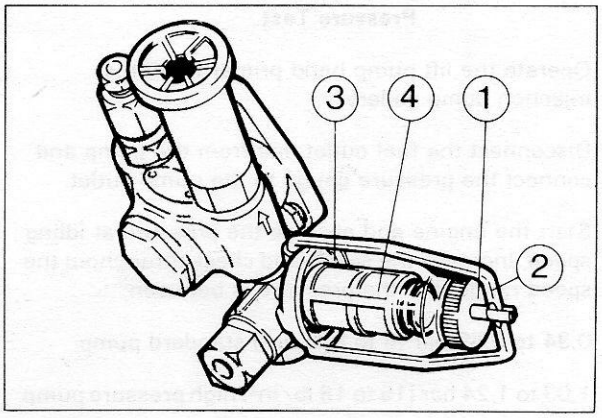


Fig. 5 - Pre-Filter Unit

1. Knurled Clamping Knob
2. "Stirrup"
3. Glass Bowl
4. Filter Element

To clean the pre-filter unit proceed as follows:

1. Fully slacken off the knurled clamping knob and swing the "stirrup" to one side.
2. Remove glass bowl and detach filter element.
3. Wash filter element and bowl thoroughly in clean test oil and dry bowl with non-fluffy rag.
4. Place filter element in glass bowl, spring first, then assemble bowl to housing, ensuring that the element spigot enters the recess in the housing.
5. Swing "stirrup" into position and tighten clamp knob sufficiently to ensure a good seal. Do not overtighten.
6. Bleen the fuel system - see under "Bleeding the Fuel System".
7. Run the engine and check for fuel leaks.

Engine Mounted Filters (Fig. 6)

The filter assembly protects the high pressure components in the injectin pump and injectors against damage from dirt. Each paper element is in the form of a renewable canister, secured between the filter head and base plate by a central bolt. A drain cap on each base plate allows water checks to be accomplished. Bleed screws on the filter head permit air to be bled from the system where necessary.

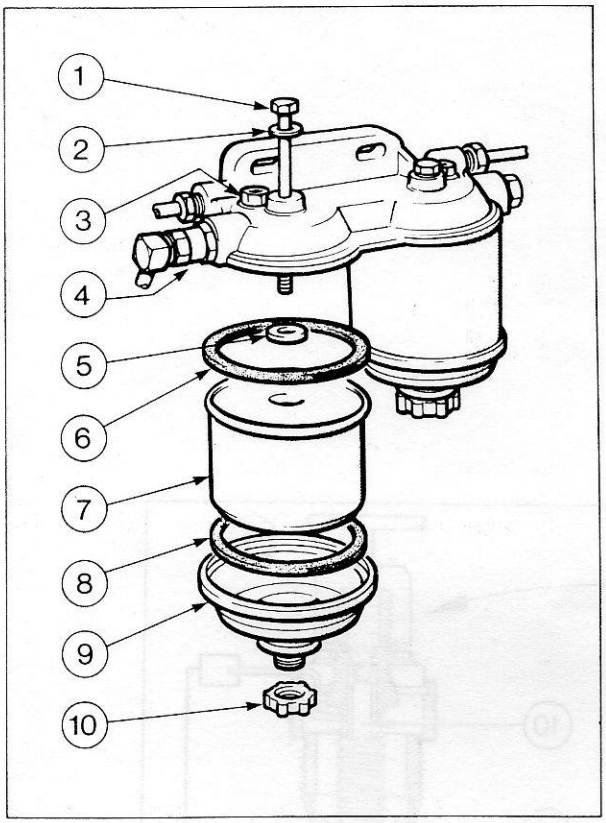


Fig. 6 - Engine Mounted Fuel Filter Unit

1. center Bolt
2. Sealing Washer
3. Bleed Screw
4. Lift Pump Relief Valve
5. Seal - Inner
6. Seal - Outer
7. Filter Element
8. Seal - Outer
9. Bowl
10. Drain Cap

Replacement of fuel filter elements:

1. Turn off the fuel supply tap.
2. Unscrew the drain caps and allow the filter contents to drain into a suitable container.
3. Remove the filter element center bolts to detach the elements and base plates. Discard the elements and all sealing rings.
4. Clean the base plates with clean test oil or kerosene and hand tighten the drain caps.
5. Install one new large and one new small sealing ring onto the underside of each filter head. Assemble the base plates with new elements and sealing rings and secure centrally to the filter heads with the center bolts and new sealing rings. Tighten the bolts to the specified torque.
6. Dry off any split fuel, turn on the fuel supply tap, then operate the priming pump to check for leaks. Rectify as necessary.

BLEEDING THE FUEL SYSTEM

Although the system is of a self purging nature, the following procedure will hasten the clearance of air from the system following any large component change, i.e. filter or injection pump.

1. After a filter change, remove the bleed screws from the engine mounted filters. Operate the priming pump until air free fuel flows, then refit the bleed screws.
2. After an injection pump change disconnect the line from the fuel gallery non-return valve (NRV). Operate the priming pump until air free fuel flows from the valve, then reconnect the line.
3. If a thermostart reservoir has been emptied, disconnect its overflow line and operate the priming pump until the bowl is full. Reconncet the line.
4. After any of the above operations, dry off any split fuel, operate the priming pump and check that all reconnections are dry.

THERMOSTART SYSTEM

Description (Fig. 7)

When selected, this system assists engine starting in cold weather conditions by pre-heating the air in the intake manifold. The system consists of a reservoir which supplies fuel to thermostart element(s) fitted in the air intake ducting. A thermostart button on the driver's instrument panel controls the operation.

The reservoir is connected by line to the injection pump fuel gallery so that it is constantly supplied during engine running. The removable lid of the reservoir incorporates a plate valve controlled and gauze protected vent. The valve closes when the reservoir is full, surplus fuel flowing out through an overflow and back to the tank via the leak-off line. An outlet at the base of the reservoir feeds fuel to the element(s).

The element consists of a thermally controlled ball valve and a combined heating and igniter coil contained within a body and shield assembly. The element is fitted into a boss on the air intake manifold.

Operation

In the non-energized state, the ball valve is held closed by a rod in the tubular valve casing.

With the ignition switch in the running position, depression of the thermostart button energizes the element coil. As the coil heats up, the valve casing expands axially to move the rod away from the ball valve. Fuel then flows by gravity from the reservoir to be warmed and vaporized by the heater and ignited by the igniter portion of the coil. Cranking the engine draws air through dilution holes in the element shield to mix freely with the burning fuel in the intake manifold.

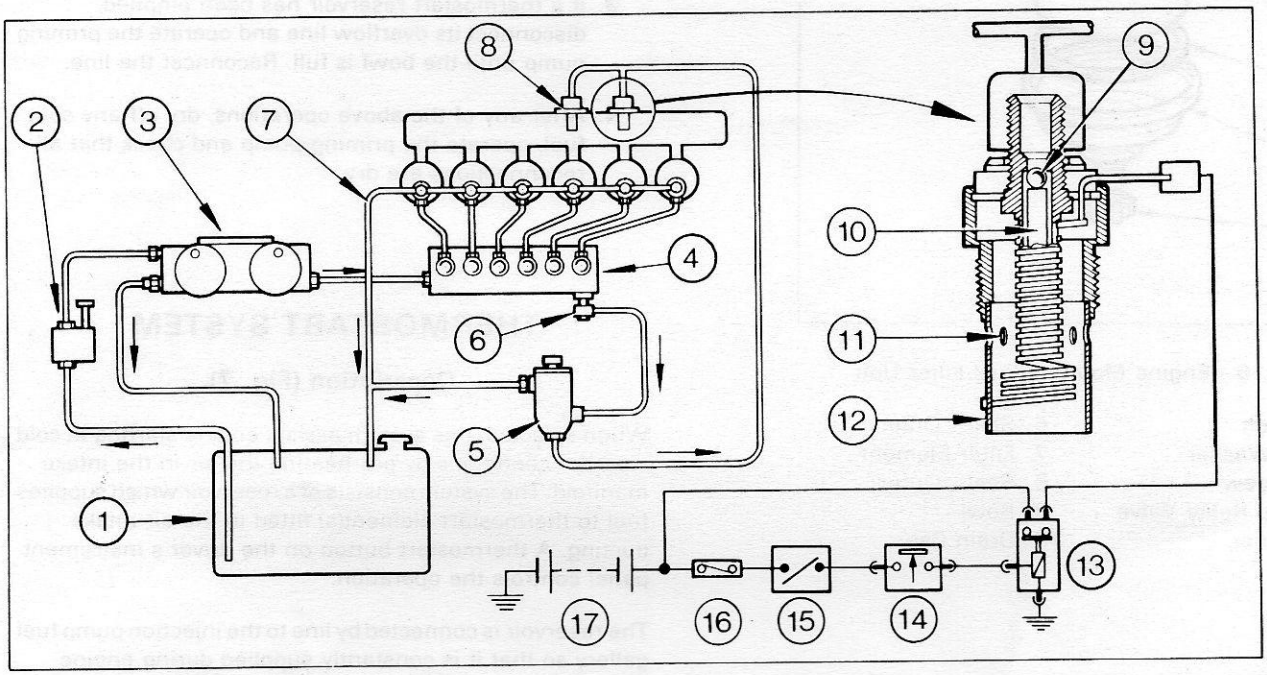


Fig. 7 - Thermostart System Schematic

1. Fuel Tank
2. Fuel Lift Pump
3. Fuel Filters
4. Injection Pump
5. Reservoir
6. Injection Pump Gallery Outlet
7. Leak-Off Pipe
8. Thermostart Element(s)
9. Ball
10. Rod
11. Dilution Holes
12. Shield
13. Thermostart Relay
14. Thermostart Button
15. Ignition Switch
16. Fusebox
17. Battery

Servicing

1. Disconnect the battery.
2. Disconnect the electrical connector and fuel lines from the thermostart element. Allow the fuel to drain into a container.
3. Unscrew the element from the intake manifold and fit a protective cap to the element and the manifold (Fig. 8).
4. Disconnect the lines from the reservoir and remove the reservoir.

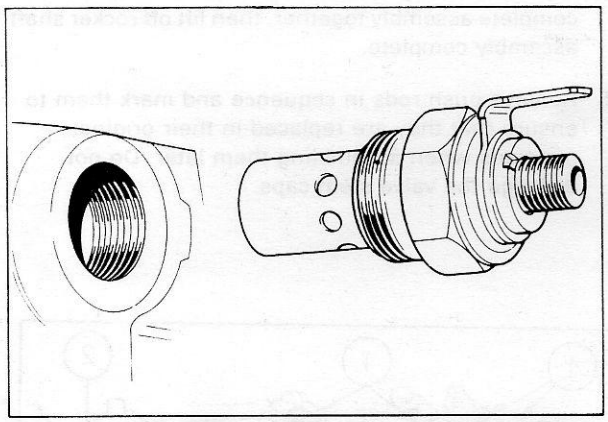


Fig. 8 - Removing/Replacing Thermostart Element

5. Remove the reservoir cover and clean the bowl and cover with kerosene or test oil. Dry the vent filter with low pressure compressed air and re-assemble the unit with a new gasket.
6. Clean the element by brusing lightly with a soft bristled brush.
7. Install the reservoir and reconnect all the fuel lines except the overflow line.
8. Prime the system by operating the lift pump priming plunger until fuel flows from the reservoir. Reconnect the line.
9. Install the thermostart element into the manifold and connect the fuel line and the electrical connector.
10. Reconnect the battery and operate the thermostart button. Check that the inlet manifold radiates warmth in the vicinity of the element. If not, investigate the fuel supply and/or electrical continuity to the element. Rectify and/or replace the element as required.

HIGH PRESSURE FUEL LINES

Fuel is supplied from the injection pump to the injectors through high pressure steel lines. Each line has an individual shape and cannot therefore be fitted in any position other than to its own cylinder. The line ends are suitably formed to connect without using separate sleeves and the lines are clamped to each other to reduce vibration.

INJECTORS

Description (Fig. 9)

The following description embraces both CAV and Bosch injectors. Although slightly different in appearance, the two makes are interchangeable providing that injectors for NA engines are not mixed with those for TC engines.

Fitted into machined recesses in the cylinder head, each injector is retained by two bolts. The recesses are angled towards the center of each piston's combustion bowl.

Each injector is basically a spring loaded needle valve acting as an on-off valve in a 4 hole nozzle. The nozzle, valve and an adaptor plate are retained to the nozzle holder of the injector by a cap nut. Dowel pins in the adaptor plate ensure that the fuel drilling is correctly aligned.

The upper, larger diameter of the needle valve is an accurately ground and lapped fit in the nozzle. These two component parts are classed as a pair for replacement purposes. The annular area formed between the two diameters of the valve spindle is the area on which the valve lifting force is subjected. The lower end of the valve spindle is ground and lapped to form a fuel tight fit on the nozzle seat.

The four spray holes in the nozzle are provided in differently angled pairs. This arrangement accommodates the injector installation angle to result in even distribution into the piston bowl.

A calibrated, self lubricating fuel leakage is permitted between the close fitting diameters of the needle valve and the nozzle. This flow returns to the tank via a "leak-off" line connection at the top of the injector.

Operation (Fig. 10)

As the injection pump delivery valve opens, pressure is felt on the annular face of the needle valves' larger diameter. When fuel pressure overcomes spring pressure, the valve will open. Flow through the spray holes creates a pressure drop which allows the valve to close until pressure rises again. This very rapid, repetitive action causes a "Chattering" or "buzzing" noise which is audible during bench testing. The very high fuel pressure and minute spray holes combine to create a high degree of atomization.

Adjustment to the valve operating pressure can only be made by dismantling and reshimming the spring - see "Servicing".

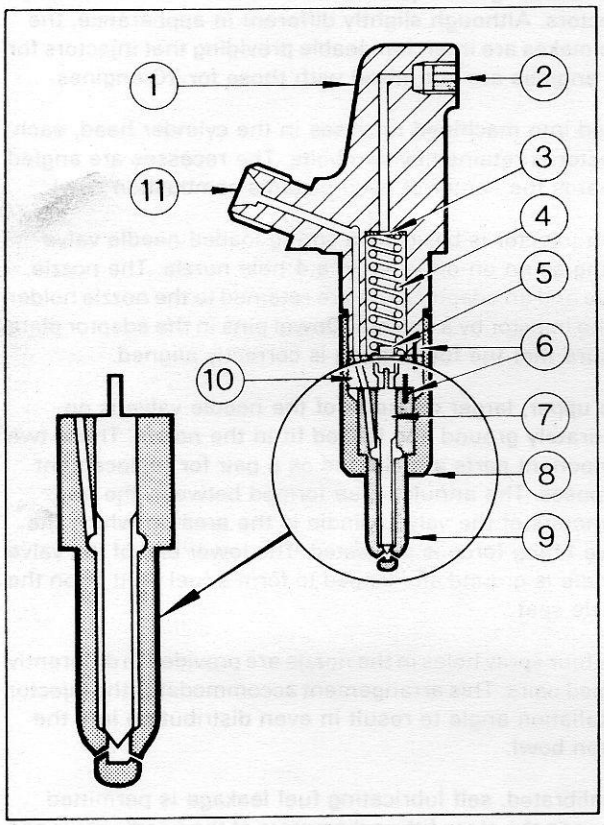


Fig. 9 - Injector

1. Nozzle Holder
2. Leak-Off Connection
3. Shim
4. Spring
5. Spring Seat
6. Dowel Pins
7. Needle Valve
8. Cap Nut
9. Nozzle
10. Adaptor Plate Assembly
11. Inlet Connection

Removing

1. Disconnect the engine breather pipe from the rocker cover.
2. Remove the rocker cover and discard the gasket.

Note: If only one injector is to be removed, proceed directly to operation 6. If several injectors are to be removed, it will be found easier to remove the rocker shaft assembly as detailed in operations 3, 4 and 5 following:

3. Loosen each rocker shaft pedistal retaining bolt approximately one turn at a time until all are loose, then remove them (Fig. 10).
4. Tie the two end rockers in position to keep the complete assembly together, then lift off rocker shaft assembly complete.
5. Remove push rods in sequence and mark them to ensure that they are replaced in their original positions when assembling them later. Do not dislodge the valve stem caps.

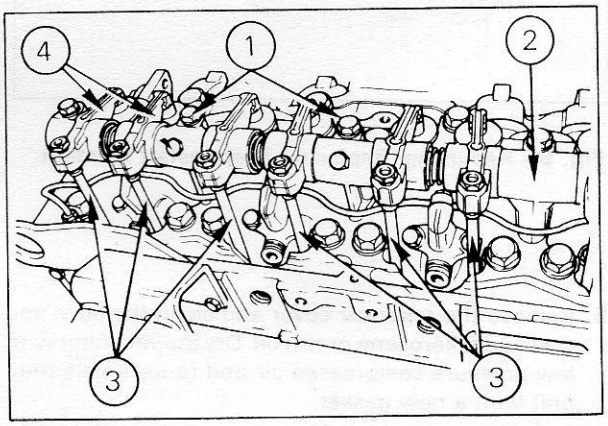


Fig. 10 - Removing Rocker Shaft Assembly

1. Rocker Shaft Pedestal Retaining Bolts
2. Rocker Shaft Assembly
3. Push Rods
4. Rocker Arms

6. Loosen the large oil seal nut (Fig. 11). Where necessary, remove high pressure line clamps to gain access.

7. Unscrew the nut securing the high pressure delivery line to the injector.

Caution: DO NOT bend the delivery line(s). If necessary, unclamp and disconnect both ends of the line(s).

8. Unscrew and remove the banjo bolt from leak-off line.

9. Unscrew attaching bolts and remove injector. Discard "O" ring.

10. Remove seating washer from recess in cylinder head and discard it.

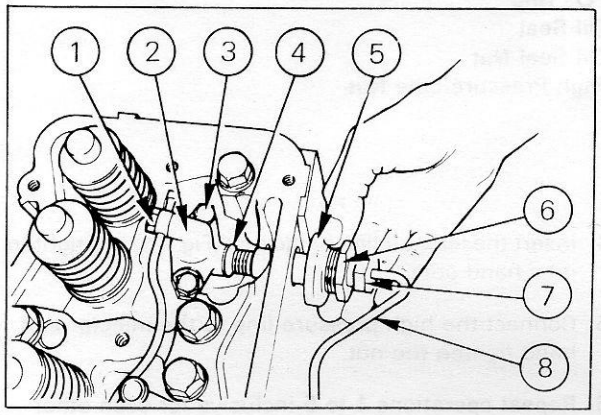


Fig. 11 - Removing Injector

1. Leak-Off Line Banjo Bolt
2. Injector
3. Injector Retaining Bolt
4. "O" Ring
5. Oil Seal
6. Oil Seal Nut
7. High Pressure Line Nut
8. High Pressure Line

11. Repeat operations 6 to 10 inclusive for all other injectors to be removed. If new or reconditioned injectors are not being fitted immediately, fit blanking plugs or caps to the cylinder head aperatures and all open line connections.

Testing

Warning: When testing injectors, great care should be taken to ensure that the atomized spray from the nozzle does not come into contact with the hands or any other part of the body. The high pressures involved with the atomization of the test oil may cause it to penetrate the skin and cause possible blood poisoning. Goggles, gloves and suitable protective clothing should be worn during testing.

1. Fit a protective cap to the inlet union and thoroughly clean the injector with kerosene or test oil.

2. Remove the protective cap and connect the injector to the tester (Fig. 12). Carefully wipe the nozzle completely dry.

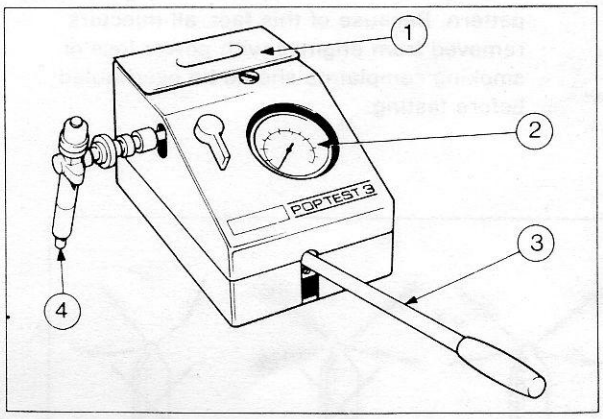


Fig. 12. - Typical Injector Tester

1. Oil Supply Tank
2. Pressure Gauge
3. Pump Handle
4. Injector

3. With the pressure gauge valve closed, operate the hand pump several times to expel air from the unit, then open the valve.

4. Pump sufficiently to raise the pressure until the gauge flickers. This indicates the pressure required to lift the needle from its nozzle seat. Recheck, note the pressure and allow it to reduce. Compare the result with the specified "setting" or "working" pressure, as appropriate.

Note: A correctly operating injector will emit a "chattering" sound while spraying.

5. Increase the pressure to the upper specified back leak test pressure. Start a stop watch and note the time for the pressure to fall naturally through 725 PSI, i.e. to the lower specified test pressure. Compare the time taken with the specified time/oil temperature.

6. Check that the nozzle tip is perfectly dry, then increase the pressure to approximately 145 lb/in² below the pressure required to lift the needle. While maintaining this pressure constant, check that droplets of fuel do not collect or drip from the nozzle face for at least 6 seconds. (A slight dampness is acceptable.)

7. Close the tester valve and operate the hand pump at approximately 1 ½ strokes per second. A correct spray pattern will be formed with fuel emitting from all holes in the nozzle and free from irregular streaks.

Caution: At certain operating pressures a partially blocked nozzle hole may produce a good spray pattern. Because of this fact, all injectors removed from engines with power loss or smoking complaints should be overhauled before testing.

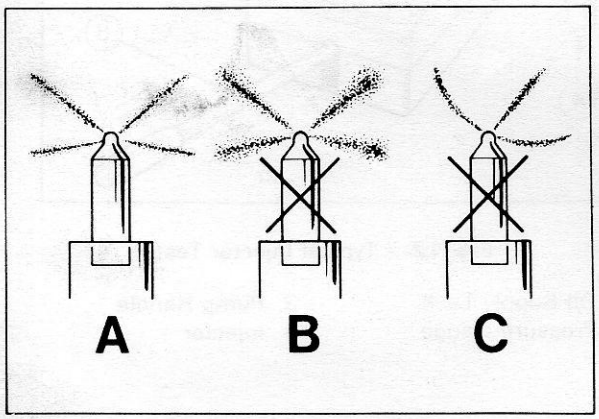


Fig. 13 - Typical Spray Patterns

A. Good
B. Reject - Poor Atomization
C. Reject - Blocked Spray Hole

Replacing

1. Ensure that the cylinder head injector hole is thoroughly clean, then fit new sealing washer (Fig. 14).

2. Install a new "O" ring seal to the injector.

3. Insert the injector into the cylinder head and install but do not tighten the securing bolts (Fig. 14).

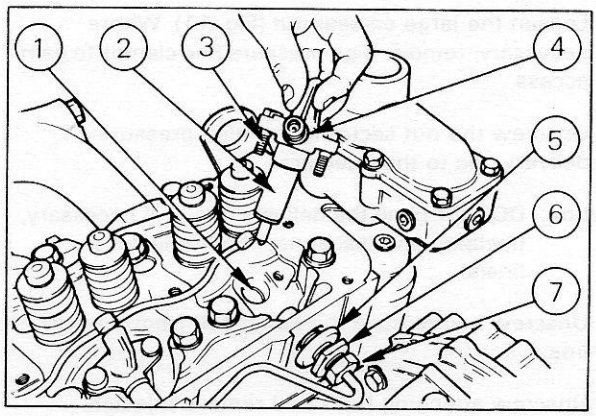


Fig. 14 - Replacing Injector

1. Recess for Copper Sealing Washer
2. Injector
3. Injector Retaining Bolt
4. "O" ring
5. Oil Seal
6. Oil Seal Nut
7. High Pressure Line Nut

4. Insert the leak-off line banjo bolt (Fig. 14) and tighten it by hand only.

5. Connect the high pressure line to the injector and hand tighten the nut.

6. Repeat operations 1 to 5 inclusive for each other injector being installed.

7. Tighten all injector attaching bolts evenly to the specified torque, then tighten the delivery line unions and the leak-off line banjo bolts to the specified torque.

8. Tighten the oil seal nuts to the specified torque and reclamp any loosened delivery lines.

Note: Before replacing the rocker shaft and/or cover, carry out the "Injector Leak-Off Rail Pressure Test".

9. Install the pushrods into the same positions as when removed. Position the rocker shaft assembly, locating the adjuster ball ends into the push rod cups, and gradually and evenly tighten the retaining bolts to the specified torque.

10. Adjust the valve clearances.

11. Pressure test leak-off unit.

12. Replace the rocker cover with a new gasket and tighten screws to the specified torque value.

13. Replace the engine breather pipe.

INJECTOR LEAK-OFF RAIL - PRESSURE TEST

The injector leak-off rail should be pressure tested whenever it is refitted to the engine or if dilution of the engine lubrication oil by fuel oil is suspected.

1. Disconnect the battery.
2. Remove the external leak-off line banjo connection at the rear of the cylinder head and install a single outlet banjo connection securely in its place (Fig. 15).
3. Connect a cooling system pressure tester to the banjo connection and pressurize the leak-off rail to 10 lb/in^2.

   If the pressure remains constant for 10 seconds or longer, the system is satisfactory - proceed to operation No. 8.

   If the pressure cannot be maintained or begins to drop in less than 10 seconds, a leak is indicated - continue with operation No. 4.
4. Check and eliminate the external connections and the pressure tester as the source of leak.
5. Recheck and, if the leak persists, remove the rocker cover for access to the leak-off rail and the injectors.
6. Inspect the leak-off rail and connections for damage and security. If the rail is cracked or split, fit a new rail. If the leak is from a banjo connection to an injector, remove the banjo bolt, check the bolt and banjo faces for scoring or damage and renew or rectify as required.

Note: The leak-off rail banjo's are made from a soft material designed to eliminate the need for sealing washers between the faces and the banjo bolts. This material is easily scored and leakages can result.

7. Recheck and when the test pressure can be maintained satisfactorily, install the rocker cover, using a new gasket.
8. Remove the pressure test equipment and the banjo connection. Refit the external leak-off line and tighten the banjo bolt securely.
9. Reconnect the battery.

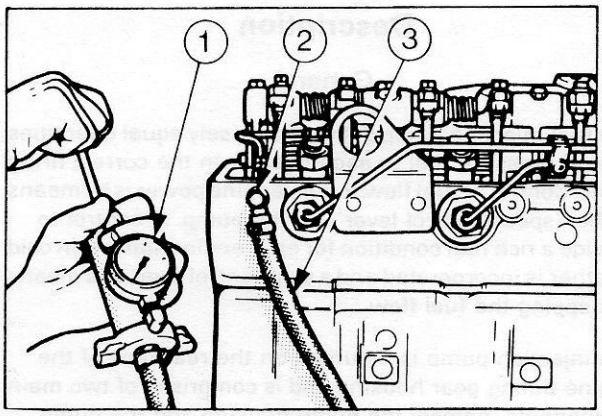


Fig. 15 - Pressure Testing the Leak-Off Rail

1. Cooling System Pressure Tester
2. Suitable Banjo Connector
3. Connecting Hose

FUEL INJECTION PUMP

Introduction

Two types of fuel injection pumps are used with the Dover range of engines. Those with general purpose governing are lubricated by a pressure fed system, the oil feed being taken direct from the engine oil fitler head; the oil return to the engine is via a drilling in the pump mounting flange which communicates with the engine timing gear case. The drive gear on these pumps has slotted holes to provide fine timing adjustment.

Injection pumps with Class "A" or close regulation governing do not have an external oil feed, lubrication being by means of an oil filled cambox. The drive gear on these pumps is not adjustable with respect to the hub, fine timing adjustment being obtained by means of slotted holes in the pump mounting flange which enable the complete pump to be rotated slightly.

Apart from the differences outlined, the two types of injection pump are very similar in construction. The following descriptive text, although written specifically for the general purpose governed pump, covers both types; where any significant differences occur, they will be dealt with in the text.

Description

General

The fuel injection pump delivers precisely equal quantities of high pressure fuel to each injector in the correct firing order. Control of fuel flow to vary engine power is by means of the "speed control lever" on the pump. A control to provide a rich fuel condition for easy engine starting in cold weather is incorporated and a stop control lever as a means of stopping the fuel flow.

The injection pump is mounted on the rear face of the engine timing gear housing and is comprised of two main components, namely the pump housing and the pump body. The light alloy housing encloses and supports a multi-lobed camshaft and associated tappets which operate spring loaded pumping plungers called "elements" The elements, one for each engine cylinder, are contained in the steel pump body mounted on the housing. The governor control mechanism is housed in the forward section of the pump housing.

Pumping Section

Camshaft and Drive Gear:

The camshaft is supported in two tapered roller bearings. Forward of the front (No. 1 cylinder) cam, the shaft is flanged to attach the governor weight carrier.

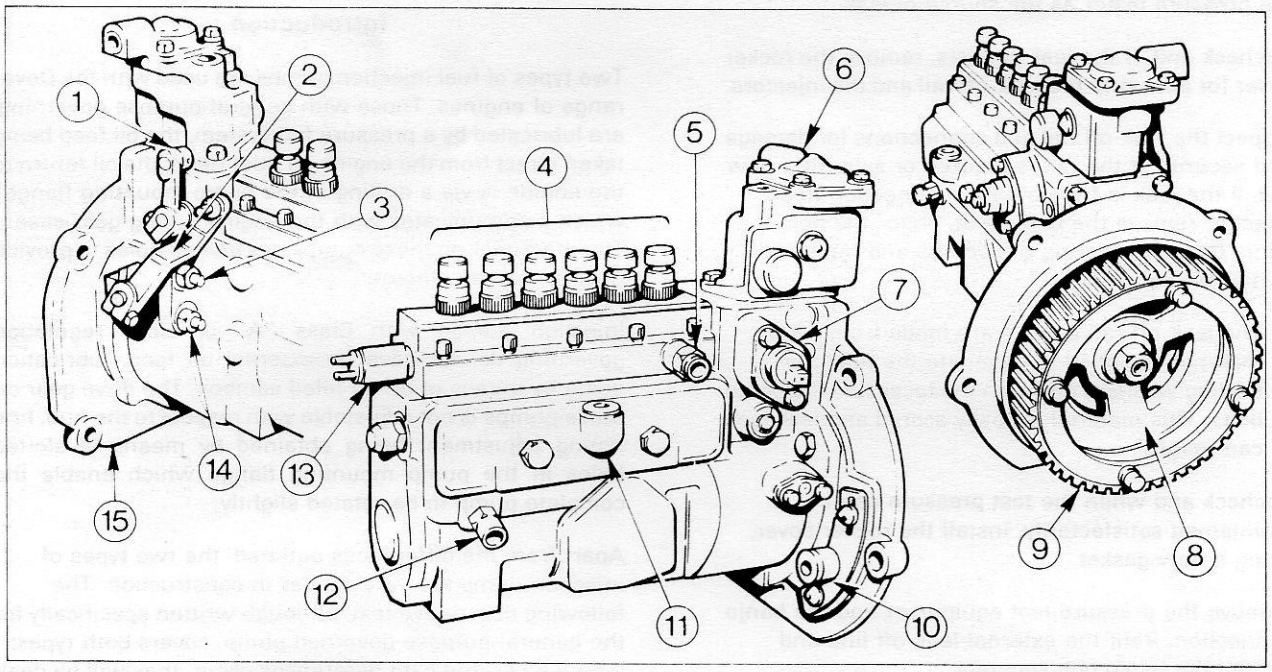


Fig. 16 - CAV Fuel Injection Pump (Turbocharged General Purpose Governed Type Shown)

1. Stop Control Lever
2. Speed Control Lever
3. Idle Speed Stop
4. Delivery Valves
5. Fuel Gallery Airbleed
6. Boost Control Unit (Turbo Only)
7. Excess Fuel Solenoid
8. Drive Hub
9. Drive Gear Ring
10. Timing Tool Adaptor
11. Oil Fill Plug (Initial Fill Only)
12. Pressure Oil Feed Connection
13. Fuel Inlet
14. Maximum Speed Stop
15. Mounting Flange

The forward end of the shaft is tapered, keyed and threaded to mount and secure a drive hub. On governed pumps, a ring gear is bolted to the hub via elongated holes which permits gear adjustment during pump timing.

On Class "A" and close regulating governed pumps, the drive hub and gear are in one piece.

A timing tool adaptor is installed on the outer face of the pump mounting flange; a threaded plug normally closing the opening. During pump installation a special tool is fitted with a plunger which locates in a hole in the drive hub. When so aligned, the No. 1 plunger inlet port has "just closed", indicating the injection timing positions.

Tappets:

Hardened steel tappets operate in plain bores in the pump housing. Each tappet embodies a hardened steel roller fitted on a floating steel bush and pin. A flat is machined on the upper outer diameter of each tappet body to allow the tappets to be radially positioned with an "E" shaped locating plate ("T" shaped on Class "A" and close regulating governed pumps). This arrangement allows the tappets to reciprocate while maintaining the roller in correct alignment with the cam lobes.

Each tappet body is fitted with a snap ring retained "phasing spacer". The spacers are available in varying thicknesses to provide a means (during pump calibration only) of adjusting the plunger "phase angles" i.e. the angle of camshaft rotation between secccissive injections.

Lubrication - General Purpose Governed Pumps

The camshaft, bearings, tappets and governor flyweights are lubricated by engine oil from a tapping on the engine oil filter/cooler assembly. The oil enters the pump via a metering adaptor fitted on the side of the pump housing. A knife edge type oil seal is fitted on the governor front cover to prevent oil draining through the front bearing. This creates an oil bath in the housing up to an overflow drain hole in the front cover through which the oil returns to the engine system.

Lubrication - Class "A" Close Regulating Governed Pumps

The cambox and governor housing are kept filled with lubricating oil to the correct level by means of the filler and level plugs. Fuel oil leakage past the pumping plungers mixes with the libricating oil, necessitating regular oil changing. A drain plug is provided for this purpose.

Pump Elements (Figs 17 and 18)

Each pump element includes a pump plunger, its cylinder barrel and a delivery valve. The elements are contained in the steel pump body fitted on the upper section of the pump housing.

The plungers and barrels are produced as very accurately machined and graded "pairs" to produce a close sliding and leak free fit. The upper side of each barrel is drilled at different levels with an (upper) "inlet" port and a (lower) "spill" port. A master serration locates the barrels radially to ensure correct relationship with a helical groove in the plungers.

The area surrounding the barrel ports is formed into a "fuel gallery" which interlinks all the barrels and is fed with fuel from the engine mounted filter(s). To provide a self clearing air bleed, an outlet to the tank is permitted via a restrictor and a disc valve. The restriction ensures that an adequate supply of fuel is always maintained in the gallery and the valve prevents fuel syphoning back to the tank during non-running periods.

A circular diaphragm type of pulsation damper is fitted on the side of the pump body of naturally aspirated engines where automotive or G.P. governing is employed. The damper is connected to the fuel gallery to assist smoothing out fuel pressure fluctuations caused by the interval between successive injections.

Plungers:

Each plunger is an accurately machined and ground rod with an arm fitted to its lower end to affect partial rotation. A deep annular groove on the mid length of the plunger connects with a shallow spiral on the upper length surface. Any leakage between the plunger and barrel is "collected" in the annular groove and passed back to the fuel gallery via the spiral. Coil springs between the pump body and a spring seat on the plunger stem maintain the plungers in contact with the tappets.

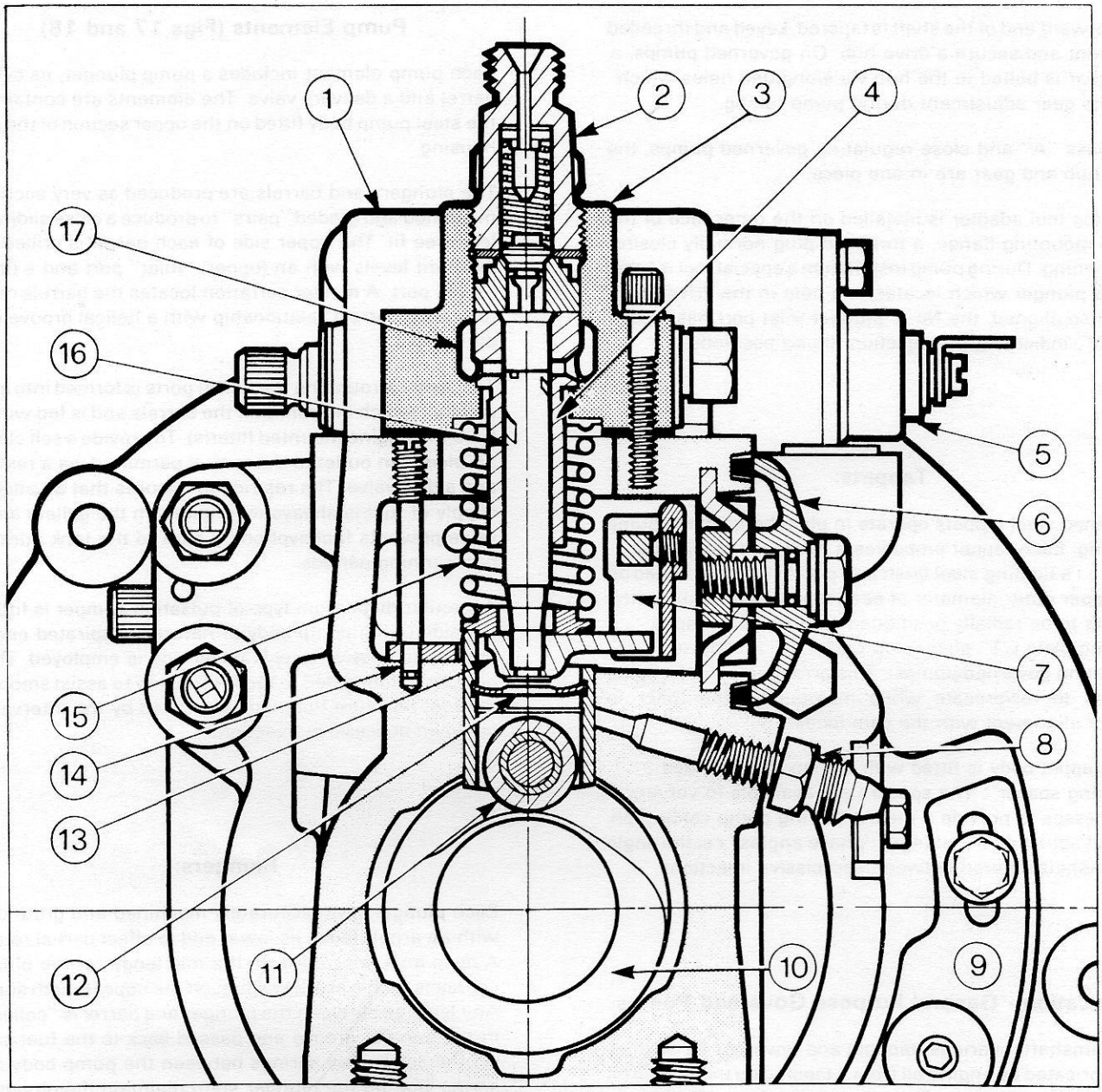


Fig. 17 - Sectional View of Injection Pump (General Purpose Pump)

1. Pump Housing
2. Delivery Valve Holder
3. Pump Body
4. Barrel
5. Excess Fuel Solenoid (G.P. Governed Pumps Only)
6. Side Cover
7. Control Fork
8. Oil Metering Adaptor
9. Timing Tool Adaptor Plate
10. Camshaft
11. Tappet Roller
12. Phasing Spacer
13. Plunger Control Arm
14. Tappet Locating Plate/Screw
15. Plunger Spring
16. Plunger
17. Fuel Gallery

A helically shaped groove is machined in the upper side of the plungers and connected by a drilled hole to a central drilling in the crown. As the plunger(s) move upward during their delivery stroke, fuel will be pressurized until the helical groove contacts the spill groove. The radial positioning of the groove in relation to the port thus determines the effective stroke of the plungers.

Radial movement is affected by the arm attached to the lower end of each plunger. The outer end of the arms locate in the "forks" which are locked onto a control rod. The open sided, box type fords permit the plunger arms to reciprocate during pumping. Any backward or forward movement of the control rod (through action of the governor mechanism) is therefore transmitted simultaneously to all plungers. The movement ranges from fuel cut-off through maximum to an "excess fuel" position.

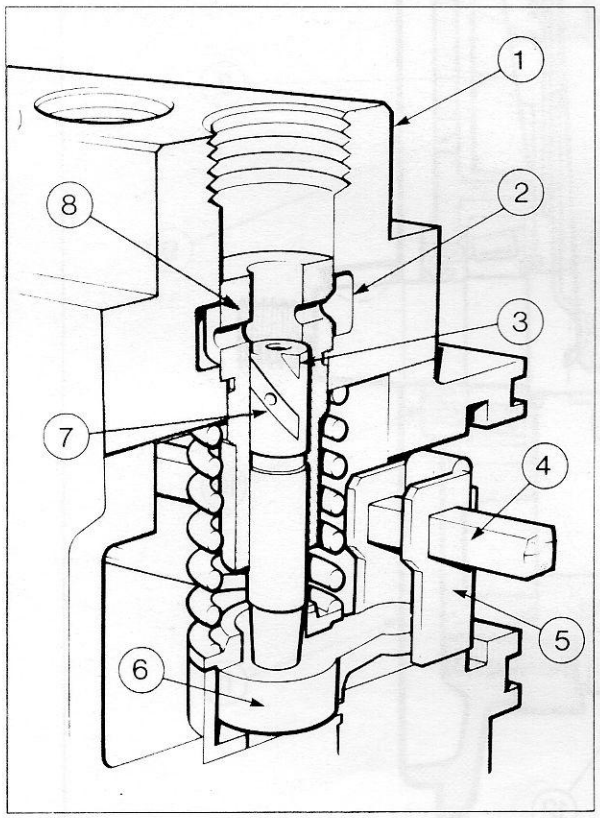


Fig. 18 - Pump Element Arrangement

1. Pump Body
2. Fuel Gallery
3. Starting Groove
4. Control Rod
5. Control Fork
6. Plunger Arm
7. Fuel Metering Groove
8. Barrel

The edge of each plunger crown incorporates a "starting groove". The groove is operative only when the plungers are in the excess fuel position and functions by delaying the point at which the inlet port closes. This retards the point (in terms of piston position) at which fuel pressure is sufficient to cause injection. As the engine accelerates to idle speed the governor/control rod mechanism repositions the plungers to nullify the starting groove and excess fuel position.

Delivery Valves (Fig. 19)

These valves are contained in the "delivery valve holders" which form the outlet of each element. The valves fulfill three functions:

a. Prevent delivery line draining during the plungers intake stroke.

b. Assist pressure build up during injection stroke.

c. Cause rapid pressure reduction in injection line at end of delivery.

Each valve is basically a poppet valve with a fluted stem sliding in a guide. A small piston land formed between the valve face and guide flutes is an accurate fit in the guide. As the plunger opens the barrel port at the end of the delivery stroke, the valve piston first "plugs" the guide bore. Further downward movement increases the volume above the piston by an amount equal to the pistons movement. This action allows the delivery pipe pressure to fall very rapidly (much quicker than by conical valve only) to effect "dribble free" closing of the injector.

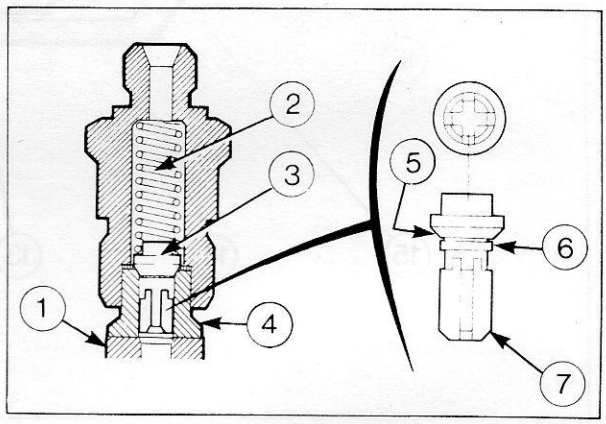


Fig. 19 - Delivery Valve Detail

1. Barrel
2. Spring
3. Delivery Valve
4. Valve Guide
5. Conical Seat
6. Piston
7. Flutes

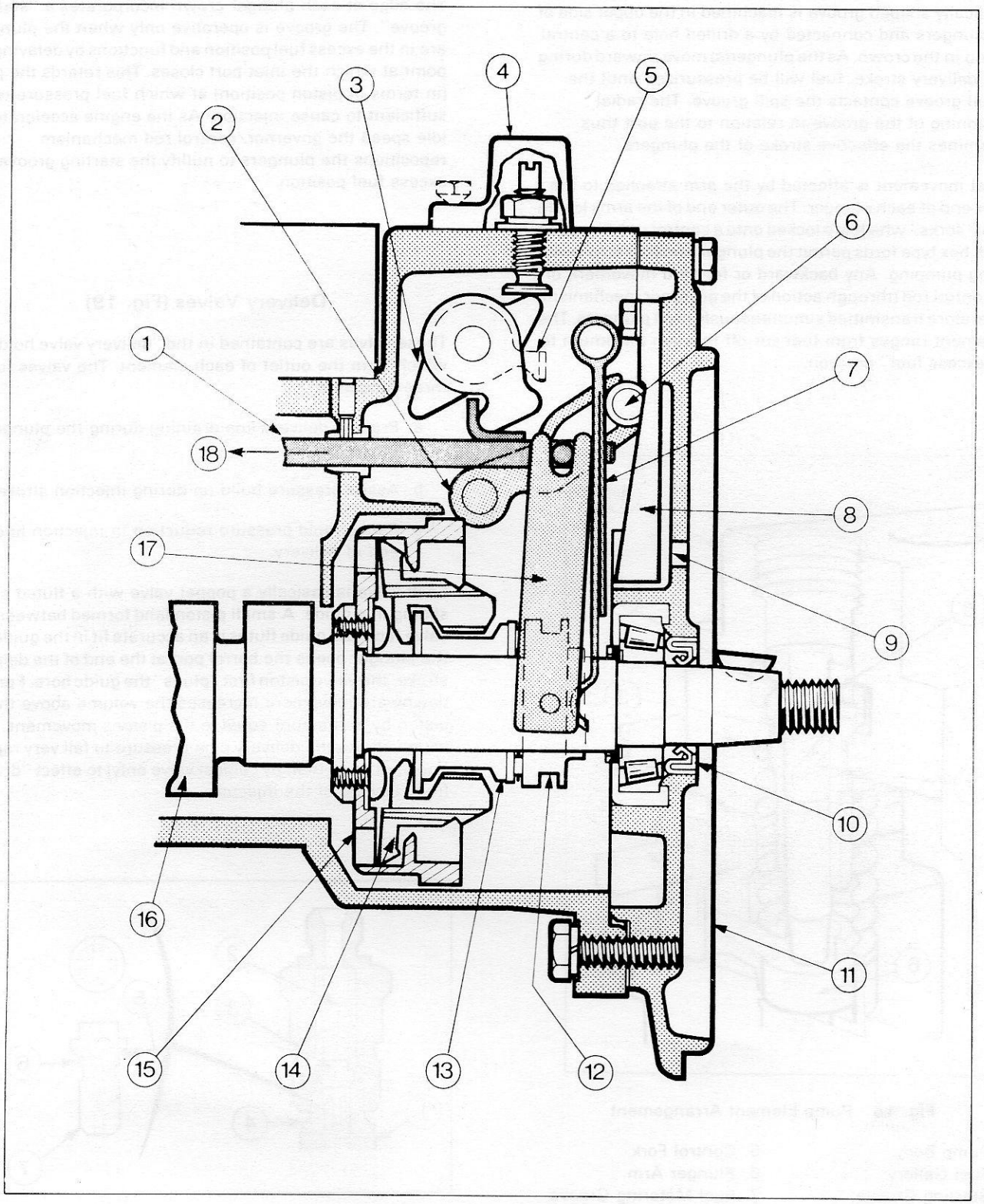


Fig. 20 - Governor Assembly Schematic

1. Control Rod
2. Roller Control Lever Moved By Speed Control Lever
3. Maximum Stop Lever
4. Maximum Fuel Stop (NA Engines)
5. Stop Control Lever
6. Roller
7. Governor Spring
8. Ramp
9. Oil Level Hole
10. Oil Seal
11. Cover (Mounting Flange)
12. Thrust Pad
13. Sleeve
14. Flyweights
15. Carrier
16. Camshaft
17. Rocking Lever
18. Direction for Minimum Fuel

Governor Section (Fig. 20)

The governor assembly maintains accurate and sensitive control of the engine speed for any given throttle setting and co-ordinates demands for starting and stopping the engine. The assembly is located at the front end of the injection pump housing and enclosed by the pump mounting flange.

The governor consists of a flyweight mechanism operating in opposition to a throttle lever tensioned spring. A carrier for the flyweights is secured onto a flange of the pump camshaft with four screws.

Six steel flyweights (four on Class "A" and two on close regulating governed pumps) are positioned in the carrier, with their inner arms located behind a thrust washer and spool shaped sleeve. Forward of the sleeve a grooved thrust pad is separated from the sleeve by a needle roller race and a thrust washer. The legs of an inverted "U" shaped governor leaf spring press against the thrust pad. The spring is pivoted on a spindle at the top of the casing and is positioned vertically in close relationship to a ramp on the governor casing front cover.

The throttle control shaft passes through both sides of the governor housing with the speed control lever clamped to one end. Internally, the shaft mounts a forked lever which passes through the legs of the governor leaf spring and carries a dumb bell shaped roller. Movement of the control shaft causes the roller to move up or down the inclined ramp. The movement changes the governor spring force in relation to the position of the thrust pad.

A rocking lever translates the position of the thrust pad into pump plunger control rod position. The lever is pivoted to the side of the governor housing, a pin in the lower end fitting into a groove of the thrust pad. The upper end is attached to the control rod by a sliding fork and pin.

Control Rod and Associated Equipment (Figs. 20 and 21)

The control rod to which the pumping plunger control forke are attached is supported in two bushes. The forward bush is mounted in the governor to pump housing dividing wall and the rear bush in an end cover in the pump housing rear wall. On some engines, the bush is incorporated in an idling speed damper, fitted in place of the end cover.

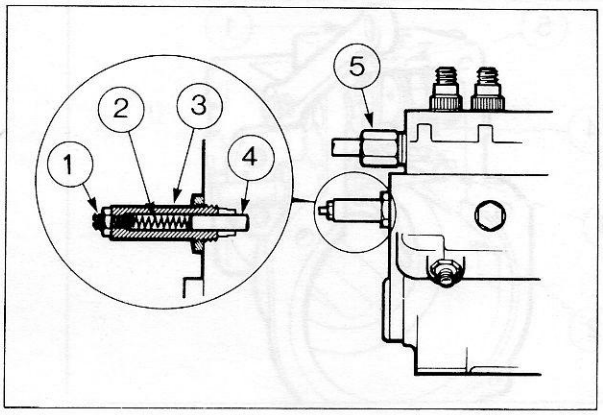


Fig. 21 - Control Rod Idling Damper

1. Adjustment Screw
2. Spring
3. Bush Retainer
4. Control Rod and Bush
5. Fuel Inlet Connection

The idling speed damper comprises an adjustable spring "buffer" for the control rod. This prevents the rod moving past the idling position into a no-delivery position during a rapid deceleration.

A bracket is riveted to the control rod where it operates in a the governor section of the pump. The bracket has two functions:

1. To relate the position of the control rod to the camlike maximum (fuel) stop lever. (This "lever" is mounted on a cross shaft in the upper section of the casing).

2. To provide the point of leverage through which the stop control lever can move the control rod rearward into a "no-delivery" position.

Engine Stop Control

A stop control lever is fitted on the engine facing side of the pump and operated by a cable or other form of linkage.

The lever controls an internally spring loaded shaft on which a camlike stop control lever is fitted. When operated, the lever pushes on the control rod bracket to rotate the pump plungers into a "no-delivery" condition. As the control is relaxed, an externally mounted spring returns the lever to the run position and the governor spring returns the control rod to the selected fuel position.

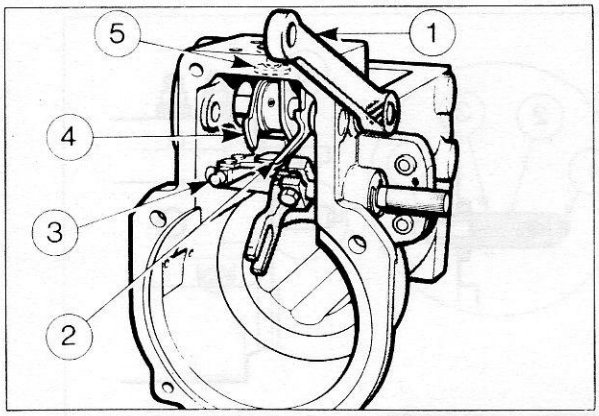


Fig. 22 - Engine Stop Control

1. External Stop Control Lever (in Stop Position)
2. Stop Control Lever in Pump
3. Control Rod
4. Maximum Stop Lever
5. Maximum Fuel Stop

Excess Fuel Device

This device is a means of overriding the maximum fuel stop so that the control rod can be moved into an "excess" fuel condition.

On Class "A" and close regulating governed pumps, the device takes the form of a push button situated on the outside of the governor housing. To select excess fuel, the button is depressed while moving the speed control lever to the maximum speed position. When the speed control lever is returned towards the idling speed position, the excess fuel button is released automatically, thus returning the control rod to a normal fuel condition. An additional unit enables the excess fuel device to be operated from a remote position automatically.

On general purpose governed pumps, the device consists of a solenoid which, when operated, pulls the maximum (fuel) stop lever clear of the control rod bracket. Operation during starting depends on whether or not the "excess fuel temperature switch" contacts are closed (Fig. 23). The switch is fitted on the engine thermostat housing to sense the metal temperature (not the coolant temperature). At or below 0 to 8°C (32 to 46°F) the closed contacts will complete a circuit to the solenoid when the starter relay is energized. Moving the speed control lever to the maximum speed position will then cause the control rod to move into the excess fuel position.

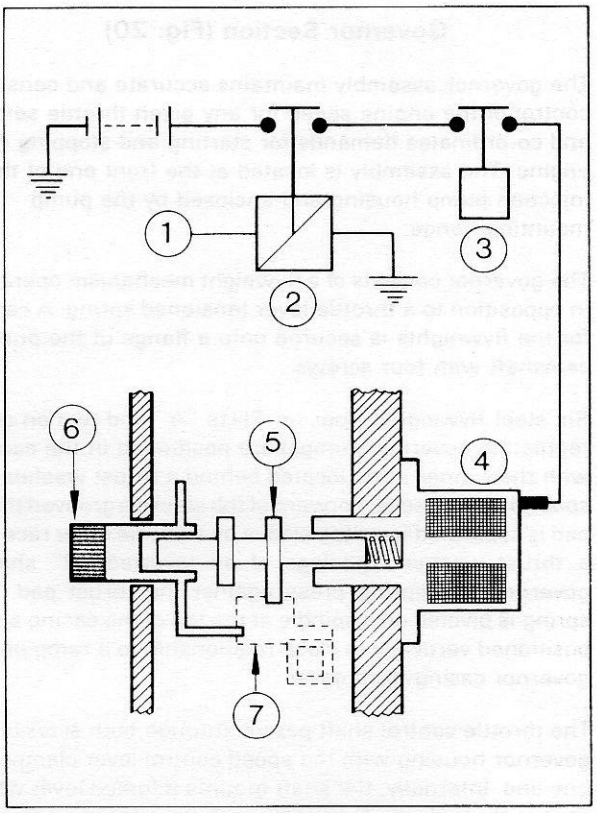


Fig. 23 - Excess Fuel Device Schematic

1. Ignition Switch Contacts
2. Starter Relay
3. Excess Fuel Temperature Switch
4. Excess Fuel Solenoid
5. Maximum Stop Lever
6. Engine Stop Lever Shaft
7. Control Rod Bracket

Boost Control Unit - Turbocharged Engines Only

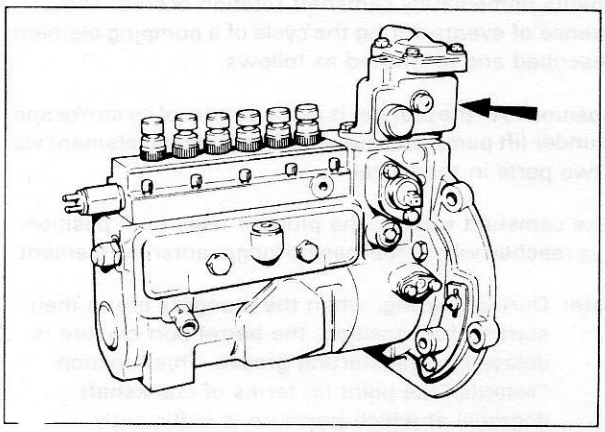


Fig. 24 - Boost Control Unit

This unit prevents overfueling during acceleration in the low turbocharger speed range by controlling fuel flow in relation to manifold air pressure.

Bolted to the top of the pump governor (Fig. 24), the unit functions as a variable position maximum fuel stop. The casing is divided into two chambers, the upper containing a spring loaded piston type diaphragm assembly. A cover plate encloses the diaphragm and is connected by sensing pipeline to the intake manifold.

As illustrated in Fig. 25, a central rod is connected to the diaphragm and passes through a guide bush in the casing the lower chamber. The fork end of a camplate is pivoted to the lower end of the rod. The opposite end of the camplate is enclosed in a "C" shaped shoe and pivoted into the slotted block of the maximum fuel adjuster. This second pivot is so positioned to create a small lever between the pivot and the center line of the block. A maximum fuel stop rod is fitted in the casing as shown. The rod is a free floating relay between the "C" shaped shoe and the maximum fuel stop lever in the governor casing.

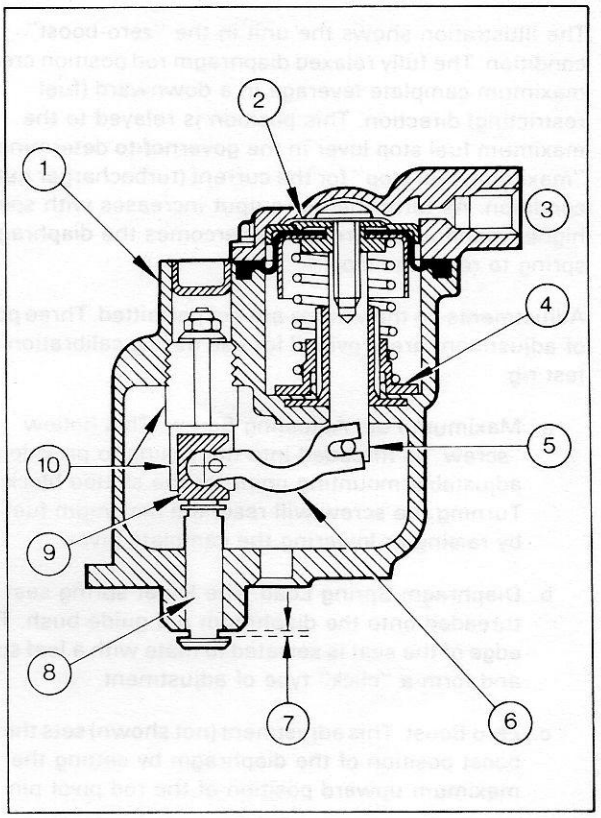


Fig. 25 - Boost Control Unit Semi-Schematic

1. Casing
2. Diaphragm and Piston Assembly
3. Air Connection
4. Spring Seat (Adjuster)
5. Rod
6. Camplate
7. Effective Movement of Rod
8. Fuel Stop Rod
9. Shoe
10. Maximum Fuel Adjuster and Slotted Block

The illustration shows the unit in the "zero-boost" condition. The fully relaxed diaphragm rod position creates maximum camplate leverage in a downward (fuel restricting) direction. This position is relayed to the maximum fuel stop lever in the governor to determine the "maximum fuel stop" for the current (turbocharger output) condition. As turbocharger output increases with speed, higher manifold air pressure overcomes the diaphragm spring to reset the stop.

Adjustments on the vehicle are not permitted. Three points of adjustment are provided for use during calibration on a test rig:

a. Maximum Fuel Adjusting Screw. This hollow "screw" is threaded into the casing to provide an adjustable mounting point for the slotted block. Turning the screw will reset the maximum fuel stop by raising or lowering the camplate pivot.

b. Diaphragm Spring Load. The lower spring seat is threaded onto the diaphragm rod guide bush. The edge of the seat is serrated to mate with a leaf spring and form a "click" type of adjustment.

c. Zero Boost. This adjustment (not shown) sets the zero boost position of the diaphragm by setting the maximum upward position of the rod pivot pin.

The adjuster is in the form of a thumb operated wheel nut which acts as a pivot stop.

Access to all adjustments is through a side cover plate which is secured by a tamperproof bolt.

Operation

Low Pressure System

Fuel is drawn through the water separator filter (if so equipped) and/or the lift pump filter by action of the lift pump. The pressure forces fuel through the engine mounted filters and pressurizes the injection pump fuel gallery. Pressure in the gallery is maintained by the self-idling action of the lift pump and limited by the relief valve on the engine mounted filter.

During engine running a small constant bleed occurs from the gallery through the restrictor/NRV assembly. The bleed, which ensures the clearance of any air in the system is normally connected to the leak-off line from the injectors. On engines with thermostart systems, the gallery bleed supplies the thermostart reservoir. Overflow from the reservoir rejoins the leak-off line to return to the tank.

High Pressure Generation (Fig. 26)

Given that the injection pump shut off lever is in the normal running position, high pressure is developed by the pump elements immediately camshaft rotation occurs. The sequence of events during the cycle of a pumping element is described and illustrated as follows.

At position "A" the plunger is at the bottom of its stroke and fuel under lift pump pressure fills the pumping element via the two ports in the barrel.

As the camshaft rotates, the plunger rises until position "B" is reached where fuel can no longer enter the element.

Note: During starting, when the plungers are in their starting fuel position, the barrel port closure is delayed by the starting groove. This function "retards" the point (in terms of crankshaft degrees) at which pressure is sufficiently developed to cause injection. Further upward movement of the plunger compresses the fuel and begins to lift the delivery valve off its seat.

When the fuel pressure is sufficient to lift the delivery valve completely off its seat and the piston is clear of its guide (position "C"), fuel passes along the pipe line to the injector.

The fuel pressure developed by the plunger lifts the injector needle valve off its seating and allows fuel in a highly atomized state to be sprayed into the cylinder. Fuel continues to be injected until the plunger reaches position "D" where the helical groove contacts the spill port. At this position the fuel in the pumping chamber dissipates to low pressure via the central drilling and helical groove in the plunger. The reduction in pressure in the element causes the delivery valve to close rapidly.

The sudden reduction in pressure as the delivery valve closes is sufficient to allow the injector needle valve to snap shut under the force of its spring. This prevents fuel dribbling from the injector which would result in carbon build up on the injector tip.

Although the plunger continues to rise to the top of the stroke, the helical groove in the plunger prevents pressure being developed. The cam holds the plunger at the top of its stroke until that particular engine cylinder is on compression stroke again. This prevents the engine running in the reverse direction in the event of a backfire.

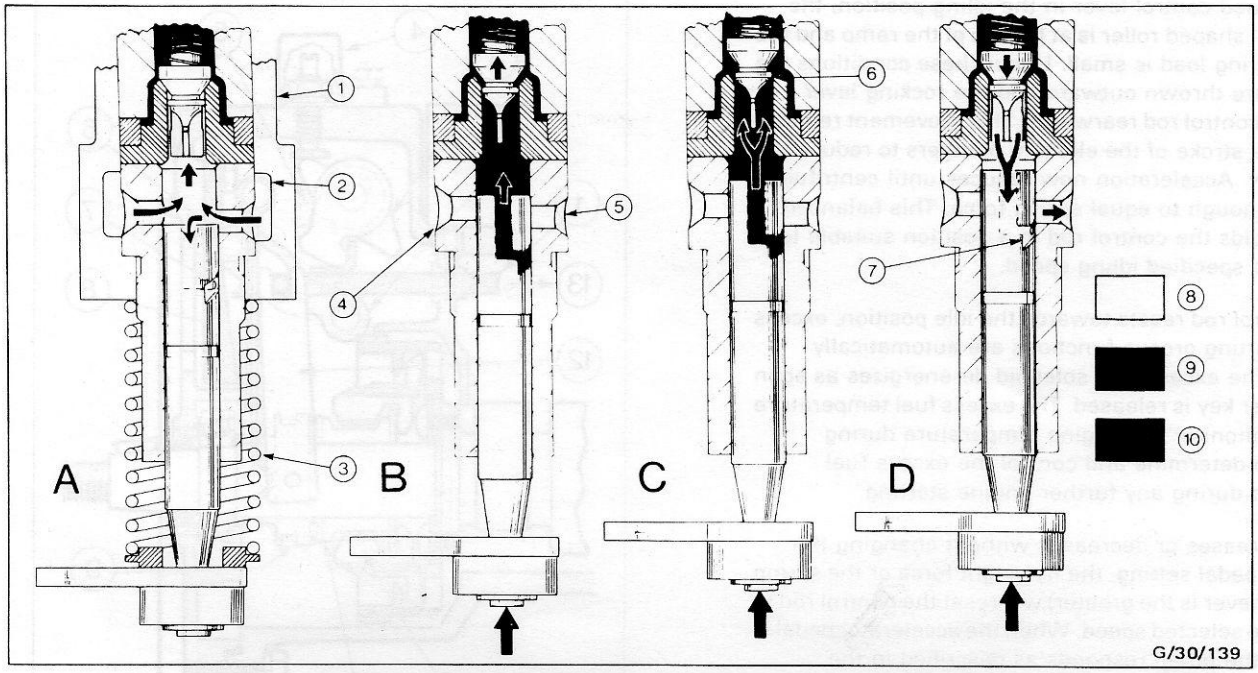


Fig. 26 - Pumping Element Action

1. Pump Body
2. fuel Gallery
3. Plunger Spring
4. Inlet Port
5. Spill Port
6. Delivery Valve Piston
7. Helical Groove
8. Lift Pump Pressure
9. Injection Pressure
10. Delivery Line Residual Pressure

A. Element Filling
B. Inlet Port Shut
C. Injection
D. Spill Port Open

Fuel Control

The mount of fuel injected into the engine cylinders is entirely dependent upon the iffective stroke of the pump plungers, i.e. inlet port closed to spill port open. This can be changed by turning the plungers to a new rotary position in their barrels, thereby altering the helical groove position in relation to the spill port.

The plungers are rotated in their barrels by means of arms attached to the base of each plunger, which in turn engage into forks on the control rod. Causing the control rod to move forward increases the effective stroke, whilst moving it rearwards decreases the stroke. The control rod is connected to the governor by a rocking lever, so that movement of the flyweights alters the volume of fuel delivered and thus controls the engine speed.

Since the governor flyweight force is opposed by the governor spring force, fuel delivery (and therefore engine speed) will be constant when the two forces are equal.

Static to Idling Speed (Fig. 27)

Before starting the engine and without any depression of the accelerator pedal, the governor flyweights will be fully closed and the plunger control rod will be in the maximum fuel position.

In cold weather conditions where the engine temperature is at or below 0 to 8°C (32 to 46°F) the excess fuel device should be operated. Where an automatic excess fuel device is fitted, the temperature switch will energize the excess fuel solenoid when the starter motor engages. In the pump this moves the maximum stop lever clear of the control rod bracket. Depression of the accelerator pedal will then cause the rod to move into the excess fuel position. This device is assisted by the starting groove on the plungers which together function to deliver a high volume supply at a retarded piston position.

As the engine starts and accelerates, governor flyweight centrifugal force increases. (At this point, the accelerator pedal should be released to idle, or acceleration will continue to maximum speed.)

With the speed control lever in the idling position, the "dumb-bell" shaped roller is at the top of the ramp and the governor spring load is small. Under these conditions the flyweights are thrown outward and the rocking lever pushes the control rod rearwards. This movement reduces the effective stroke of the element plungers to reduce the fuel quantity. Acceleration now reduces until centrifugal force falls enough to equal spring force. This balanced condition holds the control rod in a position suitable to result in the specified idling speed.

As the control rod resets towards the idle position, excess fuel and starting groove functions are automatically cancelled. The excess fuel solenoid de-energizes as soon as the starter key is released. The excess fuel temperature switch will monitor the engine temperature during operation to determine and control the excess fuel requirement during any further engine starting.

If speed increases or decreases without changing the accelerator pedal setting, the flyweight force or the spring force (whichever is the greater) will reset the control rod to maintain the selected speed. When the accelerator pedal is depressed, the pump responds as described in the following text for maximum speed.

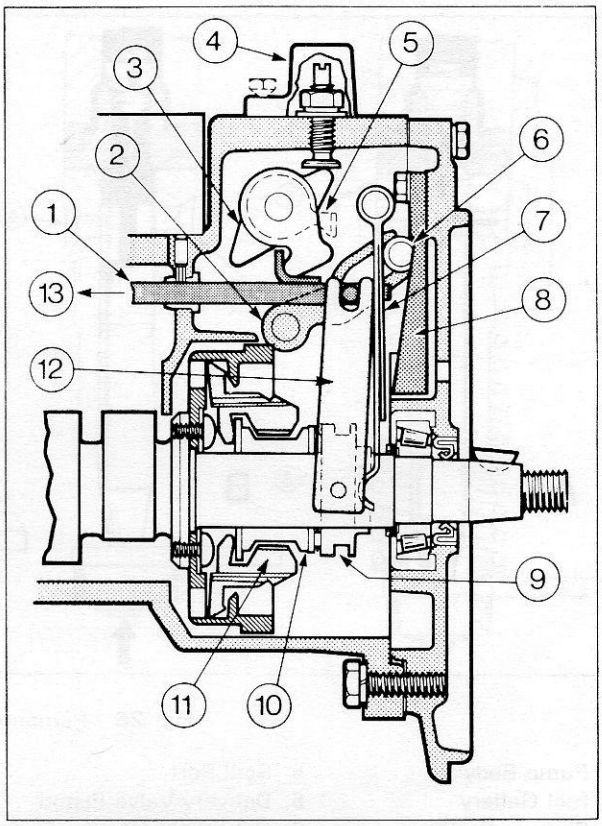


Fig. 27 - Governor Assembly

1. Control Rod
2. Roller Control Lever - Moved By Speed Control Lever
3. Maximum Stop Lever
4. Maximum Fuel Stop (NA Engines)
5. Stop Control Lever
6. Roller
7. Governor Spring
8. Ramp
9. Thrust Pad
10. Sleeve
11. Flyweights
12. Rocking Lever
13. Direction for Minimum Fuel

Maximum Speed

Moving the speed control lever to the maximum position causes the roller to move down the ramp to increase governor spring load. The spring load is then sufficient to overcome the centrifugal force of the governor weights and move the sleeve and thrust pad along the camshaft.

This motion is transmitted to the control rod by the rocking lever which pulls the rod forwards, increasing the volume of fuel injected with subsequent rise in engine speed. The maximum fuel position is reached when the control rod bracket contacts the maximum fuel stop in the top of the governor housing. (On turbo-charged engines the lever contacts the fuel stop rod in the boost control unit.)

Should the engine speed continue to increase when the control rod has reached this position, the centrifugal force of the governor weights will overcome the spring load and move the sleeve and thrust pad along the camshaft. The rocking lever will then push the control rod to reduce the volume of fuel delivered until engine speed falls.

The engine speed is therefore at all times porportional to the governor spring load, enabling accurate and sensitive speed control to be maintained throughout the engine speed range.

Servicing the Fuel Injection Pump

The complete dismantling, overhauling, assembling and testing injection pumps is to be performed by a qualified Fuel Injection Equipment repair shop. Consequently, the following information covers only removal, replacement and timing of the injection pump plus checks and adjustments that can be made while the pump is mounted on the engine.

Removing the Injection Pump

1. Disconnect the battery and, where fitted, detach the excess fuel electrical connection from the pump.
2. Disconnect the engine stop control cable or linkage and the throttle return spring and linkage.
3. Disconnect all fuel and oil lines from the pump. On turbocharged engines, disconnect the boost control pipe.
4. Remove the pump flange securing bolts and lift out the pump. Fit a suitable blanking plate or cover over the gear housing opening and fit blanking caps or plugs to all open ended lines and connectors.

   If the pump has general purpose governing and is to be renewed, remove the four outer socket headed screws from the pump driving gear and retain the gear ring, plate and screws for fitting to the new pump (Fig. 28). Examine for satisfactory condition and renew parts as necessary.

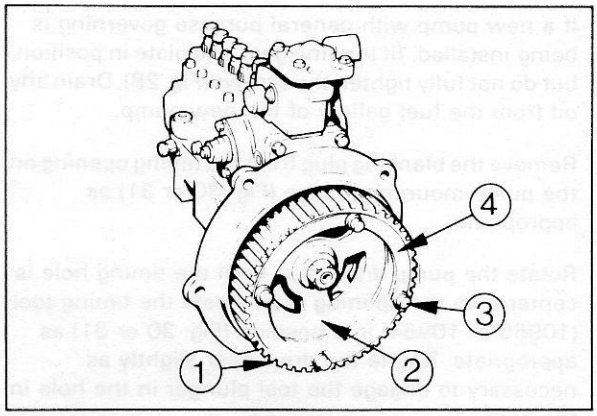


Fig. 28 - Injection Pump Drive Gear - General Purpose Governed Pumps Only

1. Ring Gear
2. Drive Hub
3. Clamping Screws
4. Clamping Plate

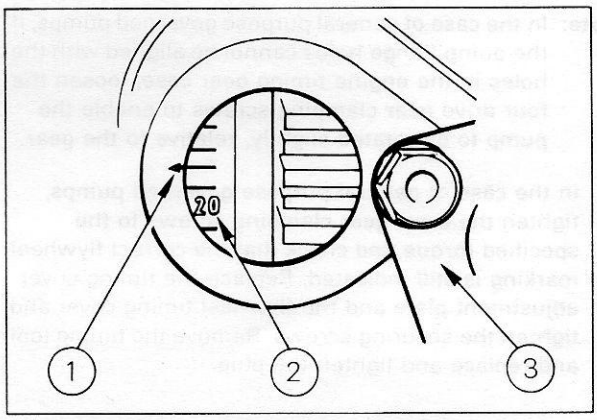


Fig. 29 - Engine Timing

1. Timing Mark on Housing
2. Timing Scale on Flywheel
3. Timing Aperture Cover

Replacing the Injection Pump

1. Remove the timing cover from the flywheel housing and turn the engine in the normal direction of rotation until the specified number of degrees before T.D.C. on No. 1 cylinder is indicated against the timing mark on the edge of the timing opening (Fig. 29). No. 1 cylinder must be on the compression stroke.

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

2. If a new pump with general purpose governing is being installed, fit the ring gear and plate in position, but do not fully tighten the screws (Fig. 28). Drain any oil from the fuel gallery of the new pump.

3. Remove the blanking plug from the timing opening on the pump mounting flange (Fig. 30 or 31) as appropriate.

4. Rotate the pump drive gear until the timing hole is centered in the opening then screw the timing tool (10965 or 10964) into position (Fig. 30 or 31) as appropriate. Rotate the drive gear slightly as necessary to engage the tool plunger in the hole in the gear.

5. On general purpose governed pumps, remove the adjustment cover plate on the front of the timing cover (Fig. 32).

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

Note: In the case of general purpose governed pumps, if the pump flange holes cannot be aligned with the holes in the engine timing gear case, loosen the four drive gear clamping screws to enable the pump to be rotated slightly, relative to the gear.

7. In the case of general purpose governed pumps, tighten the drive gear clamping screws to the specified torque and check that the correct flywheel marking is still indicated. Replace the timing cover adjustment plate and the flywheel timing cover and tighten the securing screws. Remove the timing tool and replace and tighten the plug.

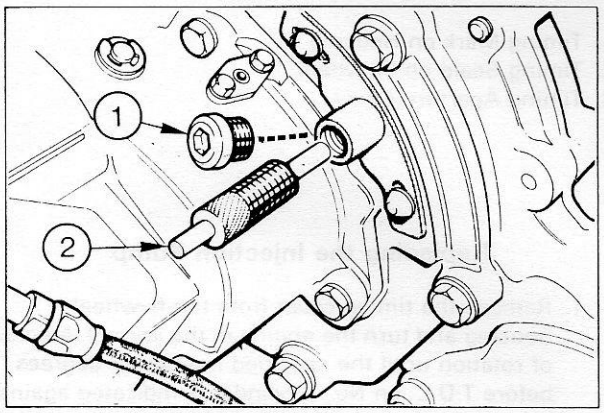


Fig. 30 - Injection Pump Timing - General Purpose Governed Pumps

1. Timing Plug 2. Timing Tool 10965

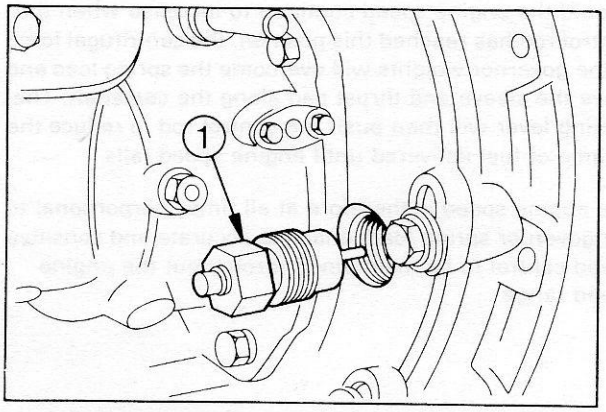


Fig. 31 - Injection Pump Timing - Class "A" and Combine Harvester Governed Pumps

1. Timing Tool No. 10964

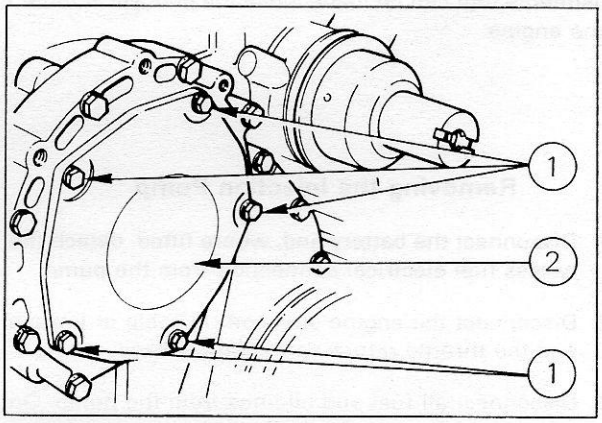


Fig. 32 - Removing Injection Pump Timing Cover Plate - General Purpose Governed Pumps

1. Securing Bolts 2. Cover Plate

8. Connect the high pressure lines, the oil feed line (where applicable) and the fuel inlet line to the pump, tightening the unions to the specified torque figures. On turbocharged engines, reconnect the boost control pipe.

9. Reconnect the throttle cable or linkage and spring and the engine stop control cable or linkage.

10. Where applicable, reconnect the excess fuel electrical connection.

11. On thermostart reservoirs which have been disconnected, reconnect all except the overflow pipe. Where no thermostart(s) are fitted, remove the fuel line from injection pump non-return valve.

12. Prime the system by operating the priming pump until air free fuel flows from the pump non-return valve or thermostart overflow. Install the line.

13. On new pumps with general purpose governing only, remove the oil filter plug and insert the specified quantity of engine oil. Refit and tighten the plug.
14. In the case of Class "A" close regulating governed pumps, remove the oil filler and level plugs and top up with new engine oil as necessary. Install and tighten plugs (Fig. 33).
15. Connect the battery.

Checking/Adjusting the Injection Pump Timing

Carry out operation 1 and 2 under "Replacing the Injection Pump" then proceed as follows:

1. Screw the appropriate timing tool into position. If the pump is correctly timed, the tool plunger will engage in the hole in the drive gear hub. If the tool plunger will not engage, carry out the following operations as applicable:
2. On general purpose governed pumps, remove the adjustment cover plate (Fig. 32) and loosen the four drive gear clamping screws. Rotate gear slightly as necessary until tool plunger engages, then tighten clamping screws to recommended torque value. Check that correct flywheel marking is still indicated. Replace the timing cover adjustment plate and tighten the securing screws (Fig. 32).
3. On Class "A" close regulating governed pumps, slacken injection pump securing bolts and rotate complete pump until tool plunger engages. If necessary, loosen high pressure line clamps to assist pump movement. Tighten pump securing bolts and check that correct flywheel marking is still indicated.
4. Remove timing tool and replace and tighten plug.
5. Replace flywheel timing cover plate and tighten securing screw.

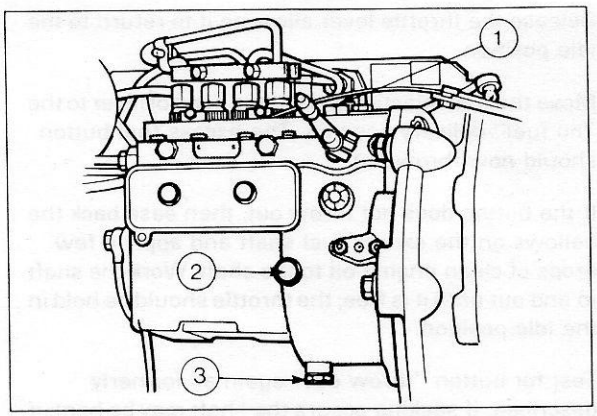


Fig. 33 - Injection Pump Oil Plugs (Class "A" Close Regulating Governing Only)

1. Filler Plug
2. Level Plug
3. Drain Plug

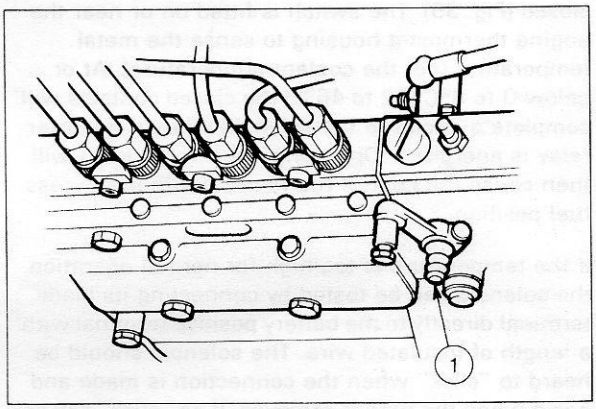


Fig. 34 - Excess Fuel Control - Manual Type

1. Excess Fuel Button

Checks and Adjustments on the Engine

Excess Fuel Operation - Class "A" Close Regulating Governed Pumps with Manual Operation.

1. Move the fuel injection pump throttle lever to the maximum fuel delivery position and hold.
2. Press the excess fuel button (Fig. 34) in until a distinct "click" is heard.

3. Release the throttle lever allowing it to return to the idle position.

4. Move the fuel injection pump stop control lever to the "no fuel" delivery position. The excess fuel button should now throw out.

5. If the button does not throw out, then ease back the bellows on the excess fuel shaft and apply a few drops of clean engine oil to the shaft. Work the shaft in and out until it is free; the throttle should be held in the idle position.

6. Test for button "throw out" again as formerly described. If sticking occurs the shaft may be bent; if so, it must be replaced by a qualified diesel injection repair shop.

   Excess Fuel - Automotive and General Purpose Governed Pumps and Class "A" Close Regulating Governed Pumps with Optional Automatic Operation.

   Operation during starting depends on whether or not the "excess fuel temperature switch" contacts are closed (Fig. 35). The switch is fitted on or near the engine thermostat housing to sense the metal temperature (not the coolant temperature). At or below 0 to 8°C (32 to 46°F) the closed contacts will complete a circuit to the solenoid when the starter relay is energized. Operating the throttle lever will then cause the control rod to move into the excess fuel position.

   If the temperature is too high for normal operation, the solenoid can be tested by connecting its blade terminal directly to the battery positive terminal with a length of insulated wire. The solenoid should be heard to "click" when the connection is made and again when the wire is removed. If no "click" can be heard the solenoid is probably faulty and should be replaced by a qualified diesel injection repair shop.

Idling Speed Adjustment

1. Run the engine until normal operating temperature is reached, then adjust the idling speed stop screw (Fig. 36) to give the idling speed recommended by the equipment manufacturer. Clip the throttle to ensure a consistent return to this setting.

2. Where an idling damper is installed, remove the cover at the front of the pump (Fig. 36), loosen the locknut and unscrew the damper screw approximately five turns.

3. When the idle speed adjustment is completed, screw in the damper screw until it just begins to affect the idling speed, then unscrew it half a turn and tighten the locknut. Replace cover.

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

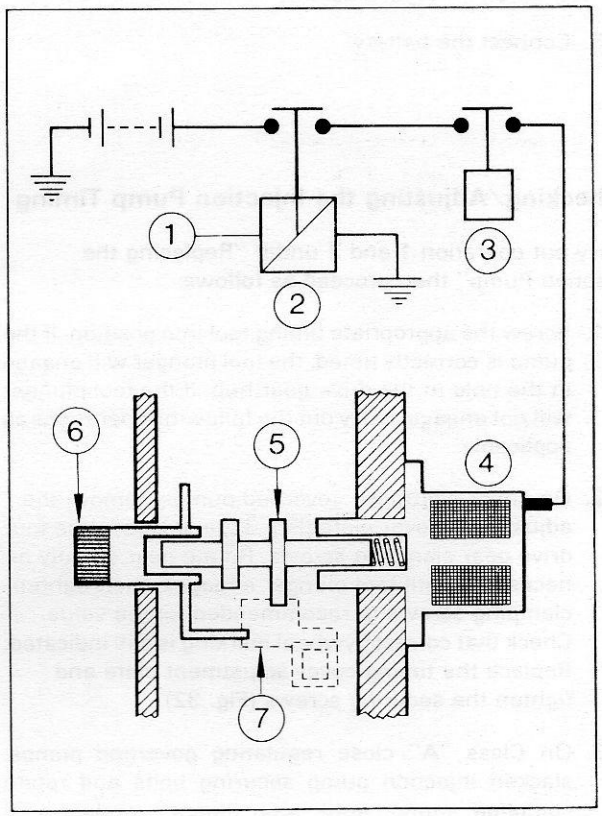


Fig. 35 - Excess Fuel Device Schematic

1. Ignition Switch Contacts
2. Starter Relay
3. Excess Fuel Temperature Switch
4. Excess Fuel Solenoid
5. Maximum Stop Lever
6. Engine Stop Lever Shaft
7. Control Rod Bracket

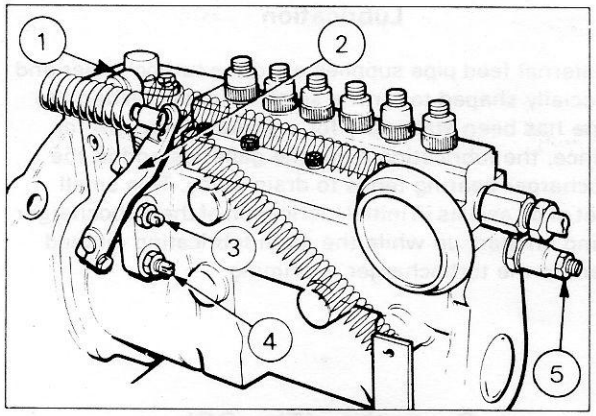


Fig. 36 - Speed Adjustments

1. Stop Control Lever
2. Speed Control Lever
3. Idle Speed Stop Screw
4. Maximum Speed Stop Screw
5. Idling Speed Damper (Cover Removed)

Maximum No-Load Speed Adjustment

1. With the engine running at normal operating temperature, with no load applied, operate the throttle control to hold the governor control lever against the maximum speed stop. Adjust the stop screw (Fig. 36) to give the specified no-load speed.
2. Tighten the locknut and seal the adjusting screw.

TURBOCHARGER

Description

The turbocharger consists of three main sections; the compressor housing, the turbine housing and the central core assembly (Fig. 37).

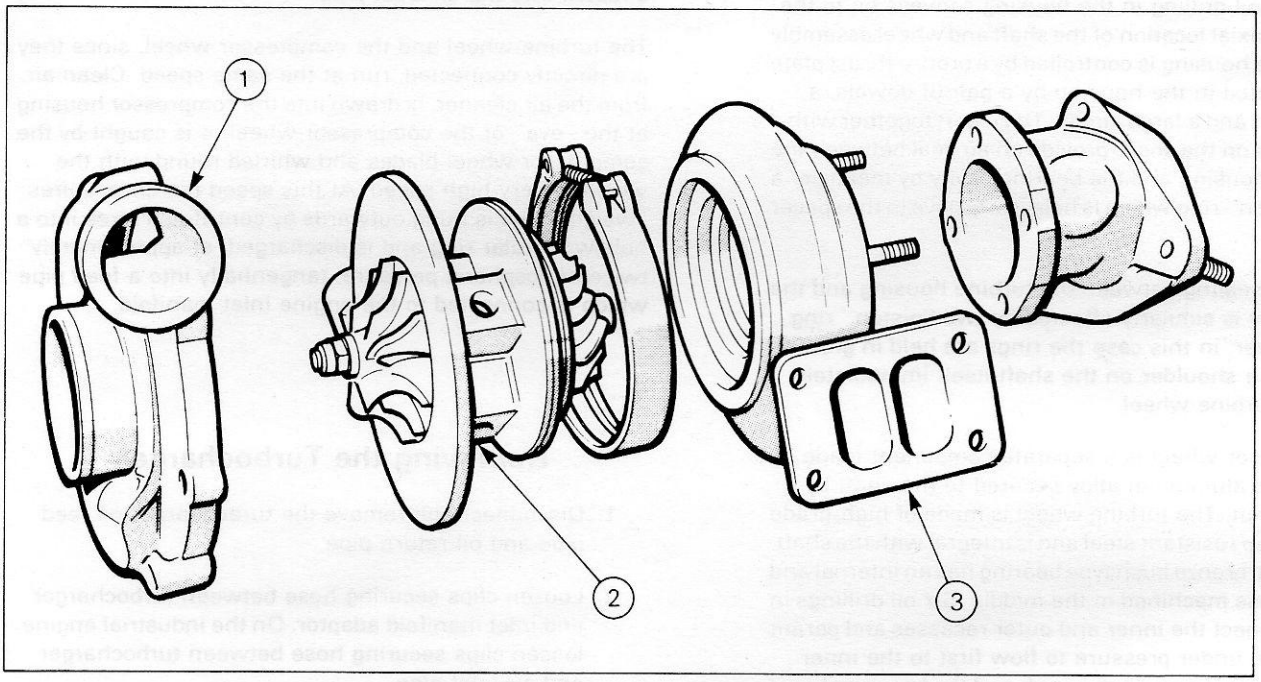


Fig. 37 - Turbocharger Main Assemblies

1. Compressor Housing
2. Center Core (or Rotor) Assembly
3. Turbine Housing

The Compressor Housing

The compressor housing is made of aluminium alloy and is partly machined locally inside to ensure a very close fit around the compressor wheel. This close fit reduces the air leakage back past the compressor wheel to a minimum and contributes to a high volumetric efficiency in the compressor.

The Turbine Housing

The turbine housing is made of high heat-resistant cast iron and is also machined locally inside, like the compressor housing, for close fit with the turbine wheel for high volumetric efficiency.

The Central Core Assembly

The central core contains a finely machined bore for the bearing. Which being fully floating, is a running fit in the housing. An oil drilling in the housing conveys oil to the bearing. The axial location of the shaft and wheel assembly relative to the housing is controlled by a bronze thrust plate which is located in the housing by a pair of dowels, a circular insert and a large circlip. The insert together with a spacer sleeve on the shaft, provide an air seal between the compressor housing and the bearing cavity by means of a sealing "piston" ring which is held in a groove in the spacer sleeve.

Exhaust gas sealing between the turbine housing and the bearing cavity is similarly effected by two "piston" ring seals. However, in this case the rings are held in grooves machined in a shoulder on the shaft itself immediately behind the turbine wheel.

The compressor wheel is a separate component made of high strength aluminium alloy secured to the shaft by a self-locking nut. The turbine wheel is made of high-grade heat and creep resistant steel and is integral with the shaft. The tin-plated bronze bush type bearing has an internal and external recess machined in the middle. Six oil drillings in the bush connect the inner and outer recesses and permit lubricating oil under pressure to flow first to the inner recess and then, between the shaft and the bearing. An oil deflector plate is fitted between the thrust plate and the housing insert to limit the amount of oil leaving the bearing at the compressor end from reaching the compressor "piston" sealing ring. Normally, pressure outboard of the "piston" sealing ring is in excess of the pressure in the bearing housing; except when the air cleaner element is blocked causing increased lubricating oil consumption.

Lubrication

An external feed pipe supplies oil to the turbocharger and is specially shaped to form a small reservoir. When the engine has been stationary for a period, overnight for instance, the lubricating oil in the galleries and in the turbocharger bearing tends to drain away. This small pocket of oil assists in initial lubrication of the turbocharger bearing on start-up while the main lubricating oil feed system to the turbocharger is priming.

Operation (Fig. 38)

The exhaust gases, as they leave the exhaust manifold, enter the turbine housing by a passage cast in the housing, which connects tangentially with a hollow annular ring. The annular ring is of progressively decreasing cross-sectional area and is also part of the casting. The hot gas, still expanding, progresses round this ring and reaches a very high velocity. At this point the gas enters the outer periphery of the turbine wheel and catches the blades of the turbine wheel, driving it round at very high speed. The gas leaves at the center or "eye", of the turbine and is directed into the exhaust pipe.

The turbine wheel and the compressor wheel, since they are directly connected, run at the same speed. Clean air, from the air cleaner, is drawn into the compressor housing at the "eye" of the compressor wheel, it is caught by the compressor wheel blades and whirled round with the wheel at very high speed. At this speed the air acquires "weight" and is flung outwards by centrifugal force into a hollow annular ring and is discharged, at approximately twice atmospheric pressure, tangentially into a feed pipe which is connected to the engine inlet manifold.

Removing the Turbocharger

1. Disconnect and remove the turbocharger oil feed pipe and oil return pipe.
2. Loosen clips securing hose between turbocharger and inlet manifold adaptor. On the industrial engine, loosen clips securing hose between turbocharger and air inlet pipe.
3. Remove nuts securing turbocharger to support plate and detach the exhaust outlet elbow and/or the exhaust pipe. discard gasket(s). Remove turbocharger support plate and bracket from cylinder block.
4. Remove bolts securing turbocharger to exhaust manifold and detach the turbocharger. Discard the gasket. Protect turbocharger from ingress of dirt and foreign bodies until it is overhauled and/or replaced on the engine.

Turbocharger Overhaul - Garrett Airesearch Type

Dismantling

1. Clean the exterior of the assembly before dismantling. Dry clean if possible. DO NOT use any caustic solvents.
2. Carefully mark and also note the position of the housings and backplate relative to the center housing for correct reassembly.
3. Bend back the locktabs, remove the bolts, clamps and lockplates, and separate the compressor and turbine housings from the center housing assembly. If the housings are tight, tap them off with a soft faced hammer.

Caution: Once the housings are removed take extreme care not to damage the compressor or turbine blades. If a turbine or compressor wheel is damaged it cannot be repaired and the wheel must be replaced.

4. Mount the center housing assembly in a suitable fixture to stop the turbine wheel turning. If the nut on the turbine end of the shaft has not been ground off for balancing this may be located in a socket held in a vice. Otherwise manufacture a simple fixture as shown in the illustration (Fig. 39).

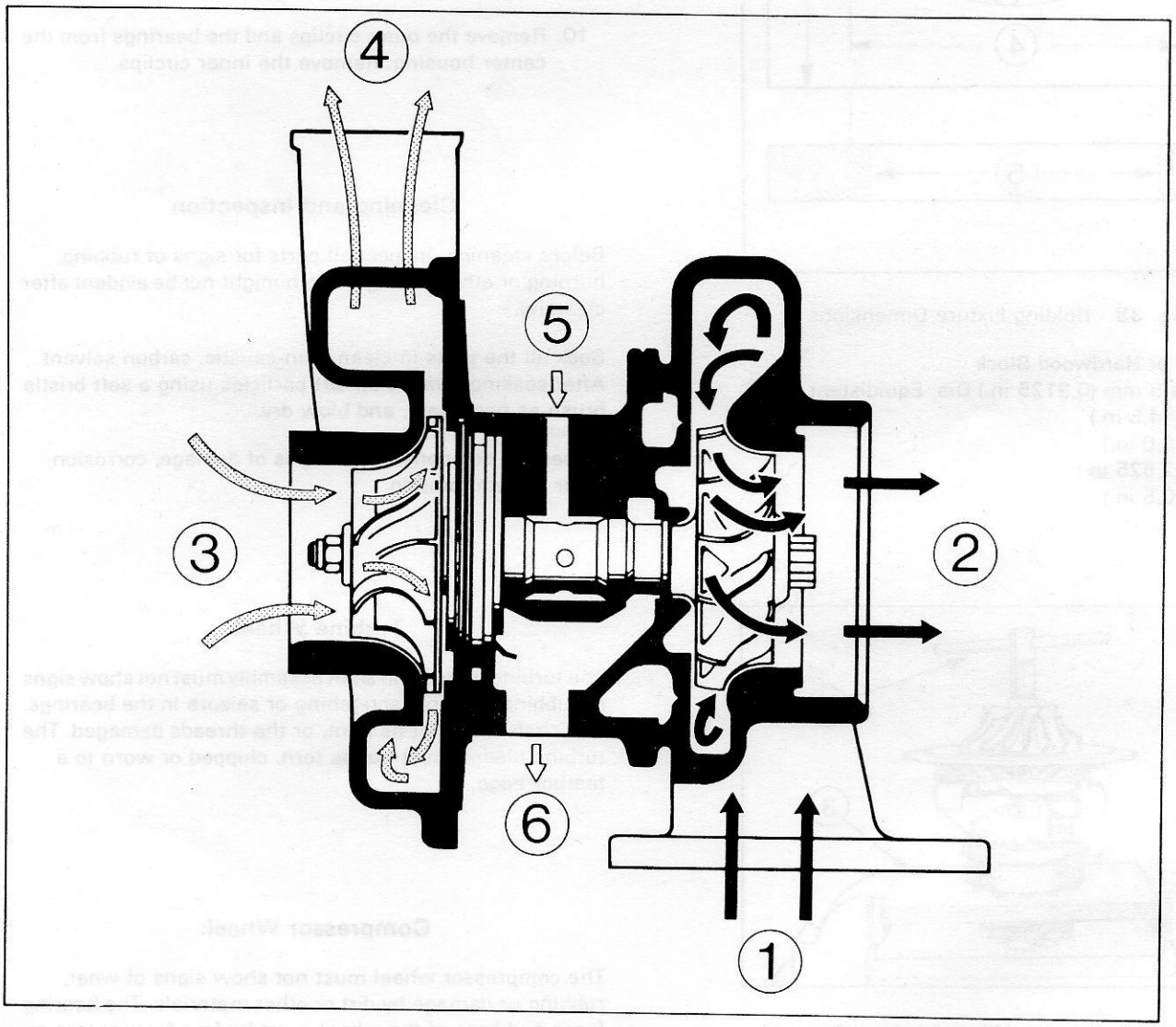


Fig. 38 - Turbocharger Operation

1. Exhaust Gases From Manifold
2. Exhaust Gases to Exhaust Pipe/Silencer
3. Air Inlet
4. Compressed Air to Inlet Manifold
5. Lubricating Oil Inlet
6. Lubricating Oil Drain

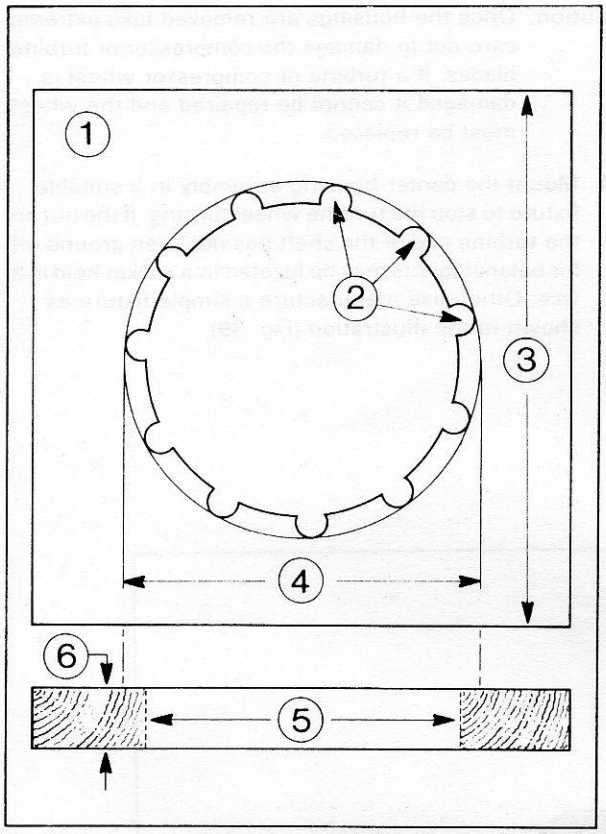


Fig. 39 - Holding Fixture Dimensions

1. Plywood or Hardwood Block
2. 11 Holes 8 mm (0,3125 in.) Dia. Equidistant
3. 115 mm (4,5 in.)
4. 75 mm (3,0 in.)
5. 66 mm (2,625 in.)
6. 12 mm (0,5 in.)

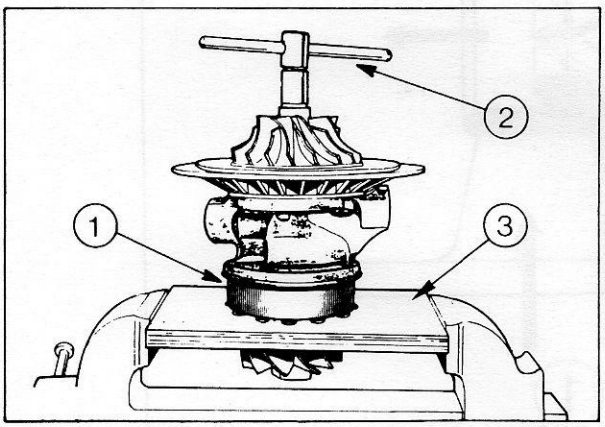


Fig. 40 - Compressor Wheel Locknut Removal

1. Center Housing Group Located in Fixture
2. T-Handled Wrench
3. Fixture Held in Vice

5. Using a T-handled wrench slacken the compressor wheel locknut, applying equal pressure to both ends of the "T" to avoid possible bending of the shaft (Fig. 40).
6. Support the turbine wheel, remove the compressor wheel locknut and lift the compressor wheel off the shaft.
7. Withdraw the turbine wheel and shaft out of the housing, keeping the shaft central until clear of the bearings. At the same time the turbine wheel shroud, which is not secured, can be lifted off.
8. Remove the locktabs and bolts, and separate the backplate from the housing. Tap the plate off with a soft faced hammer if it is tight.
9. Remove the thrust bearing and collar.
10. Remove the outer circlips and the bearings from the center housing. Remove the inner circlips.

Cleaning and Inspection

Before cleaning, inspect all parts for signs of rubbing, burning or other damage which might not be evident after cleaning.

Soak all the parts in clean, non-caustic, carbon solvent. After soaking remove all dirt particles using a soft bristle brush as necessary, and blow dry.

Inspect all components for signs of damage, corrosion, wear or deterioration.

Turbine Wheel:

The turbine wheel and shaft assembly must not show signs of rubbing, scoring, scratching or seizure in the bearings. The shaft must not be bent, or the threads damaged. The turbine blades must not be torn, chipped or worn to a feather edge.

Compressor Wheel:

The compressor wheel must not show signs of wear, rubbing or damage by dirt or other materials. The bearing faces and bore of the wheel must be free from scores or signs of "pick-up".

The piston seal grooves and surfaces must not show signs of wear, rubbing or scoring of sealing surfaces.

Housings:

The housings must not show signs of contact with rotating parts. Oil and air passages must be clean and free from obstructions. If the bearing bores in the center housing are damaged or worn, renew the housing.

Thrust Bearing:

Renew the thrust bearing and collar if they show signs of wear, scoring, nicks, varnish deposits or deeply embedded grit.

Minor surface damage can be removed from any component by polishing or burnishing with abrasive cloth. Use silicon carbide cloth for aluminium parts and polishing (crocus) cloth for steel parts.

Assembly (Figs. 41 and 42)

Note: the internal parts of the turbocharger rotate at very high speeds. It is of particular importance that scrupulous attention is given to cleanliness to prevent the ingress of foreign matter during assembly. DO NOT use fluffy cloths or cleaning materials.

1. Install the inner snap rings, lubricate and install the bearings and secure them in the center housing with the outer snap rings.
2. Fit the new piston ring seal to the turbine shaft, install the shroud over the end of the center housing and, holding the turbine wheel upright, gently slide the shaft through the shroud and bearings. Take care to ensure that the piston ring seal locates correctly in the end of the center housing and is not damaged on entry.
3. Fit the new piston ring seal to the thrust colar, assemble the collar to the thrust bearing and carefully install the assembly over the end of the shaft so that the thrust bearing locates on the anti-rotating pegs and lies flat against the center housing.

Note: The anti-rotating pins are offset to ensure correct fitting.

4. Ensure that the thrust spring is correctly located in the backplate. Place the new seal ring into the groove in the center housing, fit the backplate over the end of the shaft to locate over the end of the thrust collar, engage the piston ring seal in the bore of the backplate over the end of the shaft to locate over the end of the thrust collar, engage the piston ring seal in the bore of the backplate taking care not to damage the seal on entry. Align the mounting bolt holes using the marks made on dismantling, install the bolts with new lockplates, evenly tighten them to the specified torque and secure the locktabs.
5. Fit the compressor wheel over the end of the shaft, lightly oil the threads and face of the locknut and screw it onto the shaft. Using a T-handle torque wrench or torque driver (to avoid any possibility of bending the shaft), carefully tighten the locknut to the specified torque and then through a further angle of 90°.
6. Locate the compressor housing to the backplate, line it up correctly with the marks made on dismantling, install the clamps, lockplates and bolts and tighten them to the specified torque.
7. Locate the turbine housing to the center housing, line it up correctly with the marks made on dismantling. Apply the specified anti-seize compound to the bolt threads, install the clamps, lockplates and bolts and tighten them to the specified torque.

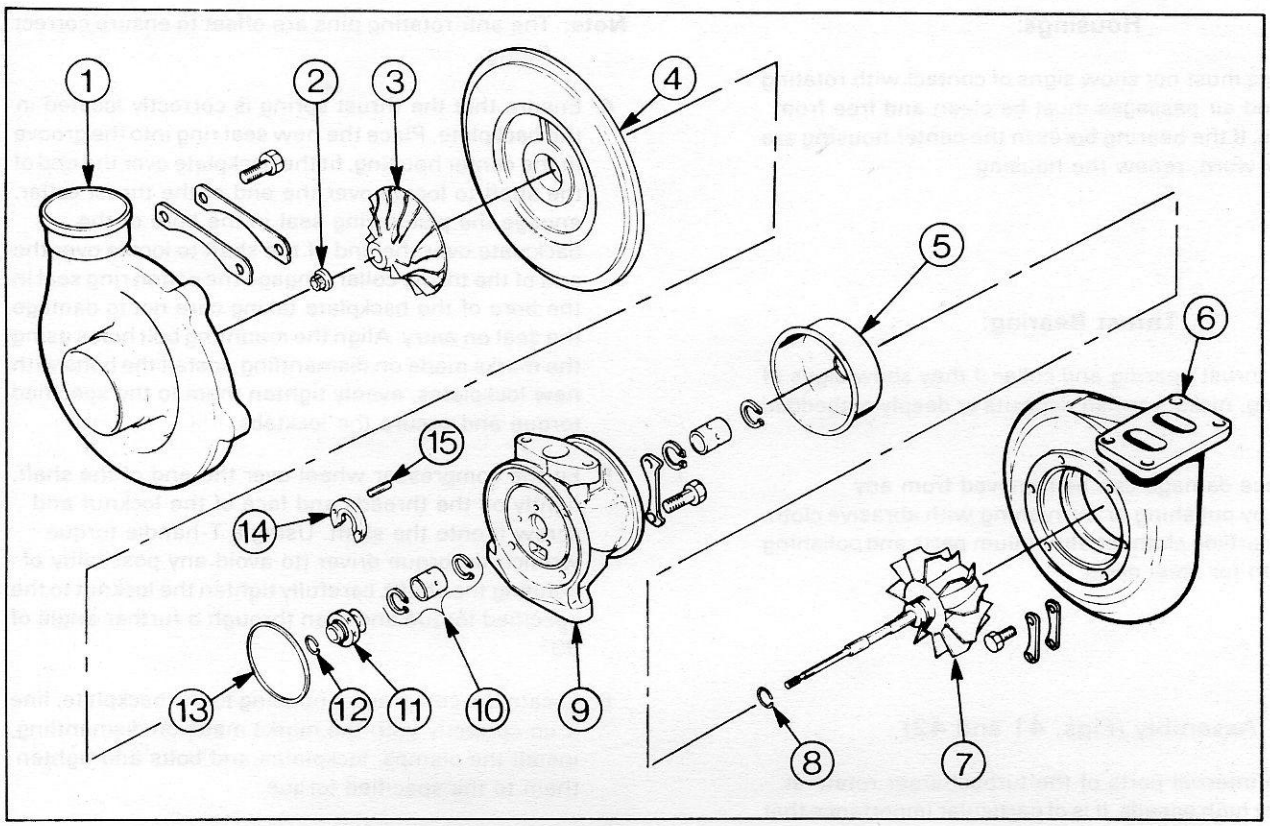


Fig. 41 - Exploded View of Garret AiResearch Turbocharger

1. Compressor Housing
2. Locknut
3. Compressor Wheel
4. Backplate
5. Shroud
6. Turbine Housing
7. Turbine Wheel and Shaft
8. Piston Ring Seal
9. Center Housing
10. Bearing and Retainers
11. Thrust Collar
12. Piston Ring Seal
13. Seal Ring
14. Thrust Bearing
15. Anti-Rotating Peg

8. Push the turbine shaft fully one way then the other and check that it rotates freely in all positions without rubbing or binding.

9. Fit protective covers to all openings until the turbocharger is fitted to the engine.

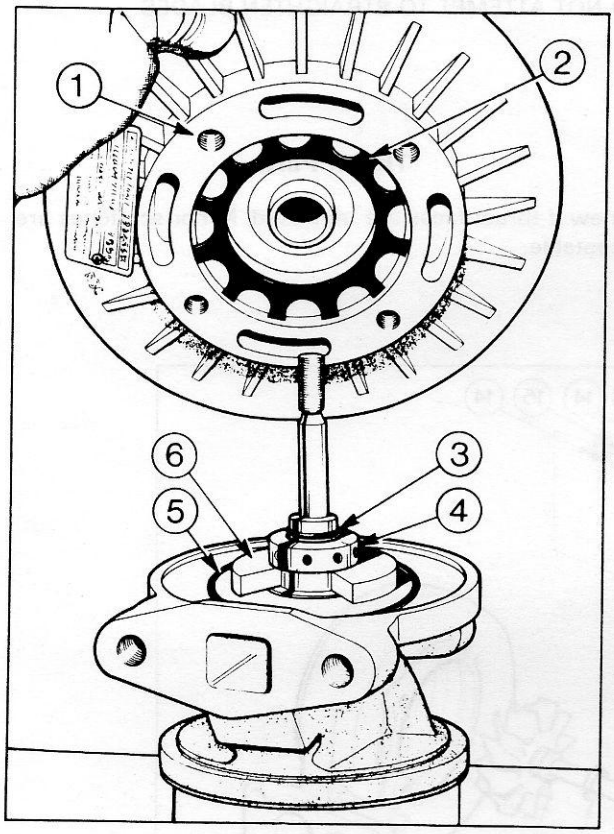


Fig. 42 - Thrust Bearing and Backplate Installation

1. Backplate
2. Thrust Spring
3. Piston Ring Seal
4. Thrust Collar
5. Seal Ring
6. Thrust Bearing

Turbocharger Overhaul - Holset Type - (Fig. 43)

Dismantling

1. Clamp unit upright in vice on turbine inlet flange.

2. Mark relative positions of turbine housing (24), bearing housing (20), compressor diffuser (4) and compressor housing (1).

3. Knock back all tabs on lockplates fitted to turbine housing bolts (16) and also compressor housing and diffuser bolts, if fitted.

4. Remove bolts (7) and clamping plates (6) fastening compressor housing (1) to compressor diffuser (4) and lift off housing.

5. Remove bolts (16) and clamping blates (18) fastening turbine housing (24) to bearing housing (20) and lift the core assembly clear of the turbine housing.

6. Holding the turbine wheel at the hub in a suitable fixture, remove the impeller locknut (2).

Note: Left Hand Thread. Take care not to bend the shaft.

7. Slide the compressor impeller (3) off the shaft.

8. Remove bolts (19) fastening compressor diffuser (4) to bearing housing (20). Remove compressor diffuser (4) with oil slinger (9) from shaft. Push out oil slinger (9) from compressor diffuser (4) and remove "SQ" ring seal (5) from rear of compressor diffuser.

9. Lift out oil baffle (10).

10. Remove the three screws (11) retaining thrust bearing (12). Lift out thrust bearing (12) and thrust collar (13).

11. Remove shaft and wheel (23) together with its seal (split ring) (22) and lift turbine heat shield (21) off shaft.

12. Remove outboard retaining ring (14) at compressor end. Insert finger tip into bearing (15) and remove. Remove inboard retaining ring (14).

13. Remove outboard retaining ring (14) at turbine end. Insert finger tip into bearing (15) and remove. Remove inboard retaining ring (14).

Cleaning and Inspection

Use a commercially approved cleaner only. Caustic solutions will damage certain parts and should NOT be used.

Soak parts in cleaner until all deposits have been loosened.

Use a plastic scraper or bristle type brush on aluminium parts. Vapour blast may also be used provided the shaft and other bearing surfaces are protected.

Clean all drilled passages with compressed air jet.

Make certain that surfaces adjacent to wheels on stationary housings are free of deposits and are clean and smooth.

Shaft and Wheel

Inspect bearing journals for excessive scratches and wear. Minor scratches may be tolerated.

Inspect seal (split ring) groove walls for scoring. Minor scratches are acceptable.

Check carefully for cracked, bent or damaged blades but DO NOT ATTEMPT TO STRAIGHTEN BLADES.

Thrust Parts

Renew if thrust faces are mutilated. Minor scratches are acceptable.

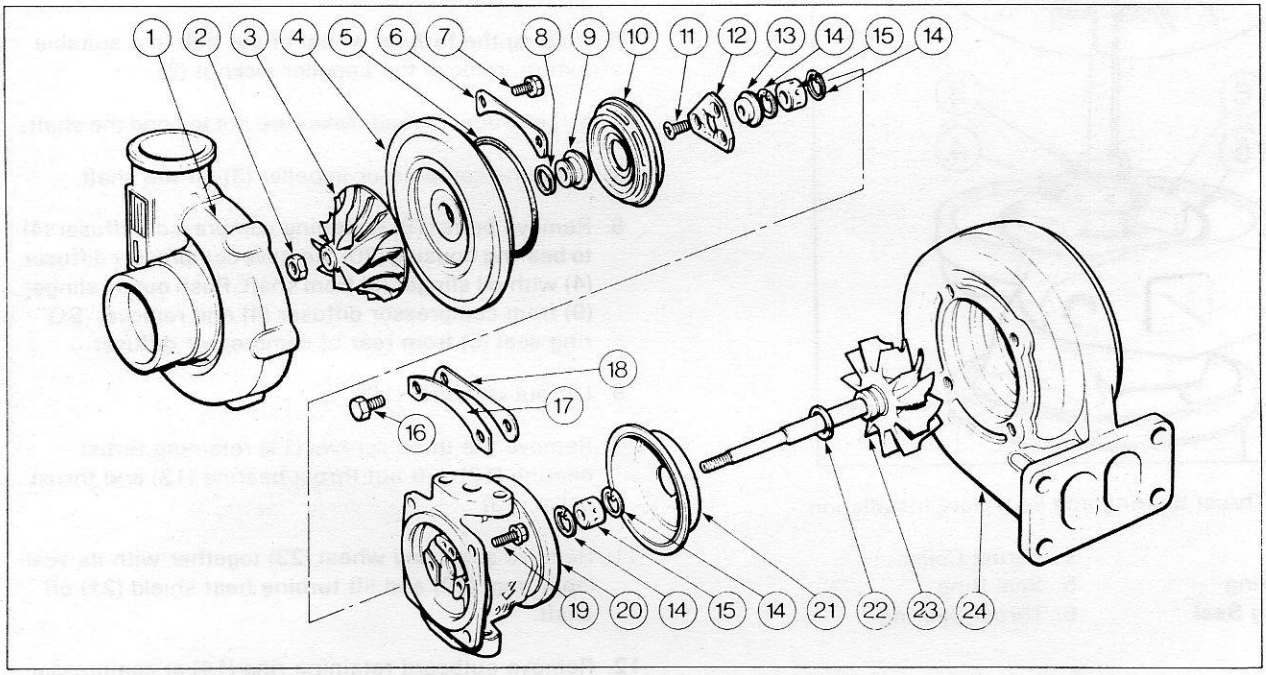


Fig. 43 - Exploded View of Holset Turbocharger

1. Compressor Housing
2. Locknut
3. Compressor Impeller
4. Compressor Diffuser
5. "SQ" Ring Seal
6. Clamping Plate
7. Hex Head Setscrew and Washer
8. Seal (Split Ring)
9. Oil Slinger
10. Oil Baffle
11. Flat Head Capscrew
12. Thrust Bearing
13. Thrust Collar
14. Retaining Ring
15. Bearing
16. Hex Head Capscrew
17. Lockplate
18. Clamping
19. Hex Head Setscrew and Washer
20. Bearing Housing
21. Heat Shield
22. Seal (Split Ring)
23. Shaft and Wheel
24. Turbine Housing

Renew thrust bearing if faces are worn excessively, enevenly or are severely scratched and otherwise mutilated.

The small feed grooves in the thrust bearing must be clean and free of obstruction.

Compressor Impeller

Check carefully for cracked, bent or damaged blades, but DO NOT ATTEMPT TO STRAIGHTEN BLADES.

Bearings

Renew bearings if excessively scratched or worn.

Bearing Housing

Renew bearing housing if bearing or seal (split ring) bores are excessively scratched or worn.

Rotor Parts

Check the rotor for balance (assembly instructions and Holset Publication "Balancing Turbochargers" gives details).

"SQ" Ring Seal

Renew if section through ring has taken a permanent set or if broken or damaged.

Compressor Housing

Inspect profile for damage due to contact with rotor. Slight damage may be tolerated, otherwise replace the housing with a new one.

Turbine Housing

Inspect profile for damage due to contact with rotor, cracks, flaking or signs of overheating. Slight damage may be tolerated otherwise renew the housing.

Assembly

When the turbocharger has been thoroughly cleaned, inspected and any damaged parts renewed, assembly can commence. It is advised that the following points be noted if a satisfactory rebuild is to be obtained.

a. The rotor should be check-balanced within 0,002 oz in (1,44 gm mm) at each end, and the parts suitably marked to ensure correct alignment (correlation during subsequent re-assembly.

b. When replacing the retaining rings (14), ensure that the bevelled face is toward the bearing (15).

c. Lubricate bearings, bearings housing bore, thrust parts, seals (split ring) and rotor shaft with clean engine oil.

1. Replace inboard retaining ring (14) at turbine end, insert bearing (15) and secure with outboard retaining ring (14).

2. Replace inboard retaining ring (14) at compressor end, insert bearing (15) and secure with outboard retaining ring (14).

3. Ensure that split ring seal (22) is in position on the rotor shaft, place heat shield (21) on the housing (20), then slide the shaft carefully through the heat shield and bearings. Do not force the split ring seal (22) into the housing bore, as an off-center ring will fracture, causing the shaft to bind.

4. Slide thrust collar (13) and thrust bearing (12) into position and secure bearing with the three screws (11). Tighten screws to specified torque value, using suitable adaptor.

5. Replace oil baffle (10).

6. Insert split ring seal (8) into compressor diffuser (4); do not force it into the bore as an off-center ring will fracture causing the shaft to bind. Push the oil slinger (9) fully into position in the compressor diffuser.

7. Insert "SQ" ring seal (5) in the compressor diffuser (4) and slide the diffuser over the shaft and up to the housing (20); take care not to trap or damage the "SQ" ring seal. Secure the diffuser to the housing with the four setscrews and washers (19) tightened to the specified torque value.

8. Slide the compressor impeller (3) onto the shaft and screw on the locknut (2). Note that it has a left hand thread.

9. Hold the turbine wheel hub in a suitable fixture and tighten the impeller locknut to the specified torque, using a "T" handled torque wrench to avoid bending the shaft. Remove from fixture and check that rotor spins freely.

10. Using a dial gauge indicator, check axial travel of the shaft between extreme positions. Total travel should be within 0,10 mm to 0,16 mm (0,004 in to 0,006 in). (This reading may be less if a great deal of oil was smeared on the thrust parts and bearings during assembly.)

11. Mount the dial gauge indicator on the housing so that the anvil is resting on the compressor impeller boss and check extreme radial travel of the shaft by pushing the impeller towards and away from the dial indicator. Total travel should be within the following limits:

    H1C/D: 0,46 mm to 0,30 mm (0,018 in to 0,012 in)
    H2A: 0,47 mm to 0,31 mm (0,0185 in to 0,012 in)

12. Assemble bearing housing (20) to turbine housing (24) in the correct relative positions - refer to marks made when dismantling. Secure assembly with the two clamping plates (18) and lockplates (17) and four setscrews (16). Tighten screws to the specified torque value and check that rotor can spin freely. Bend up corners of lockplates to secure screw heads.
13. Assemble the compressor housing (1) to the diffuser (4) in the correct relative position - refer to marks made when dismantling. Secure assembly with the three clamping plates (6) and six setscrews and washers (7). Tighten screws to the specified torque value, then check that rotor can still spin freely.
14. Fit protective covers to all openings until the turbocharger is fitted to the engine.

Replacing the Turbocharger

1. Inspect air intake system for cleanliness and to ensure absence of foreign material.
2. Inspect exhaust manifold to ensure absence of foreign bodies.
3. Inspect oil drain line. Make certain that line is not clogged.
4. Inspect oil supply line for clogging, deterioration or possibility of leaking under pressure.
5. Inspect the turbocharger mounting pad on the manifold to make certain that all of the oil gasket has been removed.
6. Assemble the turbocharger to the exhaust manifold using a new gasket. Secure with the four nuts tightened to the specified torque value.
7. Assemble the turbocharger support plate and bracket into position, placing a new gasket between support plate and turbocharger. DO NOT tighten the nuts securing the turbocharger to the support plate as a new gasket will be needed when fitting the exhaust pipe and/or elbow.
8. Connect the hose between turbocharger and inlet manifold and tighten hose clamps.
9. On industrial engines connect the hose between turbocharger and air inlet pipe and tighten hose clamps.
10. Connect the turbocharger oil feed line and oil return line but do not tighten the oil feed line union at the turbocharger.
11. Operate the starter motor while holding the injection pump fuel shut-off lever in the stop position. Crank the engine until oil flows from the turbocharger oil feed line, then tighten the connection and dry up the spilt oil. Crank again until oil pressure is indicated on the gauge (or the warning light goes out) and check for oil leaks.

Note: Before running the engine, the following "Start-up Procedure" must be followed.

Start-Up Procedure

Serious damage to the turbocharger bearing can result from inadequate lubrication if the following recommendations are not observed.

Prior to the first start after a turbocharger has been newly installed or if, for any reason, the oil supply to the turbocharger has been disconnected, you should ensure that the turbocharger housing is filled with engine oil before reconnecting the oil feed line - see under "Replacing the Turbocharger", Operation No. 11.

In the above circumstances, or in cases where the engine is being started for the first time after an oil change or after a period of 4 weeks or more without use, the following procedure should be used.

1. Fully pull out the stop control.
2. Crank the engine with the starter motor for 15 seconds.
3. Push the stop control fully in.
4. Start the engine and allow to idle (1000 rpm maximum).
5. Observe the oil pressure gauge or oil pressure warning light. If oil pressure is not registered on the gauge, or if the oil pressure warning ligt is not extinguished in the first few seconds of idling, stop the engine immediately and contact your dealer.

On every start up the engine should be allowed to idle (1000 rpm maximum) for 30 seconds before operating on load, to ensure an adequate oil supply to the turbocharger bearing. The engine should also be allowed to idle without load for two minutes before shut-down to enable the oil to dissipate the heat from the turbocharger bearing.

Note: Standby Generator and Alternator Sets. Because standby generator and alternator sets make fewer starts and stops than other industrial applications, the idling requirement of the stop/start procedure can be waived without undue risk of reduced life.

However the recommended start-up procedure must be carried out for engines which have been inoperative for periods of four weeks or more.

Thermostarts are fitted as standard equipment on Turbocharged engines. It is recommended that this starting aid is used on every initial engine start. If, however, the engine has been "shut down" for less than one hour, the thermostart operation can be waived.

Where possible, disconnect the driven equipment before starting.

PART 4 - Charging System

COMPONENT INDEX

DESCRIPTION AND OPERATION

Alternator

The alternator is belt driven from the engine. Current is supplied from the alternator-regulator system to the rotating field of the alternator through two brushes and two slip rings (Fig. 1 and 2).

The alternator produces power in the form of alternating current. The alternating current is rectified to direct current by six diodes. The alternator regulator automatically adjusts the alternator field current to maintain the alternator output voltage within prescribed limits to correctly charge the battery. The alternator is self-current limiting.

The warning lamp control circuit passes current to the warning lamp when the ignition switch is in the RUN position and there is no alternator voltage at terminal S. When the voltage at S rises to a pre-set value, current is cut off to the warning lamp. This circuit is not included in the regulator for vehicles equipped with an ammeter rather than the warning lamp.

A 500 ohm, 1/4 watt resistor is connected across the terminals of the lamp at the instrument cluster in vehicles equipped with an indicator warning lamp.

The switching circuit receives voltage from the ignition switch through the warning lamp control circuit on vehicles equipped with an indicator warning lamp or through terminal S on vehicles equipped with an ammeter. With an input voltage present, the switching circuit turns on the voltage control circuit, which in turn controls the output circuit. When the ignition switch is OFF, the output circuit remains open and no current flows to the alternator field.

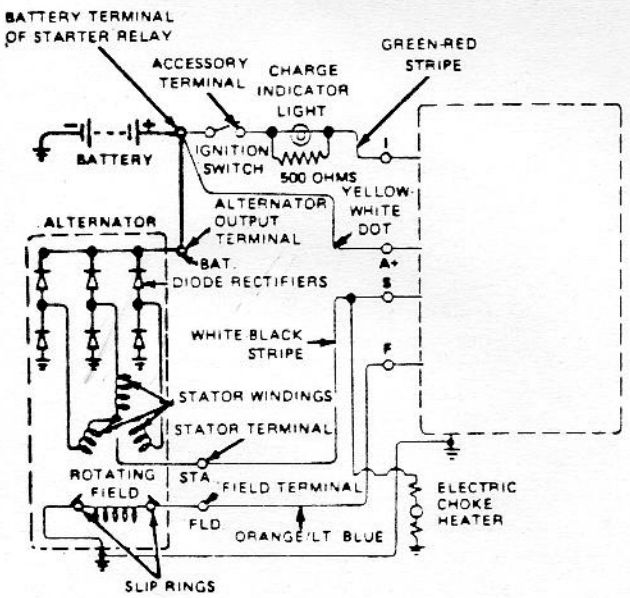


Fig. 1 - Alternator Charging System - Indicator Light

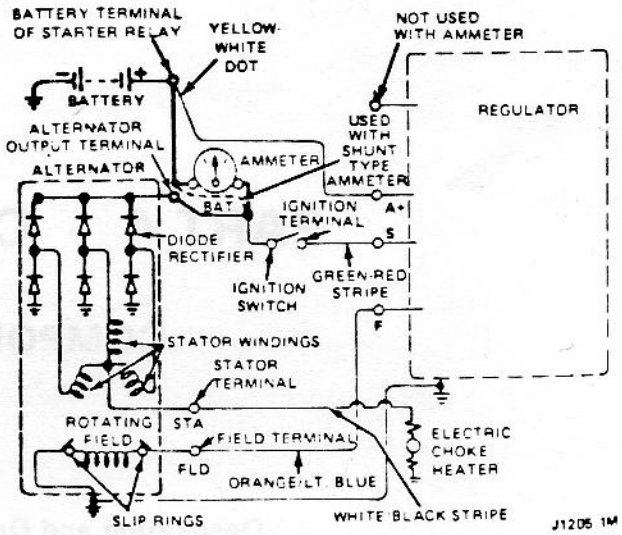


Fig. 2 - Alternator Charging System - Ammeter

Electronic Regulator

The electrical charging systems incorporate a new electronic voltage regulator. These regulators are 100 percent solid state, consisting of transistors, diodes, and resistors. The working functions are achieved using electronic components arranged in basically three circuit divisions as follows: the output stage, the voltage stage, and the solid state relay.

The new regulator will be released under two separate part numbers with color codes. The units will look alike, but are not interchangeable with the new regulator wiring harness connector plugs.

One of these units will be used on vehicles equipped with an ammeter, the other on vehicles equipped with an alternator warning-indicator-lamp. The regulators are calibrated and preset by the manufacturer. No readjustment is required or possible on these units.

The new solid state regulators are being used in conjunction with other new components in the charging system and must be properly matched to prevent damage to the charging system are as follows: (Figs. 3 and 4).

1. A new alternator with higher field current requirement.
2. A new warning indicator lamp shunt resistor.
3. The alternator to regulator wiring harness is changed to incorporate a new regulator connector plug. The new plug is designed so that the connector will not index with the regulator terminals when the wrong regulator is inadvertently installed in the vehicle.

Application

Whenever the system components are being replaced, the following precautions should be followed so that the charging system will work properly and components will not be damaged.

1. Always use the proper alternator in the system being serviced. Older model alternators, if used in the present system, will have a slightly reduced output.
2. Never use an electro-mechanical regulator in the new charging system. The connector plug on the new system wiring harness will not index properly with the electro-mechanical regulator.
3. The electronic regulators are color coded for proper installation. Always use the black color coded regulator is systems which use the warning lamp indicator. The blue color coded regulators must be used in ammeter gauge systems.
4. The charging system uses a 500 Ohm resistor on the back of the instrument cluster on units with warning indicator lamp. Do not replace this item with the 15 Ohm resistance wire.

Caution: Be sure field terminal connector is installed on the "Field" terminal stud at alternator and not the ground stud (Figs. 3 and 4).

Always Disconnect the connector plug from the regulator before checking alternator output with test probes or a jumper wire.

Always disconnect the connector plug from the regulator before removing the regulator mounting screws. Removing the connector from an un-grounded regulator with the ignition switch on will destroy the regulator.

Never attempt to polarize or test the alternator by grounding the field circuit, as this will destroy the regulator.

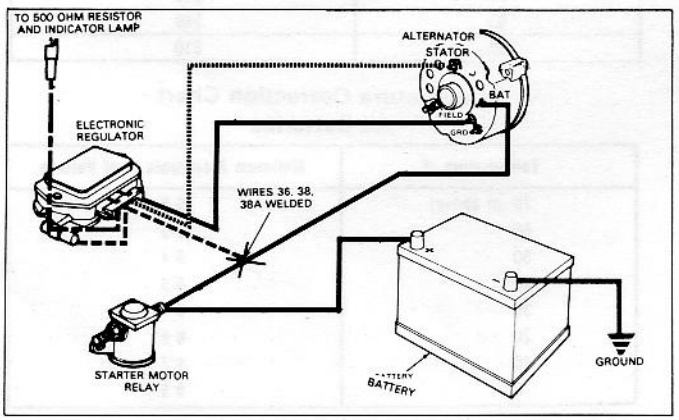


Fig. 3 - Charging System with Electronic Regulator and Warning Lamp Indicator

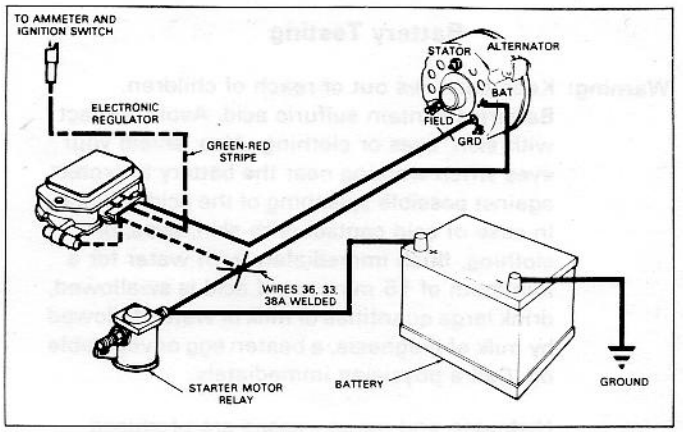


Fig. 4 - Charging System with Electronic Regulator and Ammeter

DIAGNOSIS AND TESTING

Preliminary Information

Before performing charging or starting system tests on the engine, note the complaint such as: slow cranking, battery dead or using an excessive amount of water, top of battery wet, ammeter shows charge at all times and/or no charge, alternator warning lamp does not come on and/or never goes out, voltmeter shows above or below open circuit nominal voltage. This information will aid in isolating the part of the system causing the symptom.

Next, visually inspect as follows:

1. Check battery posts and battery cable terminals for clean and tight connections. Remove the battery cables (if corroded), clean and install them securely.
2. Check for clean and tight wiring connections at the alternator, regulator and engine. Inspect for evidence of arcing.
3. Check the alternator belt tension using belt tension gauge T63L-8620-A, Model 210019 or equivalent and tighten to specification (if necessary).

Isolating the Problem

Battery, starting system, and light systems problems can be caused by poor charging system performance. It is also possible to suspect the charging system because of an overload in another area of the electrical system.

To avoid guesswork, it is necessary to isolate the battery, the charging system, and the electrical circuits to correctly identify the area where the difficulty lies. The best method to do this is to check the battery first before any electrical system diagnosis. The battery must be in proper state of charge. The battery must be operating properly before the other areas of the electrical system can perform normally.

Battery Testing

Warning: Keep batteries out of reach of children. Batteries contain sulfuric acid. Avoid contact with skin, eyes or clothing. Also, shield your eyes when working near the battery to protect against possible splashing of the acid solution. In case of acid contact with skin, eyes, or clothing, flush immediately with water for a minimum of 15 minutes. If acid is swallowed, drink large quantities of milk or water, followed by milk of magnesia, a beaten egg or vegetable oil. Call a physician immediately.

Hydrogen and oxygen gases are produced during normal battery operation. This gas mixture can explode if flames, sparks or lighted tobacco are brought near the battery. When charging or using a battery in an enclosed space, always provide ventilation and shield your eyes.

Warning: Batteries are heavy, weighing 30 lbs. or more. Lift them with your legs rather than your back to prevent muscle strains, and be careful not to drop them (possible breakage) nor to spill the contents (sulfuric acid).

Caution: 12-volt starting motors can be damaged beyond repair if connected to a 24-volt power supply (two 12-volt batteries in series, or a 24-volt motor-generator set), even when cranking loads are relatively light. Extensive starting motor damage is more likely if the starter is connected to a 24-volt supply while being subjected to prolonged heavy cranking loads such as attempting to start an engine in subzero temperatures.

Tests are made on a battery to determine the state of charge and also its capacity or ability to crank an engine. The ultimate result of these tests is to show that the battery is good, needs recharging, or must be replaced.

Before attempting to test a battery, it is important to give it a thorough examination to determine if it has been damaged. Remove battery cable clamps, negative (—) terminal first. Check for dirty or corroded connections and loose battery posts. Remove hold downs and heat shields and inspect for broken or cracked case or cover. If worn or damaged, loose or broken post, or cracked case or cover, replace battery.

The battery capacity test should be run next to remove any surface charge prior to determining state of charge of a maintenance free battery.

Capacity Test

A high rate discharge tester (Rotunda Battery-Starter Tester 02-0204) or equivalent in conjunction with a voltmeter is used for this test.

1. Turn the control knob on the Battery-Starter Tester to the off position.
2. Turn the voltmeter selector switch to the 20-volt position and test selector switch to "AMP".
3. Connect both positive test leads to the positive (+) battery post and both negative leads to the negative (—) battery post. The voltmeter clips must contact the battery posts and not the high-rate discharge tester clips. Unless this is done, the actual battery terminal voltage will not be indicated.
4. Turn the load control knob in a clockwise direction until the ammeter reaches the applicable discharge rate specified in the discharge rate table.
5. With the ammeter reading the required load for 15 seconds, note the voltmeter reading. Avoid leaving the high discharge load on the battery for periods longer than 15 seconds.

   If the voltmeter reading is above the minimum specified in the table with the test equipment for that temperature, the battery has a good output capacity and will readily accept a charge, if required. Check the state of charge.

   If the voltage reading obtained during the capacity test is below the minimum specified in the table, check the state of charge.

Battery Discharge Rates

Ampere Hours	Discharge Rate Amperes
45	190
53	200
63	260
68	235
71	235
85	240
90	310

Temperature Correction Chart - All Batteries

Temperature °F	Minimum Acceptable Load Voltage
70 (or above)	9.6
60	9.5
50	9.4
40	9.3
30	9.1
20	8.9
10	8.7
0	8.5

Alternator - Ford

Where applicable, the tests are divided into On The Engine and On The Bench procedures. Either procedure can be followed depending on the equipment available for the tests.

Troubleshooting or diagnosis is required before actual repairs can be made in the electrical system. Even where an obvious fault makes the replacement of a unit necessary, you must still find out why the unit failed. When a trouble is diagnosed correctly, unnecessary repairs are prevented, the time the engine is out of service will be decreased, and the repairs that are made will be permanent.

On Engine Tests

Before performing charging system tests on the engine, note the complaint such as: slow cranking, battery dead or using an excessive amount of water, top of battery wet, ammeter shows charge at all times and/or no charge, alternator warning lamp does not come on and/or never goes out. This information will aid in isolating the part of the system causing the problem. The battery must be in proper state of charge (at least 1.200 specific gravity).

Visual Inspection

1. Check the battery posts and battery cable terminals for clean and tight connections. Remove the battery cables (if corroded), clean and install them securely.
2. Check for clean and tight wiring connections at the alternator, regulator and engine.
3. Check the alternator belt tension and tighten to specification (if necessary).

Normal Charge Indicator Light

With ignition switch off . . . alternator light is off.

With ignition switch on (engine not running) . . . alternator light is on.

With ignition switch on (engine running) . . . alternator light is off.

1. If the charge indicator light does not come on with the ignition key in the ON position and the engine not running, check the I wiring circuit for an open circuit or burned out charge indicator lamp (ignition switch to regulator I terminal).
2. If the charge indicator light does not come on, disconnect the wiring plug connector at the regulator and connect a jumper wire from the I terminal of the regulator wiring plug to the negative battery post cable clamp.
3. The charge indicator light should go on with the ignition key turned to the ON position.
4. If the charge indicator light does not go on, check the bulb for continuity and replace (if burned out).
5. If the bulb is not burned out, an open circuit exists between the ignition switch and the regulator.
6. Check the 500 ohm resistor across the charge indicator lamp. Engines equipped with an ammeter will not have a resistor.

Normal Charge Ammeter

With ignition switch off and no electrical load . . . ammeter should show 0 or center scale.

With ignition switch on and engine running . . . needle deflects towards charge and returns toward center scale in two steps (fully charged battery).

With ignition switch off and lights on . . . ammeter should show between 0 and discharge scale.

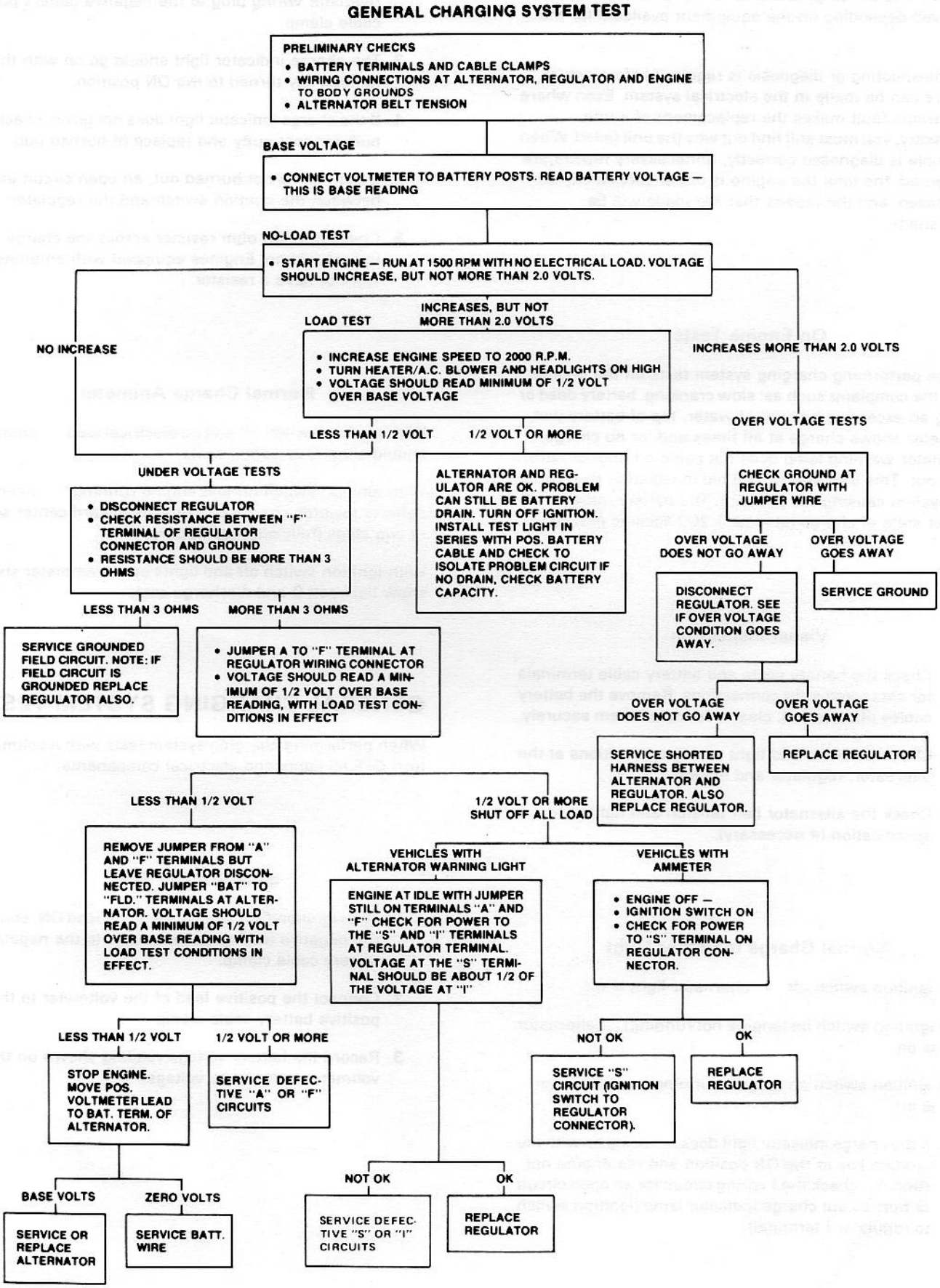
GENERAL CHARGING SYSTEM TESTS

When performing charging system tests with a voltmeter, turn OFF all lights and electrical components.

Base Voltage Test

1. With ignition OFF and no electrical load ON, connect the negative lead of the voltmeter to the negative battery cable clamp.
2. Connect the positive lead of the voltmeter to the positive battery cable clamp.
3. Record the battery voltage reading shown on the voltmeter scale (base voltage).

Diagnosis Guide



No Load Test

1. connect a tachometer to the engine.
2. Start the engine and increase speed to approximately 1500 rpm. With no other electrical load, the voltmeter pointer should move upward (increase), but not more than 2 volts above the base voltage (first recorded battery voltage reading above). The reading should be taken when the voltmeter pointer stops rising. It may take a few minutes to reach this point. If the voltage increases to proper level, perform Load Test below. If the pointer continues to rise, perform the Over Voltage Tests described below. If the voltage does not rise to proper level, perform Under Voltage Tests below.

Load Test

1. with the engine running, turn the heater or air conditioner blower motor ON (high speed) and headlights on high beam.
2. Increase the engine speed to approximately 2000 rpm. The voltmeter should indicate a minimum of 0.5 volt above the base voltage. If not, perform the Under Voltage Tests described below.

If the above tests indicate proper voltage readings (1/2 volt open circuit above base), the charging system is operating normally. Proceed to the tests below if one or more of the readings is different then shown above and use a test light to check for battery drain.

Over Voltage Tests

1. If the voltmeter reading indicates more than 2.0 volts above base voltage, connect a jumper wire between the regulator base and alternator frame. Repeat the No Load test. If over voltage condition disappears, check ground connections on alternator, regulator and from engine to firewall and to battery clean and tighten connections securely.
2. If over voltage condition still exists, disconnect the regulator wiring plug from the regulator and repeat the No Load test.
3. If over voltage condition disappears (voltmeter reads battery base voltage), replace voltage regulator.
4. If over voltage still exists with the regulator wiring plug disconnected, check for short between "A" and "F" in the wiring harness plug and service as required. Replace the regulator and connect the regulator wiring plug to the regulator.

Under Voltage Tests

1. If the voltage does not indicate more then 1/2 volt above base voltage, disconnect wiring plug from regulator and connect an ohmmeter from "F" terminal of plug to ground (Fig. 5). Meter should indicate more than three ohms. If less than three ohms is indicated, service grounded field current in wire or alternator and repeat Load Test above.
2. If ohmmeter indicates more than three ohms connect jumper wire from "A" to "F" terminals of regulator plug (Fig. 6). Repeat Load Test above. If voltmeter now indicates more than 1/2 volt above base voltage, service wiring to regulator or regulator.
3. If the Voltmeter still indicates under voltage, remove the jumper wire from the regulator plug and leave the plug disconnected from the regulator. Connect a jumper wire to the FLD and BAT terminals on the alternator (Fig. 7) and repeat the LOAD TEST. If the voltmeter now indicates more than 1/2 volt above the base voltage, perform S and I Circuit Test and service the wiring harness from the alternator to the regulator.
4. If the voltmeter still indicates under voltage, stop the engine and move the positive voltmeter lead to the alternator BAT terminal.
5. If the voltmeter now indicates the base voltage reading, service the alternator. If the voltmeter indicates zero volts, service alternator to starter relay.

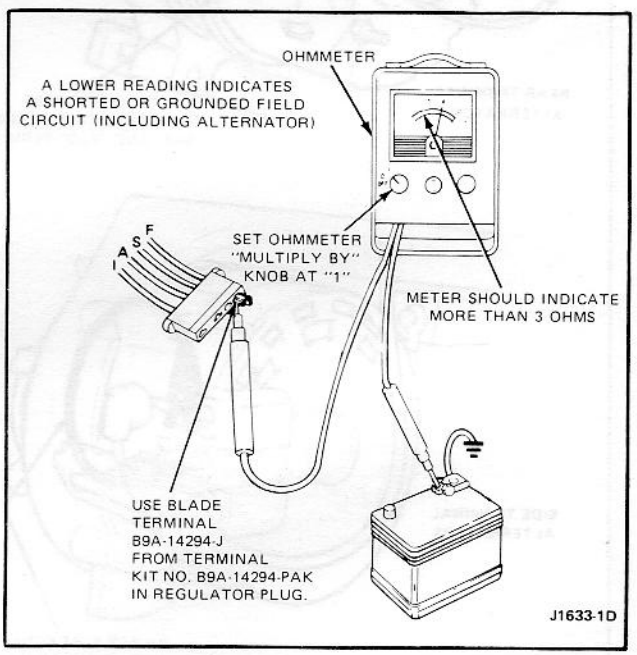


Fig. 5 - Field Circuit Test

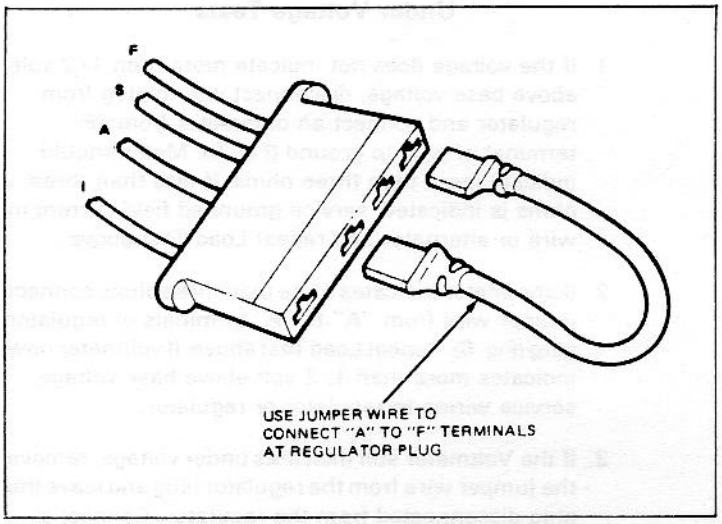


Fig. 6 - Regulator Plug Jumper Wire Connections

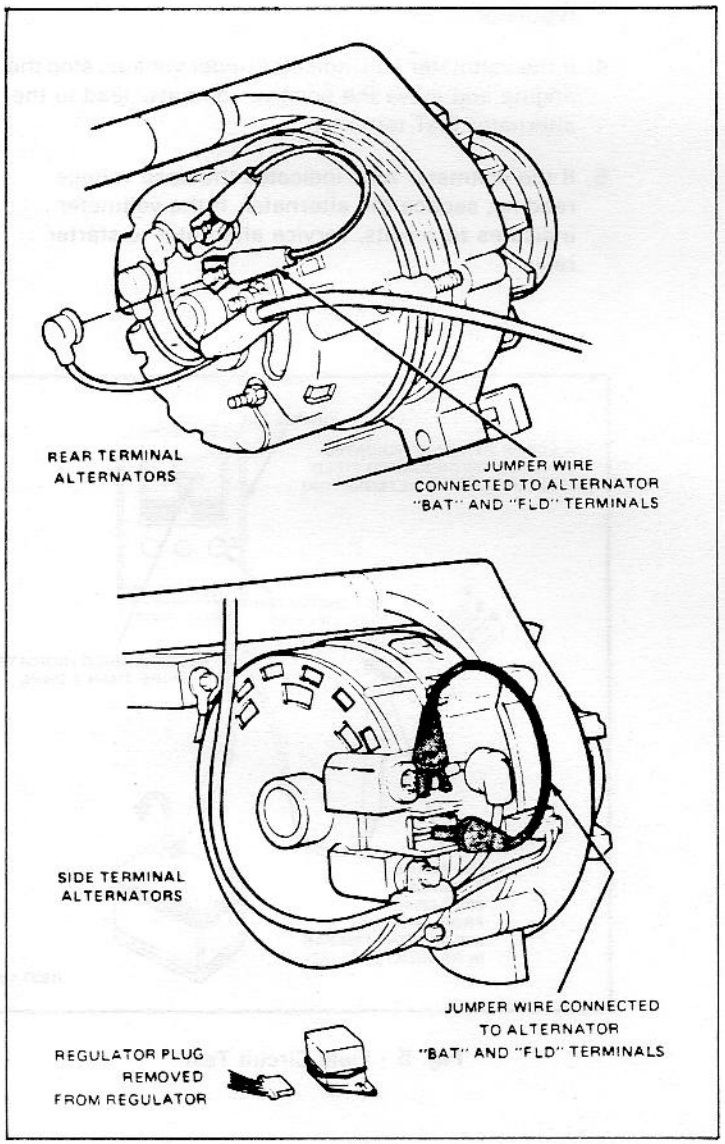


Fig. 7 - Jumper Wire Connections

Regulator S and I Circuit Tests
S-Circuit with Ammeter

1. Connect the positive lead of the voltmeter to the S terminal of the disconnected regulator wiring plug and negative lead of voltmeter to battery ground terminal Then, turn the ignition switch to the ON position. DO NOT start the engine. No voltage should be indicated with ignition switch OFF.
2. The voltmeter should indicate battery voltage.
3. If there is no voltage reading, service the S wire lead from the ignition switch to the regulator wiring plug.
4. Connect the positive voltmeter lead to the positive battery cable terminal, connect regulator wiring plug to regulator and repeat the Load Test.

S and I Circuit - With Indicator Light

1. Disconnect the regulator wiring plug and install a jumper wire between the "A" and "F" terminals (Fig. 6).
2. With the engine idling, connect the negative voltmeter lead to the battery ground terminal and the positive lead of the voltmeter to the S terminal and then to the I terminal of the regulator wiring plug. The voltage of the S circuit should read approximately one-half of the I circuit.
3. If no voltage is present, service the wiring circuit. Reconnect the positive voltmeter lead to the positive battery cable terminal.
4. Then, remove the jumper wire from the regulator wiring plug and connect the wiring plug to the regulator. Repeat the Load Test.

Bench Tests

After the general charging system diagnosis has isolated the problem to the alternator, remove it from the vehicle for bench testing and service, or replacement. Refer to Alternator Removal and Disassembly in this Section.

Rectifier Short or Grounded and Stator Grounded Test

These tests are performed with an ohmmeter (Rotunda 59-0010 or equivalent). Set the "Multiply By" knob at 1 and calibrate the ohmmeter as directed.

1. Contact one ohmmeter probe to the alternator BAT terminal (terminal with red insulator) and the other probe to the STA terminal (terminal with black insulator) (Fig. 8). Then, reverse the ohmmeter probes and repeat the test. Normally there will be no needle movement in one direction, indicating the rectifier diodes are being checked in the reverse current direction and are not shorted. A lowreading with the probes reversed indicates that rectifier positive diodes are being checked in the forward current direction. Using the referenced tester, the low reading should be about 6 ohms but may vary if another type of tester is used. A reading in both directions indicates a bad positive diode, a grounded positive diode plate or a grounded BAT terminal.
2. Perform the same test using the STA and GND terminals. A reading in both directions indicates either a grounded stator winding, a bad negative diode, a grounded stator terminal, a grounded positive diode plate, or a grounded BAT terminal.
3. If there is no needle movement with the probes in one direction and a high resistance (significantly over 6 ohms) in the opposite direction, for either test, a bad connection exists between the stator lead terminal and the stator bolt head.

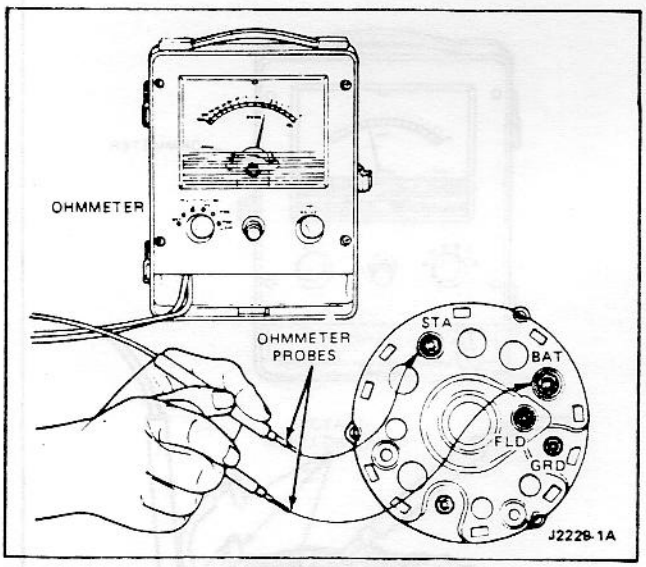


Fig. 8 - Rectifier Short or Grounded and Stator Grounded Test

Field Open or Short Circuit Test

This test is performed with an ohmmeter. Set the ohmmeter "Multiply By" knob at 1 and calibrate the ohmmeter as directed inside the instrument cover.

1. Contact the alternator field terminal with one probe and the ground terminal with the other probe (Fig. 9). Then, spin the alternator pulley. The ohmmeter reading should be between 2.4 and 100 ohms and should fluctuate while the pulley is turning.
2. An infinite reading (no meter movement) indicates an open brush lead, worn or stuck brushes or a bad rotor assembly.
3. An ohmmeter reading less than 2.4 ohms indicates a grounded brush assembly, a grounded field terminal or a bad rotor.

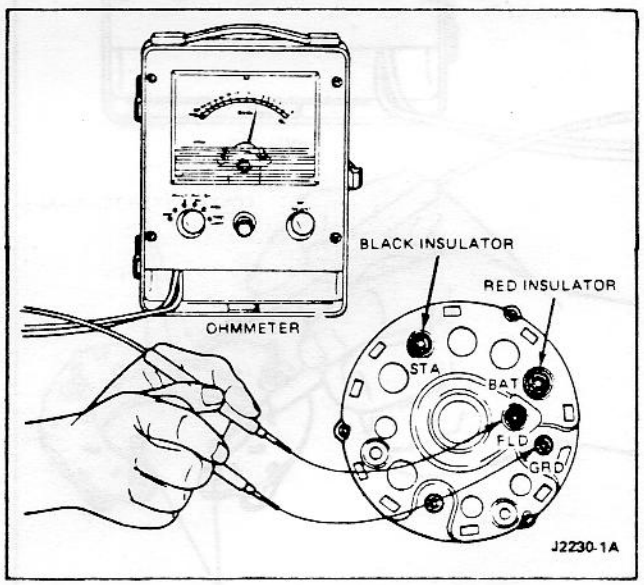


Fig. 9 - Field Open or Short Circuit Test

Diode Test

Remove the rectifier assembly from the alternator. Set the ohmmeter "Multiply By" knob at 1 and calibrate the meter as directed.

1. To test one set of diodes, contact one probe to the terminal bolt and contact each of the three stator lead terminals with the other probe (Fig. 10). Reverse the probes and repeat the test. All diodes should show a low reading of about 6 ohms in one direction and an infinite reading (no needle movement) with the probes reversed. The low reading may vary with the type of tester used. This reading may be checked against a good rectifier if it is available.
2. Repeat the preceding tests for the other set of diodes except that the other terminal screw is used.
3. If the meter readings are not as specified, replace the rectifier assembly.

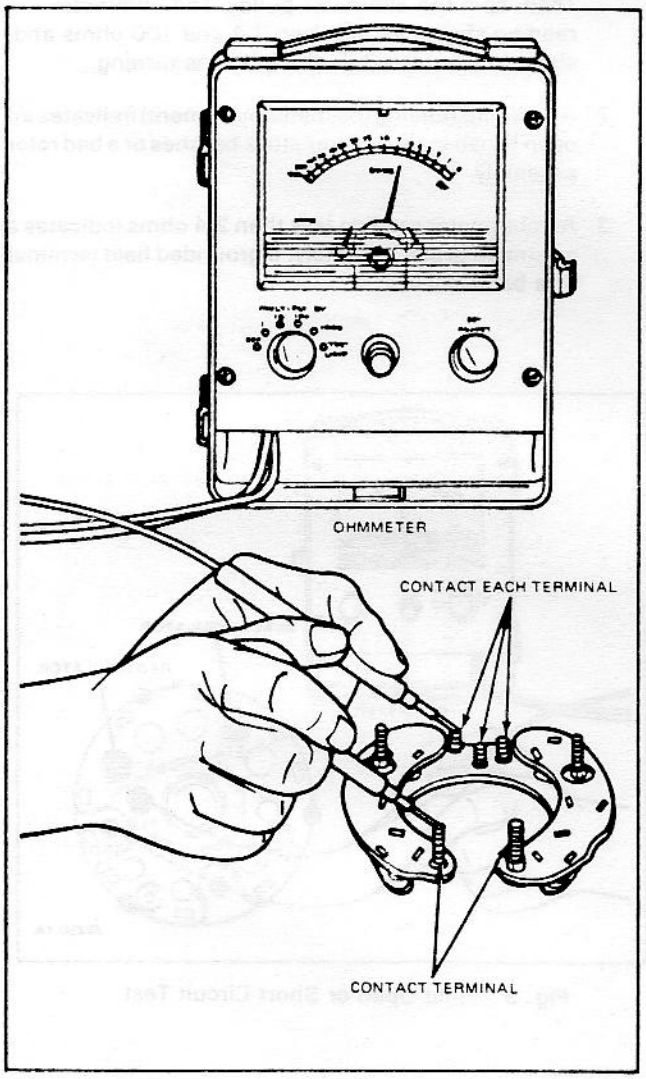


Fig. 10 - Diode Test - Rear Terminal Alternator

Stator Coil Grounded Test

These tests are made to determine if the stator coil is operating properly. Remove the stator from the alternator and disconnect from the rectifier assembly (refer to disassembly procedure in this Section). Set the ohmmeter "Multiply By" knob at 1000.

1. connect the ohmmeter probes to one of the stator leads and to the stator laminated core (Fig. 11). Be sure that the probe makes a good electrical connection with the stator core. The meter should show an infinite reading (no meter movement).
2. If the meter does not indicate an infinite reading (needle moves), the stator winding is shorted to the core and must be replaced.
3. Repeat this test for each of the stator leads. Do not touch the metal probes or stator leads with the hands. Such contact will result in an incorrect reading.

Stator Coil Open Test

This test determines if there is an open stator circuit. Disconnect the stator from the rectifier assembly. Set the ohmmeter "Multiply By" knob at 1.

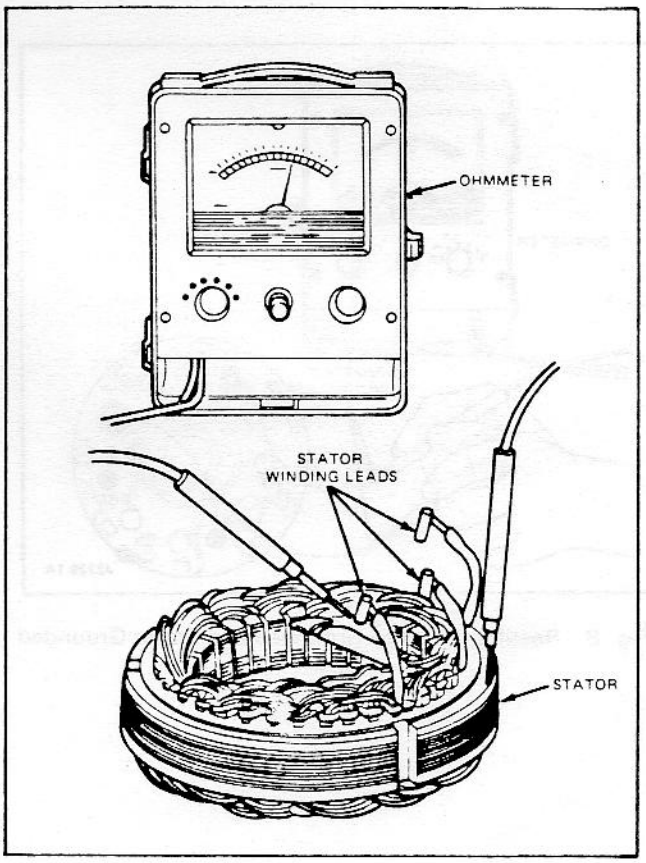


Fig. 11 - Stator Coil Test

1. Connect one ohmmeter probe to a stator phase lead (Fig. 11) and touch the other probe to another stator lead. Check the meter reading.
2. Repeat this test with the other two stator lead combinations. If no meter movement occurs (infinite resistance) on a lead paired with either of the other two leads, that phase is open and the stator should be replaced.

Rotor Open or Short Circuit Test

Remove the rotor from the alternator. Set the ohmmeter "Multiply By" knob at 1 and calibrate the meter as directed.

1. contact each ohmmeter probe to a rotor slip ring. The meter reading should be 2.0 to 3.5 ohms.
2. A higher reading indicates a damaged slip ring solder connection or a broken wire.
3. A lower reading indicates a shorted wire or slip ring. Replace the rotor if it is damaged and cannot be serviced.
4. Contact one ohmmeter probe to a slip ring and the other probe to the rotor shaft. The meter reading should be infinite (no deflection).
5. A reading other than infinite indicates the rotor is shorted to the shaft. Inspect the slip ring soldered terminals to be sure they are not bent and not touching the rotor shaft or that excess solder is not grounding the rotor shaft or that excess solder is not grounding the rotor coil connections to the shaft. Replace the rotor if it is shorted and cannot be serviced.

REMOVAL AND INSTALLATION

Warning: Hydrogen and oxygen gases are produced during normal battery operation. This gas mixture can explode if flames, sparks or lighted tobacco are brought near the battery. When charging or using a battery in an enclosed space, always provide ventilation and shield your eyes.

Warning: Keep out of reach of children. Batteries contain sulfuric acid. Avoid contact with skin, eyes or clothing. Also, shield your eyes when working near the battery to protect against possible splashing of the acid solution. In case of acid contact with skin, eyes, or clothing, flush immediately with water for a minimum of fifteen minutes. If acid is swallowed, drink large quantities of mild or water, followed by milk or magnesia, a beaten egg, or vegetable oil. Call a physician immediately.

Removal

1. Disconnect the ground cable from the battery.
2. Loosen the alternator pivot bolt and remove the adjustment arm-to-alternator bolt.
3. Disengage the alternator drive belt from the drive pulley.
4. Disconnect the wiring terminals from the back of the alternator. The stator and field wiring terminals are the push-on type. The push-on type terminal should be pulled straight off the terminal to prevent damage.
5. remove the alternator pivot bolt.
6. Remove the alternator.

Installation

1. Position the alternator on the engine.
2. Install the alternator pivot bolt and adjuster bolt.
3. Connect the wiring terminals to the back of the alternator (Fig. 12).

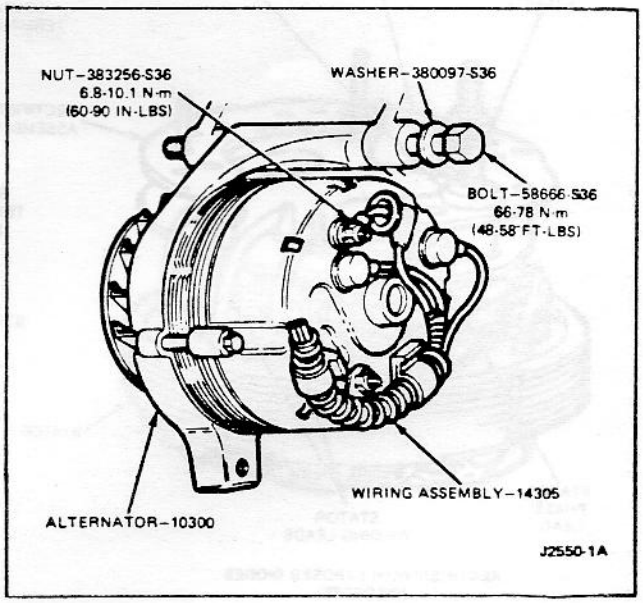


Fig. 12 - Wiring Harness Connections - Typical

4. Install the drive belt over the alternator drive pulley.
5. Adjust the belt to specification.
6. Connect ground cable to battery.

DISASSEMBLY AND ASSEMBLY

Disassembly

Note: All of the following disassembly steps may not be necessary to perform a particular test or repair. Perform only those steps that apply in your case.

The rear terminal alternator will have one of two types of rectifier assembly. One is a flat design with built-in diodes. The other type is a stacked design with exposed diodes (Fig. 13). Procedural steps affected by the differences in the rectifiers will be noted.

1. Scribe a line across the end housings and stator frame for alignment reference during assembly.
2. Remove the three housing through bolts.
3. Separate the front housing and rotor assembly from the stator and rear housing assembly. It may be necessary to tap the front housing with a plastic tipped hammer to loosen the front housing from the stator frame.
4. Remove the brush springs from the brush holder in the rear housing.
5. Remove the nuts, washers and insulators from the terminals on the back of the rear housing. Note the color and location of the insulators for assembly reference (Fig. 14).
6. Remove the stator and rectifier assembly from the rear housing.
7. Remove the screws attaching the brush holder to the rear housing.
8. Remove the brush holder, the brushes and the brush terminal insulator from the rear housing.
9. Using a suitable arbor press, remove the bearing from the rear housing. Support the housing close to the bearing boss to prevent damage to the housing.

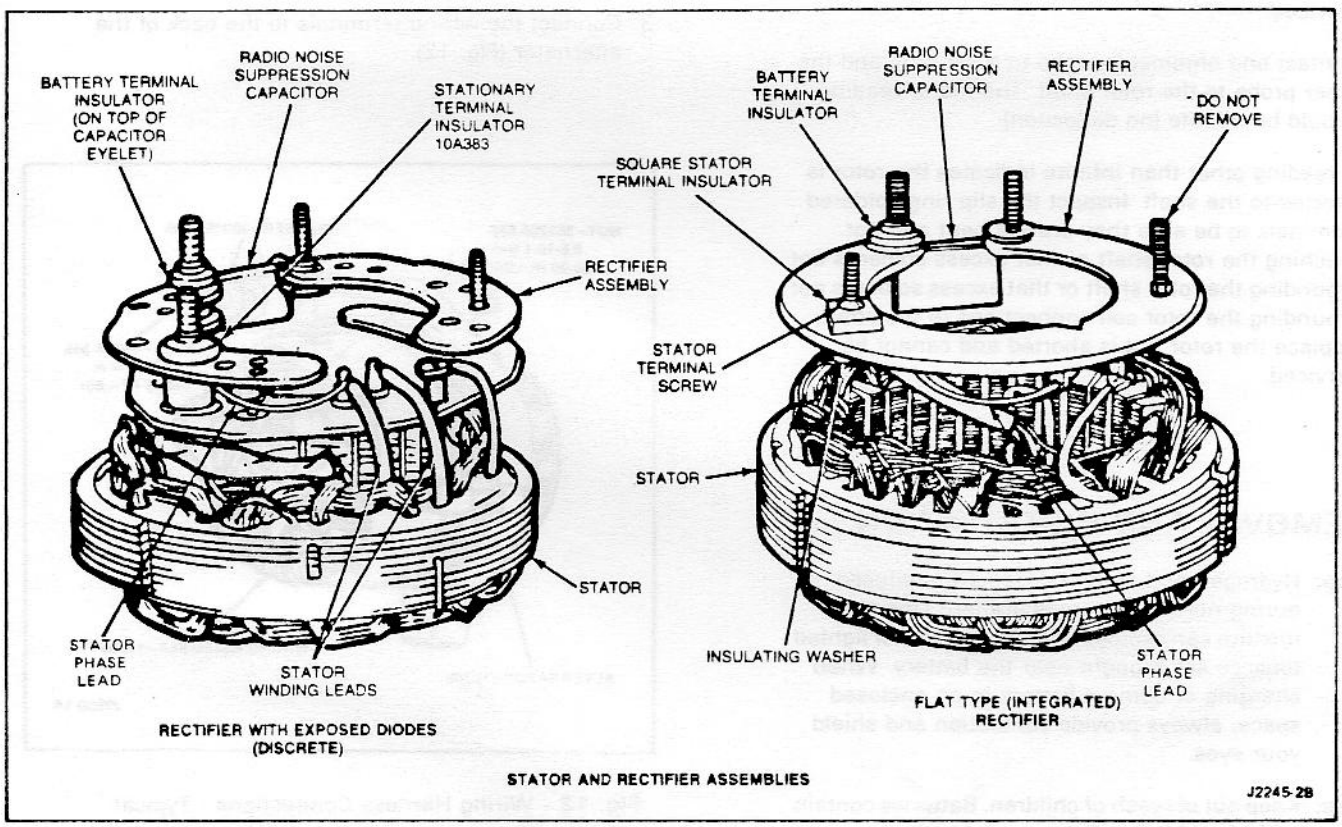


Fig. 13 - Stator and rectifier Assemblies

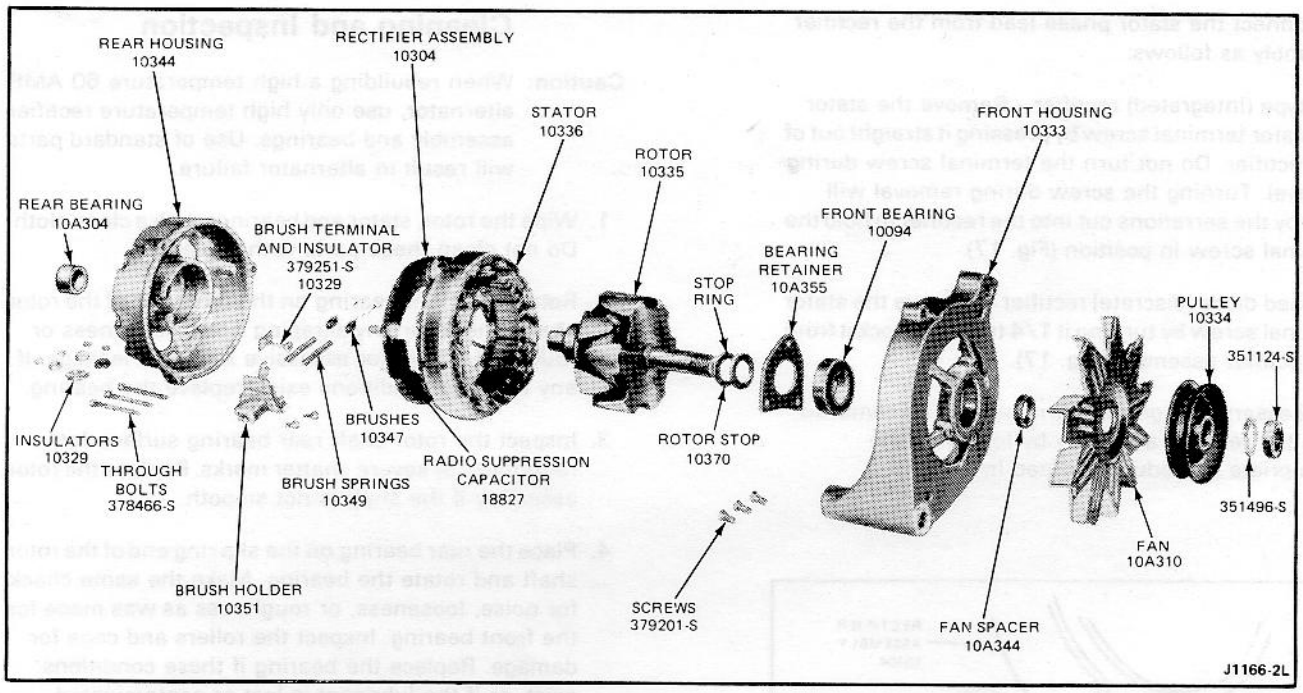


Fig. 14 - Disassembled Rear Terminal Alternator

10. Clamp the front housing in a vise with protective jaws (Fig. 15).
11. Remove the drive pulley retaining nut from the rotor shaft using Removal/Installation Tool, T65P-10300-B or equivalent (Fig. 15).

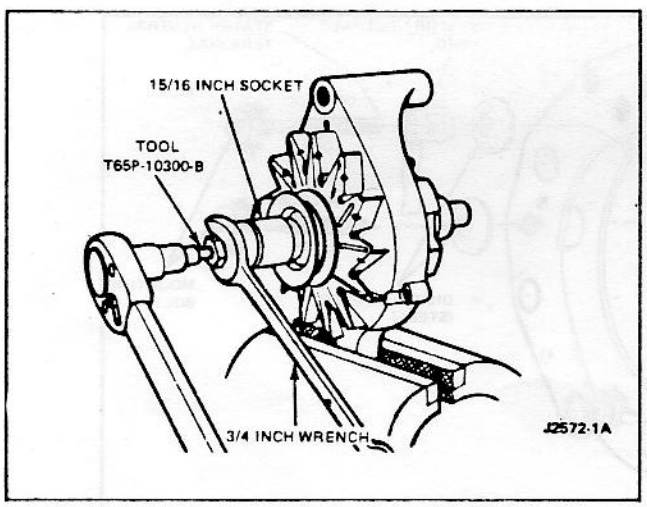


Fig. 15 - Pulley Removal

12. Remove the lockwasher, drive pulley, fan and fan spacer from the rotor shaft.
13. Remove the rotor from the front housing and remove the housing from the vise.
14. Remove the front bearing spacer from the rotor shaft. Do not remove the stop ring from the rotor shaft unless it is damaged.
15. Remove the screws attaching the bearing retainer to the front housing and remove the retainer.
16. Remove the bearing from the front housing. If the bearing will not slide out, remove it using a suitable arbor press. Support the housing close to the bearing boss to prevent damage to the housing.
17. Remove the radio suppression capacitor and the battery terminal insulator from the rectifier assembly (Fig. 13).
18. Using a 100 watt soldering iron, unsolder the stator leads from the rectifier assembly. Do not allow the soldering iron to overheat the rectifier. When removing the rectifier assembly from the alternator, do not cut the stator lead wires. Unsolder the stator terminals from the molded circuit board terminals and with needle nose pliers pull stator lead terminals upwards from the rectifier assembly (Fig. 16). While the terminals are still hot, shake the moltent solder from the terminals.

19. Disconnect the stator phase lead from the rectifier assembly as follows:

    Flat type (integrated) rectifier - Remove the stator the stator terminal screw by pressing it straight out of the rectifier. Do not turn the terminal screw during removal. Turning the screw during removal will destroy the serrations cut into the rectifier to hold the terminal screw in position (Fig. 17).

    Exposed diode (discrete) rectifier - Remove the stator terminal screw by turning it 1/4 turn to unlock it from the rectifier assembly (Fig. 17).

20. If necessary, the ground terminal can be removed from the rectifier assembly by following the appropriate procedure outlined in Step 19.

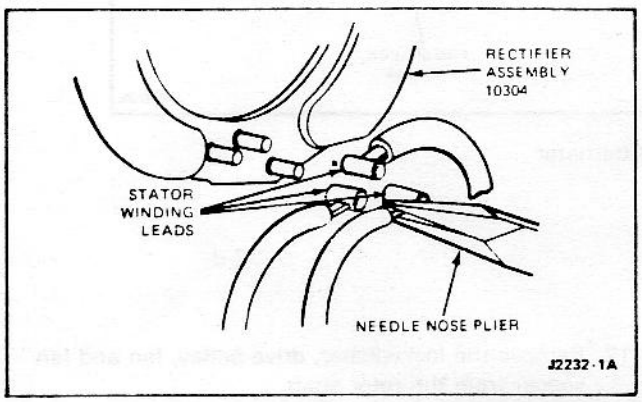


Fig. 16 - Stator Lead Removal and Installation

Cleaning and Inspection

Caution: When rebuilding a high temperature 60 AMP alternator, use only high temperature rectifier assembly and bearings. Use of standard parts will result in alternator failure.

1. Wipe the rotor, stator and bearings with a clean cloth. Do not clean these parts with solvent.

2. Rotate the front bearing on the drive end of the rotor shaft. Check for any scraping noise, looseness or roughness. Look for excessive lubricant leakage. If any of these conditions exist, replace the bearing.

3. Inspect the rotor shaft rear bearing surface for roughness or severe chatter marks. Replace the rotor assembly if the shaft is not smooth.

4. Place the rear bearing on the slip ring end of the rotor shaft and rotate the bearing. Make the same check for noise, looseness, or roughness as was made for the front bearing. Inspect the rollers and cage for damage. Replace the bearing if these conditions exist, or if the lubricant is lost or contaminated.

5. Check the pulley and fan for excessive looseness on the rotor shaft. Replace any pulley or fan that is loose or bent out of shape.

6. Check both the front and rear housing for cracks, particularly in the webbed areas and at the mounting ear. Replace damaged or cracked housing.

7. Check all wire leads on both the stator and rotor assemblies for loose or broken soldered connections and for burned insulation. Resolder poor connections connections. Replace parts that show signs of burned insulation.

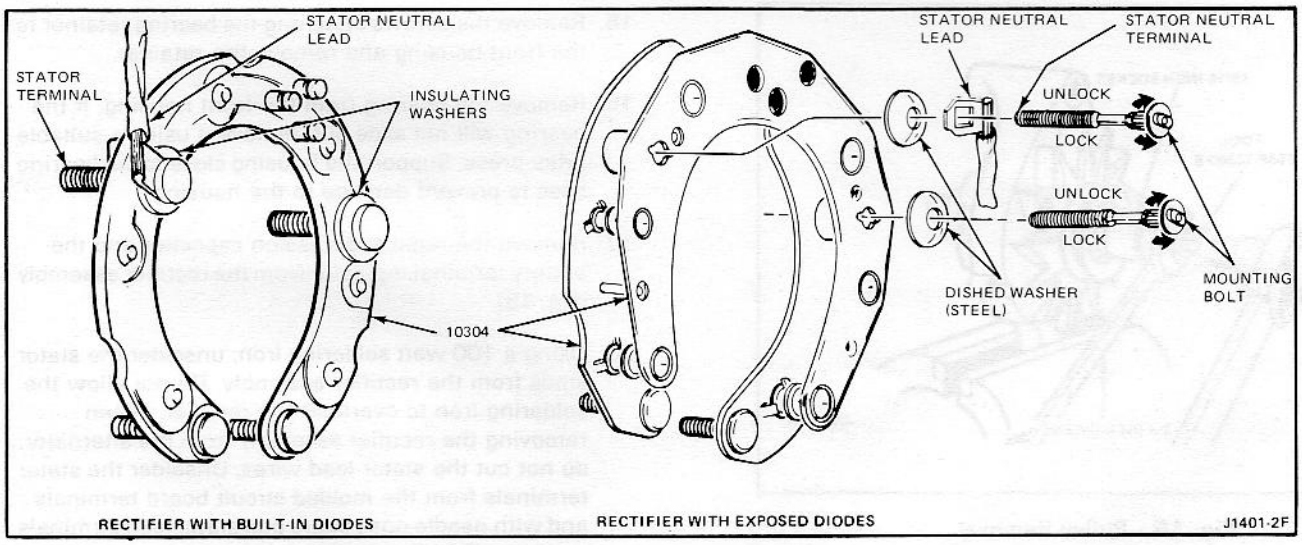


Fig. 17 - Rectifier Assemblies

8. Check the slip rings for nicks and surface roughness. Nicks and scratches may be removed by turning down the slip rings. Do not go beyond the minimum diameter of 31 mm (1.22 inches). If the rings are badly damaged, replace the rotor assembly.
9. Replace the brushes if they are worn shorter than 6.35 mm (1/4 inch).

Assembly

1. Install the bearing in the front housing. Press on the outer race only.
2. Position the bearing retainer on the front housing and install the attaching screws. Tighten the screws to 2.8-4.5 Nm (25-40 in-lbs).
3. If the stop ring was removed from the rotor shaft, install a new ring by sliding it over the end of the shaft and into the groove. Do not open the ring with snap ring pliers as permanent deformation of the ring will result.
4. Install the bearing spacer on the rotor shaft with the recessed slide against the stop ring.
5. Install the rotor in the front housing and clamp the housing in a vise.
6. Install the fan spacer, fan, drive pulley, lockwasher and nut on the rotor shaft. Tighten the nut to 82-135 Nm (60-100 ft-lbs) using removal/installation tool, T65P-10300-B or equivalent (Fig. 15).
7. Remove the rotor and housing assembly from the vise.
8. Support the rear housing close to the bearing boss to prevent damage to the housing and install the bearing using a suitable arbor press. Press the bearing into the bore until it is flush with the housing.
9. Position the brush wiring eyelet over the brush terminal and install the brush terminal insulator (Fig. 18).
10. Install the springs and brushes in the brush holder. Hold the brushes against spring tension by inserting a piece of stiff wire through the brush holder (Fig. 18).
11. Position the brush holder in the rear housing and install the attaching screws. Tighten the screws to 1.9-2.8 Nm (17-25 ft-lbs). Press the brush holder firmly against the housing while tightening the screws. Make sure the ground brush wiring eyelet is positioned under the screw before tightening (Fig. 19).

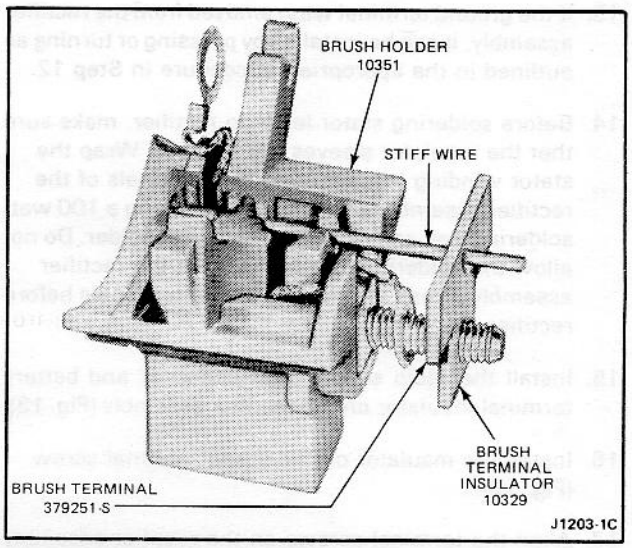


Fig. 18 - Brush Holder Assembly

12. Connect the stator phase lead to the rectifier assembly as follows:

    Flat type (integrated) diode rectifier - Position the stator terminal insulator and the stator phase lead on the rectifier assembly. Insert the terminal screw and press into position. The screw should be pressed in far enough to keep the phase lead terminal from moving (Fig. 17).

    Rectifier with exposed diodes (discrete) - Position the stator phase lead and dished washer on the rectifier assembly. Insert the terminal screw and lock into place by rotating 1/4 turn (Fig. 17).

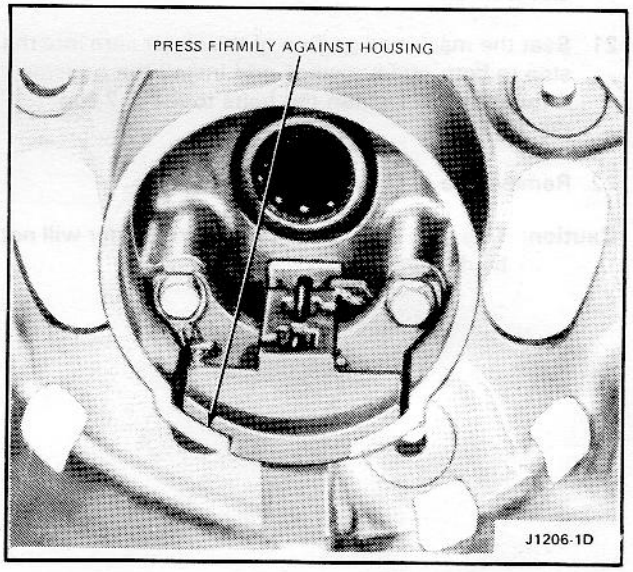


Fig. 19 - Brush Lead Positions

13. If the ground terminal was removed from the rectifier assembly, it can be installed by pressing or turning as outlined in the appropriate procedure in Step 12.

14. Before soldering stator leads to rectifier, make sure that the insulator sleeves are in place. Wrap the stator winding leads around the terminals of the rectifier assembly and solder them, using a 100 watt soldering iron and resin core electrical solder. Do not allow the soldering iron to overheat the rectifier assembly. Press the sleeves on the terminals before rectifier soldering.

15. Install the radio suppression capacitor and battery terminal insulator on the rectifier assembly (Fig. 13).

16. Install the insulator on the stator terminal screw (Fig. 13).

17. Align the terminal screws on the rectifier assembly with the holes in the back of the rear housing and install the stator rectifier assembly in the rear housing. Make certain the terminal insulators are seated in their recesses.

18. Install the external insulators, washers and nuts on the terminals. The insulators are color coded as follows:

    Black on the stator (STA) terminal. Tighten nut to 2.8-3.9 Nm (25-35 in-lbs).

    Red on the battery (BAT) terminal. Tighten nut to 3.4-6.2 Nm (30-55 in-lbs).

    Orange on the field (FLD) terminal. Tighten nut to 2.8-3.9 Nm (25-35 in-lbs).

19. Wipe the rear end bearing surface of the rotor shaft with a clean, lint-free rag.

20. Position the rear housing and stator assembly over the rotor and align the scribe marks made during disassembly.

21. Seat the machined portion of the stator core into the stop in both end housings and install the housing through bolts. Tighten the bolts to 4.1-6.7 Nm (35-60 in-lbs).

22. Remove the wire holding the brushes.

Caution: This step is important so that regulator will not be damaged.

ADJUSTMENTS

Drive Belt

The fan drive belt should be properly adjusted at all times. A loose drive belt can cause improper alternator, fan and water pump operation. A belt that is too tight places a severe strain on the water pump and alternator bearings.

A properly tensioned drive belt minimizes noise and also prolongs the service life of the belt. Therefore, it is recommended that a belt tension gauge be used to check and adjust the belt tension. **Any belt that has been operated for a minimum of 10 minutes is considered a used belt, and when adjusted, it must be adjusted to the used belt tension shown in the specifications.**

Belt Tension

1. Install the belt tension tool on the drive belt and check the tension.

2. If adjustment is necessary, losen the alternator mounting bolts and move the alternator adjusting arm bolts. Move the alternator toward or away from the engine until the correct tension is obtained. Remove the gauge.

3. Tighten the alternator adjusting arm bolt and the mounting bolts. Install the tension gauge and check the belt tension.

PART 5 - Starting

COMPONENT INDEX

DESCRIPTION

The function of the starting system is to crank the engine at a speed fast enough to permit the engine to start. Heavy cables, connectors, and switches are used in the starting system because of the large current required by the starter while it is cranking the engine. The amount of resistance in the starting circuit must be kept to an absolute minimum to provide maximum current for starter operation. Loose or corroded connections or partially broken cables will result in slower than normal cranking speeds, and may even prevent the starter from cranking the engine.

SYSTEM COMPONENTS

Major assembly components of the solenoid actuated starter, which is used on the Dover engines, are the frame and field coil assembly, armature assembly, brush plate assembly, drive assembly, shift lever assembly, drive housing assembly and starter solenoid assembly.

Description and Operation

The pre-engaged Lucas starter (Fig. 1) is a four pole four brush unit of 5 in. (127 mm.) 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. 2, 3, and 4).

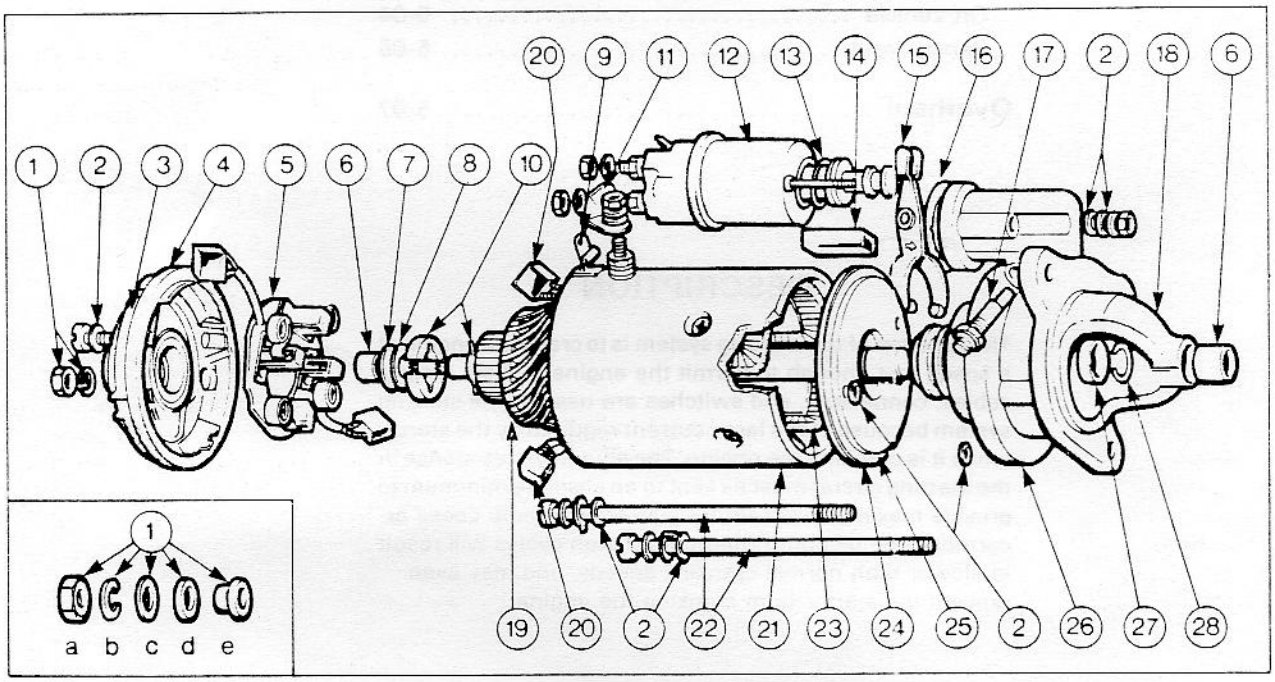


Fig. 1 - Lucas Starter - Dismantled

1. Nut & Spring Washer (C/E Cover Earth Stud)
2. Sealing Washers
3. Commutator End Cover
4. Sealing Ring
5. Brushgear Assembly Comprising, Earth Brushes & Springs
6. Bearing Bush
7. Fibre Washer
8. Steel Thrust Washer
9. Flexible Link
10. Brake Shoes & Cross Peg
11. Cooper Link
12. Solenoid Unit
13. Return Spring
14. Sealing Grommet
15. Engagement Lever
16. Gasket
17. Eccentric Pivot Pin
18. Drive End Fixing Bracket
19. Armature
20. Insulated Brushes (Field Coils)
21. Yoke
22. Through Bolts
23. Field Coils
24. Sealing Ring
25. Intermediate Bracket
26. Drive Assembly
27. Thrust Collar
28. Jump Ring

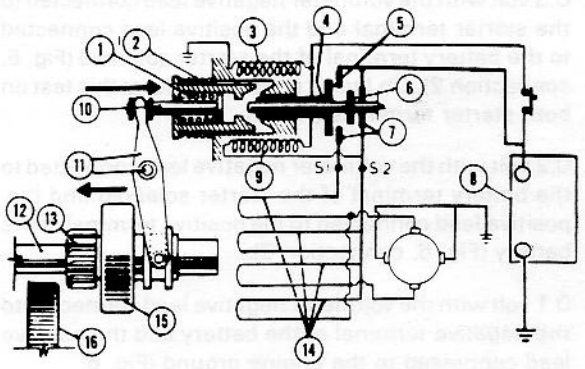


Fig. 2 - Explanation of Two-Stage Switching

1. Engagement Spring
2. Return Spring
3. Solenoid Hold-On Winding
4. Switch Operating Spindles (Concentric)
5. First Switch Contacts
6. Second Switch Contacts
7. Fixed Contacts
8. Battery
9. Solenoid Operating Winding
10. Plunger
11. Operating Lever & Pivot
12. Armature Shaft
13. Pinion
14. Field System: Four Field Coils in Parallel
15. Roller Clutch
16. Gear Ring

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

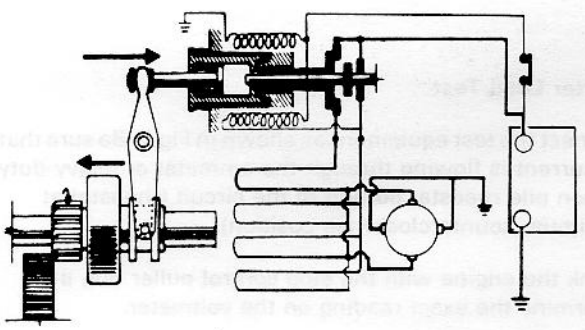


Fig. 3

If tooth-to-tooth abutment occurs, the first set of solenoid contacts close and energize one field coil only, thus giving low power indexing to move the pinion teeth into a meshing position.

On full drive engagement, the second set of solenoid contacts close giving full cranking power.

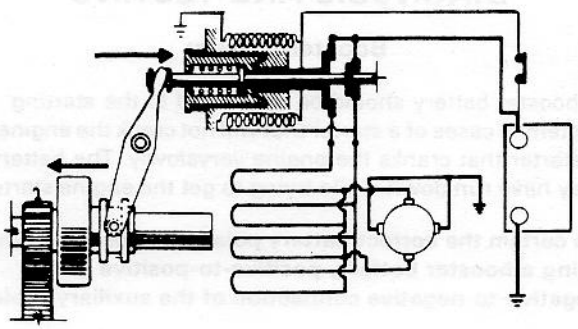


Fig. 4

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 grounding stud, solenoid fixing studs and brush gear plate securing screws in the outer face of the commutator end cover (Fig. 1).

DIAGNOSIS AND TESTING

Booster Battery

A booster battery should be connected to the starting system in cases of a starter that will not crank the engine or a starter that cranks the engine veryslowly. The battery may have run down while trying to get the engine started.

Be certain the correct battery polarity is observed when using a booster battery; positive-to-positive and negative-to-negative connection of the auxiliary cables.

If the starter does not turn the engine over with a booster battery attached refer to the following tests.

On Vehicle Testing

Starter Cranking Circuit Test

These tests will determine whether or not there is excessive resistance in the cranking circuit. Make each test connection as shown in Fig. 6. While cranking the engine, observe the voltage drop reading for each test. **Connect a remote control switch between the battery terminal of the starter relay and the S terminal of the relay.**

The voltage drop in the circuit will be indicated by the voltmeter (0 to 2 volt range). Maximum allowable voltage drop should be:

1. 0.5 volt with the voltmeter negative lead connected to the starter terminal and the positive lead connected to the battery positive terminal (Fig. 6, connection 1). On Lucas starters, perform this test on both starter terminals (Fig. 5).
2. 0.3 volt with the voltmeter negative lead connected to the starter terminal and the positive lead connected to the battery terminal of the starter solenoid (Fig. 6, connection 2). On Lucas starters, perform this test on both starter terminals (Fig. 5).
3. 0.2 volt with the voltmeter negative lead connected to the battery terminal of the starter solenoid and the positive lead connected to the positive terminal of the battery (Fig. 6, connection 3).
4. 0.1 volt with the voltmeter negative lead connected to the negative terminal of the battery and the positive lead connected to the engine ground (Fig. 6, connection 4).

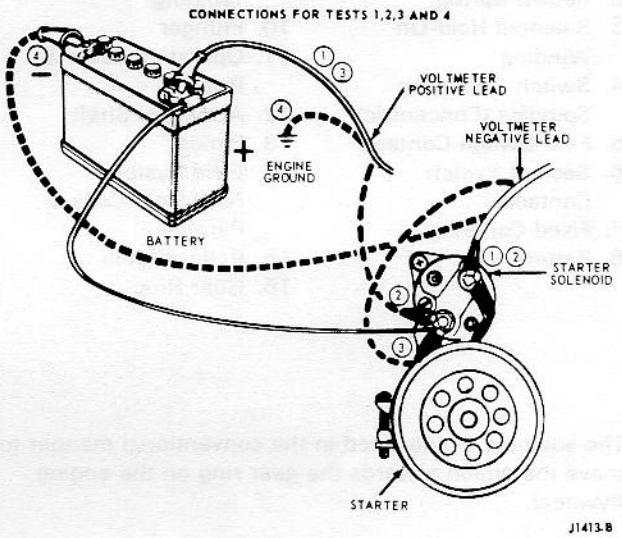


Fig. 6 - Starter Cranking Circuit Test - Typical

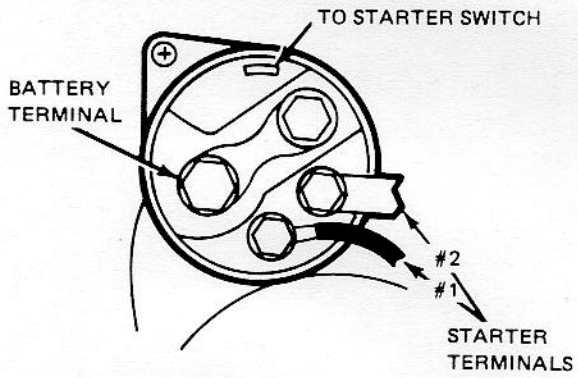


Fig. 5 - Lucas Starter Solenoid

Starter Load Test

Connect the test equipment as shown in Fig. 7. Be sure that no current is flowing through the ammeter or heavy-duty carbon pile rheostat portion of the circuit (rheostat at maximum counterclockwise position).

Crank the engine with the stop control puller out, and determine the exact reading on the voltmeter.

Stop cranking the engine, and reduce the resistance of the carbon pile until the voltmeter indicates the same reading as that obtained while the starter cranked the engine. The ammeter will indicate the starter current draw under load.

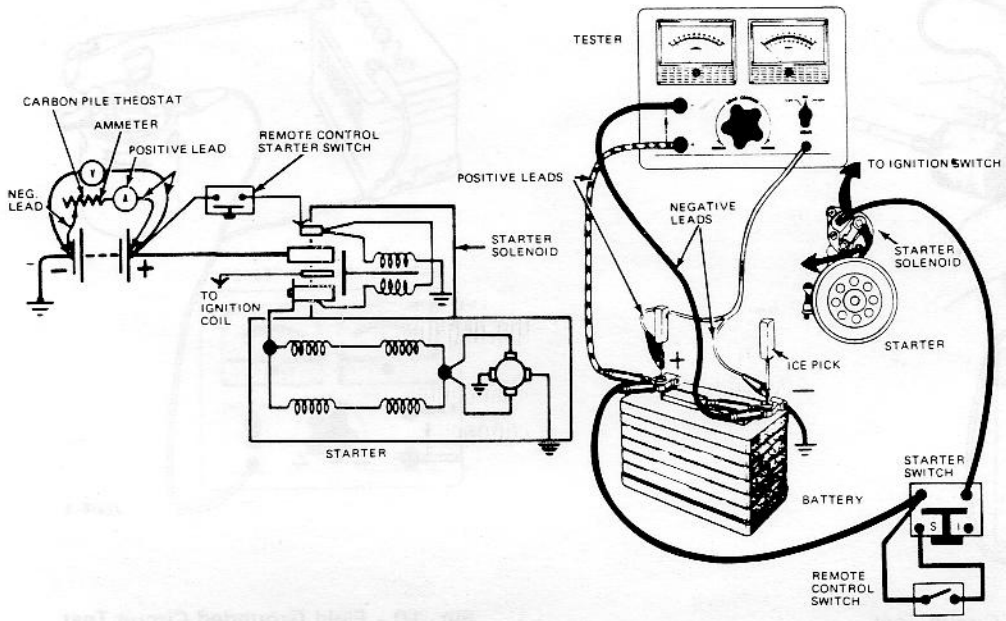


Fig. 7 - Starter Load Test

Starter Solenoid Test

If the solenoid does not pull in (starter load test) measure the voltage between the starter mounted solenoid switch terminal and ground with the starter switch closed. If the reading is 10 volts or more, a worn or damaged solenoid is indicated. Remove the starter assembly for solenoid replacement.

Bench Tests

Starter No-Load Test

This test will uncover such faults as open or shorted windings, rubbing armature, and bent armature.

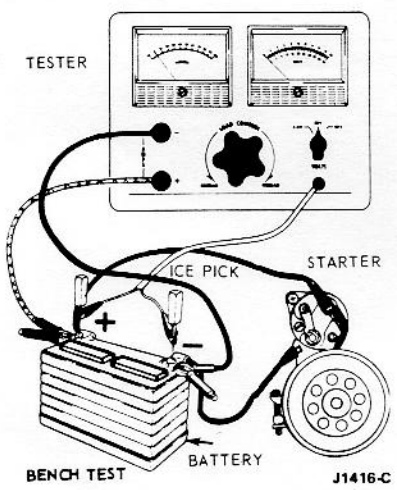


Fig. 8 - Starter No Load Test on Test Bench - Typical

Make the test connections as shown in Fig. 8. On Lucas starters, connect the positive lead to both starter field terminals. The starter will run at no load. Be sure that no current is flowing through the ammeter (rheostat at maximum counterclockwise position). Determine the exact reading on the voltmeter.

Disconnect the starter from the battery, and reduce the resistance of the rheostat until the voltmeter indicates the same reading as that obtained while the starter was running. The ammeter will indicate the starter no-load current draw.

Armature Open Circuit Test

An open circuit armature may sometimes be detected by examining the commutator for evidence of burning. A spot burned on the commutator is caused by an arc formed every time the commutator segment, connected to the open circuit windings, passes under a brush.

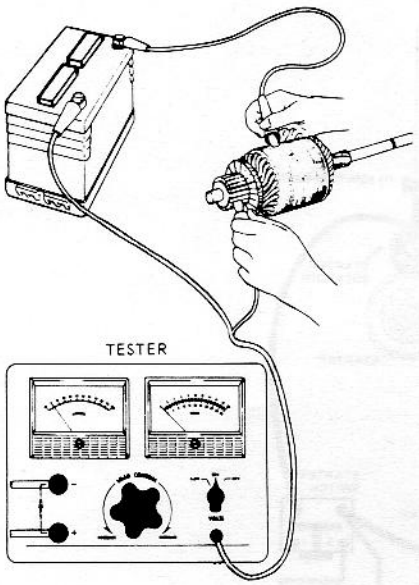


Fig. 9 - Armature Grounded Circuit Test

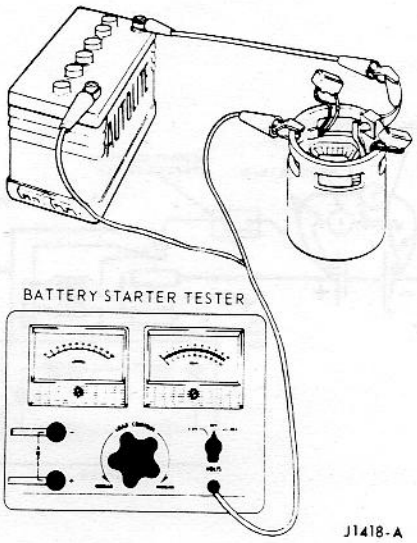


Fig. 10 - Field Grounded Circuit Test

Armature and Field Grounded Circuit Test

This test will determine if the winding insulation has failed, permitting a conductor to touch the frame or armature core.

To determine if the armature windings are grounded, make the connections as shown in Fig. 9. If the voltmeter indicates any voltage, the windings are grounded.

Grounded field windings can be detected by making the connections as shown in Fig. 10. On Lucas starters, perform the test on both field leads. If the voltmeter indicates any voltage, the field windings are grounded.

OVERHAUL

Solenoid Actuated Starter Cleaning and Inspection

1. Do not wash the drive because **the solvent will wash out the lubricant causing the drive to slip.** Use a brush or compressed air to clean the drive, field coils, armature, commutator, armature shaft front end plate, and rear end housing. Wash all other parts in solvent and dry the parts.

2. Inspect the armature windings for broken or burned insulation and unsoldered connections.

3. Check the commutator for runout (Fig. 11). Inspect the armature shaft and the two bearings for scoring and excessive wear. If the commutator is rough, or more than 0.005 inch out-of-round, turn it down.

5. Check the brush holders for broken springs and the insulated brush holders for shorts to ground. tighten any rivets that may be loose. Replace the brushes if warn to 5/16 inch in length.

6. Check the brush spring tension. Replace the springs if the tension is not within specified limits.

7. Inspect the field coils for burned or broken insulation and continuity. Check the field brush connections and lead insulation. A brush kit is available. All other assemblies are to be replaced rather than repaired.

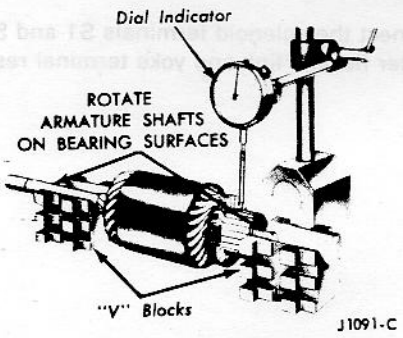


Fig. 11 - Commutator Runout Check

8. Examine the wear pattern on the starter drive teeth. The pinion teeth must penetrate to a depth greater than 1/2 the ring gear tooth depth (Fig. 12) to eliminate premature ring gear and starter drive failure.

9. Replace starter drives and ring gears with milled, pitted or broken teeth of evidence or inadequate engagement (Fig. 12).

Disassembly

1. Remove the 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 nuts, washers and seals and remove the solenoid unit with the gasket from the drive end retaining bracket. Remove the small seal washer from the solenoid studs.

Note: The solenoid plunger will remain attached to the starter when the main part of the solenoid is removed. To remove the solenoid plunger, grip the plunger with your hand and lift the front end of the plunger up. Remove the plunger from the fork in which it pivots at the top of the drive engagement lever.

4. Remove the sealing grommet which is located between the retaining bracket and yoke.

5. Remove the through bolts complete with washers and sealing washers.

6. Remove the two screws that retain the brush gear to the inside face of the commutator end cover.

The commutator end cover assembly, consisting of the seal ring, brake shoe assembly, steel thrust washer, fiber packing washer and bearing brush, can now be removed while the brush gear remains in position on the commutator.

7. To remove the brushgear assembly, grasp the commutator end of the armature shaft and pull the armature forward so that the commutator and brushgear are exposed. Use a wire hook or a small screwdriver to lift up the brush spings so that the brushes can be disengaged from the brushboxes. Remove the brushgear assembly.

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

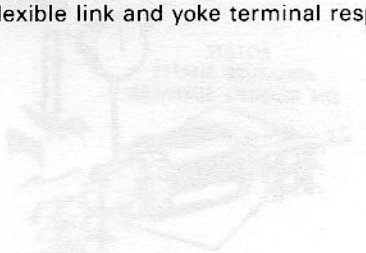
9. Loosen the pivot pin from the retaining bracket and remove the drive end retaining bracket drive engagement lever, the armature, complete with roller clutch drive, and the intermediate bracket.

Note: Separation of the retaining and intermediate bracket may cause the two small seal washers to become lodged in a recess in the through bolt holes in the retaining bracket. Be sure to obtain these washers.

10. Disassemble the armature assembly roller clutch and intermediate bracket using a tubular tool. Remove the thrust collar from the armature shaft, making sure that you have obtained any packing shims that may have been fitted.

Assembly

1. Fit the intermediate bracket and drive assembly to the armature. (Check that the shims have been inserted between armature core and intermediate bracket).
2. Fit the seal ring to groove in the intermediate bracket. Also fit seal washers to retaining bracket, one at each end, through bolt entry point and one on dowel peg.
3. Assemble the armature sub-assembly to the retaining bracket, installing the intermediate bracket with dowel peg in the retaining bracket.
4. Slide the yoke assembly over the armature and install 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.
5. Install the two earth brushes part way in their holders and install 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 bursh flexibles will allow). Install the two through bolts in the half-holes of the brush gear plate and turn the bolts a few times 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 installed 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 fiber washer, steel washer and brake shoe parts into the commutator end cover.
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 the seal ring to the commutator end cover.
13. Install the dowel peg in the end cover approximately in line with the dowel hole in the end face of the yoke. Loosely assemble the end cover on the armature shaft and to the yoke.
14. Attach the two through bolts and then attach the two brush gear securing screws. (Difficulty in installing the threads of the brush gear securing screws is avoided by attaching the through bolts to the brush gear securing screws first).
15. Loosely fit the eccentric pivot pin through the drive engagement lever and into the retaining 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.



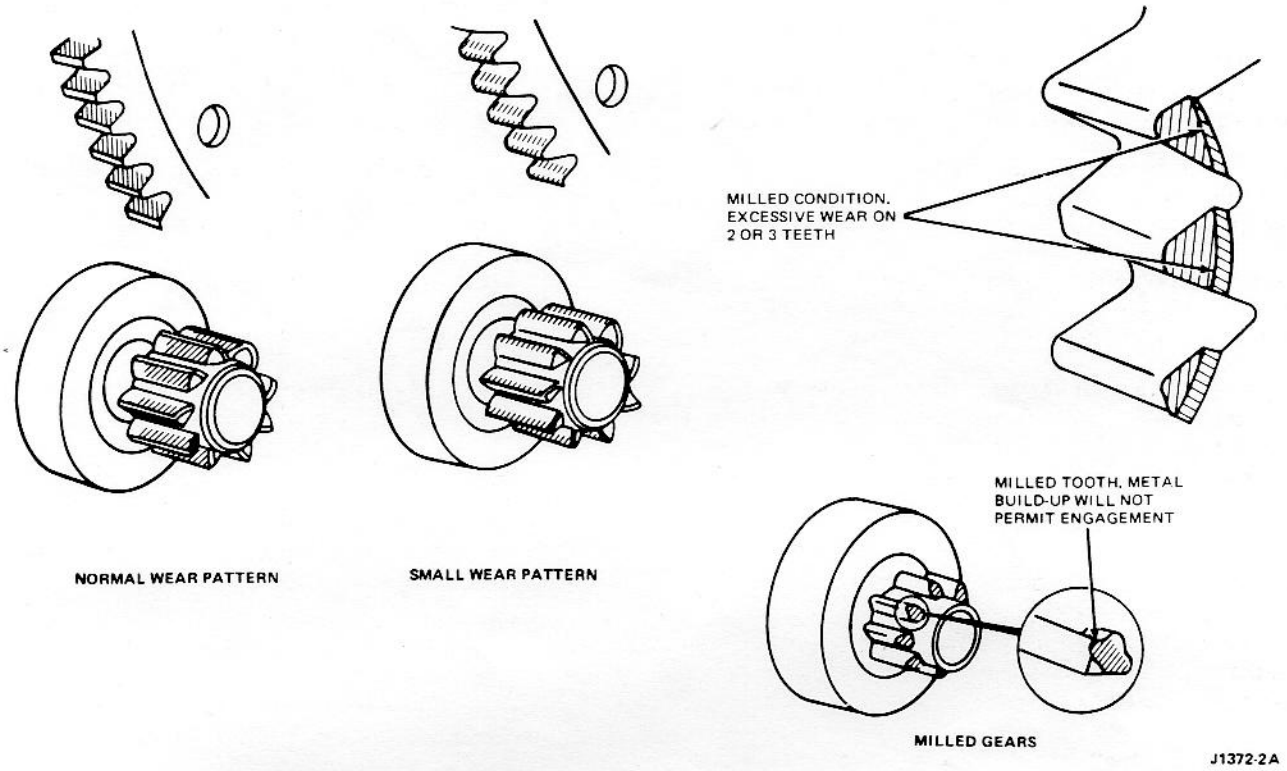


Fig. 12 - Pinion and Ring Gear Rear Patterns

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°. The center of this limit is denoted by an arrow on the retaining 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° limit of the retaining bracket marking. After adjustment, secure the pinion setting by tightening the pivot pin lock nut to a torque of (16.0 lb. ft.) 21.70 Nm.

To check or carry out the adjustment, connect a 6 volt supply between the solenoid "Lucar" terminal and the starter frame. (This will move the drive forward to the fully engaged position.) With the pinion pressed lightly back measure the space between the front pinion and the thrust collar on the armature shaft. This should be 0.015 to 0.025 in. (0.40 to 0.63 mm).

Brush Replacement

Insulated Brushes (Field Coil)

Place the yoke assembly on its end, with the brush and terminal on top (Fig. 13). Cut the worn brush flexible lead as near as possible to the field coil conductor. Carefully pry the bursh flexible joint part of the conductors, away from the yoke, to allow sufficient space for soldering the new brushes in position. Separate the ends of the two brush flexibles and position one on each side of the conductor. Pinch the ends of the flexibles and conductors together with long nosed pliers and bend the brush and flexibles firmly down over the edge and outside of the yoke (Fig. 13).

Earth Brushes (Brushgear Plate)

Place the hot soldering iron on the portion of the brush flexible joint that is rolled over. When the solder inside the joint is sufficiently heated, use a screw driver and lift the rolled portion up enough to allow the worn brush flexible lead to be pulled clear of the joint.

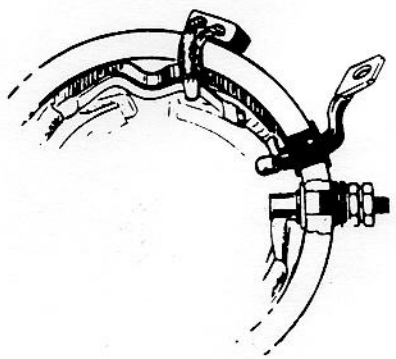


Fig. 13 - Brush and Terminal Arrangement

PART 7 - Cooling

COMPONENT INDEX

Description and Operation

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

For industrial applications, a conventional radiator is employed in conjunction with an engine driven fan. The actual size and type of radiator used will be determined by the requirements of the installation. Rapid warming-up is achieved by the use of a thermostat(s) mounted in the cylinder head water outlet position.

The four cylinder engine uses a single thermostat which opens at the coolant temperature specified. It is located in the cylinder head and is retained by the bolted-on water outlet connection used for industrial applications.

The industrial versions of the six cylinder engines are equipped with twin thermostats which operate at different coolant temperatures and incorporate a full flow radiator by-pass facility. Both thermostats are located in a special housing which is bolted to the cylinder head in place of the water outlet connection. The housing is ribbed internally to ensure that each thermostat can only be fitted in it's correct position. A specially designed water outlet connection bolts to the top of the housing and retains the thermostats. The primary thermostat has an extended center shaft which carries an additional valve to close off the by-pass port - Fig. 1 illustrates the complete operating sequence.

The same standard pump can be fitted to 4 and 6 cylinder engines. It is designed for industrial applications and has a 25,4 mm (1,0 in) diameter shaft, heavy duty bearings and a "cassette" type of seal.

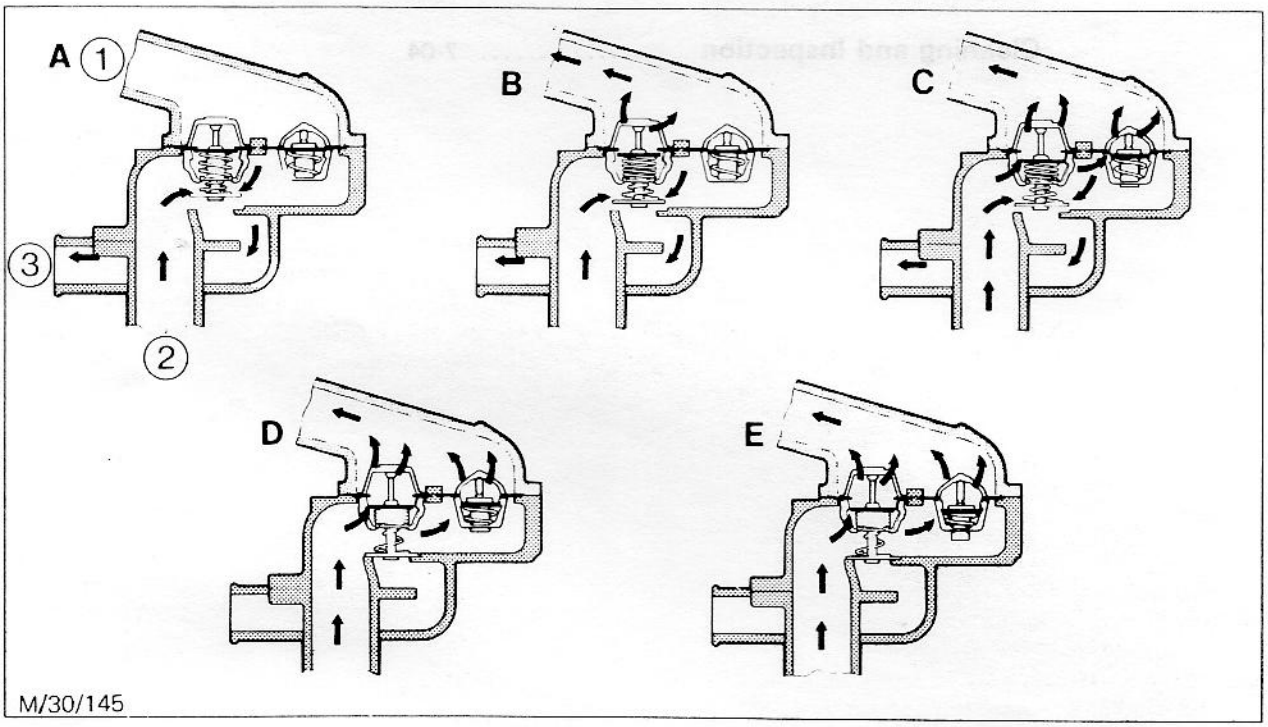


Fig. 1 - Twin Thermostat Operation

A. Primary and Secondary Thermostats Closed By-Pass Valve Open
B. Primary Opening, By-Pass Closing, Secondary Closed
C. Primary Opening, By-Pass Closing, Secondary Opening
D. Primary Fully Open, Secondary Opening, By-Pass Closed
E. Primary and Secondary Fully Open, By-Pass Valve Closed

1. Coolant Flow to Radiator
2. Coolant Flow From Engine
3. Coolant Flow to By-Pass

DIAGNOSIS AND TESTING

Thermostat Test

It is good practice to test new thermostats before installing them in the engine. It is also possible to test a thermostat that is not operating properly.

Remove the thermostat and suspend it in a container of water. gradually heat the water and check the temperature with an accurate thermometer. Be certain that the thermostat and the thermometer **do not touch** the container. The thermostat should open at the temperatures shown in the Specifications section of this manual. If the thermostat fails to open at the specified temperatures, the unit must be replaced.

If the problem being investigated is sufficient heat, the thermostat should be checked for leakage. This may be done by holding the thermostat up to a lighted background. Leakage of around the thermostat valve (thermostat at room temperature) is unacceptable and the thermostat should be replaced. It is possible, on some thermostats, that a slight leakage of light at one or two locations on the perimeter of the valve may be detected. This should be considered normal.

Pressure Test

It is recommended that a cooling system pressure test gauge be used to properly test the system for:

a. Blown or leaking cooling system sealing gaskets.

b. Internal or external cooling leakage.

c. Pressure cap malfunction.

Some modification of existing pressure testers may be required in order to use this procedure.

1. **Shut off the engine. To prevent loss of coolant and to avoid the damage of being burned, place a cloth over the cap and rotate the cap slowly counterclockwise to first stop and allow pressure to escape completely, then, turn cap again slowly counterclockwise to remove.**

2. After the cooling system pressure has been released, remove the radiator cap, wet the rubber sealing surface and re-install cap tightly on the radiator.

3. Disconnect the electrical connector from the engine temperature sending unit and remove the temperature sending unit from the manifold. (With the radiator cap installed, only a small amount of coolant will be lost when the sending unit is removed.)

4. Install an adaptor fitting tightly (3/8 N.P.T. male thread on one end, and a hose connection on the other end to accomodate the tester hose) into the intake manifold or cylinder head in place of the sending unit.

5. Remove the radiator overflow hose from the retainer clips. **Make sure the hose is firmly installed on the radiator overflow tube and is in good condition.** Insert the free end of the overflow hose into a container of water.

6. Attach the pressure pump and gauge to the adapter fitting and pressurize the cooling system until bubbles are observed in the water container. Discontinue pumping when bubbles appear.

   When the bubbles cease, read the pressure gauge. The gauge reading is the pressure relief of the cap and should be within specifications. If the pressure reading exceeds the specified limit, replace the radiator cap.

7. If bubbles continue and the pressure drops below 10 psi for engines with a 13 psi system, or below 5 psi for a 7 psi system, the radiator cap is not holding pressure. Release pressure and wash cap in clean water to dislodge any foreign matter from the valves. Check the rubber sealing surface of the cap and also the cap sealing surface in the radiator neck. Inspect the cam for maximum cap engagement.

8. Re-check the cooling system as outlined in Step 6. If the cap still does not hold pressure, the cap is damaged and must be replaced. Re-check the system after a new cap is installed to assure that the system will now hold pressure.

9. If the bubbles in the water container cease and the radiator cap is within pressure specifications, observe gauge reading for approximately two minutes. Pressure should not drop during this time.

10. If pressure drops, check for leaks at engine to radiator hoses, bypass hose, thermostat housing gasket, etc. Any leaks which are found must be corrected and the system re-checked.

11. If the system holds pressure, remove the radiator cap to release the pressure; then, reinstall the cap.

12. Remove the adaptor from the manifold or cylinder head and reinstall the temperature sending unit. Check cooling level and replenish, if necessary, with the correct coolant solution.

ADJUSTMENTS

Drive Belt

The fan drive belt should be properly adjusted at all times. A loose drive belt can cause improper alternator, fan and water pump operation. A belt that is too tight places a severe strain on the water pump and alternator bearings.

A properly tensioned drive belt minimizes noise and also prolongs the service life of the belt. Therefore, it is recommended that a belt tension gauge be used to check and adjust the belt tension. **Any belt that has been operated for a minimum of 10 minutes is considered a used belt, and when adjusted, it must be adjusted to the used belt tension shown in the specifications.**

Belt Tension

1. Install the belt tension tool on the drive belt and check the tension.
2. If adjustment is necessary, loosen the alternator mounting and adjusting arm bolts. Move the alternator toward or away from the engine until the correct tension is obtained. Remove the gauge.
3. Tighten the alternator adjusting arm bolt and the mounting bolts. Install the tension gauge and check the belt tension.

CLEANING AND INSPECTION

Cooling System

To remove rust, sludge and other foreign material from the cooling system, use either Ford Motor Company Regular Cooling System Cleanser or in severe cases use Heavy Duty Cleanser. Removal of such material restores cooling efficiency and avoids overheating.

In severe cases where cleaning solvents will not properly clean the cooling system for efficient operation, it will be necessary to use the pressure flushing method.

Various types of flushing equipment are available. If pressure flushing is used, make sure the cylinder head bolts are properly tightened to prevent possible water leakage into the cylinders.

Always remove the thermostat prior to pressure flushing.

A pulsating or reversed direction of flushing water flow will loosen sediment more quickly than a steady flow in the normal direction of coolant flow.

SPECIFICATIONS

Model		ESD-442	ESD-659	ESD-662	ESD-660T
Type		OHV Direct Injection Diesel			
		Naturally Aspirated			Turbocharged
Number of Cylinders		4	6	6	6
Bore	mm (in)	107.21 (4.221)	104.80 (4.126)	107.21 (4.221)	104.80 (4.126)
Stroke	mm (in)	114.80 (4.524)	114.80 (4.524)	114.80 (4.524)	114.80 (4.524)
Capacity	Liter (CID)	4.2 (254)	5.9 (362)	6.2 (380)	6.0 (363)
Compression Ratio		15.9:1	15.9:1	15.9:1	15.45:1
Firing Order		1,2,4,3	1,5,3,6,2,4	1,5,3,6,2,4	1,5,3,6,2,4

CYLINDER BLOCK

Bore Diameter - Standard

659 Engine ..... 104.770 mm (4.1248 in)
104.820 mm (4.1268 in)

660 Engine ..... Grade 1 - 104.783 to 104.795 mm (4.1253 to (4.1258 in)
Grade 2 - 104.795 to 104.818 mm (4.1258 to 4.1263 in)

442 and 662 Engines ..... 107.188 mm (4.2200 in)
107. 238 mm (4.2220 in)

Cylinder Bore Taper - Maximum Service Limit ..... 0.0013 mm (0.0005 in)

Cylinder Liners - 660 Engine Only

Bore Diameter in the Cylinder Block ..... Grade 1 - 108.966 to 108.991 mm (4.290 to 4.291 in)
for the Cylinder Liner ..... Grade 2 - 108.991 to 109.016 mm (4.291 to 4.292 in)

Cylinder Liner Outside Diameter ..... Grade 1 - 108.953 to 108.979 mm (4.289 to 4.290 in)
Grade 2 - 108.979 to 109.004 mm (4.290 to 4.291 in)

Cylinder Liner Protrusion above or below the ..... 0.254 mm (0.001 in) max below face to
Top Face of the Cylinder Block ..... 0.127 mm (0.005 in) max above face

Bore Diameter for Main Bearings

Standard Size ..... 80.429 to 80.459 mm (3.1665 to 3.1676 in)
Oversize 0.381 mm (0.015 in) - Service Only ..... 80.810 to 80.843 mm (3.1815 to 3.1826 in)

Bore Diameter for Camshaft Bearing

Standard Size ..... 58.750 to 58.775 mm (2.313 to 2.314 in)
Oversize 0.508 mm (0.02 in) - Service Only ..... 59.260 to 59.285 mm (2.333 to 2.334 in)

PISTON, PISTON RINGS AND PISTON PIN

Piston

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

Naturally Aspirated Engines	X = 56.3 mm (2.217 in)
Turbocharged Engines	X = 25.6 mm (1.01 in)

Skirt Diameter - Standard Size

659 Engine	104.658 mm (4.1204 in) 104.707 mm (4.1223 in)
442 and 662 engines	107.076 mm (4.2156 in) 107.125 mm (4.2175 in)
660T Engines	Grade 1 - 104.592 to 104.618 mm (4.1178 to 4.1188 in) Grade 2 - 104.618 to 104.693 mm (4.1188 to 4.1198 in)

Skirt Diameter - Oversize (Measured at the Grade Point)

659 Engine	
Oversize 0.381 mm (0.015 in)	105.089 to 105.113 mm (4.137 to 4.138 in)
0.889 mm (0.035 in)	105.597 to 105.621 mm (4.157 to 4.158 in)
1.397 mm (0.055 in)	106.105 to 106.129 mm (4.177 to 4.178 in)
442 and 662 Engines	
Oversize 0.381 mm (0.015 in)	107.507 to 107.531 mm (4.2326 to 4.2335 in)
0.889 mm (0.035 in)	108.015 to 108.039 mm (4.2526 to 4.2535 in)
1.397 mm (0.055 in)	108.523 to 108.547 mm (4.2726 to 4.2735 in)

Piston Skirt Clearance in the Cylinder Bore - at the grade point

Naturally Aspirated Engines	0.088 to 0.137 mm (0.0035 to 0.0054 in)
Turbocharged Engines	0.152 to 0.203 mm (0.006 to 0.008 in)

Piston Protrusion

Height above the Cylinder Block Top Face at T.D.C. (See Connecting Rod Length)	0.152 tp 0.381 mm (0.006 to 0.015in)

Piston Ring Grooves

Number of Ring Grooves	
Naturally Aspirated Engines	3
Turbocharged Engines	4
Width of Ring Grooves for - Top Compression Ring	
Turbocharged Engines	Tapered Ring
Naturally Aspirated Engines	2.465 to 2.485 mm (0.097 to 0.098 in)
Second Compression Ring (All Engines)	2.445 to 2.465 mm (0.096 to 0.097 in)
Third Compression Ring - (Turbocharged Engines Only)	2.444 to 2.469 mm (0.096 to 0.097 in)
Oil Control Ring	
Turbocharged Engines	4.800 to 4.826 mm (0.189 to 0.190 in)
Naturally Aspirated Engines	4.767 to 4.787 mm (0.188 to 0.189 in)

Piston Pin Bore Diameter

Naturally Aspirated Engines	36.508 to 36.516 mm (1.4373 to 1.4376 in)
Turbocharged Engines	40.991 to 41.001 mm (1.6138 to 1.6142 in)

PISTON, PISTON RINGS AND PISTON PIN - Continued

Piston Rings	
Piston Ring Gap	
Naturally Aspirated Engines	
Compression Rings - All	0.33 to 0.58 mm (0.013 to 0.023 in)
Oil Control Ring	0.33 to 0.71 mm (0.013 to 0.028 in)
Turbocharged Engines	
Compression Rings - Top	0.43 to 0.64 mm (0.017 to 0.025 in)
- Second and Third	0.33 to 0.58 mm (o.013 to 0.023 in)
Oil Control Ring	0.33 to 0.58 mm (o.013 to 0.023 in)
Piston Ring Width	
Naturally Aspirated Engines	
Compression Rings - Top	2.362 to 2.375 mm (0.0930 tp 0.0935 in)
- Second	2.351 to 2.375 mm (0.0926 to 0.0935 in)
Oil Control Ring	4.717 to 4.737 mm (0.1857 to 0.1865 in)
Turbocharged Engines	
Compression Rings - Top	Tapered
- Second and Third	2.351 to 2.375 mm (0.0926 to 0.0935 in)
Oil Control Ring	4.717 to 4.737 mm (0.1857 to 0.1865 in)
Piston Ring to Piston Groove Clearance	
Naturally Aspirated Engines	
Compression Rings - Top	0.090 to 0.123 mm (0.0035 to 0.0048 in)
- Second	0.070 to 0.114 mm (0.0028 to 0.0045 in)
Oil Control Ring	0.030 to 0.070 mm (0.0012 to 0.0028 in)
Turbocharged Engines	
Compression Rings - Rop	0.000 to 0.127 mm (0.0000 to 0.0050 in)
- Second and Third	0.069 to 0.118 mm (0.0027 to 0.0047 in)
Oil Control Ring	0.064 to 0.109 mm (0.0025 to 0.0043 in)
Piston Pin	
Outside Diameter	
Naturally Aspirated Engines	36.502 to 36.510 mm (1.4371 to 1.4374 in)
Turbocharged Engines	40.985 to 40.993 mm (1.6136 to 1.6139 in)
Clearance in Piston Bosses at 20°C (68°F)	
Note: Piston pins are fitted selectively to pistons to obtain the specified clearance. These components should be retained as matched sets if re-assembling to an engine.	
Selective Fit	0.002 to 0.010 mm (0.00008 to 0.00040 in)
Length	
Naturally Aspirated Engines	85.80 to 86.20 mm (3.378 to 3.394 in)
Turbocharged Engines	86.74 to 87.12 mm (3.415 to 3.430 in)

CONNECTING RODS

Length - Center of Crank Bore to Center of Pin Bore

Note: Grade letter is center letter of the three identifying letters on crank thrust face. Graded rods are used to control piston protrusion (See Piston Specifications).

Grade A	203.175 to 203.251 mm (7.999 to 8.002 in)
Grade B [Plus 0.076 mm (0.003 in)]	203.251 to 203.327 mm (8.002 to 8.005 in)
Grade C [Plus 0.152 mm (0.006 in)]	203.327 to 203.403 mm (8.005 to 8.008 in)
Grade D [Plus 0.228 mm (0.009 in)]	203.403 to 203.479 mm (8.008 to 8.011 in)

Crank Bore Diameter (Steel)

659 Engine	67.208 to 67.223 mm (2.6460 to 2.6466 in)
All Other Engines	70.879 to 70.894 mm (2.7950 to 2.7911 in)

Pin Bore Diameter (Steel)

Naturally Aspirated Engines	39.67 to 39.72 mm (1.562 to 1.564 in)
Turbocharged Engines	44.08 to 44.13 mm (1.7354 to 1.7374)

Pin Bushing Bore Diameter

Naturally Aspirated Engines	36.523 to 36.541 mm (1.4379 to 1.4386 in)
Turbocharged Engines	41.006 to 41.024 mm (1.6144 to 1.6151 in)

Piston Pin Bushing to Piston Pin Clearance	0.013 to 0.039 mm (0.0005 to 0.0015 in)
End Play on Crankshaft	0.076 to 0.279 mm (0.003 to 0.011 in)

CRANKSHAFT, CRANKSHAFT BEARINGS AND OIL SEAL

Main Bearing Journals

Diameter - Standard Size

Naturally Aspirated Engines	
Standard Size 1	76.200 to 76.230 mm (3.0000 to 3.0012 in)
Standard Size 2	75.946 to 75.976 mm (2.9900 to 2.9912 in)
Turbocharged Engines	76.205 to 76.225 mm (3.0002 to 3.0010 in)

Diameter - Service Regrind

All Engines	
Standard Size 1	
Undersize 0.254 mm (0.010 in)	75. 958 to 75.971 mm (2.9905 to 2.9910 in)
0.508 mm (0.020 in)	75.704 to 75.717 mm (2.9805 to 2.9810 in)
0.762 mm (0.030 in)	75.450 to 75.463 mm (2.9705 to 2.9710 in)
1.016 mm (0.040 in)	75.196 to 75.209 mm (2.9605 to 2.9610 in)

Naturally Aspirated - Standard Size 2	
Undersize 0.254 mm (0.010 in)	75.704 to 75.717 mm (2.9805 to 2.9810 in)
0.508 mm (0.020 in)	75.450 to 75.463 mm (2.9705 to 2.9710 in)
0.762 mm (0.030 in)	75.196 to 75.209 mm (2.9605 to 2.9610 in)

Length

Front	32.89 to 33.15 mm (1.295 to 1.305 in)
Center	45.695 to 45.745 mm (1.799 to 1.801 in)
Rear	46.51 to 46.76 mm (1.831 to 1.841 in)
Intermediate	35.43 to 35.69 mm (1.395 to 1.405 in)

CRANKSHAFT, CRANKSHAFT BEARINGS AND OIL SEAL - Continued

Main Bearing Journals	
Runout	
Runout of Intermediate and Center Bearings Journals with Crankshaft Mounted on Front and Rear Journals	
4 Cyl.	0.064 mm (0.025 in) T.I.R. Maximum
6 Cyl.	0.051 mm (0.022 in) T.I.R. Maximum
Thrust Faces	
Taper on Each Face	0.051 mm (0.002 in) Maximum
Runout at Outside Edge	0.013 mm (0.0005 in) T.I.R. Maximum
Crankpin Bearing Journals	
Diameter - Standard Size	
659 Engine	
Standard Size 1	63.492 to 63.512 mm (2.4997 to 2.5005 in)
Standard Size 2	63.213 to 63.258 mm (2.4887 to 2.4905 in)
442 and 662 Engines	
Standard Size 1	66.654 to 66.675 mm (2.6242 to 2.6250 in)
Standard Size 2	66.400 to 66.421 mm (2.6142 to 2.6150 in)
Turbocharged Engines	66.654 to 66.675 mm (2.6242 to 2.6250 in)
Diameter - Service Regrind	
659 Engine - Standard Size 1	63.246 to 63.258 mm (2.4900 to 2.4905 in)
Undersize	
- 0.254 mm (0.010 in)	63.246 to 63.258 mm (2.4900 to 2.4905 in)
- 0.508 mm (0.020 in)	62.992 to 63.004 mm (2.4800 to 2.4805 in)
- 0.762 mm (0.030 in)	62.738 to 62.750 mm (2.4700 to 2.4705 in)
- 1.016 mm (0.040 in)	62.484 to 62.496 mm (2.4600 to 2.4605 in)
659 Engine - Standard Size 2	
Undersize	
- 0.254 mm (0.010 in)	62.992 to 63.004 mm (2.4800 to 2.4805 in)
- 0.508 mm (0.020 in)	62.738 to 62.750 mm (2.4700 to 2.4705 in)
- 0.762 mm (0.030 in)	62.484 to 62.496 mm (2.4600 to 2.4605 in)
442 and 662 Engines - Standard Size 1	
Undersize	
- 0.254 mm (0.010 in)	66.408 to 66.421 mm (2.6145 to 2.6150 in)
- 0.508 mm (0.020 in)	66.154 to 66.167 mm (2.6045 to 2.6050 in)
- 0.762 mm (0.030 in)	65.900 to 65.913 mm (2.5945 to 2.5950 in)
- 1.016 mm (0.040 in)	65.646 to 65.659 mm (2.5845 to 2.5850 in)
442 and 662 Engines - Standard Size 2	
Undersize	
- 0.254 mm (0.010 in)	66.154 to 66.167 mm (2.6045 to 2.6050 in)
- 0.508 mm (0.020 in)	65.900 to 65.913 mm (2.5945 to 2.5950 in)
- 0.762 mm (0.030 in)	65.646 to 65.659 mm (2.5845 to 2.5850 in)
Turbocharged Engines - Standard Size 1	
Undersize	
- 0.254 mm (0.010 in)	66.408 to 66.421 mm (2.6145 to 2.6150 in)
- 0.058 mm (0.020 in)	66.154 to 66.167 mm (2.6045 to 2.6050 in)
- 0.762 mm (0.030 in)	65.900 to 65.913 mm (2.5945 to 2.5950 in)
- 1.016 mm (0.040 in)	65.646 to 65.659 mm (2.5845 to 2.5850 in)
Length	42.160 to 42.266 mm (1.660 to 1.664 in)

CRANKSHAFT, CRANKSHAFT BEARINGS AND OIL SEAL - Continued

Main and Connecting Rod Bearing Journals	
Fillet Radii	4.32 to 4.83 mm (0.17 to 0.19 in)
Out of Round - Maximum Permitted	
Rod Journal	0.006 mm (0.00025 in)
Main Journal	0.010 mm (0.00040 in)
Taper - Maximum Permitted	0.013 mm (0.0005 in)
Main Bearing Inserts	
Thickness - Standard	
Standard Size 1	2.071 to 2.080 mm (0.08250 to 0.08215 in)
Standard Size 2	2.198 to 2.207 mm (0.08750 to 0.08715 in)
Thickness - Service Regrind	
Standard Size 1	
Undersize 0.254 mm (0.010 in)	2.198 to 2.207 mm (0.08655 to 0.08690 in)
0.508 mm (0.020 in)	2.325 to 2.334 mm (0.09155 to 0.09190 in)
0.762 mm (0.030 in)	2.452 to 2.461 mm (0.09655 to 0.09690 in)
1.016 mm (0.040 in)	2.579 to 2.588 mm (0.10155 to 0.10190 in)
Standard Size 2	
Undersize 0.254 mm (0.010 in)	2.325 to 2.334 mm (0.09155 to 0.09190 in)
0.508 mm (0.020 in)	2.452 to 2.461 mm (0.09655 to 0.09690 in)
0.762 mm (0.030 in)	2.579 to 2.588 mm (0.10155 to 0.10190 in)
Note: For 0.381 mm (0.015 in) oversize bearing housings, liners are 0.191 mm (0.0075 in) thicker than dimensions specified above.	
Length - Front and Intermediate	26.29 to 26.67 mm (1.035 to 1.050 in)
- Center and Rear	35.81 to 36.19 mm (1.410 to 1.425 in)
Clearance - Main Bearing to Journal	0.038 to 0.086 mm (0.0015 to 0.0034 in)
Thrust Washer	
Thickness	
Standard	2.311 to 2.362 mm (0.091 to 0.093 in)
Oversize 0.063 mm (0.0025 in)	2.375 to 2.426 mm (0.0935 to 0.0955 in)
0.127 mm (0.0050 in)	2.438 to 2.489 mm (0.0960 to 0.0980 in)
0.190 mm (0.0075 in)	2.502 to 2.553 mm (0.0985 to 0.1005 in)
0.254 mm (0.010 in)	2.565 to 2.616 mm (0.101 to 0.103 in)
0.381 mm (0.015 in)	2.692 to 2.743 mm (0.106 to 0.108 in)
0.508 mm (0.020 in)	2.819 to 2.870 mm (0.111 to 0.113 in)
Clearance (Crankshaft End Play)	0.050 to 0.254 mm (0.002 to 0.010 in)
Connecting Rod Bearings Inserts	
Thickness - Standard	
659 Engine	
Standard Size 1	1.821 to 1.830 mm (0.07170 to 0.07205 in)
Standard Size 2	1.948 to 1.957 mm (0.07670 to 0.07705 in)
442. 662 and 660T Engines	
Standard Size 1	2.075 to 2.084 mm (0.08170 to 0.08205 in)
Standard Size 2	2.202 to 2.211 mm (0.08670 to 0.08705 in)

CRANKSHAFT, CRANKSHAFT BEARINGS AND OIL SEAL - Continued

Thickness - Service Regrind	
659 Engine - Standard Size 1	
Undersize 0.254 mm (0.010 in)	1.948 to 1.957 mm (0.07670 to 0.07705 in)
0.508 mm (0.020 in)	2.075 to 2.084 mm (0.08170 to 0.08205 in)
0.762 mm (0.030 in)	2.202 to 2.211 mm (0.08670 to 0.08705 in)
1.016 mm (0.040 in)	2.329 to 2.338 mm (0.0917 to 0.09205 in)
659 Engine - Standard Size 2	
Undersize 0.254 mm (0.010 in)	2.075 to 2.084 mm (0.08170 to 0.08205 in)
0.508 mm (0.020 in)	2.202 to 2.211 mm (0.08670 to 0.08705 in)
0.762 mm (0.030 in)	2.329 to 2.338 mm (0.09170 to 0.09205 in)
442, 662 and 660T Engines - Standard Size 1	
Undersize 0.254 mm (0.010 in)	2.202 to 2.211 mm (0.08670 to 0.08705 in)
0.508 mm (0.020 in)	2.329 to 2.338 mm (0.09170 to 0.09205 in)
0.762 mm (0.030 in)	2.456 to 2.465 mm (0.09670 to 0.09705 in)
1.016 mm (0.040 in)	2.583 to 2.592 mm (0.10170 to 0.10205 in)
442, 662 and 660T Engines - Standard Size 2	
Undersize 0.254 mm (0.010 in)	2.329 to 2.338 mm (0.09170 to 0.09205 in)
0.508 mm (0.020 in)	2.456 to 2.465 mm (0.09670 to 0.09705 in)
0.762 mm (0.030 in)	2.583 to 2.592 mm (0.10170 to 0.10205 in)
Width	33.655 to 34.036 mm (1.325 to 1.340 in)
Clearance - Connecting Rod Bearing to Journal	
Standard	0.036 to 0.086 mm (0.0014 to 0.0034 in)
Service Regrind	0.036 to 0.079 mm (0.0014 to 0.0031 in)
End Play	0.076 to 0.279 mm (0.003 to 0.011 in)

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

Crankshaft Oil Seal	
Seal Protrusion Above Cylinder Block/Rear Main Bearing Cap Face	
- Both Sides, Both Faces	0.635 to 0.762 mm (0.025 to 0.030 in)
Crankshaft Turning Torque	
Crankshaft Only in Block	
442 Engine	8 to 16 NM (6 to 12 lbft)
659. 662 and 660T	11 to 20 Nm (8 to 15 lbft)
Complete Engine Less Injectors and Driven Equipment	
442 Engine	34 to 61 Nm (25 to 45 lbft)
659 and 662 Engines	47 to 75 Nm (35 to 55 lbft)
660T Engine	41 to 68 Nm (30 to 50 lbft)

CAMSHAFT AND TAPPETS

Camshaft	
Cam Lift - Maximum	7.87 mm (0.310 in)
Bearing Journal Diameter	55.48 to 55.50 mm (2.1842 to 2.1850 in)

CAMSHAFT AND TAPPETS - Continued

Bearing Journal Clearance	
Front	0.038 to 0.076 mm (0.0015 to 0.0030 in)
Intermediate and Rear	0.025 to 0.064 mm (0.0010 to 0.0025 in)
End Play	0.050 to 0.533 mm (0.002 to 0.021 in)
Tappets	
Stem Diameter	17.475 to 17.488 mm (0.6880 to 0.6885 in)
Length - Cup to Face	56.75 to 57.25 mm (2.2343 to 2.2539 in)
Clearance - Tappet to Cylinder Block	0.012 to 0.063 mm (0.0005 to 0.0025 in)

TIMING GEARS

Number of Teeth	
Crankshaft Gear	35
Camshaft Gear	70
Fitting	
Camshaft Gear to Camshaft	0.042 mm (0.0016 in) to 0.002 mm (0.0008 in) Interference
Crankshaft Gear to Crankshaft	0.0000 mm (0.00 in) to 0.50 mm (0.002 in) Interference
Temperature - Crankshaft and Camshaft Gears	82°C (180°F)
Backlash	
Crankshaft Gear to Camshaft Gear	0.025 to 0.279 mm (0.001 to 0.011 in)
Camshaft Gear to Injection Pump Gear	0.025 to 0.279 mm (0.001 to 0.011 in)

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

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

FLYWHEEL AND STARTER RING GEAR

Runout of Flywheel Face at a Radius of 140 mm (5.5 in)	0.178 mm (0.007 in) T.I.R. Maximum
Number of Teeth on Ring Gear	128
Fitting Temperature of Ring Gear	190°C (375°F)

CYLINDER HEAD, VALVE GUIDES AND VALVE SEAT INSERTS

Cylinder Head	
Datum Face	Rocker Cover Face
Height - (New)	92.68 to 92.81 mm (3.649 to 3.654 in)
- Minimum After Re-surfacing	92.17 to 92.30 mm (3.629 to 3.634 in)
Bow/Twist Within	0.254 mm (0.010 in) Max. Overall
Valve Guide	
Length	76.2 mm (3.0 in)
Diameter - Internal	9.528 to 9.558 mm (0.3751 to 0.3763 in)
- External - Standard	15.893 to 15.905 mm (0.6257 to 0.6262 in)
Protrusion Above the Top Face	
- Inlet	18.29 mm (0.72 in)
- Exhaust	26.67 mm (1.05 in)

CYLINDER HEAD, VALVE GUIDES AND VALVE SEAT INSERTS - Continued

Valve Seat Insert Recess - Standard Size

Diameter - Inlet	46.876 to 46.901 mm (1.8455 to 1.8465 in)
- Exhaust	39.764 to 39.789 mm (1.5655 to 1.5665 in)
Depth - Inlet and Exhaust	6.553 to 6.832 mm (0.258 to 0.269 in)

Valve Seat Insert Recess - Oversize	0.254 mm (0.010 in)

Diameter - Inlet	47.130 to 47.155 mm (1.8555 to 1.8565 in)
- Exhaust	40.018 to 40.043 mm (1.5755 to 1.5765 in)
Depth - Inlet and Exhaust	6.807 to 7.085 mm (0.268 to 0.279 in)

Valve Seat Insert - Standard Size

Outside Diameter - Inlet	46.977 to 46.990 mm (1.8495 to 1.8500 in)
- Exhaust	39.865 to 39.878 mm (1.5695 to 1.5700 in)
Thickness - Inlet and Exhaust	6.794 to 6.845 mm (0.2675 to 0.2695 in)

Valve Seat Insert - Oversize 0.254 mm (0.010 in)

Outside Diameter - Inlet	47.231 to 47.244 mm (1.8595 to 1.8600 in)
- Exhaust	40.119 to 40.132 mm (1.5795 to 1.5800 in)
Thickness - Inlet and Exhaust	7.048 to 7.099 mm (0.2775 to 0.2795 in)

Valve Seat Face Width	1.60 to 2.38 mm (0.063 to 0.094 in)

Valve Seat Angle	30° 00' to 30° 30'

VALVES

Head Diameter - Inlet	45.47 to 45.72 mm (1.790 to 1.800 in)
- Exhaust	38.15 to 38.40 mm (1.502 to 1.512 in)
Stem Diameter - Inlet	9.474 to 9.500 mm (0.373 to 0.374 in)
- Exhaust	9.456 to 9.482 mm (0.3723 to 0.3733 in)
Stem to Guide Clearance - Inlet	0.028 to 0.084 mm (0.0011 to 0.0033 in)
- Exhaust	0.045 to 0.102 mm (0.0018 to 0.0004 in)

Angle of Valve Face	29° 00' to 29° 30'

Valve Head Protrusion Compared to Head Face	
- Inlet	+ 0.254 to - 0.508 mm (+ 0.010 to - 0.020 in)
- Exhaust	+ 0.431 to + 1.016 mm (+ 0.017 to + 0.040 in)

VALVE SPRINGS

Inlet

Number of Coils	7.5 Total
Free Length of Spring	58.7 mm (2.31 in)
Spring Load at a length of 40 mm (1.56 in)	71.21 to 76.66 kg (157 to 169 lb)
(Assembled Height) 50 mm (1.97 in)	28.12 to 30.84 kg (62 to 68 lb)
Identification	Blue Paint Line

Exhaust

Number of Coils	7.98 Total
Free Length of Spring	69.93 mm (2.753 in)
Spring Load at a length of 40 mm (1.56 in)	70.31 to 77.56 kg (155 to 171 lb)
(Assembled Height) 50 mm (1.97 in)	46.11 to 50.96 kg (102 to 112 lb)
Identification	Yellow Paint Line

ROCKER SHAFT, ROCKERS AND PUSH RODS

Rocker Shaft	
Diameter	18.872 to 18.898 mm (0.743 to 0.744 in)
Number of Springs	
- 4 Cylinder Engines	4
- 6 Cylinder Engines	6
Load of Rocker Shaft Spring	1.81 to 2.27 kg at 26.92 mm (4 to 5 lb at 1.06 in)
Rocker - Bore Diameter	18.923 to 18.949 mm (0.7450 to 0.746 in)
Push Rod - Length (Cup to Ball)	301.88 to 302.64 mm (11.89 to 11.91 in)

VALVE CLEARANCE

Clearance (Hot and Cold - All Valves)	
Naturally Aspirated Engines	0.38 mm (0.015 in)
Turbocharged Engines	0.46 mm (0.018 in)

LUBRICATION SYSTEM

Engine	442	659	662	660T
Oil Temperature (Max)	116°C (241°F)			
Oil Pressure (Min) 1600 min	41 PSI		30 PSI	
2000 rpm	47 PSI		43 PSI	
Service Oil Fill capacity (Including Filter)				
Front Well, Rear Well or Shallow Oil Pan	9.1 litre (9.6 qts)		13.6 litre (14.4 qts)	
Engine with High Inclination Oil Pan	10.8 litre (11.5 qts.)		22.5 litre (23.8 qts)	
Oil Filter Capacity	1 litre (1.057 qts)			
Oil Type	Naturally Aspirated ..... API - SF and or CD Turbocharged ..... API - CD Only **Caution:** Lubricants qualified to Dexron II automatic transmission fluid specification are **not to be used.**			
Oil Grade (Viscosity)				
Below 20°C (70°F)	SAE 10W			
Between 0°C and 32°C (32°F and 90°F)	SAE 20W/20			
Above 30°C (85°F)	SAE 30			
Oil Pump				
Delivery in Litres (Gallons)/Min				
Front Well, Rear Well or Shallow Oil Pan	36.37 (9.6) at 2000 rpm			
Engine with High Inclination Oil Pan	27.9 (7.4) at 1000 rpm	36.37 (9.6) at 1000 rpm		
Rotor End Play	0.127 mm (0.005 in) max			
Clearance - Drive Gear to Pump Housing	0.13 to 0.38 mm (0.005 to 0.015 in)			
Clearance - Inner to Outer Rotor Lobes	0.229 mm (0.009 in) max			
Clearance - Outer Rotor to Pump Housing	0.304 mm (0.012 in) max			

FUEL SYSTEM

INJECTION PUMP - C.A.V. In-Line with Mechanical Governor - Clockwise Rotation (From Front End)

Oil Priming Quantities G.P. Governed Pumps Only	4 Cylinder Engines 6 Cylinder Engines	215 ml/7.25 oz 430 ml/14.5 oz

Engine/Governing	Injection Pump Part No.	CAV Pump Part No.
442/G.P.I	826F-9A543-DBB	P5510/2
442/G.P.II	826F-9A543-DCB	P5513/2
442/Class A, 1500/1800	826F-9A543-DDA	P5537/A
659/G.P.I	826F-9A543-EBB	P5515/2
659/Class A, 1500/1800	826F-9A543-EDA	P5538/A
662/G.P.I	826F-9A543-FCB	P5519/2
662/G.P.II	826F-9A543-FDB	P5520/2
662/Class A, 1500/1800	826F-9A543-FFA	P5539/A
662/Combine	826F-9A543-FEA	P5543
660T/G.P.	826F-9A543-HCB	P5523/2
660T/Class A, 1500/1800	826F-9A543-HFA	P5540/A

Engine/Governing	Pump Timing B.T.D.C.	Engine Idling Speed in RPM	Engine Maximum No Load Speed in RPM
442/G.P.I	22°	625 to 675	2705 to 2715
442/G.P.II	22°	625 to 675	2815 to 2825
Class A, 1500/1800	24°	850 to 950	1565 to 1575 1880 to 1890
659/G.P.I	23°	625 to 675	2705 to 2715
659/Class A, 1500/1800	26°	850 to 950	1565 to 1575 1880 tp 1890
659/Combine	24°	1150 to 1250	2645 to 2650
662/G.P.I	22°	625 to 675	2705 to 2715
662/G.P.II	22°	625 to 675	2815 to 2825
Class A, 1500/1800	24°	850 to 950	1565 to 1575 1880 to 1890
662/Combine	25°	1150 to 1250	2640 to 2645
660T/G.P.	24°	625 to 675	2600 to 2610
660T/Class A, 1500/1800	24°	850 to 950	1565 to 1575 1880 to 1890

EXCESS FUEL TEMPERATURE SWITCH

Contacts Close (Decreasing Temperature)	+3° to -3°C (37° to 022°F)	Contacts Open (Increasing Temperature)	5° to 11°C (41° to 52°F)

INJECTORS - CAV

Engine/Governing	Setting Pressure - New or Reconditioned with new spring that has not exceeded 10 hours life in an engine	Working Pressure - For Injectors that have exceeded 10 hours in an engine
All	208 to 218 bar (3016 to 3160 P.S.I.)	197 bar (2856 P.S.I.)

INJECTORS - CAV - Continued

Nozzle Holes	
Quantity:	Four (All Types)
Diameter:	Naturally Aspirated: 0.295 to 0.305 mm Turbocharged Type 6801016: 0.325 to 0.335 mm

Back Leakage Time

	Test Oil Ambient Temperature		
	°C	°F	Back Leak Time in Seconds
For a fall in pressure from 150 to 100 bar (2175 to 1450 P.S.I.)	10	50	7 to 34.5
	16	60	6 to 30
	21	70	5.5 to 27
	27	80	5 to 24
	32	90	4.5 to 21

Test Oil	Shell Calibration Fluid "B" or "C" or Equivalent

HOLSET TURBOCHARGERS

	Model HIC/D		Model H2A	
	mm	in	mm	in
Center (Bearing) Housing				
Bearing Bore Diameter	15.875 - 15.885	0.6250 - 0.6254	15.875 - 15.885	0.625 - 0.6254
Seal (Piston Ring) Bore Diameter	19.305 - 19.330	0.760 - 0.7610	19.305 - 19.330	0.760 - 0.7610
Turbine Wheel Assembly				
Shaft Journal Diameter	10.972 - 10.980	0.432 - 0.4323	10.972 - 10.980	0.432 - 0.4323
Piston Ring Groove Width	1.680 - 1.730	0.0661 - 0.0681	1.680 - 1.730	0.0661 - 0.0681
Journal Bearings				
Inside Diameter	11.006 - 11.013	0.4333 - 0.4336	11.006 - 11.013	0.4333 - 0.4336
Outside Diameter	15.801 - 15.811	0.6221 - 0.6225	15.801 - 15.811	0.6221 - 0.6225
Rotating Assembly				
Radial Movement at Compressor Impeller Hub	0.300 - 0.458	0.0118 - 0.018	0.282 - 0.464	0.0111 - 0.0138
Total End Play	0.100 - 0.155	0.0039 - 0.0061	0.100 - 0.155	0.0039 - 0.0061
Turbine Speed at Normal Full Speed/Full Load Engine Conditions	125.000 rpm		110.000 rpm	

GARRETT AIRESEARCH TURBOCHARGER TYPE TA 3503

Turbine Speed at Maximum rated Power	100.000 rpm
Center Housing	
Bearing Bore Diameter	15.80 - 15.81 mm (0.6220 - 0.6223 in)
Seal Bore Diameter	17.75 - 17.81 mm (0.699 - 0.701 in)
Turbine Wheel Assembly	
Journal Diameter	10.152 - 10.16 mm (0.3997 - 0.4000 in)
Seal Hub Diameter	17.32 - 17.35 mm (0.682 - 0.683 in)
Ring Groove Width	1.64 - 1.74 mm (0.0645 - 0.0735 in)
Blackplate	
Seal Bore Diameter	12.687 - 12.713 mm (0.4995 - 0.5005 in)

GARRETT AIRESEARCH TURBOCHARGER TYPE TA 3503 - Continued

Thrust Collar	
Bearing Groove Width	4.42 - 4.44 mm (0.1740 - 0.1748 in)
Ring Groove Width	1.621 - 1.659 mm (0.0638 - 0.0653 in)
Thrust Bearing Thickness	4.36 - 4.37 mm (0.1716 - 0.1720 in)
Journal Bearing	
Outside Diameter	15.70 - 15.71 mm (0.6182 - 0.6187 in)
Inside Diameter	10.19 - 10.20 mm (0.4010 - 0.4014 in)
Impeller Bore	6.345 - 6.353 mm (0.2498 - 0.2501 in)
Rotating Assembly	
Radial Clearance of Shaft Bearings	0.076 - 0.165 mm (0.003 - 0.0065 in)
End Float	0.025 - 0.102 mm (0.0005 - 0.004 in)
Turbocharger Turbine Housing Bolts	
Anti-seize Compound	FORD Specification SAM-1C-9107-A

COOLING SYSTEM

Thermostats	Starts to Open	Fully Open
442 Engine - Industrial or Marine	80-84°C (176-183°F)	94°C (201°F)
659, 662 and 660T Industrial Engines		
Primary	75-79°C (167-174°F)	91°C (196°F)
Secondary	80-84°C (176-183°F)	96°C (205°F)
Minimum Travel of Valve	9.1 mm (0.360 in)	
Antifreeze	50/50 Mix Water and Permanent Coolant	

CHARGING SYSTEM

Alternator - Ford

		Rating		Field Current	Slip-Ring Turning mm (inches)		Brush Length mm (inches)		Pulley Nut
Supplier	Stamp Color	Amperes @ 15V	Watts @ 15V	Amps @ 12V	Min. Dia.	Max. Runout	New	Wear Limit	Torque Nm (Lb-Ft)
Ford	Orange	40	600	4.0	31 (1.22)	.0127 (0.0005)	12.19 (.480)	6.35 (1/4)	82-135 (60-100)
Ford	Green	60	900	4.0	31 (1.22)	.0127 (0.0005)	12.19 (.480)	6.35 (1/4)	82-135 (60-100)

Belt Tension

Belt Width	Minimum Tension (For Use at Maintenance Interval Only) (Hot Engine)	Installation Tension	
		Used Belt [1]	New Belt
1/4"	18 kg (40 lbs.)	18-27 kg (40-60 lbs.)	2.27-36.2 kg 50-80 lbs.
3/8" and 15/32"	34 kg (75 lbs.)	40.8-54.4 kg (90-120 lbs.)	54.5-72.5 kg 120-160 lbs.

CHARGING SYSTEM - Continued

1/2"	34 kg (75 lbs.)	40.8-54.4 kg (90-120 lbs.)	54.5-72.5 kg 120-160 lbs.

[1] Any Belt that has operated for ten minutes or more is considered a used belt.

BATTERIES (12 VOLT) 120 AMP HOURS

Starter

Solenoid Actuated Starter Motor (Ford)				Starter Brushes			Bolt Torque (Ft.-Lbs.)
Engine	Starter Current Draw Under Normal Load (Amps)	Normal Engine Cranking Speed (rpm) @ 50°F	No Load (Amps)	Mfg. Length (Inches)	Wear Limit (Inches)	Spring Tension (Ounces)	Through Bolt Torque (In.-Lbs.)
442	420	170	100-	—	5/16	42	8
659-662	420	130	150	—	(8 mm.)	(11.07N)	(10.84 Nm)
660	480	120					

TORQUE LIMITS Nm (Ft.-Lbs.)

Cylinder Block
- Main Oil gallery Plugs (Front and Rear) ..... 27 to 34 Nm (20 to 25 lbft)
- Main Oil Gallery Cross Drilling Plug ..... 27 to 34 Nm (20 to 25 lbft)
- Connector - Turbocharger Oil Feed ..... 34 to 40 Nm (25 to 30 lbft)
- Fuel Lift Pump Mounting Studs ..... 19 to 24 Nm (14 to 18 lbft)
- Oil Pan Locating Studs ..... 31 to 39 Nm (23 to 29 lbft)
- Water Pump Mounting Stud ..... 19 to 24 Nm (14 to 18 lbft)
- Oil Pressure Sender Unit ..... 19 to 22 Nm (14 to 16 lbft)
- Drain Cock/Plug ..... 20 to 27 Nm (15 to 20 lbft)
- Crankshaft Mainbearing cap bolts.
  - 1st Stage ..... 149 to 156 Nm (110 to 115 lbft)
  - Final Stage ..... 156 to 163 Nm (115 to 120 lbft)
- Connecting Rod Cap Nuts (659 Engine Only)
  - 1st Stage ..... 60 to 75 Nm (45 to 55 lbft)
  - Final Stage ..... 75 to 82 Nm (55 to 60 lbft)
- Connecting Rod Cap Bolts (All Engines Except 659)
  - 1st Stage ..... 108 to 115 Nm (80 to 85 lbft)
  - Final Stage ..... 115 to 122 Nm (85 to 90 lbft)
- Crankshaft Pulley (All Engines)
  - Center Bolt ..... 313 to 340 Nm (230 to 250 lbft)
- Flywheel Retaining Bolts ..... 102 to 122 Nm (75 to 90 lbft)
- Oil Filter Head to Cylinder Block Bolts ..... 50 to 62 Nm (37 to 46 lbft)

Timing Gears
- Timing Gear Housing to Cylinder Block Bolts ..... 34 to 40 Nm (25 to 30 lbft)
- Camshaft Thrust Plate Bolts ..... 34 to 40 Nm (25 to 30 lbft)
- Camshaft Gear Retaining Bolt ..... 203 to 210 Nm (150 to 155 lbft)
- Timing Gear Housing Cover
  - 5/16 UNC Bolts ..... 19 to 22 Nm (14 to 16 lbft)
  - 3/8 UNC Bolts ..... 30 to 34 Nm (22 to 25 lbft)
- Timing Gear Housing Cover Inspection Plate Bolts ..... 8 to 11 Nm (6 to 8 lbft) (G.P. Governed Pumps Only)

TORQUE LIMITS - Continued

Cylinder Head	
Inlet and Exhaust Manifold Studs	37 to 40 Nm (27 to 30 lbft)
Cylinder Head Retaining Bolts	
1st Stage	60 to 75 Nm (45 to 55 lbft)
2nd Stage	122 Nm (90 lbft)
3rd Stage	Tighten Through a Further 90°
Rocker Shaft Pedestal Bolts	23 to 30 Nm (17 to 22 lbft)
Valve Clearance Adjusting Screw (Inherent Torque)	12 to 35 Nm (9 to 26 lbft)
Rocker Cover Retaining Screws	4 to 5.5 Nm (3 to 4 lbft)
Fuel Filter Mounting Bracket Retaining Bolts	31 to 39 Nm (23 to 29 lbft)
Injectors	
Injector Retaining Bolts	17 to 22 Nm (12 to 16 lbft)
High Pressure Fuel Line Nuts	17 to 20 Nm (12 to 15 lbft)
Oil Seal Nuts	22 to 27 Nm (16 to 20 lbft)
Injector Leak-Off Banjo Bolt	16 to 20 Nm (12 to 15 lbft)
Injection Pump	
Drive Gear Hub Nut (General Purpose Governed Pump Only)	60 to 65 Nm (44 to 48 lbft)
Drive Ring Gear Locking Bolts (General Purpose Governed Pump Only)	20 to 25 Nm (15 to 18 lbft)
Pump Mounting Bolts	22 to 27 Nm (16 to 20 lbft)
Filler, Level and Drain Plugs	4 to 6.8 Nm (3 to 5 lbft)
Bleed Screws	4 to 6.8 Nm (3 to 5 lbft)
Fuel Lift Pump	
Adaptor to Cylinder Bolck Nuts	19 to 24 Nm (14 to 18 lbft)
Pump Retaining Nuts - Std. Low Pressure Pump	20 to 25 Nm (15 to 18 lbft)
Pre-Filter Banjo Bolts	30 to 40 Nm (22 to 29 lbft)
Pump Retaining Bolts - High Pressure Pump	9 to 11 Nm (7 to 8 lbft)
Priming Plunger Assembly	45 to 55 Nm (33 to 40 lbft)
Inlet and Outlet Adaptors	30 to 40 Nm (22 to 29 lbft)
Plunger Spring Plug	80 to 100 Nm (60 to 74 lbft)
Low Pressure Fuel Line Unions	11 to 16 Nm (8 to 12 lbft)
Fuel Filters	
Filter Element Retaining Bolts	6.8 to 9.5 Nm (5 to 7 lbft)
Bleed Screws	6.8 to 9.5 Nm (5 to 7 lbft)
Oil Pump	
Pump Securing Bolts	18 to 22 Nm (13 to 16 lbft)
Pick-Up Tube to Pump Nut	75 to 88 Nm (55 to 65 lbft)
Pick-Up Tube Support Bracket Bolt	18 to 22 Nm (13 to 16 lbft)
End Cover Plate Retaining Bolts	16 to 20 Nm (12 to 15 lbft)
Oil Pan	
Retaining Bolts/Nuts	30 to 33 Nm (22 to 24 lbft)
Drain Plug(s)	47 to 54 Nm (35 to 40 lbft)
Water Pump	
Pump Retaining Bolts/Nuts	18 to 22 Nm (13 to 16 lbft)
Water Pump Extension Tube Bolts	43 to 50 Nm (32 to 37 lbft)
Thermostats	
Housing to Cylinder Head Retaining Bolts (Twin Thermostats Only)	18 to 22 Nm (13 to 16 lbft)
Water Outlet Connection to Housing or Cylinder Head Nut/Bolts	20 to 25 Nm (15 to 18 lbft)
Electrical	
Starter Motor Retaining Bolts	
- CAV	33 to 39 Nm (24 to 29 lbft)
- Lucas	50 to 55 Nm (37 to 40 lbft)

TORQUE LIMITS - Continued

Fans and Drive Belt	
Fan Retaining Bolts	16 to 20 Nm (12 to 15 lbft)
Turbochargers	
Turbocharger Mounting Studs - Exhaust Manifold	20 to 25 Nm (15 to 18 lbft)
Exhaust Pipe/Elbow Mounting Studs - Turbocharger	15 to 20 Nm (11 to 15 lbft)
Turbocharger to Exhaust Manifold Nuts	41 to 51 Nm (30 to 38 lbft)
Turbocharger to Support Plate Nuts	20 to 25 Nm (15 to 18 lbft)
Support Plate to Support Bracket Bolts	41 to 51 Nm (30 to 38 lbft)
Support Bracket to Cylinder Block Bolts	
5/16 UNC Bolts	18 to 22 Nm (13 to 16 lbft)
7/16 UNC Bolts	50 to 62 Nm (37 to 46 lbft)
Oil Feed Tube Flange Bolts	20 to 25 Nm (15 to 18 lbft)
Oil Feed Tube Cylinder Block Connection	34 to 40 Nm (25 to 30 lbft)
Oil Drain Tube Flange Bolts	20 to 25 Nm (15 to 18 lbft)
Oil Drain Tube Adaptor to Oil Pan	54 to 61 Nm (40 to 45 lbft)

TORQUE LIMITS

Turbocharger - Garret AiResearch Type	
Thrust Bearing Screws	4.5 Nm (3.4 lbft)
Bearing Housing to Diffuser Bolts	5.7 Nm (4.2 lbft)
Diffuser to Compressor Housing Bolts	5.7 Nm (4.2 lbft)
Bearing Housing to Turbine Housing Bolts	11.3 Nm (8.3 lbft)
Compressor Impeller Locknut	14 Nm (10 lbft)
Turbocharger - Holset Type	
Bearing Housing to Blackplate Bolts	8.5 to 10 Nm (6.5 to 7.5 lbft)
Compressor Housing to Backplate Bolts	11.5 to 14.5 Nm (8.5 to 10.5 lbft)
Bearing Housing to Turbine Housing Bolts	11.5 to 14.5 Nm (8.5 to 10.5 lbft)
Compressor Impeller Locknut	
1st Stage	2.0 to 2.2 Nm (1.5 to 1.7 lbft)
2nd Stage	Tighten Through a Further 90°

SERVICE TOOLS

Tool Number	Description
Special Service Tools	
10885	Valve Guide Remover/Installer
10881	Valve Stem Seal Installer
10880	Crankshaft Front Seal Installer
10886	Crankshaft Rear Seal Installer
10964	CAV Pump Timing Tool - Class "A" Governed Pumps
10965	CAV Pump Timing Tool - General Purpose Governed Pumps
Desirable Service Tools	
10966	Camshaft Bearing Remover/Installer
10876	Adapter For
10883	Adapter For
10877	Valve Spring Compressor
10884	Adaptor for 10877
10878	Adaptor for 10877
2691	Compression Test Kit
7698	Adaptor - Compression Tester - Use With 2691
72-0003 (Rotunda)	Engine Oil/Cooling System Leak Test Kit
21-0013 (Rotunda)	Radiator Pressure Tester Either of the above can be used for Injector Leak-Off Rail Test
14-0300 (Rotunda)	Diesel Fuel Injector Nozzle Tester