THREE, FOUR AND SIX CYLINDER

SERIES 71

TWO-CYCLE

DIESEL ENGINES

MAINTENANCE MANUAL

REVISED

DETROIT DIESEL ENGINE DIVISION

GENERAL MOTORS CORPORATION

DETROIT 28, MICHIGAN

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Detroit Diesel Engine Division
of
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FOREWORD

This manual presents a complete detailed description of the General Motors Series "71" two-cycle 3, 4 and 6-cylinder engines, together with tested maintenance procedures.

Various applications are dealt with consisting of numerous generator sets, also diversified power take-off units providing for belt drives.

While this manual does not deal with all the possible applications of the Diesel engines, it does describe those most commonly used. For specific adaptations, manuals are available dealing with various model numbers.

The manual is divided into sections. Each section deals with a sub assembly of the engine or a complete system comprising those units which go to make up such a system. As for example, the fuel system; which includes the injector, fuel oil pump, fuel oil filters and the fuel oil manifolds. Other systems are made up of units in the same manner.

Satisfactory performance of a machine depends on intelligent maintenance and care which necessitates thorough familiarity with the various engine parts. Before maintenance operations are attempted, therefore, the manufacturer of these units suggests that the information in this manual be carefully studied and followed.

SUBJECT INDEX

ALPHABETICAL INDEX

ALPHABETICAL INDEX—Continued

THE TWO-CYCLE DIESEL ENGINE

The Diesel Principle—The Diesel engine is an internal combustion power unit, in which the heat of fuel is converted into work in the cylinder of the engine.

Diesel engines differ from gasoline engines principally in the method used to introduce and ignite the fuel. Gasoline engines draw a mixture of fuel and air through the carburetor into the combustion chamber, where it is ignited by an electric spark. In the Diesel engines, air alone is compressed in the cylinder; then, a charge of fuel is sprayed into the cylinder, after the air has been compressed, and ignition is accomplished by the heat of compression.

Two-Cycle Diesel Engine—Four strokes are required to complete a cycle in the four-cycle engine, which functions half the time as an air pump. In the two-cycle engine, intake and exhaust take place during part of the compression and power strokes. A two-cycle engine, therefore, does not function as an air pump, so an external means of supplying the air is provided. A specially designed blower, bolted to the side of the engine, forces air into the cylinders in order to expel the exhaust gases and fill the cylinders with fresh air for combustion, as shown in Figs. 1, 2, 3, and 4.

A series of ports cut into the circumference of the cylinder wall, above the piston, in its lowest position, admits the air from the blower into the cylinder as soon as the top face of the piston uncovers the ports, as shown in Fig. 1. The unidirectional flow of air towards the exhaust valves produces a scavenging effect, leaving the cylinders full of clean air when the piston again covers the inlet ports.

As the piston continues on the upward stroke, the exhaust valves close and the charge of fresh air is subjected to the final compression, as shown in Fig. 2. In any internal combustion engine, the higher the compression ratio the greater the efficiency. These engines are designed for a 16:1 compression ratio.

Shortly before the piston reaches its highest position, the required amount of fuel is sprayed into the combustion space by the unit fuel injector, as shown in Fig. 3. The intense heat generated during the high compression of the air ignites the fine fuel spray immediately, and the combustion continues as long as the fuel spray lasts. The resulting pressure forces the piston downward until the exhaust valves are again opened. As shown in Fig. 4, the burnt gases escape into the exhaust manifold as the downward moving piston is about to uncover the inlet ports.

When these ports are uncovered, the cylinder volume is again swept with clean scavenging air, as shown in Fig. 1. This entire combustion cycle is completed in each cylinder for each revolution of the crankshaft, or, in other words, two strokes; hence, the ***"two stroke cycle."***

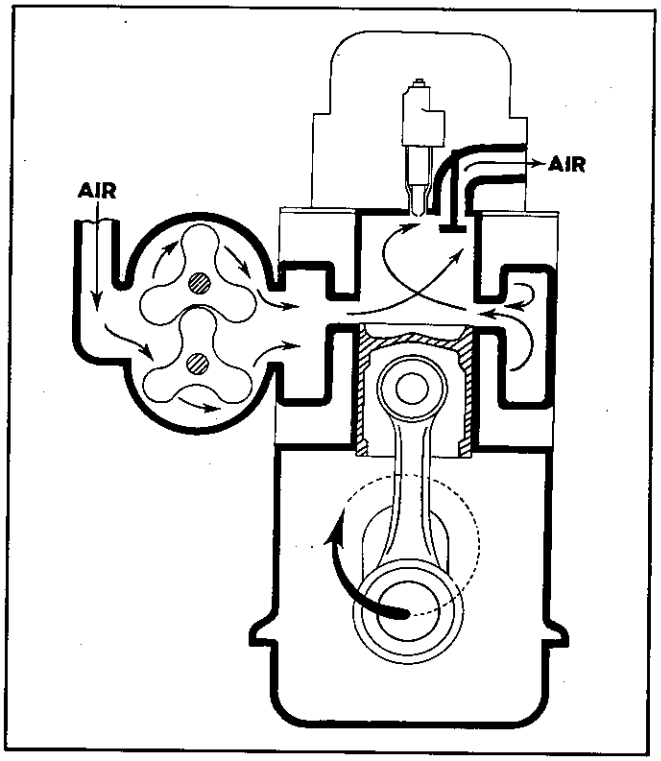


Fig. 1—Air Entering Through Port to Combustion Chamber.

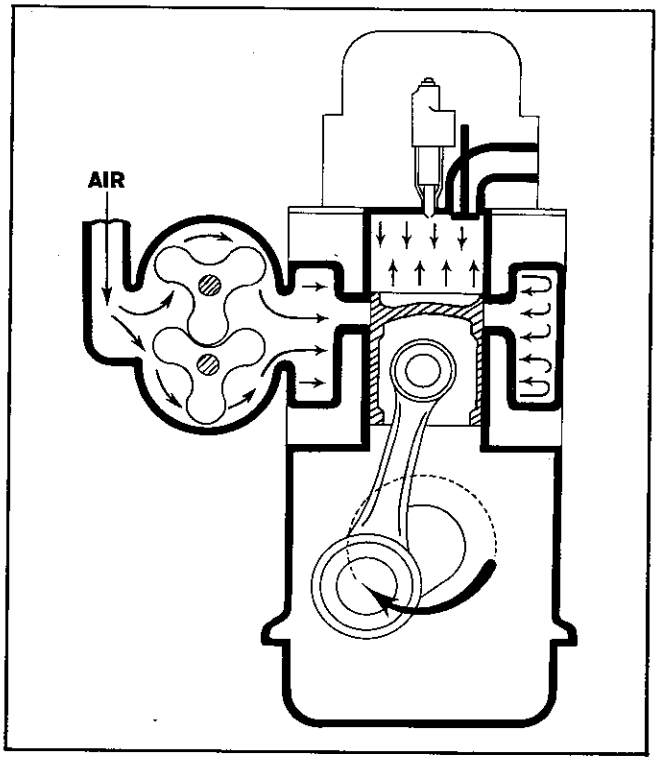


Fig. 2—Air Being Compressed with Exhaust Valves Closed.

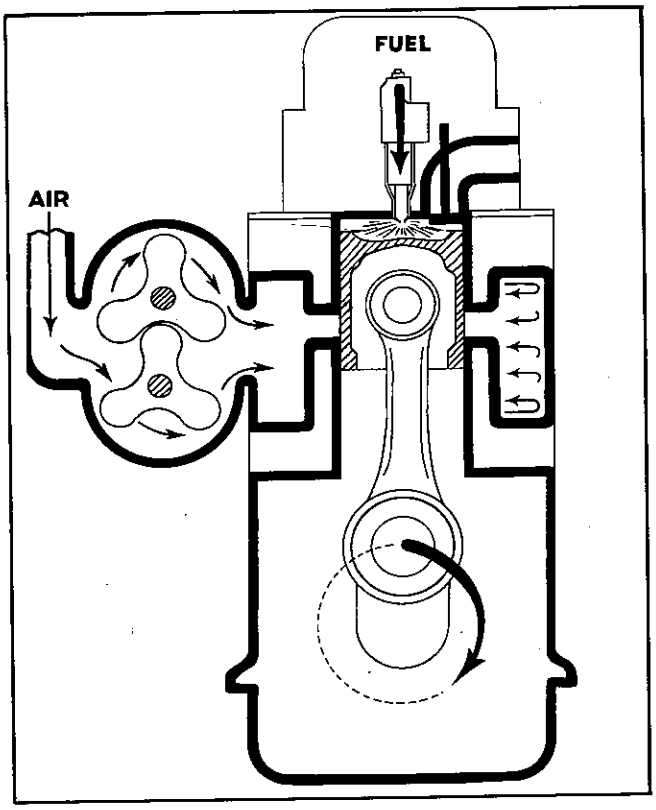


Fig. 3—Charge of Fuel Being Injected into Combustion Chamber.

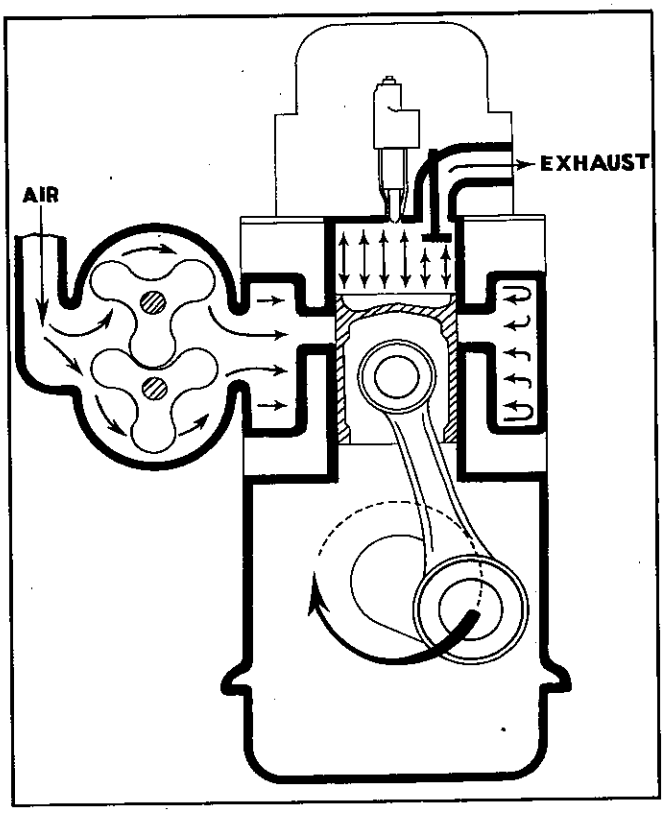


Fig. 4—Exhaust Taking Place and Cylinders About to Be Swept with Clean Scavenging Air.

MODEL, SERIAL AND UNIT DESIGNATIONS

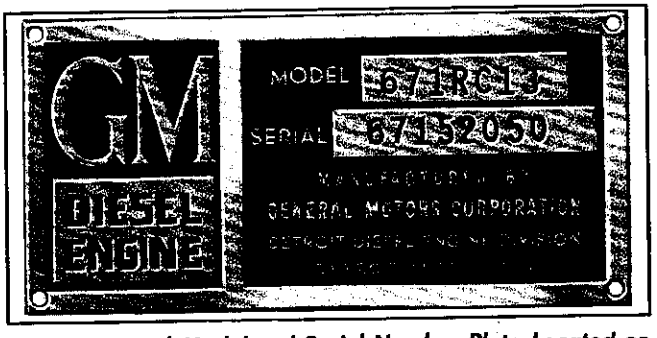


Fig. 5—Typical Model and Serial Number Plate Located on Engine Block.

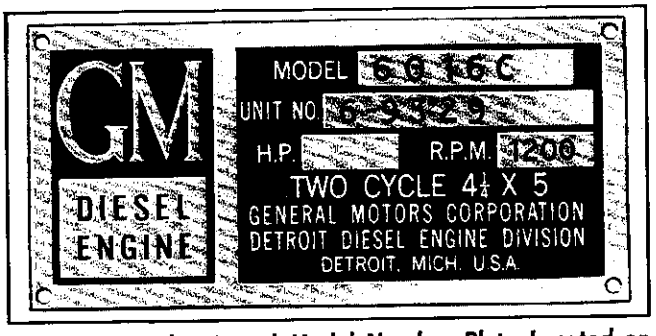


Fig. 6—Typical Unit and Model Number Plate Located on Flywheel Housing.

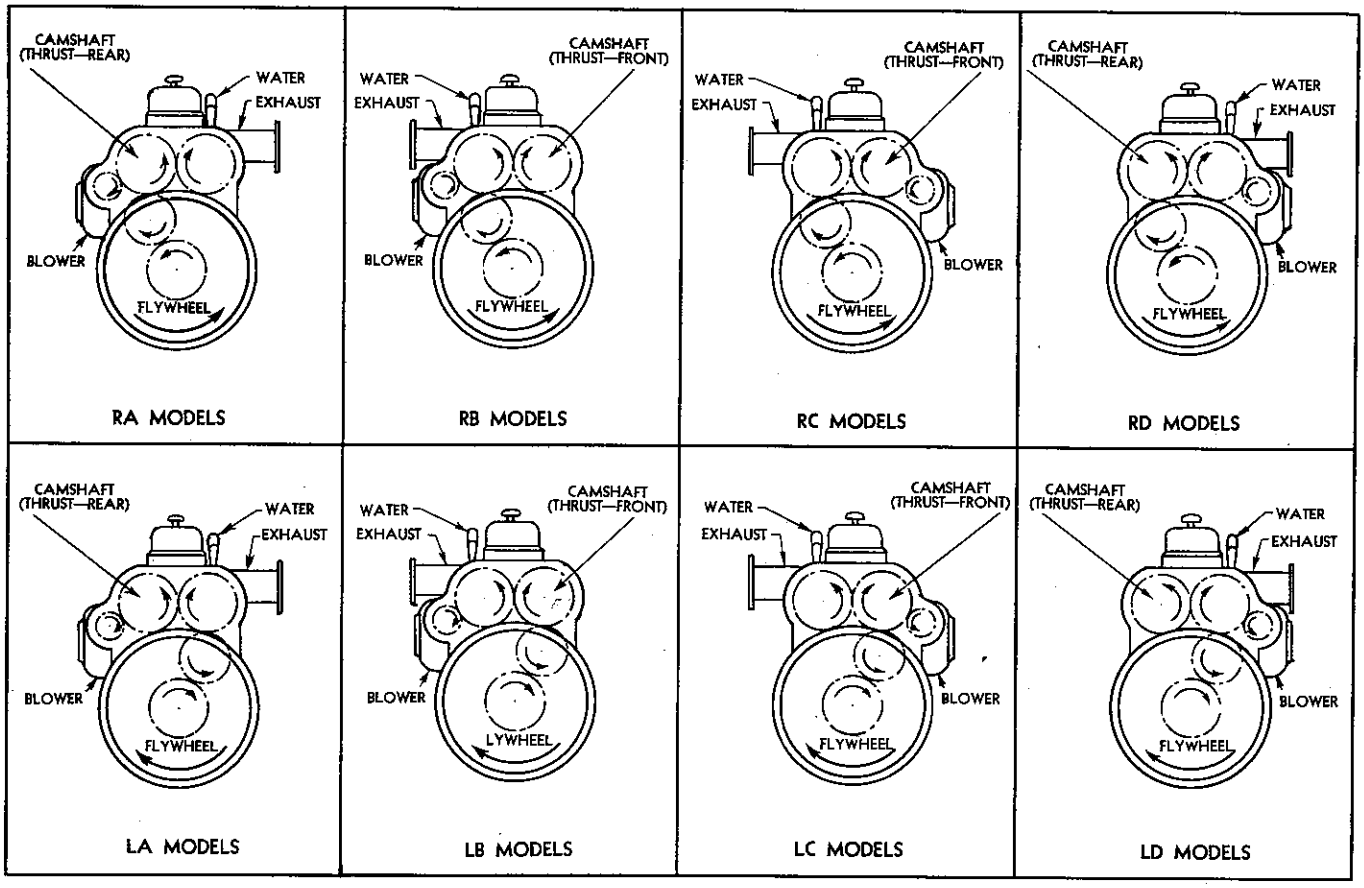
An engine model and serial number plate as illustrated in Fig. 5 is attached to the blower side of the cylinder block at the upper right hand corner.

In addition to the model and serial number plate on the cylinder block, each power unit has a unit number plate attached to the starting motor side of the flywheel housing, as illustrated in Fig. 6.

When ordering engine parts, order by part number and description, and refer to engine model and serial numbers, also model and unit numbers.

The two-cycle Diesel engines discussed in this text are offered in three, four, and six-cylinder models having the same bore and stroke and using the same parts wherever possible. Thus, different power capacities are available in the same type of engine, in which the major working parts, such as injectors, pistons, connecting rods, and all bearings and other numerous parts are interchangeable. Engines with either direction of rotation can be supplied to suit specific requirements.

Furthermore, the blower, water pump, oil cooler, oil filter, governor, and fuel pump form a group of standard accessories which can be located on either the right or left side of the engine, regardless of the



ALL VIEWS FROM FLYWHEEL END OF ENGINE

Fig. 7—Rotation and Accessory Arrangements—3, 4, and 6 Cylinder Engines.

direction of rotation. Still further flexibility in meeting installation requirements can be had by placing the exhaust manifold and the water outlet manifold on either side of the engine. This flexibility in the arrangement of parts is obtained by having both the cylinder block and cylinder head symmetrical at both ends and with respect to each other. Fig. 7, shows these various arrangements, which are designated by the letter R or L in the model number, denoting right-hand or left-hand rotation, and the letters A, B, C or D designating the accessory arrangements. The table on this page shows the particular arrangement of standard accessories and exhaust and water outlet manifolds designated by letter A, B, C or D shown as part of the model numbers in Fig. 7.

Selection of the proper flywheel housing permits placing the starting motor on either the right or left side of the engine. A generator may be driven from either the camshaft or balancer shaft timing gear at the rear end of the engine or by a V-belt from the front end of the crankshaft. When the generator is driven by the V-belt, it must be mounted on the side of the engine opposite to the blower.

Engine Type	On Left Side	On Right Side
A	All standard accessories	Exhaust outlet. Water outlet
B	All standard accessories Exhaust outlet Water outlet	
C	Exhaust outlet Water outlet	All standard accessories
D		All standard accessories Exhaust outlet Water outlet

Accessory and Manifold Arrangements (Viewing Engine from the Rear).

TYPICAL GENERAL MOTORS SERIES 71 PACKAGED POWER UNITS

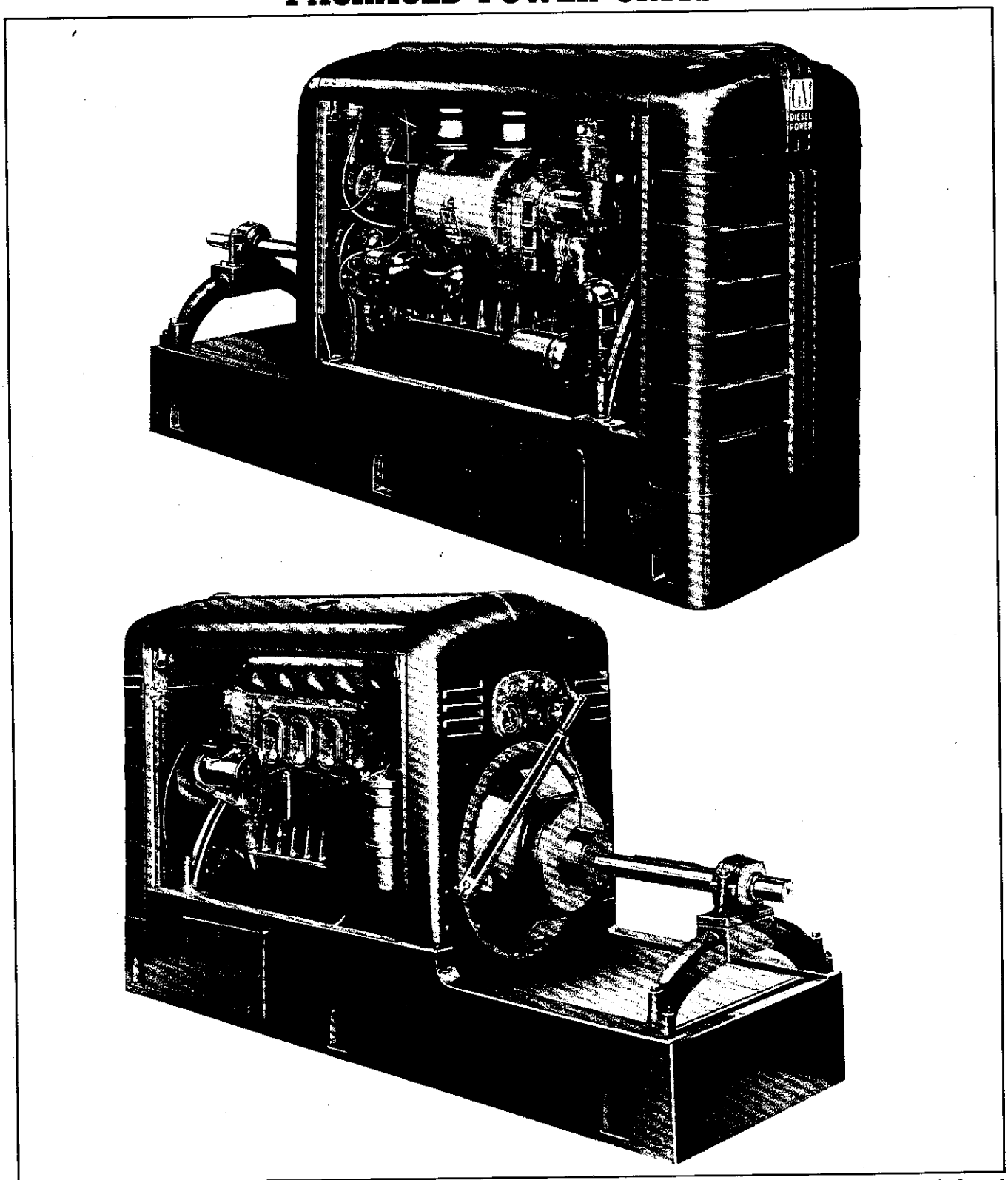


Fig. 8—Two Views of Model 6029 Six Cylinder Diesel Power Unit Featuring Clutch Power Take-Off, Long Drive Shaft and Outboard Bearing. (Side Panels Removed)

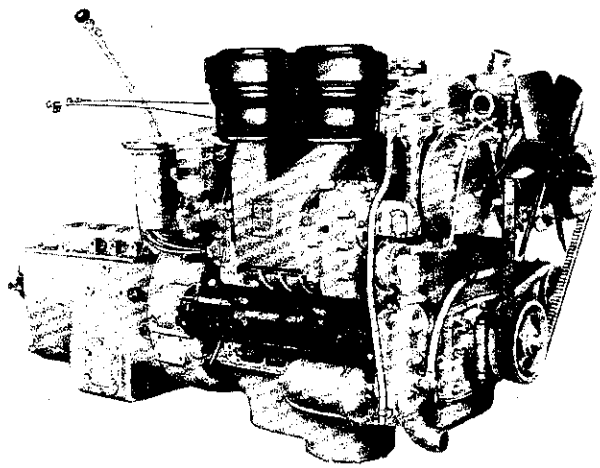


Fig. 9—(Above) Four-Cylinder Diesel Power Unit with Clutch and Transmission for Vehicle Installation.

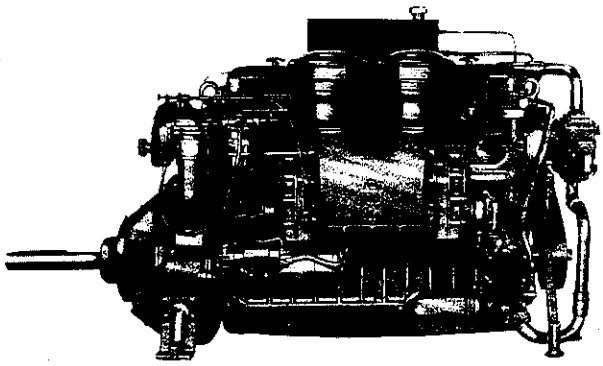
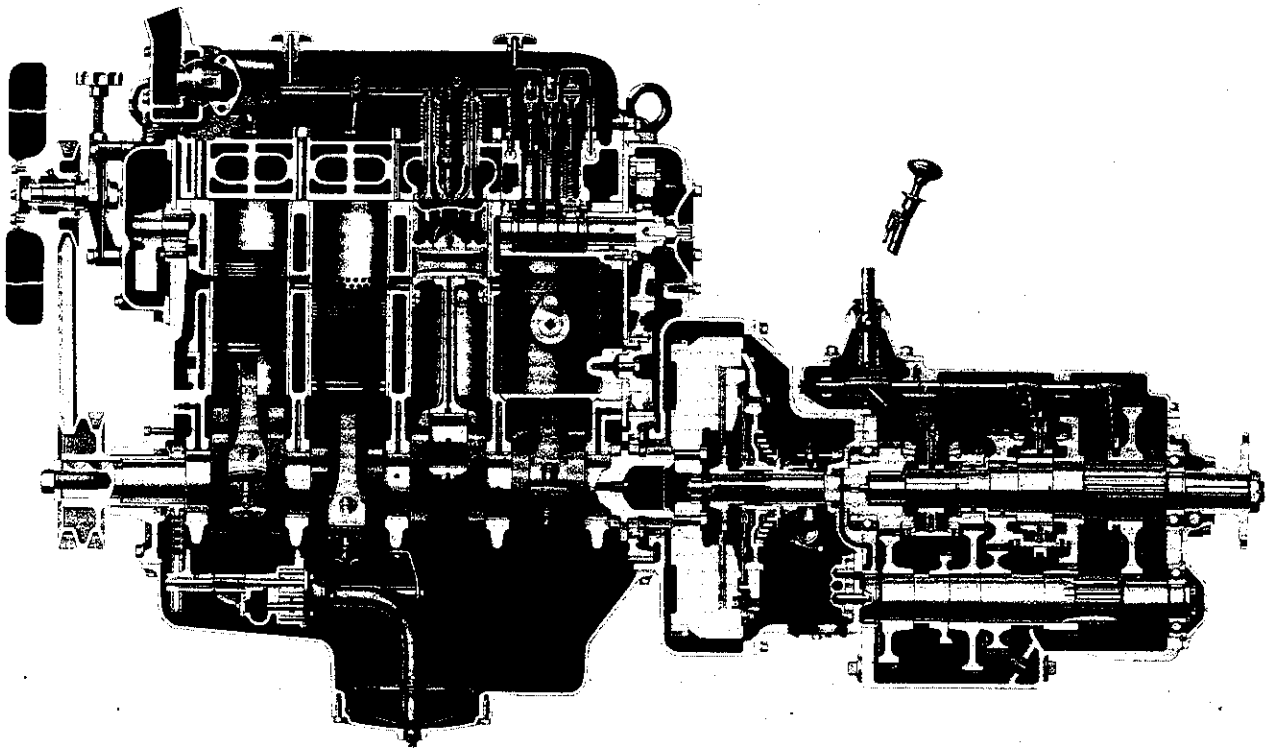


Fig. 10—(Right) Six-Cylinder Diesel Power Unit with Clutch and Extending Drive Shaft. Heat Exchanger Used for Engine Cooling.

Fig. 11—(Below) Side Cross Section of Unit for Vehicle Installation Shown Above.



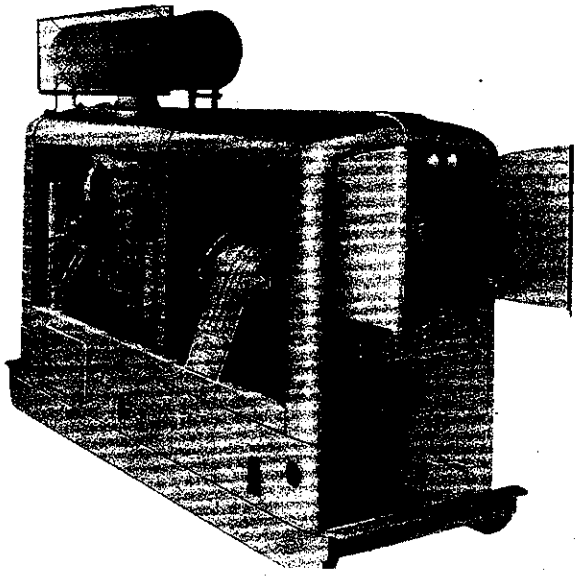


Fig. 12—(Above) Six-Cylinder Portable Diesel Generator Set. Side Panels Removed.

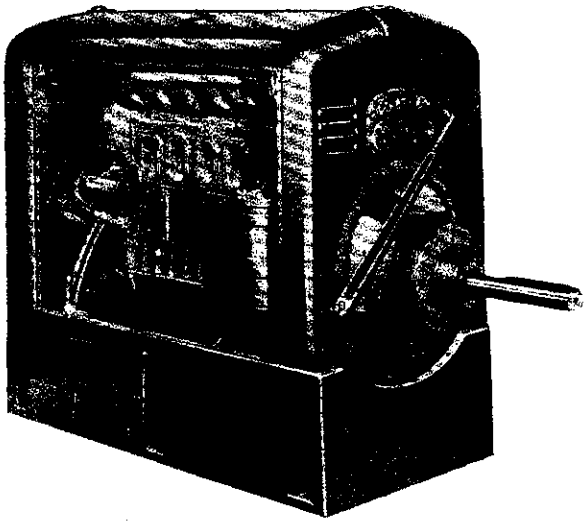
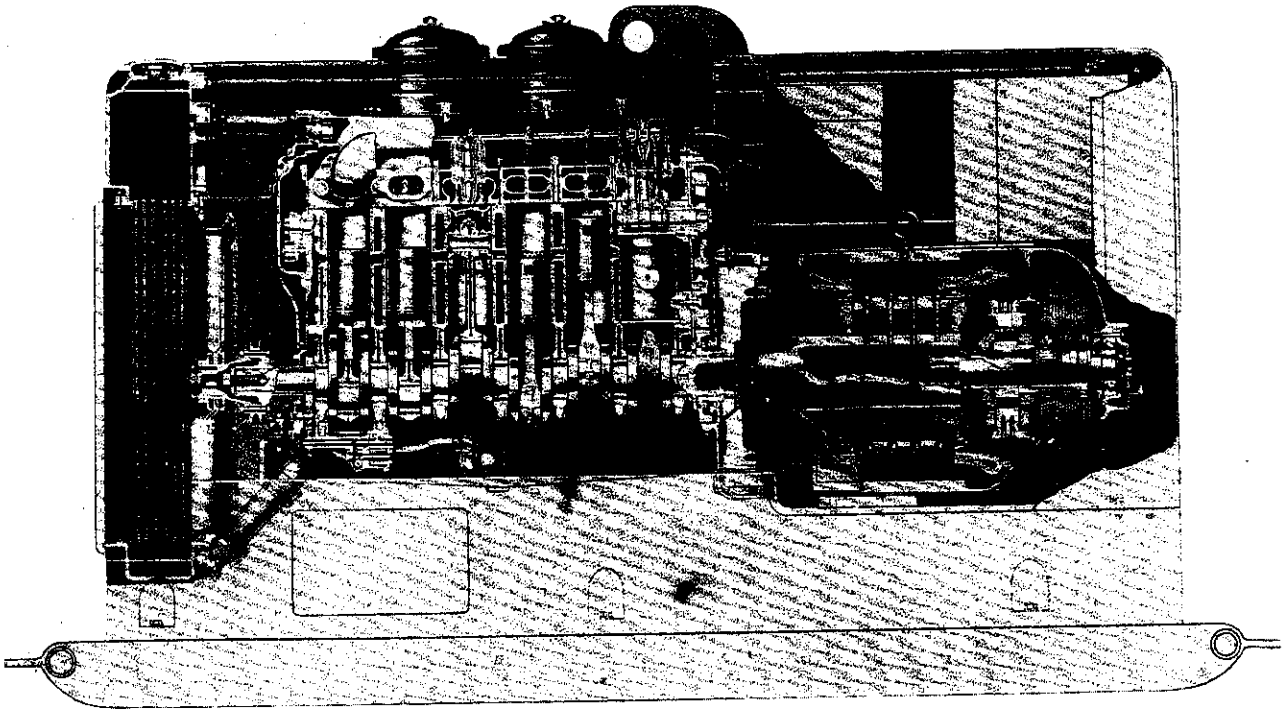


Fig. 13—(Left) Six-Cylinder Portable Diesel Power Unit with Clutch and Long Drive Shaft. Radiator and Fan for Engine Cooling. Side Panels Removed.

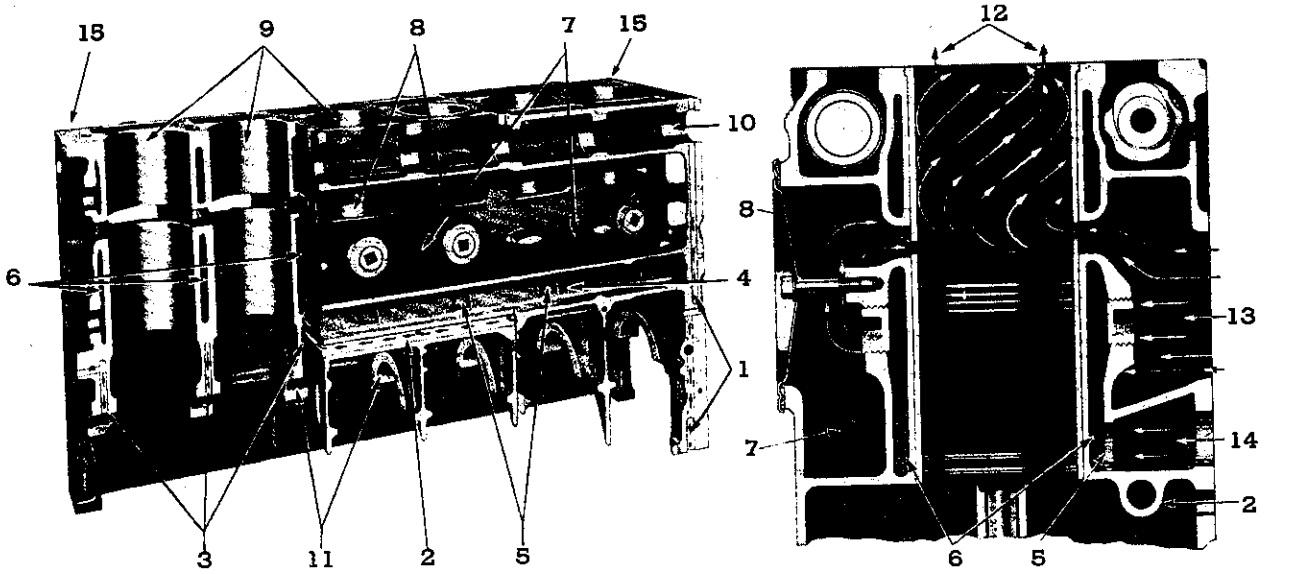
Fig. 14—(Below) Side Cross Section of Portable Generator Set Shown Above.



GENERAL SPECIFICATIONS

SUBJECT	MODEL 3-71	4-71	6-71
Number of Cylinders	3	4	6
Bore	4¼"	4¼"	4¼"
Stroke	5"	5"	5"
Total Displacement—Cubic inches	212.69	283.58	425.31
H.P.—Maximum at 2000 RPM (Std. Injector)	83	110	165
Maximum Torque in Lbs. Ft. at 1000 RPM	262	350	525
Compression Ratio—Nominal	16:1	16:1	16:1
Piston Speed—Ft.-min. at 1000 RPM	833	833	833
Firing Order—R.H. Rotation	1-3-2	1-3-4-2	1-5-3-6-2-4
Firing Order—L.H. Rotation	1-2-3	1-2-4-3	1-4-2-6-3-5

CYLINDER BLOCK



1. Vertical Oil Passage.
2. Oil Gallery.
3. Oil Passage to Crankshaft.
4. Coolant Passage.
5. Coolant Inlet to Liner Jacket.
6. Liner Cooling Jacket.
7. Air Box.
8. Air Passages to Cylinder.
9. Bore for Cylinder Liner.
10. Bore for Cam or Balance Shaft.
11. Upper Half of Main Bearing Seat.
12. Water to Cylinder Head.
13. Air from Blower.
14. Water from Pump.
15. Plugged Holes Each Corner

Fig. 1—Cylinder Block and Crankcase, Showing Air, Lubricating Oil, and Water Passages

Description—The cylinder block and crankcase, which is the main structural part of the engine, is a box-like, one-piece casting made of alloy cast iron. The blocks for the three-, four-, and six-cylinder engines are identical in design and dimensions, except the necessary length for the additional bores of the four and six-cylinder, and the correspondingly larger blower mounting flanges. The two ends of the block are absolutely identical, so that the same flywheel housing and gear train can be put on either end of any one of the three models. On Model LB, LD, RB, and RD engines, the balancer shaft gallery oil drain holes are plugged so that the oil drain-back from the balancer shaft pockets must pass through the blower end compartments rather than via the gear train and balance weight compartments to the oil pan.

Rugged transverse members, cast integral, provide utmost rigidity and strength, insuring perfect alignment of bores and bearings under all loads. The cylinders are bored to receive the cylinder liners, into the circumference of which a number of air inlet ports are drilled. The water jackets extend the full length of the bores and are divided into upper and lower sections, which are connected by hollow struts. Cooling water enters at the bottom of the water jacket from the water pump, and leaves the jacket at the top through holes which register with corresponding openings in the cylinder head. Surrounding the water space is an air chamber, which conducts the air from the blower to all of the inlet ports.

Located in the top of the cylinder block are the camshaft and balancer shaft.

The upper halves of the main bearing seats are cast integral with the block. Drilled passages in the block carry lubricating oil to all moving parts and eliminate piping. Hand-hole plates on the side opposite to the blower permit access to the air chamber, and inspection of pistons and rings through the air intake

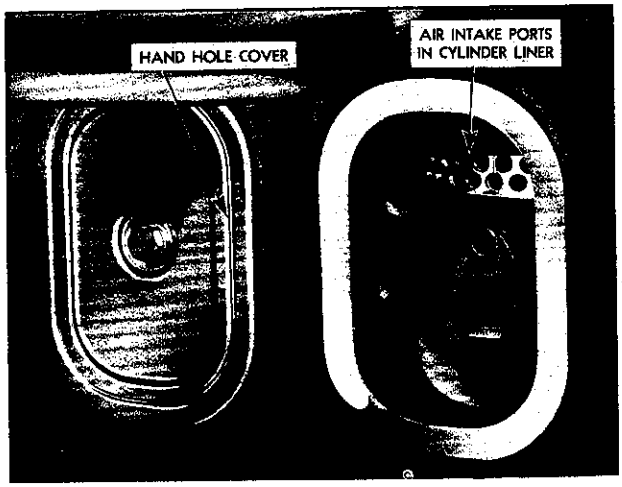


Fig. 2—Hand-Hole Plates and Air Intake Ports

ports in the cylinder walls. The six-cylinder engine has also two hand-hole plates on the blower side.

Cylinder blocks are regularly furnished with main bearing caps, studs and the necessary plugs. If cylinder block is ordered for an engine built previous to the time slip fit cylinder liners were adopted, liners will be included. (See "Cylinder Liners, Description," Page 1, Sec. 3.)

Service—Cylinder Block—Since the cylinder block is the main structural part of the engine, whenever engine is being overhauled, the block should be thoroughly inspected for any conditons that would render the block unfit for further use. Such inspections will take place after the block has been thoroughly cleaned in either live steam or suitable solvent, and blown off with dry compressed air.

Check block for cracks and remove old gaskets before rebuilding engine. If cylinder liners are not be changed, all air ports should be thoroughly cleaned, as well as the air box. Air box drains should be opened and blown out with dry compressed air after air box has been cleaned. Oil galleries and oil passages should be thoroughly cleaned with cleaning solution under pressure.

AIR BOX DRAIN CLEANERS

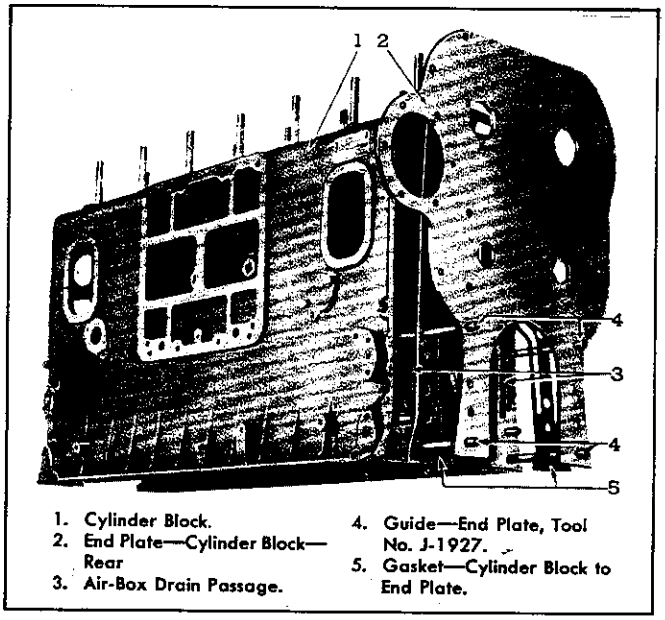
Air box drain cleaners (bent wire agitators) are incorporated in the air box drain passages at both ends of the cylinder block. The flow of air past these agitators keeps them in constant motion and prevents formation of solid deposits.

Cleaners (one in the passage to each drain) should be taken out, cleaned, and replaced whenever end plates are serviced.

CYLINDER BLOCK END PLATES

Description—A flat steel end plate, bolted to each end of the cylinder block, affords a very rigid construction and a means of attaching the flywheel housing at the rear, and the balance weight and crankshaft cover at the front. Since the blower drive gear assembly is supported on the rear end plate, this plate has a different contour than the one used at the front. As both ends of the cylinder block are alike, the same special paper gasket is used between the block and each end plate.

Service—Cylinder block end plates should require very little service under ordinary conditions. At the time of complete engine overhaul or of cylinder block change, the end plates will be removed and replaced. When such change is necessary, certain features in connection with the change should be borne in mind.



1. Cylinder Block.
2. End Plate—Cylinder Block—Rear
3. Air-Box Drain Passage.
4. Guide—End Plate, Tool No. J-1927.
5. Gasket—Cylinder Block to End Plate.

Fig. 3—Installing Cylinder Block End Plates—Rear Plate Shown.

After end plates have been removed, all of the old gaskets should be removed from inner and outer surfaces of the plates. Both surfaces must be flat and smooth. Any nicks or other damaging marks that would prevent a tight seal between the surfaces should be removed.

The guide tools, No. J-1927, shown in Fig. 3, will be found very useful when locating the plates on the cylinder block.

Attach Front and Rear End Plates to Cylinder Block—The holes in the end plates for the cam and balancer shaft bearing cages are not the same size. The smaller hole is accurately machined to 2.1870" diameter while the larger hole measures 2¼" in diameter. When installing the end plates, the smaller hole must be accurately aligned with the bearing bore in the cylinder block before the end plate attaching bolts are tightened. The smaller hole on the front end plate should be on the same side of the cylinder head as the smaller hole in the rear end plate. The installation may be properly accomplished by proceeding as follows:

1. Clean all traces of old gasket from the surfaces of both end plates. Remove any burrs with a large mill file and make sure the surfaces are smooth and flat.
2. With all necessary plugs properly installed in block (See "Instructions for Use of Service Cylinder Block Assemblies," Form DE-529), and end plate-to-cylinder block dowels in place, set air box drain cleaners into passages to drain open-

ings and then cement a new gasket to rear end of block being careful not to get cement into bore for cam and balancer shaft thrust bearings. Screw two or four guide tools J-1927 into block as shown in Fig. 3; coat the exposed surface of the gasket with cement (non-hardening preferred) and set the rear end plate into place over guides with the large bore in the plate for the blower drive mechanism on the blower side of block.

3. Start six attaching bolts into place and draw up finger tight only. Wipe the bores in plate and block for bearing cages clean of any gasket cement and hand press a bearing assembly into place through the smaller of the two holes in the end plate which is in all cases the hole on the blower side. The six attaching bolts may now be tightened and the beaing assembly removed. Guide tools can be left in place until after the flywheel housing is installed.

4. Front end plate should now be installed in a similar manner, cementing both sides of the end plate-to-block gasket and aligning the plate with the block by use of a bearing assembly temporarily installed. The smaller bore in the front end plate must also be on the blower side of the engine.

CYLINDER LINERS

Description—The replaceable liner, made of hardened alloy cast iron, in each cylinder is accurately honed to a very smooth finish. A flange at the top of the liner fits into a recess in the cylinder block, insuring proper positioning in the block.

Even temperature and minimum distortion are insured by cooling each liner over its entire length, except at the ports, which are cooled by the scavenging air. To permit introduction of fresh air into the cylinder, sixty-four 5/16-inch ports are drilled into the circumference of each cylinder liner. These ports are arranged in rows—32 to each row—and are equally spaced and staggered as shown in Fig. 1.

Starting with engine numbers 3711474, 4712187 and 6712455 on the three, four and six-cylinder engines, respectively, liners with a loose fit in the cylinder were used. Engines built previous to these numbers used a pressed-in liner. Servicing the loose liner and the pressed-in liner is discussed below in this section.

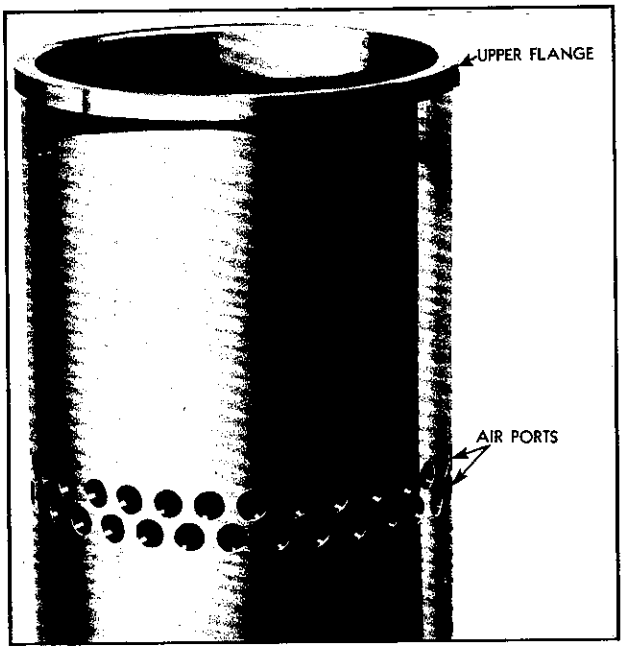


Fig. 1—Replaceable Cylinder Liner.

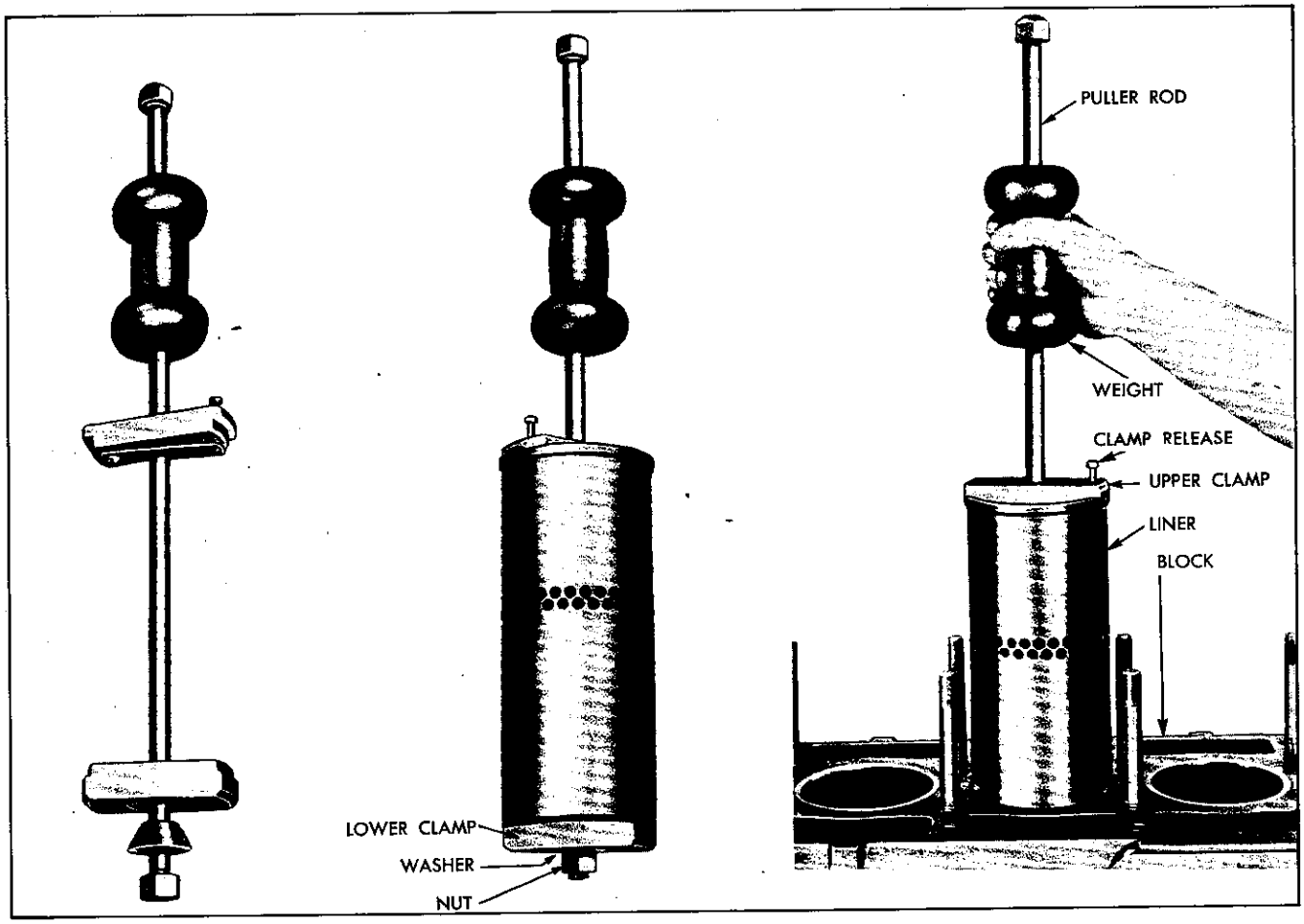


Fig. 2—Removing Cylinder Liner with Tool J-1918.

Service—By virtue of the material from which cylinder liners are made, they will render satisfactory service for extended periods if the engine has proper care. The wear on a cylinder liner and piston is directly related to the amount of dust and dirt (abrasive) introduced into the engine combustion chambers via air intake. Dust so introduced and combined with lubricating oil on the cylinder walls forms an ideal lapping compound. To avoid such a condition, the air cleaners provided as standard equipment on each engine should be serviced regularly, as recommended by the manufacturer. Whenever possible, locate the power plant where the surrounding air is free from dust.

To take advantage of the long life designed and built into these engines, the sections of this manual pertaining to Lubrication and Air Cleaners should be carefully read and followed.

Cylinder liners honed to standard size and ready for use in the cylinder block are available through the Parts Department.

No set rule can be established on the amount of wear permissible before a liner change is necessary; the engine performance will be the best guide in this direction.

When a cylinder liner change is necessary, due to either wear or scoring, the old liner may be removed from the cylinder block and a new liner installed, or the old liner may be honed oversize and reinstalled. New cylinder liners are furnished in standard size inside diameter only. Oversize pistons are available, see Parts List for sizes.

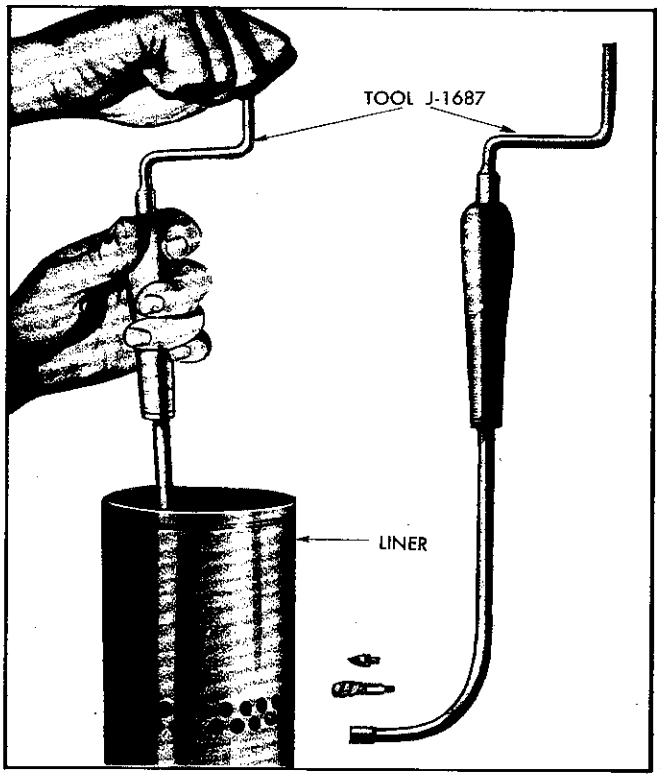


Fig. 3—Cleaning Carbon from Air-Intake Ports with Tool J-1687.

Remove Cylinder Liner—Loose Fit—To remove a cylinder liner, the following preliminary operations will be necessary:

1. Remove the cylinder head (See Section 9, Page 2).
2. Remove the oil pan.
3. If necessary, remove the lubricating oil pump and discharge line assembly together with the pump drive shaft (See Section 12, Page 8).

NOTE: Before attempting to remove the piston from the cylinder block, scrape the carbon from the upper inner diameter of the cylinder liner.

4. Remove piston and connecting rod assembly. (See Section 6, Page 1.)
5. Since the cylinder liners are a loose fit, they may be removed easily from the top of the cylinder block by hand after loosening with the tool shown in Fig. 2.

   To use the tool:

   (a) Slip the lower puller clamp up the puller rod and off its tapered seat, and cock clamp on rod so it will slide down through liner. When rod is lowered down through liner, clamp will drop back onto its seat in a horizontal position.

   (b) Slide the upper puller clamp down against the top edges of the liner.

   (c) With tool so mounted, strike the upset head on upper end of puller rod a sharp blow with the puller weight, thus releasing the liner.

Cleaning Air Inlet Ports—Inspection of the air inlet ports, after removing the air box hand hole covers, is the best indication of port condition. If this inspection shows ports to be 30% or more plugged, cleaning is necessary. Port inspection should be made at least every 500 hours of engine operation.

Tool J-1687, shown in Fig. 3, or some similar angular shaped tool may be used to advantage for cleaning the ports while the liner and piston are in place.

Proceed as follows for port cleaning with liner and piston in place; cylinder head and hand hole covers removed.

1. Hand crank engine until the piston, in liner whose ports are to be cleaned, is at bottom of stroke.

2. With cutter in place on the tool shown in Fig. 3, or with some equivalent tool, cut carbon from each port. Place burnishing head on the tool shown and clean all ports again.
3. Using compressed air, blow all carbon particles away from head of piston and inside of liner and out through ports into the air box. ***Inside of liner and piston head must be clean.***
4. With a fine grit honing stone or 250 grit emery paper, touch up the area around the ports. ***Slight burrs and tool marks must not be left to damage rings and liners.***
5. After cleaning and burr removal is finished in all cylinders, thoroughly clean all carbon particles from air box. ***Air Box drains must be open;*** remove elbow at each drain and clean thoroughly.
6. Replace cylinder head and hand hole covers.

With cylinder liners removed from block as at engine overhaul, air port cleaning may be carried out as follows:

Sharpen a stick of hard wood to a tapering point with square edges. Clean each of the ports by inserting pointed end of the stick or similar tool in the port and twisting. Resharpen stick as often as necessary.

After cleaning ports, examine the inside of the liner around the port area for burrs. If burrs are found, remove them by hand with 250 grit emery paper. Burrs must be removed by hand whether liner is to be honed or not. Failure to remove these burrs can result in early failure of the engine.

An alternate method of cleaning air inlet ports is to soak the liner in a hot caustic soda or lye solution long enough to loosen the carbon deposits. Final cleaning can then be accomplished with a bristle brush.

Honing Cylinder Liner—A cylinder liner may be honed on the inside diameter and used again if the honing operation is carried out in the proper manner. The safest way to hone cylinder liners, and be sure that none of the abrasive gets into the air box or ports, is to remove the liners from the cylinder block, place in a honing fixture (a scrapped cylinder block makes an excellent honing fixture), and then hone to the proper size. After honing, the liners may then be replaced in the cylinder block.

The early honing fixtures were designed for honing the pressed-in liners. When honing a loose-fit liner, the liners should not be pressed into this fixture because of the possibility of decreasing the diameter of the bore. Before honing a loose-fit liner, the honing fixture should be relieved on the inside diameter the same as a cylinder block is reworked to receive the loose-fit liner, and as outlined, under "Hone Cylinder Block for Loose-Fit Liner that Previously Used Pressed-in Liner," Page 5.

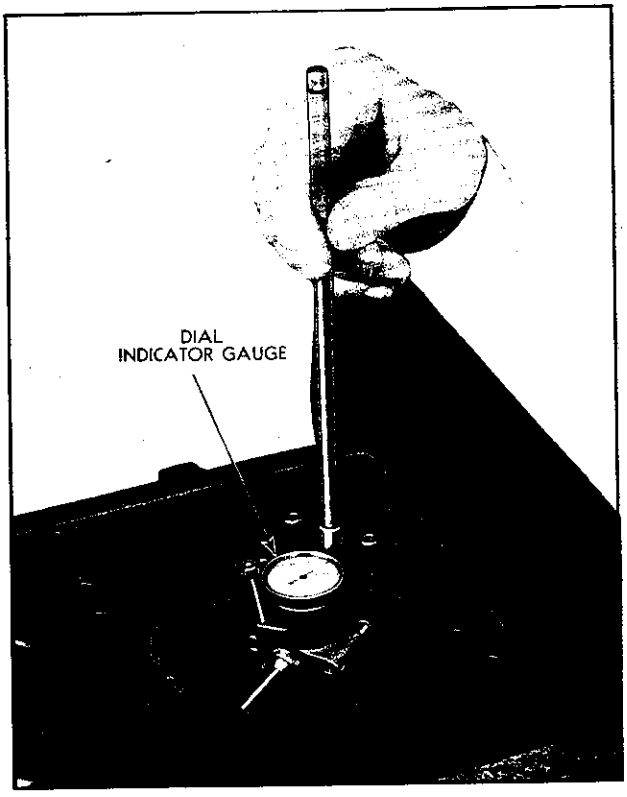


Fig. 4—Checking Bore of Cylinder Liner.

The only way the liners can be honed in the cylinder block is by completely dismantling the engine and then after honing wash the block in a solution of hot caustic soda, to be sure that all the abrasive is removed from openings in the block and liners.

The ordinary medium honing stones used on soft cylinder blocks are rather ineffective on these hard cylinder liners. For rough honing, use a coarse stone of 180 grit and for the smooth mirror finish required for the inside of liners use a stone of 280 grit.

When liners have been in service for any length of time, the inside diameter becomes very smooth, or "glazed." This "glaze," if not removed, lengthens the time required to seat new rings. Therefore, even though inspection reveals a liner to be within specifications and honing unnecessary, the 280 grit stone should be worked up and down in the liner a few times in order to break this "glaze."

The liners should be straight from top to bottom and round on the inside diameter to within .0015" when the liner is in place in the cylinder block. The honing operation is carried out by first removing the liner from the cylinder block; second, placing liner into

liner honing fixture; third, honing the liner in the fixture with the honing stones described above; fourth, removing liner from honing fixture and installing in the cylinder block.

As the honing operation progresses, the inside diameter of the liner may be checked with the gauge as shown in Fig. 4.

After a cylinder liner has been honed and removed from the honing fixture, it must be thoroughly washed and blown off with air before installing into the cylinder block. If this precaution is not taken, some of the honing abrasive might be drawn into and damage the engine.

Replace Loose Fit Cylinder Liner. Check bore in cylinder block. Bore must be round and smooth within .0015″ from top to bottom. When checking for these conditions, use a dial indicator, or if a new, undamaged (round) liner will slip fit into the bore, the fit is satisfactory. Hone bore as outlined under Item 3, page 5, to remove roughness or distortion.

As a final operation, before replacing a loose fit liner, wipe the outside of the liner and the cylinder bore clean. Remove any burrs that might be present on the outside surface of the cylinder liner or on the liner seat in the recess by hand, with a flat honing stone.

When the cylinder bore has been properly prepared, insert the liner. When in place, top face of the liner will be from .000″ to .004″ above top surface of cylinder block.

CYLINDER LINER—PRESS FIT

Description—Cylinder liners used for a press fit and for a loose fit in the cylinder block are identical. The bore in the block for the liners is different, however. For description of cylinder liners see, "Description—Cylinder Liners," Page 1.

Service — Engines built previous to numbers 3711474, 4712187 and 6712455 for three, four and six-cylinder, respectively, have liners pressed into the block. When a liner removal is necessary on these engines, it is recommended that a loose, rather than the original press fit liner be installed. To make this change, the bores in the cylinder block for the liners must be honed to a larger diameter to provide for the loose fit. A block should not be used with some liners loose, and others press fit. All liners must be removed before the block is honed for the loose liners. The work in connection with these operations may be carried out as follows:

As hone grit will ruin an operating engine—and to remove this grit from the cylinder block is a very difficult operation—the recommended practice is to strip the block, remove all liners, hone, and then thoroughly clean block in a solution of hot caustic soda or its equivalent.

1. **Strip Cylinder Block**—Owing to the numerous applications of these engines, and the necessarily different accessories accompanying the various installations, no fixed procedure of stripping the cylinder block is attempted here. Good judgment and experience will be the best guide in this direction. When removing the various parts and subassemblies from the block, reference may be

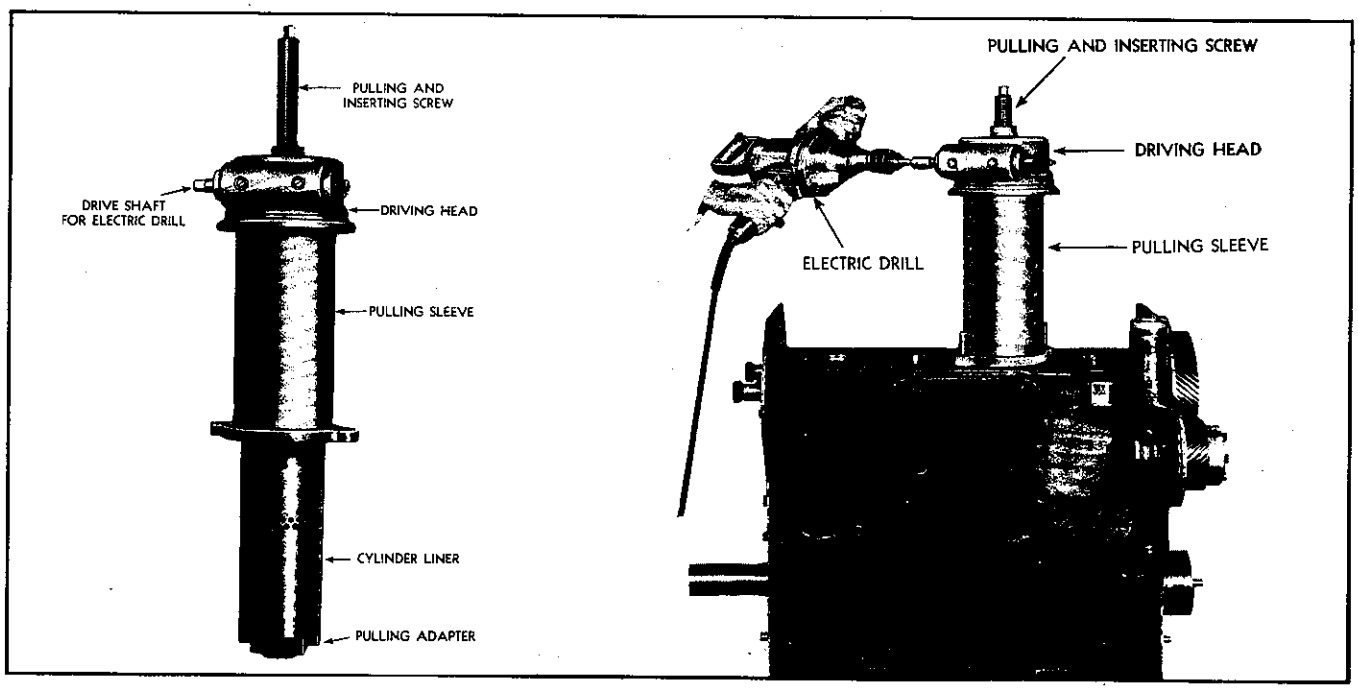


Fig. 5—Removing a Press Fit Cylinder Liner.

made to the various sections of this text that deal with the separate units. A time-saving practice, when dismantling an engine, is to keep the various sub-assemblies and attaching parts separate for easy identification when reassembling.

2. **Remove Cylinder Liner—Press Fit**—The screw and driving head of the tool, illustrated in Fig. 5, is used both for pulling and replacing the cylinder liner, different adapters being used.

   For pulling the liner, the short adapter, which seats on the lower edge of the liner, is used on the lower end of the screw, and the long, hollow sleeve is used between the screw head and the cylinder block. As the liner is pulled from the cylinder block, it rises inside the sleeve.

3. **Hone Cylinder Block for Loose Liner That Previously Used Pressed-In Liner**—With the cylinder block stripped and liners removed:

   (a) Remove oil, dirt, and grease from the bore and inlet port openings.

   (b) Measure the bore for high spots and the most narrow section.

   (c) Liners are fitted from .001″ to .002″ loose. A clearance of .001″ produces a slip fit, .002″ clearance allows the liner to slide freely into place. A straight, round bore of 4.6265″-4.6275″ diameter in the block produces a factory fit.

   The fit of a liner depends partly upon the condition of the bore before honing. Distortion may cause low spots that will not clean up. A low spot is not objectionable above the ports if it does not exceed the size of a half dollar. Below the ports, larger spots are permissible.

   The hone, selection of hone stones, and method of honing are important, especially when truing distorted bores. An adjustment for setting the cutting radius of the stones is preferable to spring loaded stones. Spring loaded stones will follow, instead of remove irregularities in the bore. Keep the stones dressed and brush them frequently to prevent loading. Follow the hone manufacturer's instructions regarding the use of oil or kerosene on the stone. With a dry type hone, such cutting agents should not be used. Roughing and finishing stones should be fairly coarse. A number 46 grit stone may be used for roughing, and a number 150 grit stone is satisfactory for finishing.

   (d) Insert the hone in the bore and adjust the stones snugly to the most narrow section.

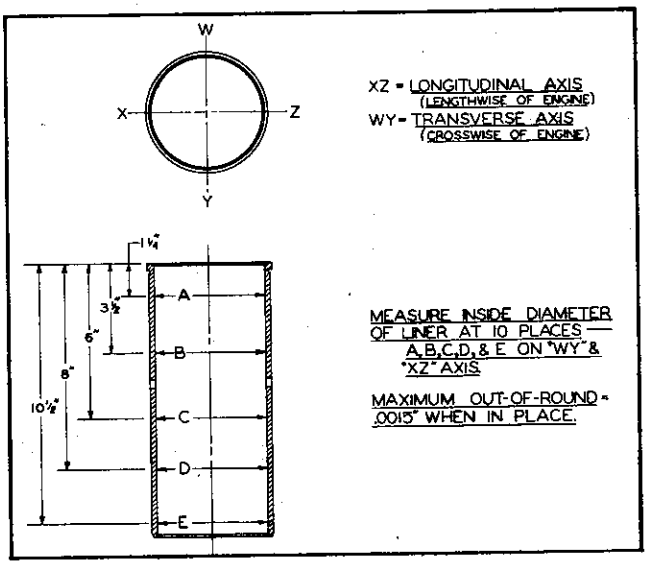


Fig. 6—Diagram of Cylinder Liner Measurements

When correctly adjusted, the hone will not shake in the bore, but will still drag freely up and down the bore while the hone is stopped.

(e) **Rough Hone**—Start the hone and "feel out" the bore for high spots. These will cause an increased drag of the hone. Move the hone up and down the bore with short overlapping strokes about 1″ long. Concentrate on the high spots in the first cut. As these are removed, the drag of the hone will become lighter and smoother. Do not hone as long at the ports as in the rest of the bore—this area, as a rule, cuts away more rapidly. When the drag of the hone becomes quite light and smooth, increase the feed on the stones. Feed lightly to avoid an oversize bore; roughing stones cut rapidly even under low tension.

When the bore is fairly clean, remove the hone to inspect the stones and measure the bore. Decide carefully which spots must be honed most. To move the hone from top to bottom of the bore will not correct an out of round condition. To remain in one spot too long may cause taper. Where and how much to hone can be judged by feel. A heavy cut in distorted bore produces a more steady drag of the hone than a light cut and so makes it difficult to feel the high spots. Therefore it pays to use a light cut with frequent stone adjustment.

(f) **Fit the Liner and Finish Hone**—Rough hone until the liner can be pushed from 3″ to 4″ into the bore, or to within approximately .0005″ of the outside diameter of the

liner. Do not expect finishing stones to remove more than .001" of stock, or to true up the bore to any extent. Work the finish hone with short, rapid strokes up and down the bore. Use light tension on the stones and hone only enough to allow the liner to enter the bore either with a light push fit or a free slip fit.

4. **Hone Cylinder Liner**—If new liners are to be used after honing the block, follow instructions on Page 4, for replacing loose liners. If old liners requiring rehoning on the inside diameter are to be used, follow instructions on Page 3.

Having replaced the cylinder liners, the pistons may be fitted and the engine rebuilt. In this process, see "Fitting Pistons," Page 2, Sec. 6; also refer to the various other sections of this text for detailed instructions relative to correct location of parts, bearing clearances, etc. Operate engine on run-in schedule as outlined in Sec. 22.

MAIN BEARINGS

Description—Large, main bearing shells of the precision type are readily replaceable without machining. The main bearing caps are attached to the crankcase and carefully machined in place to receive the precision bearing shells. Each bearing cap is marked 1, 2, 3, etc., and when removed should always be replaced in its respective position.

Crankshaft thrust loads are taken by separate thrust washers at the rear main bearing. The upper halves of the main bearing shells are seated in the crankcase. The lower halves are held in place by the main bearing caps, each of which is bolted to the crankcase by two special steel studs, as shown in Fig. 1. Each half of the bearing shell is prevented from endwise or radial movement by a tang at the parting line on one side of the bearing. Each bearing cap is locked from sidewise movement by a milled slot in the crankcase.

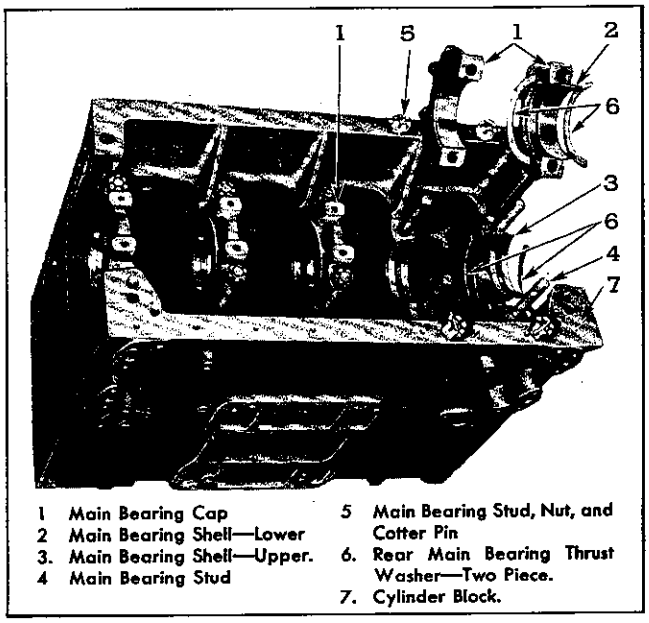
All Upper Halves of the Main Bearing Shells are alike—These shells carry a circular groove midway between the bearing edges which runs from parting-line-to-parting line, and furnishes registration with the oil holes in the crankshaft journals at all times. An oil hole in this groove midway between the parting lines, as shown in Fig. 1, provides oil registry with holes in the cylinder block, by way of the bearing shells, to the drilled passages in the crankshaft leading to the various connecting rod bearings.

All lower halves of the main bearing shells are alike but have no oil grooves; consequently, the upper and lower halves of these bearing shells are not interchangeable.

A very effective oil seal has been incorporated at the rear main bearing. This seal consists of a special treated leather ring (seal) set into the flywheel housing. The rolled-over inner diameter of the leather is held snug against the crankshaft journal by a coil spring, to prevent oil from creeping along the journal into the flywheel compartment. The crankshaft timing gear acts as an oil slinger and throws surplus oil from the gear teeth back into a cavity adjacent to the gear. The oil from this cavity flows back into the oil pan. The leather ring and coil spring constitute the oil seal assembly, which is readily replaceable.

Engines built prior to numbers 3715767, 4717411 and 67131859 were equipped with an oil slinger attached to the rear face of the crankshaft timing gear; however, as the gear itself acts as an oil slinger, the oil slinger proper is not required and may be discarded at overhaul.

An oil seal of the same design is used forward of the front main bearing. This seal is pressed into the crankshaft front cover; and the leather seal bears against a removable sleeve on the end of the crankshaft, next to the drive sprocket for the oil pump or ahead of the balancer when one is used. (See engine lubrication diagram, Page 2, Sec. 12.)



1 Main Bearing Cap
2 Main Bearing Shell—Lower
3. Main Bearing Shell—Upper.
4 Main Bearing Stud
5 Main Bearing Stud, Nut, and Cotter Pin
6. Rear Main Bearing Thrust Washer—Two Piece.
7. Cylinder Block.

Fig. 1—Upper and Lower Main Bearing Shells, Bearing Caps, and Rear Main Bearing Thrust Washers.

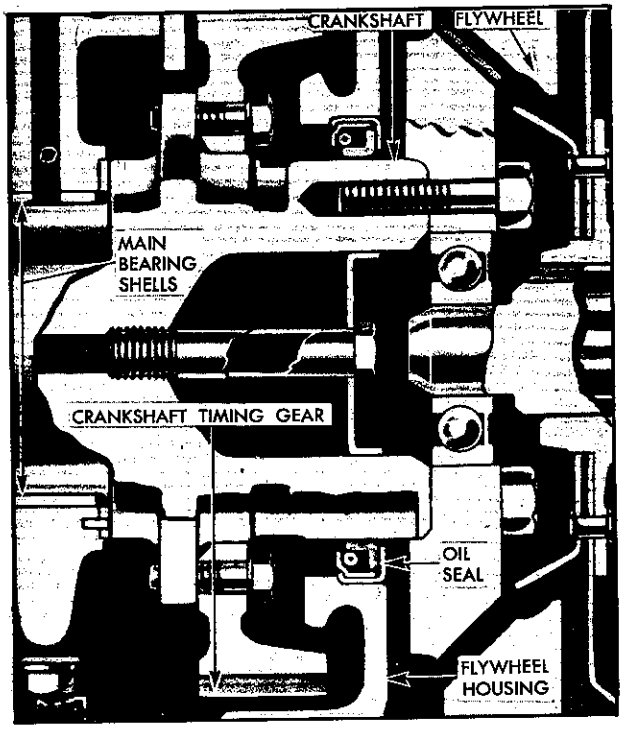


Fig. 2—Rear Main Bearing Oil Seal.

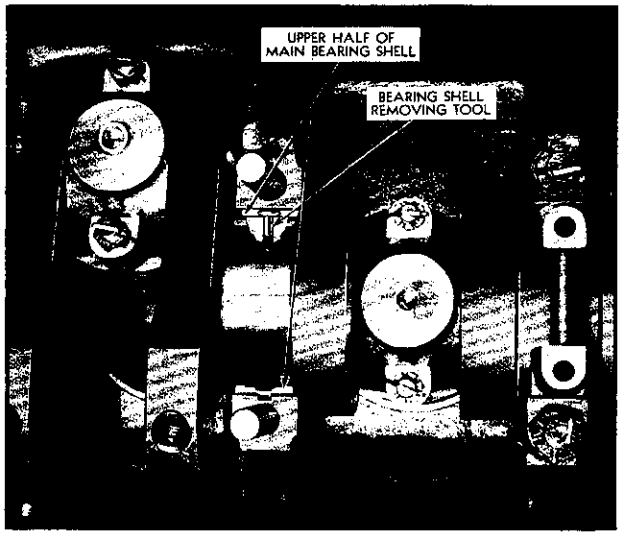


Fig. 3—Removing Main Bearing Upper Shell with Tool as Shown (Except Rear Main)—Cranshaft in Place.

Service—All the main bearing load of these engines is carried on the lower half of the bearings only. Any chipping, pitting, scoring, or over-heating, of the main bearing shells, therefore, may be observed by removing the main bearing caps.

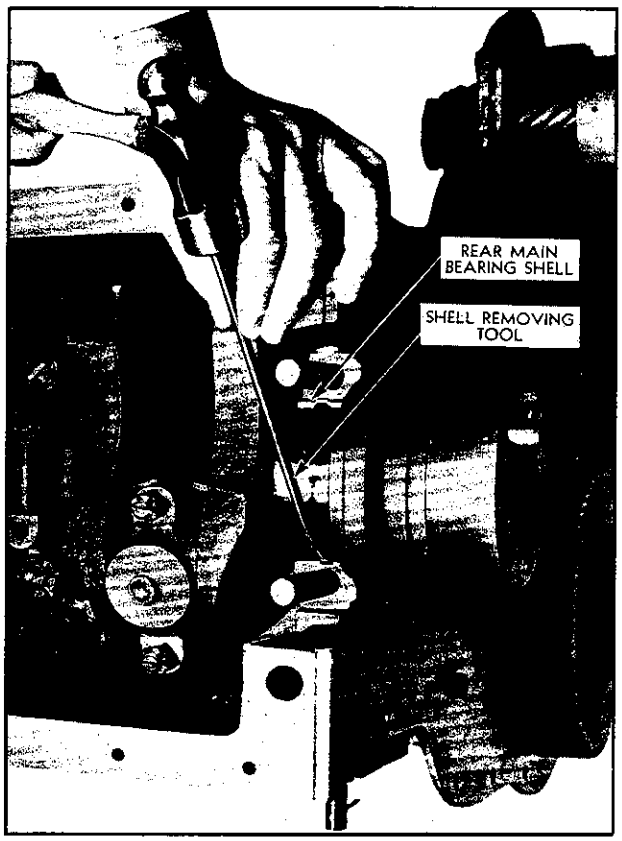


Fig. 4—Removing Rear Main Bearing Upper Shell (Crankshaft in Place).

If main bearing trouble is suspicioned from the running of the engine, remove the oil pan; then remove the main bearing caps—one at a time—and examine the bearing shells. As no load is imposed on the upper half of the shell, this half may not require changing. Bearing shells are furnished as upper or lower halves separately.

In cases of main bearing shell changes, the crankshaft journal should be examined for over-heating, scoring, or excessive wear. If crankshaft journals have been over-heated, the crankshaft should be changed. If they have been scored or worn and not over-heated, they may be reground and undersize main bearing shells used. (See Crankshaft Service, Page 1, Sec. 5.)

Remove Crankshaft Main Bearing Shells (Crankshaft in Place)—When removal of upper half of main bearing shells becomes necessary and the removal of the crankshaft is undesirable, this operation can be performed by using the following procedure as a guide and by referring to Fig. 3.

All main bearing journals except the rear are drilled for an oil passage. The procedure, therefore, for removing the upper half of the shells, with crankshaft in place, is somewhat different on the drilled journal than on the one that is not drilled. The method for removal of both types is shown below.

1. Remove the oil pan to expose the main bearing caps.
2. On the three and four cylinder engines, the lubricating oil pump assembly is bolted to one of the main bearing caps and the pump drive sprocket and bearing assembly is bolted to the front main bearing cap. If necessary, remove the oil pump and discharge pipe assembly, or the drive sprocket bearing, and then remove the bearing cap.
3. Two-piece thrust washers are used each side of the rear main bearing. These washers will be removed when removing the rear main bearing cap.
4. The bearing cap having been removed, insert a $\frac{1}{4}$" x 1" bolt with a $\frac{1}{2}$" diameter and a $\frac{1}{16}$" thick head into the crankshaft main bearing oil hole, then revolve the shaft to the right (clockwise) and roll the bearing shell out of position, as shown in Fig. 3. The head of the bolt should not extend beyond the outside diameter of the shell.

The upper half of all the main bearing shells may be removed in the above manner except the rear main. On this bearing, the upper shell must be removed by driving on the edge of the bearing shell with a small curved rod, at the same time revolving the crankshaft, thus rolling the shell from position, as shown in Fig. 4.

Main Bearing Shell Inspection—As stated above, the main bearing shells are of the precision type and replacable without machining. The clearance between the main bearing shells and the crankshaft journals is from .002" to .006". Main bearing shells are furnished in standard, and undersizes.

As will be seen from Fig. 6, bearing shells when in place have .001" larger diameter at the parting line than 90° from the parting line. Also, the thickness of the bearing shells 90° from the parting line is .155". The two shells do not form a true circle when not installed and when measured for inside diameter should be installed in the caps and block, with caps bolted in place.

The two halves of the shells have a squeeze fit in the case and cap, and must be tight when the cap is drawn down. The shells may be measured with micrometers at the points marked "C," and any variation from .155" will show the amount of wear on the particular shell being measured.

A recommended method of determining running clearance is to insert a 1/32" diameter soft lead wire or foil across center of each lower bearing shell by removing and replacing one bearing cap at a time. When all insertions have been made, tighten the bearing cap stud nuts, thus "squeezing" the wire or foil to shim thickness between the shells and crank journals. Remove the lead shims and measure for thickness; the clearance between shells and journals should be from .002" to .006".

If one or two shells are worn or scored to exceed the maximum clearance of .006" and the other shells are within the recommended limits, the worn shells only may be replaced; otherwise, all main bearings should be changed.

NOTE: If all shells are worn beyond limit, then all shells must be replaced. Observe that lower half only of main bearings are loaded and subject to wear; therefore, if upper halves are not scored and are serviceable, lower halves only may be changed.

The crankshaft journals may be inspected for scoring or overheating without removing the crankshaft. To measure journal diameters, however, removal of the crankshaft is necessary. (See Crankshaft Inspection, Page 2, Sec. 5.)

Install Crankshaft Main Bearing Shells—To install a main bearing shell with the crankshaft in place, reverse the sequence of operations for removal.

The upper and lower halves of the main bearing shells are *not* alike. The upper half is grooved for lubrication and the lower half is *not*. Be sure always to install the grooved shell in the crankcase and the non-grooved shell in the bearing cap, otherwise the oil supply to the bearing will be cut off.

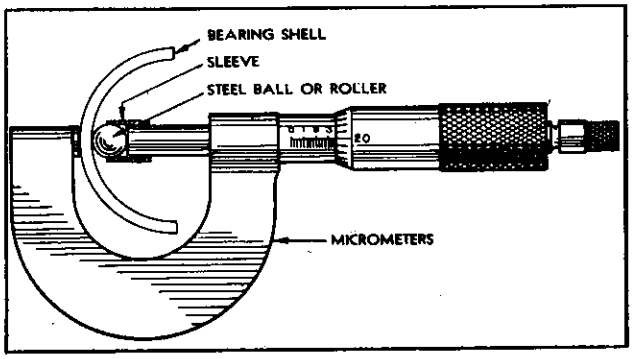


Fig. 5—Measuring Thickness of Bearing Shell.

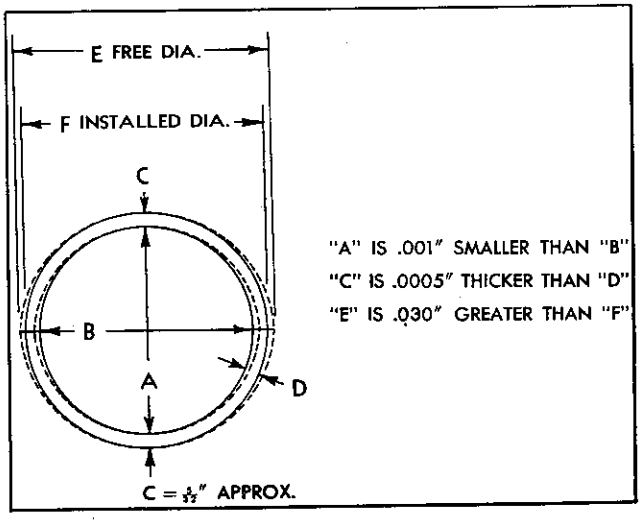
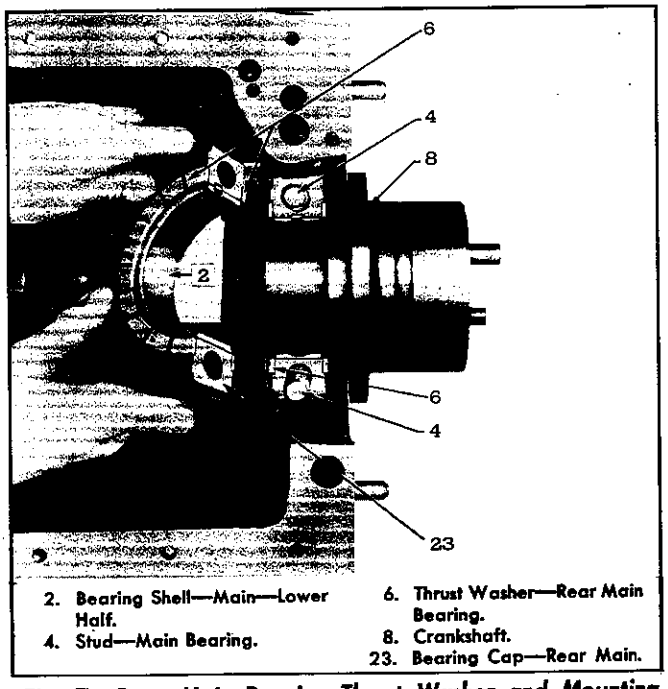


Fig. 6—Inside Diameter of Bearing Shell at Parting Line and 90° to Parting Line.



2. Bearing Shell—Main—Lower Half.
4. Stud—Main Bearing.
6. Thrust Washer—Rear Main Bearing.
8. Crankshaft.
23. Bearing Cap—Rear Main.

Fig. 7—Rear Main Bearing Thrust Washer and Mounting.

1. When replacing the upper half of main bearing shells with crankshaft in place, start the end of the shell having no tang around the crankshaft journal, so that when shell is in place tang will fit into groove in the shell support.

NOTE: Main bearing caps are bored in position and marked 1, 2, 3, etc. Whenever bearing caps are removed, they should be replaced in their original positions with marked side of caps toward blower side of cylinder block.

2. With lower half of bearing installed in bearing cap, replace cap and draw tight. The caps should first be drawn up snugly, then rapped sharply to align the bearing shell. The cap stud nuts may be tightened and locked.

NOTE: Since the bearing shells have a squeeze fit in the cap and block, bearing cap nuts should be drawn tight so shells will not shift. When a torque wrench is available, 155-185 foot pounds is satisfactory.

NOTE 2: If bearings have been installed properly, the crankshaft will turn freely with all main bearing caps bolted tight.

3. Install lubricating oil pump, drive and discharge pipe assembly. (See Page 12, Sec. 12.)

4. Install oil pan with new gasket.

After installing new bearing shells, the engine should be operated on a run-in schedule as outlined on Page 15, Sec. 22.

Rear Main Bearing Thrust Washers—As will be seen from Fig. 7, the crankshaft thrust washers located at the rear main bearing consist of two pieces on each side of the bearing. The lower portion is doweled to the bearing cap in two places at each side of the cap. If these washers have become scored, or otherwise damaged, they should be replaced. Washers for replacement are available in standard and .005" oversize in thickness.

CRANKSHAFT, FLYWHEEL AND VIBRATION DAMPER

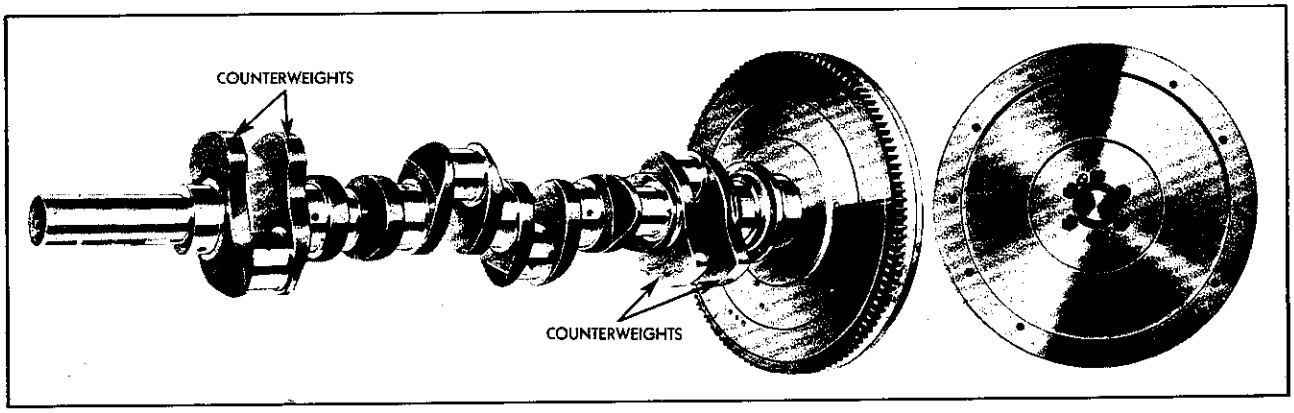


Fig. 1—Six Cylinder Crankshaft and Flywheel.

CRANKSHAFT

Description—The rigid crankshaft is a high-carbon steel drop forging, carefully heat-treated to insure utmost strength and durability. All main and connecting rod bearing journal surfaces are electrically hardened by the Tocco process.

Complete static and dynamic balance of the rotating parts has been achieved by counterweights incorporated with the crankshaft as shown in Fig. 1.

The crankshaft thrust is taken through two-piece washers on each side of the rear main bearing. The crankshaft is drilled for full pressure lubrication to the main and connecting rod bearings.

The 3-71 engine crankshaft has 4, the 4-71 engine, 5, and the 6-71 engine, 7 main bearings, each 3½ inches in diameter and 1⅛ inches long.

The crankshaft pins are 2¾ inches in diameter and 2⅛ inches long on all Series 71 engines.

Service—If main bearing or connecting rod trouble is suspicioned, the oil pan and the man bearing caps, as well as the connecting rod bearing caps, should be removed one at a time and the lower half of the main bearing shells and the upper half of the connecting rod bearing shells inspected for scoring, chipping, cracking, or signs of overheating. If crankshaft has been overheated, examine the journals for cracks. The backs of the bearing shells should also be inspected for any bright spots. Bright spots on backs of the shells will indicate that shells have been shifting in their supports, and are unfit for further use.

If the crankshaft journals do not show signs of scoring, overheating, or abnormal wear, it will be unnecessary to remove the crankshaft as the condition may be corrected by changing the worn half of the bearing shells only. (See Main Bearing Service, Page 2, Sec. 4, for removing upper half of main bearing shells.)

Low oil pressure is an indication of worn main bearings, as evidenced by slow response of oil pressure gage when starting, and insufficient pressures at running speeds. Excessive crankshaft-main bearing clearances are determined by prying up on front or rear ends of shaft and noting movement of pry bar.

If the crankshaft journals show signs of over-heating or are badly scored, then the crankshaft must be removed from the engine and either changed or reconditioned.

The journals may be reground undersize and undersize main bearings shells used. See parts list for undersize bearings available. If the crankshaft journals have been over-heated, the heat-treating will be destroyed and a new crankshaft should be used.

Remove Crankshaft—When crankshaft removal becomes necessary, the operation may be performed as follows:

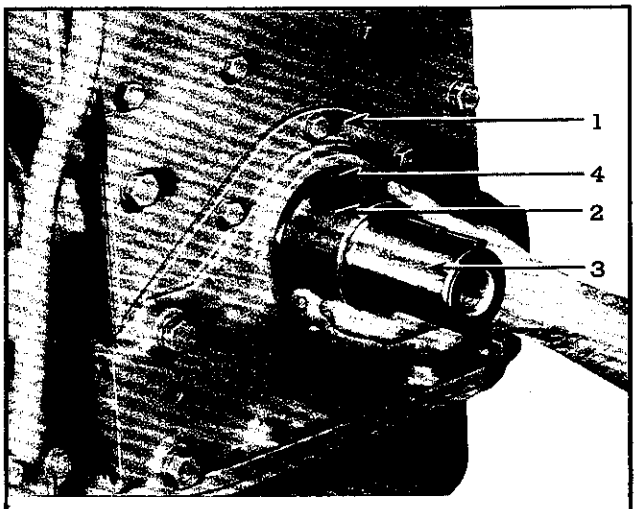
1. Drain the cooling system and oil pan.
2. Remove the oil pan.
3. Remove the lubricating oil pump, discharge pipe and drive shaft assembly.
4. Remove vibration damper assembly, if used. (See Page 6.)
5. Remove the lubricating oil pump driven sprocket and bearing assembly from the front main bearing cap on three and four-cylinder engines. On the six-cylinder engine, the sprocket (or gear) is keyed to the pump shaft and will be removed together with the oil pump assembly.
6. Remove the flywheel.
7. Remove the flywheel housing.

8. Remove the crankshaft front cover from cylinder block end plate.
9. Remove the connecting rod bearing caps.
10. Remove the main bearing caps.
11. Remove the thrust washers from each side of the rear main bearing.
12. Remove the spacer or vibration damper rear cone from front end of crankshaft.
13. Remove the crankshaft, timing gear, oil pump drive (gear or sprocket and chain) as an assembly.

Crankshaft Inspection—When a crankshaft has been removed for reconditioning for any reason whatsoever, a thorough inspection should be carried out before the shaft is again installed in the engine. Such a check should include:

1. Blow out all oil passages with air.
2. Measure the main bearing and connecting rod journals. The journals should be measured at several places on the diameter in order to show the smallest diameter in case the journal has worn out of round.
3. Measure the thickness of the main bearing and connecting rod bearing shells as described under Main Bearing Inspection, Page 3, Sec. 4.

   The specified clearance on the main and connecting rod bearings is from .0014" to .0044". If measurements show abnormal clearances and shells only show wear, change or refit the shells. If the journals are worn excessively, they should be reground under size and undersize shells used.



1. Front Cover—Crankshaft
2. Oil Seal Spacer—Crankshaft.
3. Crankshaft
4. Oil Seal—Crankshaft Front Cover.

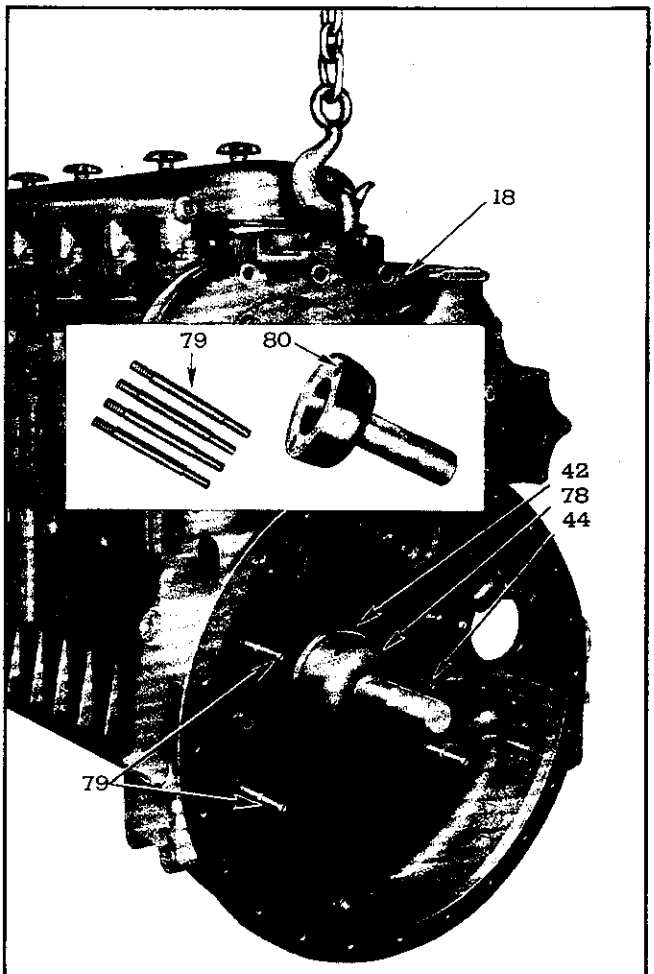
Fig. 2—Replacing Spacer on Front End of Crankshaft.

Main bearing shells and connecting rod lower bearing shells are furnished in standard size and also in undersizes.

Install Crankshaft—Timing Gear in Place.

The crankshaft must be installed by reversing the sequence of operations for removal as described above.

The crankshaft main bearing upper shells are grooved for lubrication; the lower shells are not grooved. When replacing the bearing shells, preliminary to setting the crankshaft in place, see that the grooved shells are placed in the cylinder block, as shown in Fig. 1, Sec. 4.



18. Flywheel Housing.
42. Oil Seal—Crankshaft (Rear).
44. Dowel Hole—Flywheel Housing-to-Cylinder Block Dowel Pin.
78. Expander — Crankshaft Rear Oil Seal—Tool No. J-1359.
79. Aligning Stud—Flywheel Housing—Tool No. J-1927.
80. Dowel Hole (Receive Crankshaft Flywheel Dowel).

Fig. 3—Installing Flywheel Housing, Using Tools J-1359 and J-1927, to Expand Oil Seal and Pilot Housing to Position, Respectively.

1. After the bearing upper shells have been placed in the crankcase, apply some clean engine oil to all crankshaft journals and set crankshaft in place. When setting the crankshaft in place with the timing gear bolted to the crankshaft flange, be sure the timing marks on the gears align as shown in Fig. 1, Sec. 7.
2. Install the two-piece thrust washers on each side of the rear main bearing.
3. The main bearing caps are numbered 1, 2, 3, etc., indicating their respective positions. The marked side is always toward the blower side of the cylinder block. Heeding the marks, place the bearing lower shells in the bearing caps and install caps, locking in place with nuts and cotters

   When torque wrench is available tighten to 155-185 ft.-lbs.

   When tightening bearing cap bolts, rap caps a couple of sharp blows with a hammer to assist in positioning shells.

NOTE: If bearing has been properly installed, the crankshaft will turn freely with all main bearing caps bolted tight.

4. The connecting rods and caps are numbered 1, 2, 3, etc., indicating their respective positions. The marked side is always toward the blower side of the cylinder block. Heeding the marks, apply some clean engine oil to connecting rod journals, install the connecting rod bearing caps with shells in place and lock with nuts and cotter pins. If torque wrench is used, tighten to 65-70 ft.-lbs.
5. With chain looped tightly around oil pump drive sprocket, slide sprocket and chain over key and into position front end of crankshaft. Place oil slinger up against hub of drive sprocket.

   The driven sprocket of the oil pump assembly may be placed in the loop of the drive chain, and the drive sprocket, chain, driven sprocket, and pump then slid back into place as a unit. Install two bolts to hold pump in place until ready to complete pump installation.
6. Shellac new gasket to bolting flange of crankshaft front cover, and attach to cylinder block with lockwashers and capscrews—finger tight only. Do not tighten capscrews until after front spacer is put in position, as described in next item, number 6.
7. Replace the spacer or vibration damper inner (rear) cone if used on front end of crankshaft next to the oil slinger, as shown in Fig. 2.

NOTE: This spacer or cone must not be put in place until after the front cover is in place, otherwise the oil seal in the cover may be destroyed.

8. Refer to Fig. 3 for use of guide tools and install the flywheel housing as follows:
   (a) Shellac new gaskets to bolting flanges of flywheel housing.
   (b) Install the oil seal guide tool on the two dowels at rear end of crankshaft; put housing in place and secure with lockwashers and capscrews.

NOTE: The tool shown, or its equivalent, must be used when locating flywheel housing; otherwise the leather of the oil seal will be destroyed.

9. Using the two "T" head studs shown in Fig. 5, set flywheel in place over the two dowels and secure with six capscrews. Omit lockwashers, but lock capscrews with a continuous wire through head of each screw with ends of wire twisted together.
10. Refer to Page 12, Section 12, under "Replace Lubricating Oil Pump" and follow each detail when replacing the lubricating oil pump.

FLYWHEEL

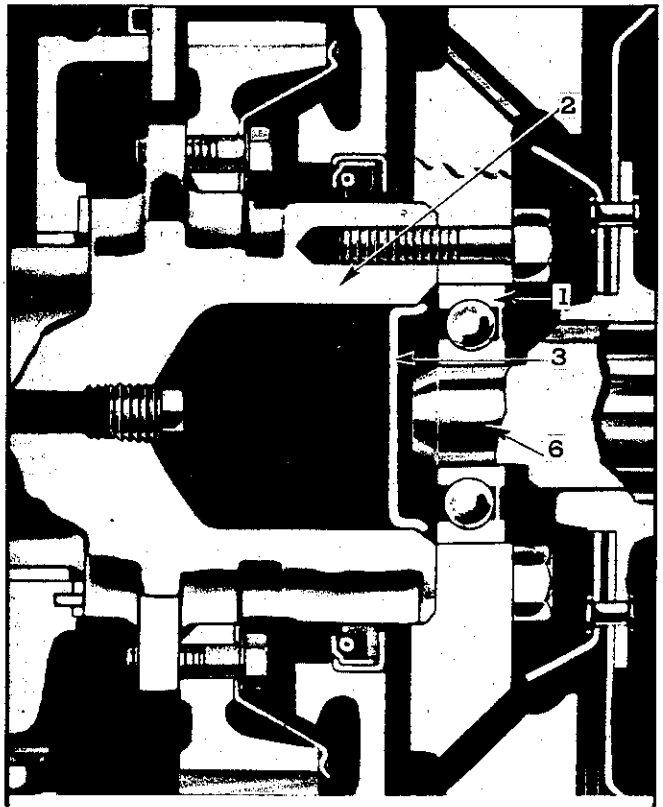
Description—The even torque of the Model 71 engines permits the use of a relatively light, cast iron flywheel, which insures exceptional operating flexibility. The flywheel is bolted securely to a flange on the crankshaft and doweled in two places. One of the bolting studs being off-set, the flywheel can be attached to the crankshaft flange in only one position.

A starter ring gear made from heat-treated steel is shrunk onto the rim of the flywheel. The ends of the teeth are chamfered on both sides, so the same flywheel can be used on either a right or left-hand rotation engine.

The design of the flywheel can be made to suit any conventional clutch or industrial drive and provision has been made for installing a clutch pilot bearing.

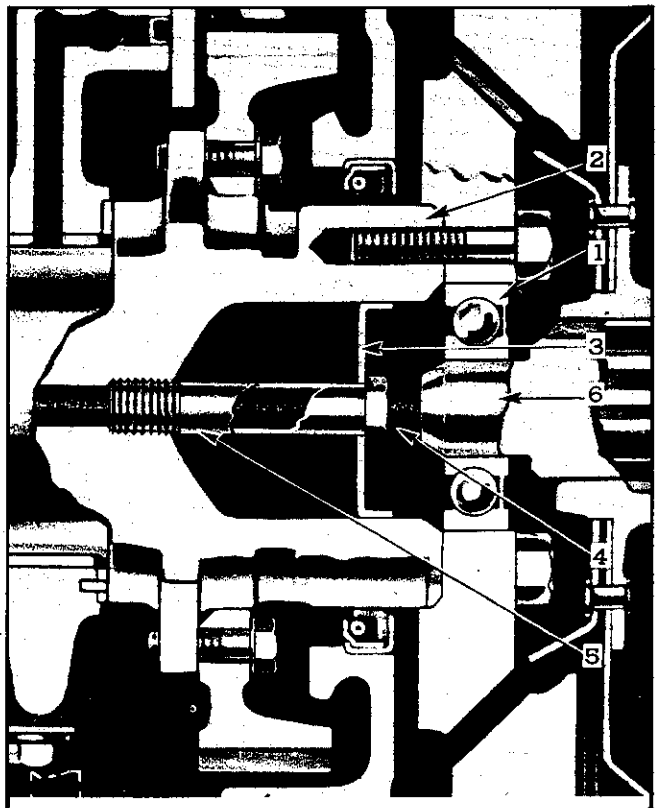
Service—The rugged construction of the flywheel makes the necessity for service on this part very remote. Other service operations, however, such as removing and replacing clutch pilot bearing, or removing or replacing the starter ring gear—in which event the flywheel must be removed—are necessary.

These operations are outlined below.



1. Clutch Pilot Bearing.
2. Crankshaft.
3. Oil Baffle.
6. Pinion Shaft.

Fig. 4—Grease Lubricated Pilot Bearing Installation.



1. Clutch Pilot Bearing.
2. Crankshaft.
3. Oil Baffle.
4. Wick.
5. Wick Holder.
6. Pinion Shaft.

Fig. 5—Oil Lubricated Pilot Bearing Installation.

Removing Clutch Pilot Bearing—Refer to Fig. 6, and remove clutch pilot bearing from flywheel with tool J-1914 as follows:

1. Back out center stud on puller tool so that puller fingers will collapse and can be inserted through inner race of pilot bearing.

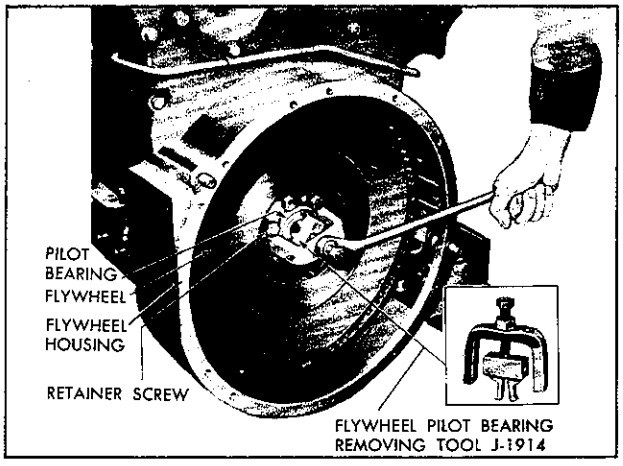


Fig. 6—Removing Clutch Pilot Bearing from Flywheel with Tool J-1914.

2. Set tool up against rear face of flywheel as shown, and turn clockwise on inner stud so that pulling fingers will expand and bear against inner face of bearing inner race.
3. If necessary, hold center stud from turning and screw puller nut clockwise and withdraw bearing.

Pilot Bearing Inspection—After removal and before replacing, the clutch pilot bearing should be thoroughly washed in clean gasoline, blown out with compressed air, and inspected for corrosion or rough spots on either the balls or the races. This may be done by holding the inner race from turning and revolving the outer race slowly by hand. A few revolutions in this manner will show any rough spots on either balls or races. If bearing does not turn freely, or is excessively loose, it should be replaced.

Install Clutch Pilot Bearing—Two different methods of lubricating the clutch pilot bearings are used, as shown in Fig. 4 and 5.

Crankshafts equipped with the lubrication arrangement shown in Fig. 4 have the bearing and the cavity in the crankshaft packed with grease.

Through the arrangement illustrated in Fig. 5 lubrication of the pilot bearing is accomplished by means

of an oil wick which is installed in the crankshaft as shown. The wick extends into the hollow crankshaft from which it draws oil by capillary action. The end of the clutch pilot shaft must be in contact with the oil wick at all times.

Pilot bearing installation instructions are different for each type.

Install Grease Lubricated Pilot Bearing (Fig. 4)

1. Fill cavity in crankcase and lubricate bearing with high quality bearing grease.
2. Start bearing into bore of flywheel by hand.
3. Place fixture J-1910 on outer race of bearing and drive bearing flush with outer face of flywheel.

Install Oil Lubricated Pilot Bearing (Fig. 5)

1. Inspect lubricating oil wick. If damaged or charred or if wick does not extend ½" beyond the end of the wick holder replace the wick assembly.
2. Start bearing into bore of flywheel by hand.
3. Place fixture J-1910 on outer race of bearing and drive bearing flush with outer face of flywheel.

Remove Flywheel—The power transmitting unit and clutch, having been removed from the flywheel housing and flywheel respectively, the flywheel may be removed from the crankshaft flange using tool J-1904, illustrated in Fig. 8.

1. Withdraw the lockwire from the six capscrew heads and remove capscrews.
2. Screw the two puller wrenches into the tapped holes provided at flywheel bolting flange until inner ends of tool press against crankshaft flange. Continue to turn wrenches until flywheel is removed from dowels.

Remove Flywheel Ring Gear—With flywheel removed from crankshaft, the old ring gear may be taken from the flywheel by grinding a notch through the ring at the root of one tooth, then expanding the ring and driving from position. Unless the ring gear is already broken at the root of a tooth, no attempt should be made to drive it from position without following out instructions as outlined above.

Replace Ring Gear on Flywheel—The ring gear is shrunk on the flywheel by uniformly heating the gear to 450° F. (red heat visible in the dark) then placing it in position on the flywheel which is at room temperature.

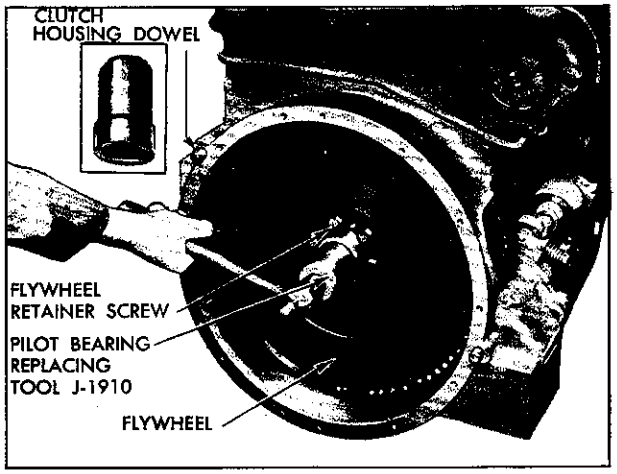


Fig. 7—Replacing Pilot Bearing in Flywheel with Tool J-1910

After heating, start ring gear onto flywheel so that, when flywheel is installed, the chamfered ends of the teeth on the ring gear will face the cylinder block. These edges of the teeth engage the pinion on the starting motor. Drive gear down tight against shoulder on flywheel. Let cool in air before using.

The ring gear should not be heated too high, as the original heat treatment will be destroyed. On the other hand, it must be heated sufficiently to expand the ring and make a tight fit on the flywheel.

Replace Flywheel—The two puller wrenches illustrated in Fig. 8, may be conveniently used to support the flywheel when it is being located on the dowels. Due to one offset hole in the crankshaft holding flange, the flywheel can be located in only one position. Having located the flywheel on the dowels in this manner, install and tighten the six retaining capscrews, then run a continuous wire through the heads of each screw and twist ends together.

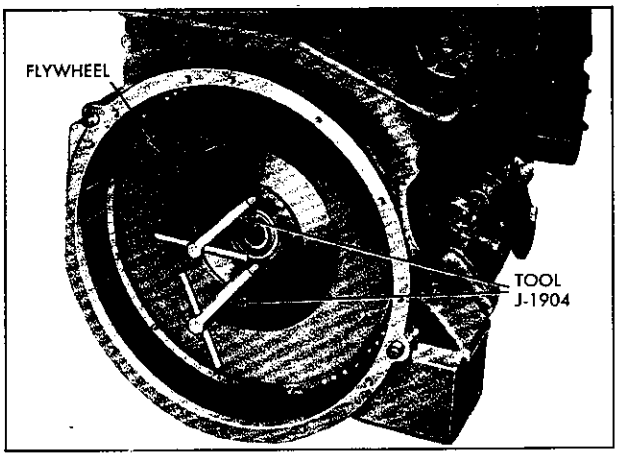
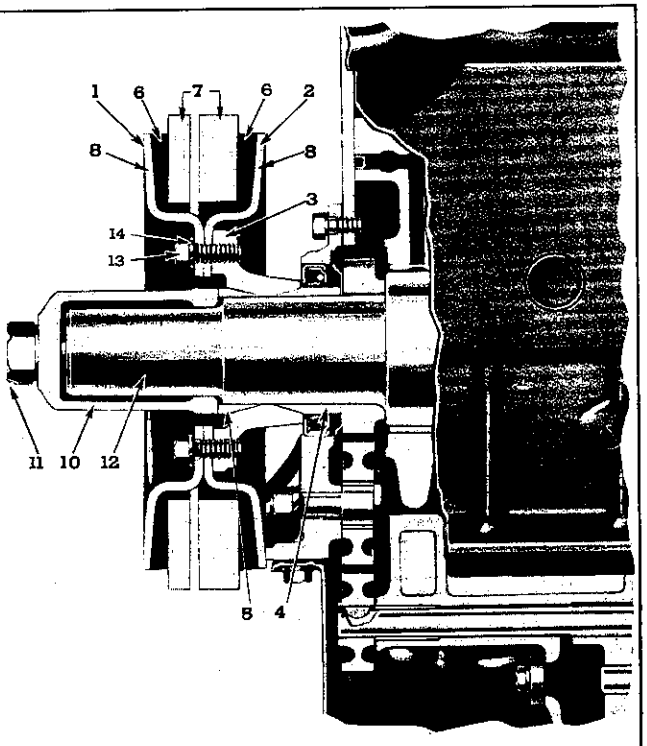


Fig. 8—Removing Flywheel with Tool J-1904.

VIBRATION DAMPER



1. Light Damper Assembly.
2. Heavy Damper Assembly.
3. Hub.
4. Inner Cone.
5. Outer Cone.
6. Rubber Block.
7. Inertia Mass (Metal Ring).
8. Metal Disc.
10. Cone Retainer Cap.
11. Retaining Bolt.
12. Crankshaft.
13. Attaching Bolt.
14. Lockwasher.

Fig. 9—Vibration Damper Assembly and Mounting.

Description—Engines which operate in the higher speed ranges or under unusual conditions are equipped with vibration dampers elastically connected to the front end of the crankshaft. The damper is in the form of a flywheel and operates to reduce crankshaft stresses to a safe value.

Each damper assembly is made up of a light and heavy damper assembly, a hub, an inner cone, and an outer cone. Both the light and heavy damper assemblies are in turn made up of rubber blocks bonded to an inertia mass in the form of a metal ring on one side, and a stamped metal disc on the opposite side. The two metal parts are, therefore, entirely separated and free to move radially, within certain prescribed limits by virtue of the rubber blocks. (See Figs. 9 and 11.)

Both light and heavy dampers are bolted and doweled to the vibration damper hub.

NOTE: An accessory drive pulley is sometimes installed between the vibration damper and the damper hub. In this case the damper is doweled to the pulley and the pulley in turn is doweled to the damper hub. Longer attaching bolts are then used to bolt the assembly together.

The inner and outer cones provide a rigid mounting for the hub when the cone retaining cap is drawn up tight against the outer cone by the bolt in the end of the crankshaft.

Two puller holes are provided on the circumference of the inner cone so that cone may be removed readily from the shaft after removal of the damper assembly.

Service—Even though the vibration damper is rigidly constructed, and should give no trouble if given the proper care, nevertheless, rubber is used in the assembly, as pointed out above, and certain precautions are necessary because of this construction. Fuel oil and lubricating oil, as well as excessive heat, are destructive to rubber. The assembly, therefore, should be protected against these destructive agents. Furthermore, for the damper to function properly and safeguard the crankshaft, it should be securely fastened to the shaft by the cones and cone retaining cap and bolt.

Remove Vibration Damper from Crankshaft—Vibration damper removal is accomplished as follows:

1. Back out bolt and remove cone retaining cap.
2. Strike the front face of the damper, near the outside diameter, a sharp blow with a heavy rubber hammer, as shown in Fig. 10, to loosen the outer cone wedged between the crankshaft and the damper hub. After loosening in this manner, the cone may be "fished" from beneath damper hub with two screwdrivers at opposite diameter of cone.
3. Pry against dampers, using a bar between heavy damper and crankshaft front cover. At the same time, strike opposite outer face with rubber hammer. Pull dampers and hub from shaft.
4. Remove inner cone by inserting a small bolt or rod in the two puller holes provided in the cone.

Inspect Vibration Damper—After removal, and before damper is assembled to crankshaft, it should be inspected to see that rubber is firmly bonded to the metal parts at each side and that flanges are not bent. If damper assembly has been exposed to fuel oil, lube oil, or excessive heat, the rubber may have loosened from the metal. In this event, the damper assembly should be discarded and replaced by a new unit.

Inspect both retaining cones (inside and outside diameters), damper hub and crankshaft front end

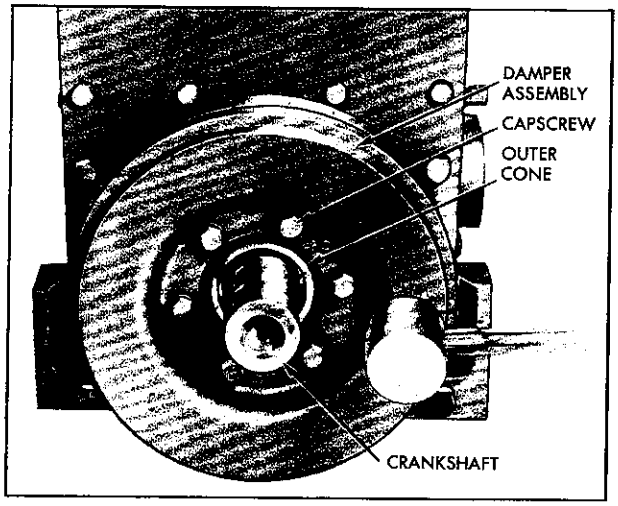
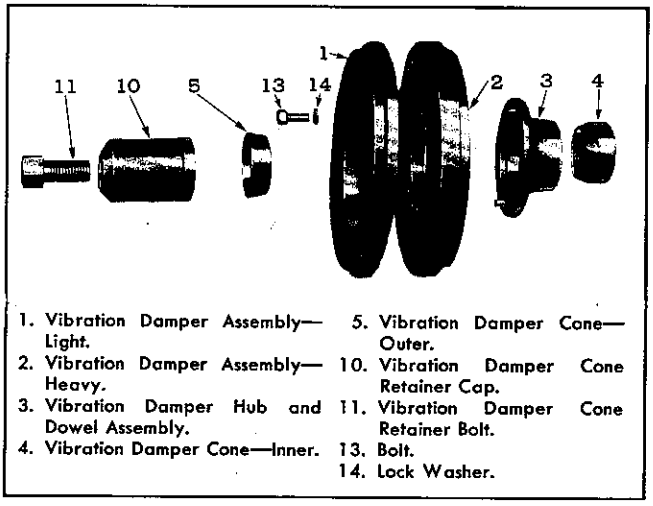


Fig. 10—Removing Vibration Damper Front Cone Lock.



1. Vibration Damper Assembly—Light.
2. Vibration Damper Assembly—Heavy.
3. Vibration Damper Hub and Dowel Assembly.
4. Vibration Damper Cone—Inner.
5. Vibration Damper Cone—Outer.
10. Vibration Damper Cone Retainer Cap.
11. Vibration Damper Cone Retainer Bolt.
13. Bolt.
14. Lock Washer.

Fig. 11—Vibration Damper Details and Relative Location of Parts.

for gall marks or burrs. Slight scratches or burrs may be removed with emery cloth. If seriously damaged the damper parts should be replaced and the crankshaft remachined.

Install Vibration Damper on Crankshaft—Before installing vibration damper, refer to Fig. 11, for relative location of the parts, and assemble as follows:

1. Having inspected each part as directed under "Service," above, slide inner cone on crankshaft next to oil slinger, with tapered end of cone pointing toward front end of crankshaft.
2. If, for any reason, the light and heavy damper assemblies were removed from the hub, place the two flat faces of the two assemblies facing each other as shown in Fig. 6, and attach same to hub with bolts and lockwashers.
3. Slide damper assembly—long end of hub facing crankshaft cover—into position.
4. Slide outer cone over shaft and into hub of damper.
5. Place cone retaining cap against outer cone and insert bolt through cap and into end of crankshaft.
6. Draw bolt up tight.

CAUTION: Damper assembly must be securely fastened to crankshaft.

PISTON AND CONNECTING ROD

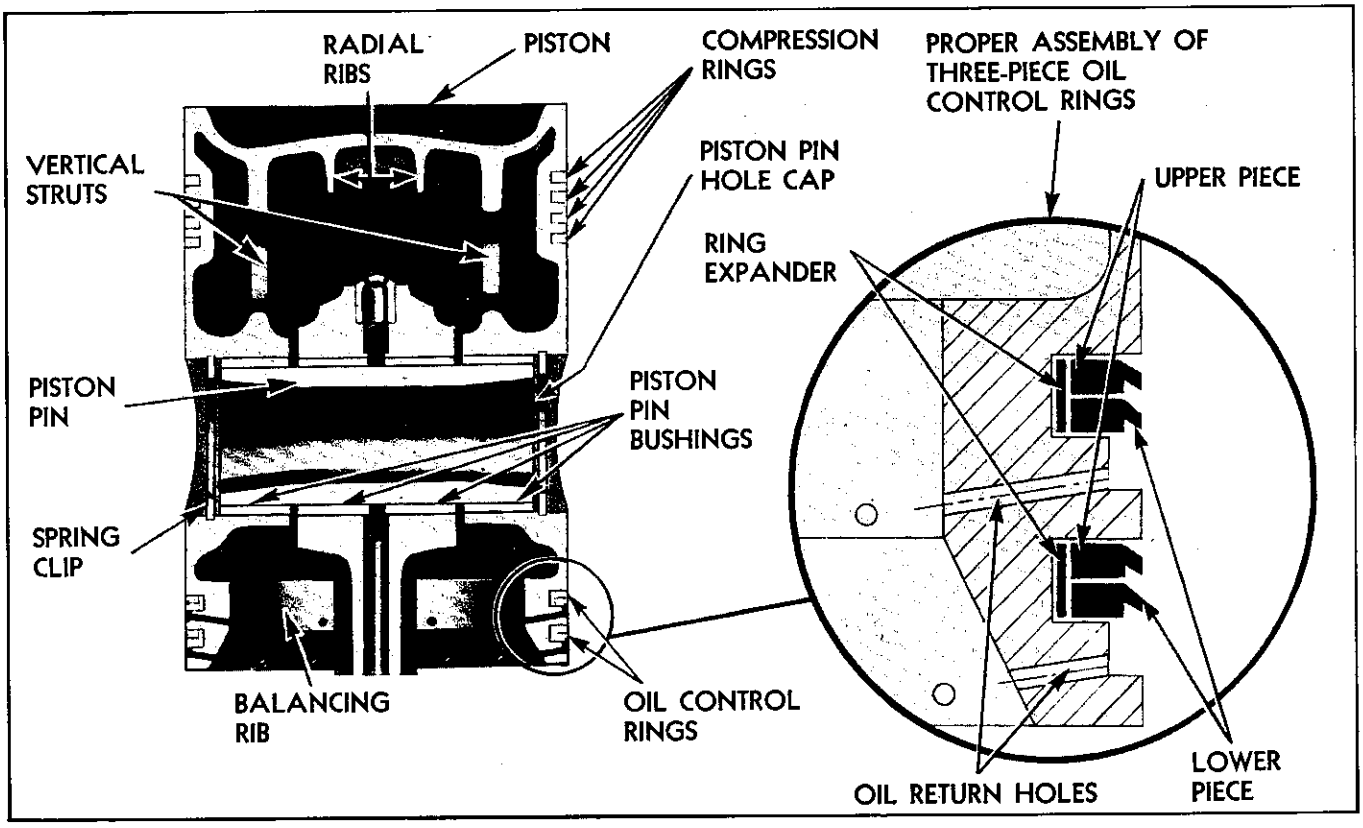


Fig. 1—Piston, Piston Pin Mounting, and Piston Ring Locations.

PISTON

Description—Malleable iron pistons with extra long skirts, accurately ground the full length, are plated with a protective coating of tin, which permits close fitting. The top of the piston forms the combustion chamber and is designed to displace the air into close proximity to the fuel spray.

To add strength, rigidity, and cooling effect, the head of each piston is cast with radial ribs on the inside and is connected to the piston pin bosses at their inner end, by vertical struts placed at a right angle to the piston pin. The ribbed head is cooled by lubricating oil forced from a spray jet on the top of the connecting rod, as shown in Fig. 2A, Sec. 12.

There are two different methods used to support the piston pins in the pistons. In some cases the pin is supported on a bearing surface machined directly in the piston while in others two bronze bushings are pressed into the piston to provide the bearing surface.

After the piston pin has been installed, the hole in the piston at each end of the pin is sealed with a tight steel cap locked in place with a spring clip. Thus lubricating oil returning from the sprayed piston head and working through the grooves in the piston bushings is prevented from reaching cylinder walls.

A balancing rib is provided on the inside at the bottom of the piston skirt. Because of this design, all pistons are balanced to within .05 lbs., whether the piston is standard or oversize. Because of this feature, one or more oversize pistons may be installed in an engine in which the other pistons are standard size, without upsetting the engine balance.

Each piston is fitted with six cast iron rings of the cut-joint type. Four $\frac{1}{8}$" wide, tin plated compression rings are placed above the pin and two $\frac{3}{16}$" wide special oil control rings scrape off the excess lubricating oil thrown into the cylinder bore by the crankshaft and the lower end of the connecting rod.

Service—Piston and Connecting Rod Removal—When the engine condition necessitates a piston inspection, the removal of the piston and connecting rod assembly becomes necessary.

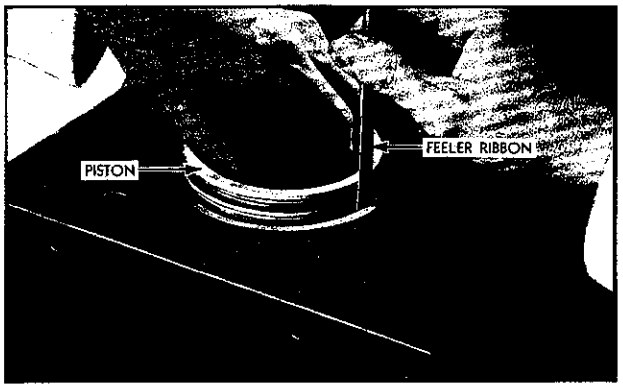


Fig. 2—Measuring Piston Clearance.

The piston and connecting rod are so closely associated from a service standpoint that one cannot be entirely separated from the other; the two will, therefore, be treated collectively in the following discussion on pistons and connecting rods.

The piston and connecting rod as an assembly is removed from the top of the cylinder block after removal of the other necessary engine parts listed below:

1. Remove cylinder head. (See Sec. 9, Page 2.)
2. Remove oil pan.
3. Remove the lubricating oil pump and discharge line assembly, where necessary. (See Sec. 12, Page 8.)
4. Remove the carbon from the upper inside diameter of the cylinder liner.
5. Remove the cotter pins, nuts, and bearing cap, from the lower end of the connecting rod and push the piston and rod assembly out through the top of the cylinder block. Pistons cannot be removed from bottom of cylinder block.
6. The piston rings may be inspected and changed and measurements taken on the outside diameter of the piston skirt without further disassembly.

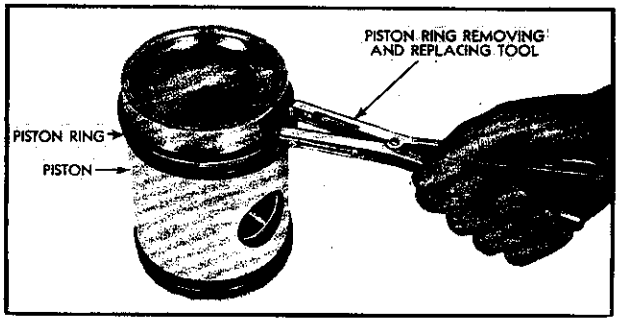


Fig. 3—Removing and Replacing Piston Rings with Tool KMO-232.

Piston and Piston Ring Inspection—As the gummy deposits are not always easily removed from the piston walls and ring grooves with fuel oil or gasoline, these parts may be cleaned by using a chrome cleaner, or its equivalent, and then blowing off with dry compressed air. After cleaning, the piston skirt, the piston rings, and ring grooves, should be thoroughly inspected.

The tin coating on the skirt is from .0016″ to .0042″ thick and the presence of this coating of soft metal will, therefore, indicate the practical absence of wear. If, however, the tin is worn off in spots, a careful examination should be made for score marks or other indications of improper piston clearance. A badly scored piston should be discarded.

Closely examine the inside of the piston for cracks across the struts or ribs. Such cracks if present make the piston unfit for further use.

The standard clearance between cylinder liner and piston skirt is from .006″ to .008″.

Fitting Pistons—Measurements of pistons and bore for pistons in cylinder liners should be taken at room temperature (70° F.).

Measurements should be taken on the piston skirt lengthwise and crosswise of the piston pin.

Cylinder bores should be measured with the gauge shown in Fig. 4, Sec. 3, both lengthwise and crosswise of the bore throughout the entire length of the cylinder liner.

The piston should be round within .001″. The cylinder bore should be round and straight within .001″.

With these conditions existing, the clearance of the piston in the bore may be checked crosswise of the pin by using a ½ inch wide feeler ribbon, 12″ to 18″ long, between the piston and cylinder liner as shown in Fig. 2. The feeler ribbon must be perfectly flat and free of nicks or scratches.

With a .006″ clearance between piston and liner, a .005″ feeler is withdrawn with a force not to exceed 6 pound pull at room temperature (70° F.).

As an alternate to the 6 pound pull method, the fit is correct if the weight of a bare piston (less pin and rings) will cause it to slide through the liner with the .005″ feeler inserted in the bore. If piston or feeler binds, remove piston and examine both piston and liner for burrs. A honing stone is the most suitable tool for dressing. If, after removing burrs, piston still fails to fit properly, wire brush the piston area uniformly below the ring lands. Use a medium size wire brush and continue brushing until the specified .006″ clearance is attained.

Pistons are furnished in standard size and oversizes. Since the cylinder liners are furnished in standard size only, the installation of oversize pistons becomes

necessary only when standard liners have been rehoned. (See Sec. 3, Page 3.) The upper part of the piston (above the upper compression ring) is not tin-plated and does not touch the cylinder wall. If this part of the piston shows any coating of hard carbon, the rings must be removed and the piston surface, as well as the ring grooves, thoroughly cleaned. The piston head should be absolutely clean on the outside as well as on the cooling ribs on the underside. Any thick coating of carbon on the parts indicates failure of cooling oil supply and necessitates the cleaning of orifice at lower end of connecting rod, spray jet at upper end of connecting rod, and oil passage in the connecting rod.

Before disassembling the rings, they should be inspected for free fit in the grooves, side clearance, and wear. The presence of the original tool marks on the piston ring surfaces indicates the practical absence of wear.

To avoid any breakage, use of a special tool, shown in Fig. 3, is advisable when removing or replacing piston rings. Care must be taken not to overstress the piston rings by spreading the ends more than necessary to slip ring off and on the piston.

New piston rings should always be used with new pistons; furthermore, if the engine has been in service for some time, even though the same pistons are again used, it is advisable to use new rings.

Inspect and measure the inside diameter of the piston pin bores or bushings and, if worn excessively, install new piston.

Fitting Piston Rings—Replace rings at each overhaul period. When fitting piston rings, the gap between the ends of the ring should be measured with the ring inserted in the bore parallel with the top of the cylinder block as shown in Fig. 4. This may be done by starting the ring in the bore and then locating the ring by sliding piston into bore on top of ring.

The specified gap on the compression rings is from .020" to .025" and on the oil control rings from .010" to .020". The gap may be changed by using a thin, flat, fine mill file. After the proper gap has been fixed, the rings may be installed on the piston with tool as shown in Fig. 3.

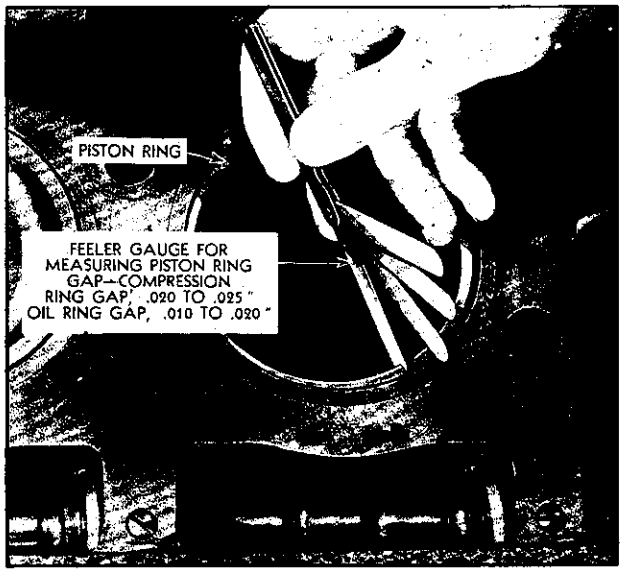


Fig. 4—Measuring Piston Ring Gap.

NOTE: The oil rings are the three-piece type and should be placed in the grooves as shown in Fig. 1. This is important to control piston lubrication properly. To obtain best results, the piston rings specified by the manufacturer should be used.

Space the rings on the piston to stagger the gaps around the piston and apply some oil to the piston wall, rings, and lower connecting rod bearings before replacing in cylinder block. See Page 3, Sec. 3, for removing GLAZE from liner before installing new piston rings.

Remove Connecting Rod from Piston—If inspection of the piston pin bearings or the connecting rod upper bearing is desired, the connecting rod must be removed from the piston. This operation may be performed in the following manner:

1. By means of a pair of small nose pliers, dislodge spring clip which retains steel cap at end of piston pin.
2. Tap piston on wood block and remove cap and pin through open pin hole. Should cap lodge in the groove for the spring clip, it may be readily removed with a rubber suction cup—same as is used for lapping valves.

CONNECTING ROD

Description—Each connecting rod is made of drop-forged heat-treated carbon steel, and forged to an "I" section with a closed hub at the upper end and an integral cap at the lower end. The rod is rifle-drilled for lubrication of the upper end and is equipped with an oil spray jet for cooling of the piston head.

The lower end of the connecting rod shank is fitted with an orifice which meters oil to the rifle-drilled connecting rod. The crankpin bearings are shells of the precision type, without shim adjustments.

The upper and lower halves of the connecting rod bearing shells are different, therefore are not interchangeable but are replaceable without machining.

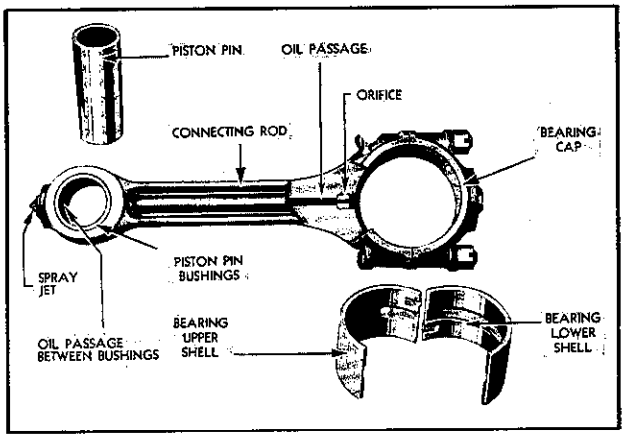


Fig. 5—Connecting Rod Assembly.

The upper bearing shell is grooved midway between the bearing edges part way up from each parting line, with an oil hole through the shell at the termination of each groove. The lower shell has an oil groove in line with that of the upper shell and circling the shell from parting line-to-parting line. These grooves maintain a continuous registry with the oil holes in the crankpins, thereby providing a constant supply of cooling oil through the hollow connecting rod to the piston pin bearings and the spray jet.

A helically-grooved steel-backed bronze bushing is pressed into each side of the connecting rod upper end for the piston pin bearing. A cavity of 3/16" between the inner ends of these bushings registering with the oil passage in the connecting rod, forms a duct around the piston pin whereby the pin bearing is lubricated and oil can be forced to the spray jet. The upper connecting rod bearing floats on the piston pin the same as the pin floats in the piston bushings.

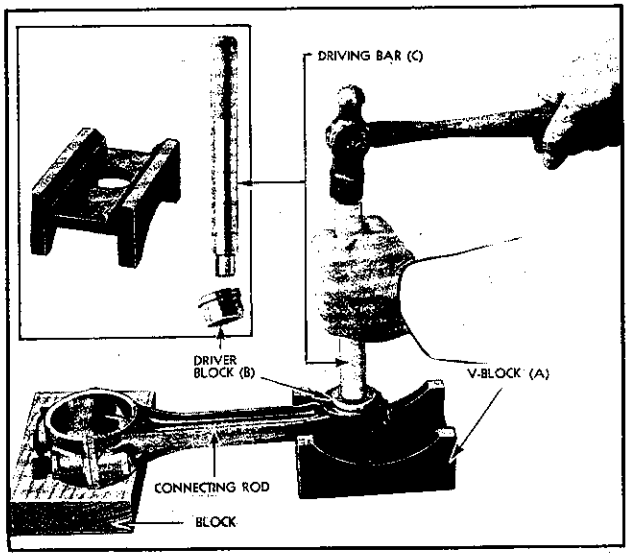


Fig. 6—Removing or Replacing Piston Pin Bushing.

Service—The connecting rod assembly as purchased includes the lower bearing cap and retainers (less bearing shells), the oil orifice, spray jet and the upper piston pin bearing pressed in place and bored to size.

The orifice and spray jet are not removable; the lower bearing shells (upper and lower) are replaceable without machining, and the upper piston pin bushings are replaceable.

If occasion requires, the connecting rod piston pin bushings may be removed, replaced, and reamed, as follows:

1. **Remove Piston Pin Bushings From Connecting Rod**—Piston pin bushings may be removed from the connecting rod with the tools shown in Fig. 6, and in the following manner:

   (a) Rest lower end of connecting rod on block and place upper end on "V" block with hole in block and rod in alignment.

   (b) Drive bushings from position, as shown.

2. **Replace Piston Pin Bushings in Connecting Rod**—Piston pin bushings are replaced in the connecting rod with the same tool that was used for their removal (See Fig. 6). Each bushing is pressed into the rod, with the split or joint at the top, until outer end of bushing is flush with outer edge of rod; this will leave an oil space of approximately 3/16".

Reaming Piston Pin Bushings in Connecting Rod—Since the inside diameter of replacement bushings are smaller than the final finished diameter, the bushing must be reamed after pressing into place. This operation is accomplished with Tool J-1686, as illustrated in Figs. 7 and 8, respectively. Figure 7 illustrates how the connecting rod is placed on the fixture preparatory to reaming. Figure 8 shows the actual reaming operation.

To use the tool:

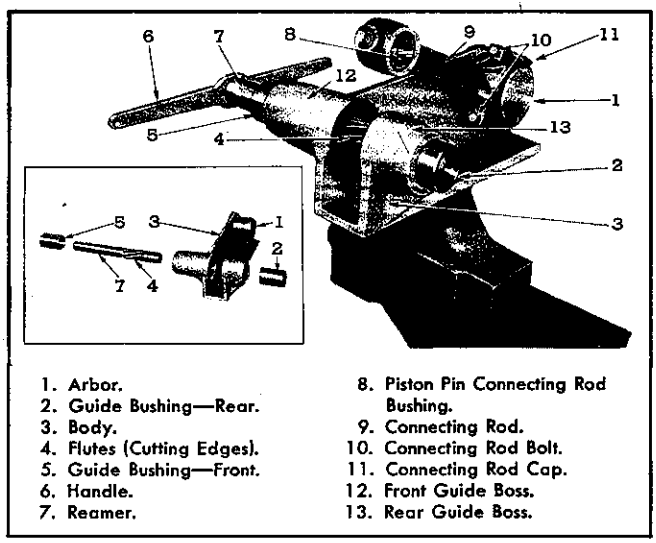
(a) Place bore at lower end of rod over arbor (1) on fixture (3), and draw bearing cap up tight.

(b) Slide bushing (2) into rear guide boss (13) of fixture with hollow end facing slot in fixture for upper end of connecting rod.

(c) Rotate connecting rod into position for reaming so that upper end of rod rests on boss of tool bed.

(d) Install bushing (5) on reamer (7). Insert reamer into front guide boss (12) and turn clockwise with uniform motion. Do not crowd reamer too hard as better results will be obtained by moderate pressures when turning.

(e) After reaming, inspect for good bearing in bushings, by a very light coating of Prussian Blue,



1. Arbor.
2. Guide Bushing—Rear.
3. Body.
4. Flutes (Cutting Edges).
5. Guide Bushing—Front.
6. Handle.
7. Reamer.
8. Piston Pin Connecting Rod Bushing.
9. Connecting Rod.
10. Connecting Rod Bolt.
11. Connecting Rod Cap.
12. Front Guide Boss.
13. Rear Guide Boss.

Fig. 7—Preparation for Reaming Piston Pin Bushings in Connecting Rod with Tool J-1686.

and slide a standard piston pin through the bushings to check for clearance. If bushings have been properly reamed, the clearance will be not less than .0025".

Inspection of Connecting Rod Assembly—After washing connecting rod assembly in clean gasoline, or fuel oil, the bushings at the upper end, oil passages, spray nozzle, etc., should be examined to see that all parts are satisfactory before assembling rod to piston and ino engine. Such an inspection would include the following:

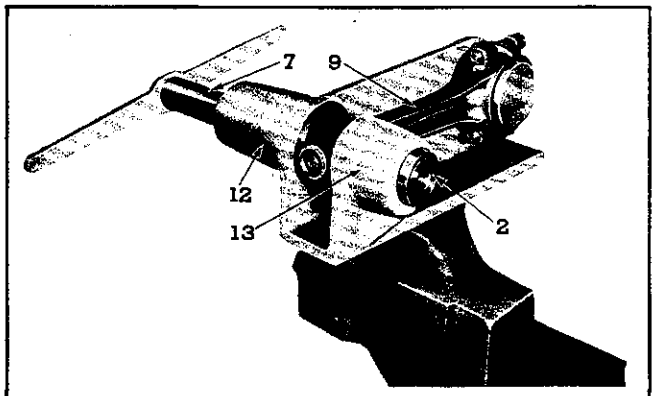
(a) Measure the outside diameter of piston pin to determine wear. Standard dimensions for piston pin diameter are 1.500"-1.4998".

(b) The standard inside diameter of the bushing in the connecting rod is 1.5030"-1.5025". These dimensions of pin and bushings provide a clearance of .0025"-.0032". If bushings show excessive wear, they may be removed, replaced, and reamed to size as outlined above. Worn clearances up to .010" are permissible.

(c) Open holes in orifice at lower end, and spray jet at upper end of connecting rod and blow dry compressed air through rifle drilling in rod. Be sure all oil passages are open.

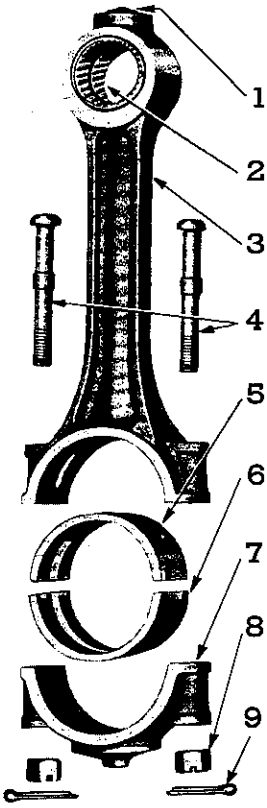
(d) The connecting rod bearing shells (at lower end of rod) are furnished both in standard size, and undersizes. The inside diameter of standard shells when installed in rod is 2.752"-2.753".

(e) The connecting rod bearing load is on the upper half of the shell only. Any wear, therefore, will show only on upper half of shell. If connecting rod bearing trouble is suspected from the running of the engine, the upper half of the shells should be examined for scoring, chipping, corrosion, cracking, or signs of overheating. The backs of the bearing shells should also be inspected for any bright spots. Bright spots on the backs of the shells will indicate that shells have



2. Guide Bushing—Rear.
7. Reamer.
9. Connecting Rod.
12. Front Guide Boss.
13. Rear Guide Boss.

Fig. 8—Reaming Piston Pin Bushings in Connecting Rod with Tool J-1686.



1. Piston Spray Nozzle.
2. Bushing—Piston Pin—Connecting Rod.
3. Connecting Rod.
4. Bolts—Connecting Rod.
5. Bearing Shell (Upper).
6. Bearing Shell (Lower).
7. Bearing Cap—Connecting Rod.
8. Nut—Connecting Rod.
9. Cotter Pin.

Fig. 9—Piston and Connecting Rod Details and Relative Location of Parts.

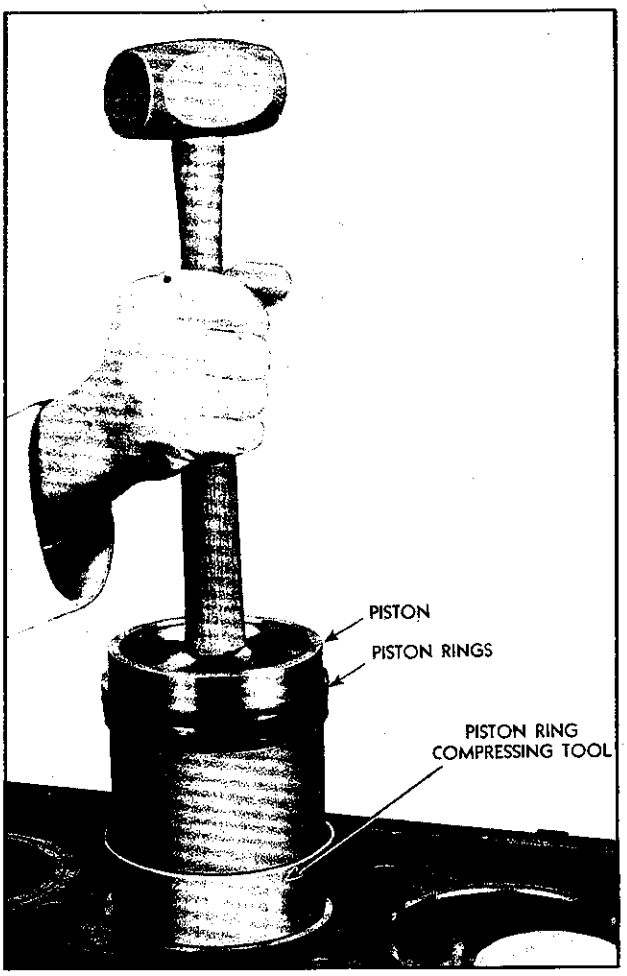


Fig. 10—Installing Piston in Cylinder Bore with Tool to Compress Piston Rings.

been moving in their supports and are unfit for further use. If any of these conditions exist, the shells must be changed. If crankshaft journals are badly scored, if checks appear, or if journals show signs of overheating so that heat treatment has been nullified, the crankshaft should be changed. (See "Crankshaft Inspection," Page 2, Sec. 5; also "Main Bearing Shell Inspection," Page 3, Sec. 4).

Assemble Connecting Rod to Piston—The connecting rod and piston parts having been inspected and necessary parts replaced, the former may be joined to the latter, as follows:

1. Install one piston hole cap and lock ring into either end of pin bore. (See Fig. 1.)
2. Place upper end of connecting rod between piston bosses in line with pin holes. Lubricate piston pin with clean engine oil, and slide into position.

NOTE: Pin should slip readily into position without forcing if fits are correct.

3. Install second piston pin hole cap, and lock ring, at exposed end of pin.

Install Piston and Connecting Rod Assembly Into Engine—The lower end of each connecting rod, as well as the caps, are stamped on one side—1, 2, 3, etc. These numbers identify the caps with the rods and show the particular cylinder with which each rod is used. These positions should always be maintained when rebuilding an engine; the marked side of the rod always faces the blower side of the cylinder block.

1. Stagger the piston ring gaps around the piston, apply some clean engine oil to piston and rings, then slide a piston ring compressor tool, KMO-231, over the lower end of the piston skirt, with flared end toward top of piston (see Fig. 10). Turn the piston and rod assembly so that the identification mark on lower end of the connecting rod is toward the blower side of the cylinder block.

   Align lower end of rod with crankshaft before pushing piston in cylinder. By tapping on upper end of piston with a wood block, drive the piston in the cylinder bore. Be sure the compressor tool is down tight on top of liner so rings cannot snap out before entering the liner bore.
2. Wipe clean and lubricate each connecting rod crankshaft journal. Install upper bearing shell with the one short groove at each parting line—in the connecting rod and position rod onto crankshaft journal. (See Fig. 9.)
3. Heeding the marks on the bearing caps, install lower bearing shell with the one continuous groove from parting-line-to-parting line—into bearing cap with tang of shell in groove of cap, and put cap and shell in place.
4. Lock cap securely in place with bearing cap bolts and nuts and install cotter pins.
5. Install lubricating oil pump assembly. (See Page 12, Sec. 12.)
6. Attach oil pan.
7. Attach cylinder head. (See Page 5, Sec. 9.)
8. After installing new pistons, rings, main bearings, or connecting rod bearings, the engine should be operated on a run-in schedule, as outlined in Page 15, Sec. 22.

GEAR TRAIN

Description—Located at the rear end of the engine is a completely enclosed train of five helical gears, as shown in Fig. 1. A gear bolted to the crankshaft flange drives the camshaft and balancer shaft gears, as well as the blower and accessory drive gear, through on idler gear mounted between the crankshaft and either the camshaft or balancer shaft gear.

The camshaft gear and balancer shaft gear mesh with each other and run at the same speed as the crankshaft. Either one of these gears may be driven from the crankshaft through an intermediate idler gear, the drive arrangement depending upon the crankshaft rotation.

The camshaft and balancer shaft gears are keyed to their respective shafts, each gear being held securely against a shoulder on the shaft by a nut. These gears do not change position for either direction of rotation. While the camshaft and balancer shaft may be placed on either side of the cylinder block, the right hand gear always remains on the right side, and the left hand gear on the left side. The balance weights used on the camshaft and balancer shaft gears are different for three, four, and six-cylinder engines. The necessary balance weights are an integral part of the gears on the three-cylinder engine, one additional weight is attached to each gear for the four-cylinder and two additional weights are attached to each gear for the six-cylinder engine.

The idler gear is fitted accurately with a bushing and rotates on a stationary hollow stub shaft, which is accurately located in the cylinder block end plate on either the right or left side of the engine, depending upon the direction of rotation. A dummy hub is used to cover the opening in the cylinder block end plate that is not used for the idler gear mounting.

The crankshaft gear and idler gear are different for right-hand and left-hand rotation.

Arranged on the blower side of engine is an auxiliary drive (blower drive gear) which transmits power to the blower, governor, water pump, and fuel pump. This drive is cushioned by a spring-loaded, flexible coupling, insuring uniform rotation of blower rotors.

Gear Train Lubrication—The gear train is lubricated by overflow of oil from camshaft and balancer shaft pockets, through communicating passages into the gear train cover. A certain amount of oil also spills into gear cover from bearings of camshaft, balancer shaft and idler gear.

Service—The service instructions on the gear train include crankshaft gear, idler gear, dummy hub, and blower drive gear assembly. The camshaft and balancer shaft gears are dealt with under "Camshaft," Page 1, Sec. 8.

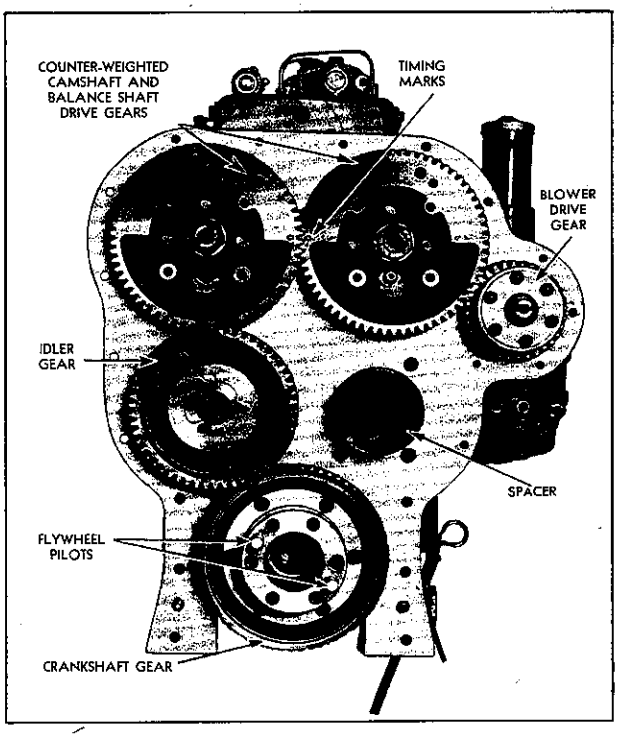


Fig. 1—Gear Train and Timing Marks—Right-Hand Rotation Shown.

Effective on engines serially numbered 371–3858, 471–5786, and 671–10193, the helix angle of all-gear train gears was reduced from 41° to 19°, resulting in a reduction of gear thrust loads. Use new design (19° helix angle) gears when complete replacement of gear train is necessary. However, for partial replacement, the old style (41° helix angle) gear may be used.

The gear train will be quiet if it has been properly set up and the gears and bearings are in good condition. The backlash between the various mating gears in the train ranges from .003" to .008" on a new engine.

If the gears or bearings have become worn, this lash will be increased and the gear train may become noisy. Furthermore, if the gear teeth become chipped or burred from careless handling, the gear train will be noisy.

When these unusual conditions exist in the gear train, the cover should be removed and careful inspection made of gears and bearings.

The entire gear train is exposed when the combination flywheel housing and gear train cover is removed from cylinder block rear end plate.

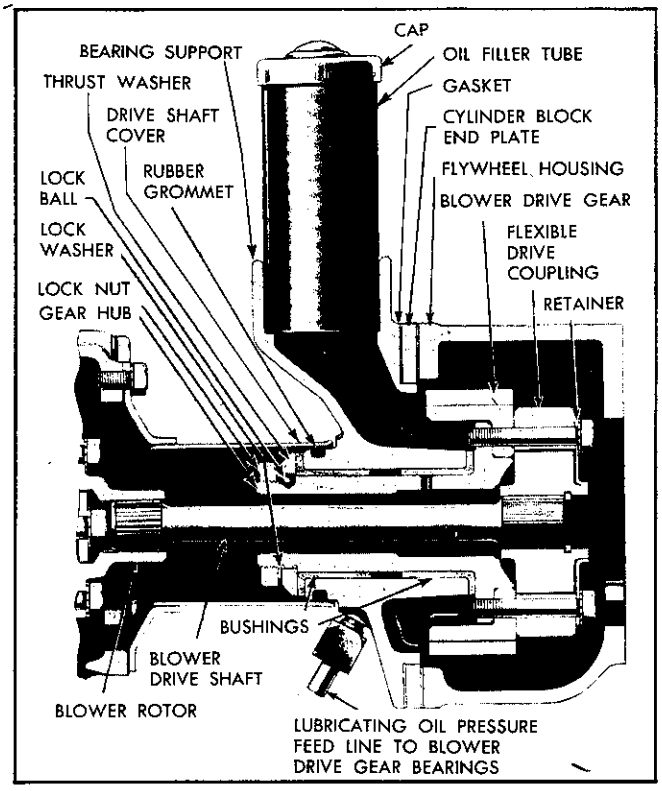


Fig. 2—Blower Drive Gear Assembly.

Remove the Combination Flywheel Housing and Gear Train Cover—Provision has been made at the camshaft timing gear, balancer shaft timing gear, and blower drive gear, for attaching a coupling for driving accessories. An accessory may be driven from any one or all of these points. If so, these accessories must be removed before removing flywheel housing and gear train assembly. Furthermore, a clutch and housing or a generator may be attached to the flywheel housing; if so, these parts must be removed before removing flywheel housing.

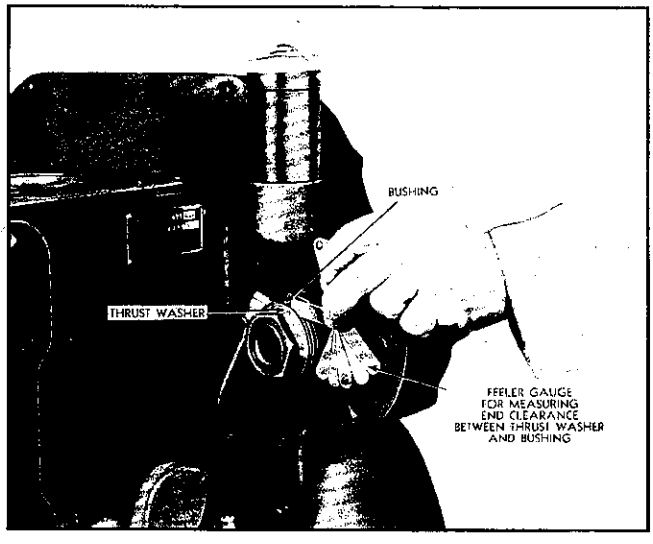


Fig. 3—Checking End Clearance of Blower Drive Gear Assembly.

All accessories and attaching parts having been detached, the flywheel housing and gear train cover may be removed as follows:

1. Remove lock wire and six cap screws holding flywheel to crankshaft flange and remove flywheel. (See "Flywheel," Page 3, Sec. 5.)
2. Remove two bolts holding engine lifting bracket to flywheel housing.
3. Remove oil pan.
4. Remove bolts which attach the flywheel housing and gear train cover to rear end of cylinder block, and remove housing.

The combination flywheel housing and gear train cover should not be replaced until after all parts beneath the cover have been inspected and installed.

With the combination flywheel housing and gear train cover removed, carefully examine the teeth of all the gears in the train for any evidence of chipping, burrs, or abnormal wear. Any one of these conditions will cause noisy gears.

Examine the leather crankshaft oil seal in the flywheel housing for wear or cracking and if necessary, replace with a new seal.

As will be seen from Figs. 1 and 2, the blower drive gear hub bearing support is bolted to the front face of the cylinder block rear end plate, and the gear hub is locked in position at front end of hub.

Furthermore, since the blower drive shaft cover slides over the inner end of the blower drive gear bearing support and also bolts to the blower end plate cover, the blower must be slid forward before the blower drive gear housing and hub assembly is removed from cylinder block end plate.

BLOWER DRIVE ASSEMBLY

Remove Blower Drive Gear Assembly—In view of the above described construction, the following procedure applies in removing and replacing blower drive gear assembly. After gear train cover has been removed:

1. Loosen blower from cylinder block and also from the various other attaching points, as described under "Remove Blower" on Page 4, Sec. 14.
2. Slide blower assembly forward, exposing lock nut on inner end of blower drive gear referred to in Fig. 2.
3. Before loosening lock nut on gear hub, a check should be made for end clearance between gear hub bushing and thrust washer. If end clearance is excessive, this condition alone is sufficient reason for renewing the support and inner babbitt bearing assembly.

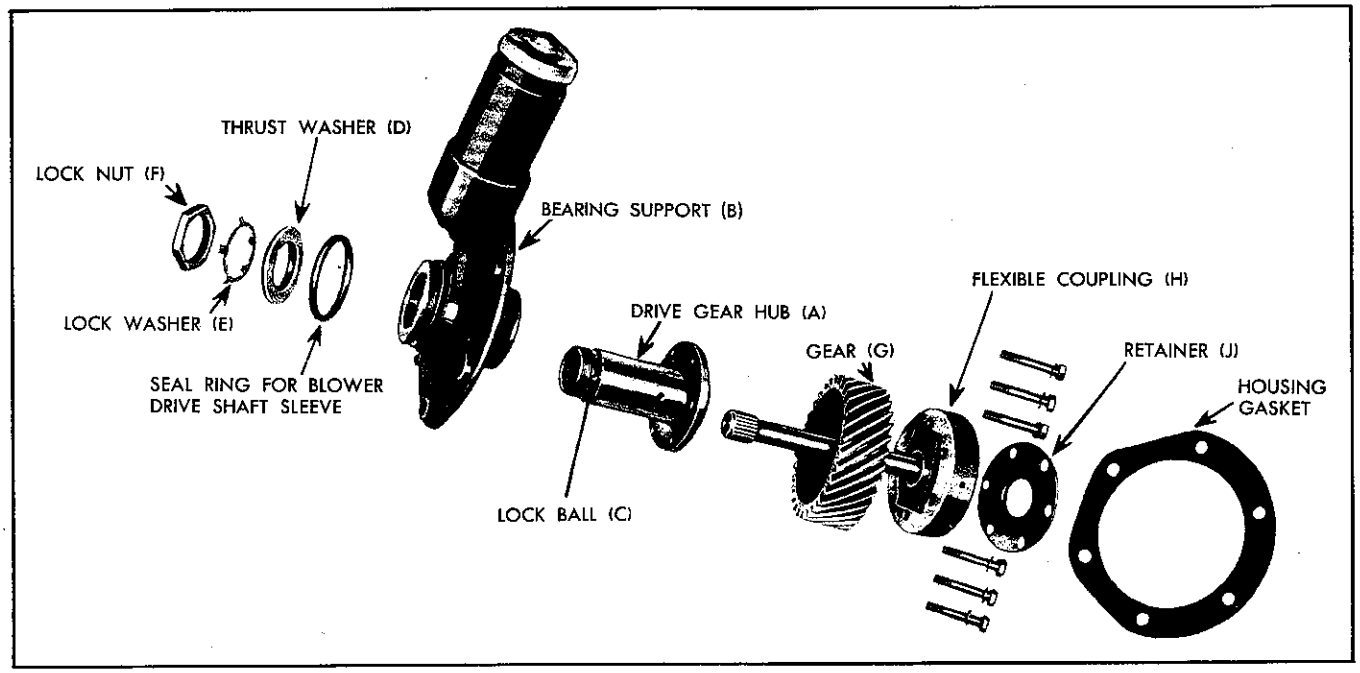


Fig. 4—Details of Blower Drive Gear Assembly and Relative Location of Parts.

The specified end clearance between gear hub and thrust shoulder of hub bushing is from .003″ to .006″ and should not exceed .010″.

4. If gear has not been removed from hub and still engages either the camshaft or balancer shaft gear, the ears on lockwasher may be straightened and lock nut loosened before support is completely loosened from cylinder block end plate, as shown in Fig. 2. If the gear was previously removed, loosening of the lock nut may follow removal of support, by holding the assembly in a bench vise.
5. Loosen nuts at each end of oil line leading from cylinder block to blower drive gear bearing. The oil line will be freed from the connectors when gear support is withdrawn.
6. Remove the two remaining cap screws holding gear bearing housing to cylinder block end plate, and tap the assembly forward away from the plate.

Disassemble Blower Drive Gear Unit—If blower drive gear assembly is to be disassembled for inspection or to change any parts, the following procedure applies:

1. Withdraw blower drive shaft through drive gear hub from rear.
2. Remove the six cap screws securing drive gear, drive coupling, and retainer from gear hub and remove drive coupling.
3. Press drive gear from gear hub.
4. Remove the previously loosened lock nut, lockwasher, lock ball, and thrust washer, from rear end of gear hub and withdraw hub from bearing support.
5. If occasion requires, the rubber grommet may be removed from front end of bearing support.
6. If bearing support is to be changed, remove oil line connection.

Inspection of Parts Included in the Blower Drive Gear Assembly—Before assembling blower drive parts into bearing support, all parts should be inspected for wear.

1. Inspect the inside diameter and thrust faces of bushings inside blower drive gear hub bearing support. If bushings show score marks that would affect bearing efficiency, a new support and bushing assembly must be installed. These bushings are diamond bored in place; therefore, in case of bushing failure, the support and bushing assembly must be replaced.
2. Check inside diameter of bushings for wear and roundness, also outside diameter of hub at bearing surfaces (journals) for wear. The proper clearance between bushings and hub journals is from .001″ to .002″ and must not exceed .005″. Should check show bushings or journals worn to exceed .005″ clearance, a new support and bushing assembly should be installed.
3. Inspect serrations on blower drive shaft and if worn so that appreciable back lash is felt when

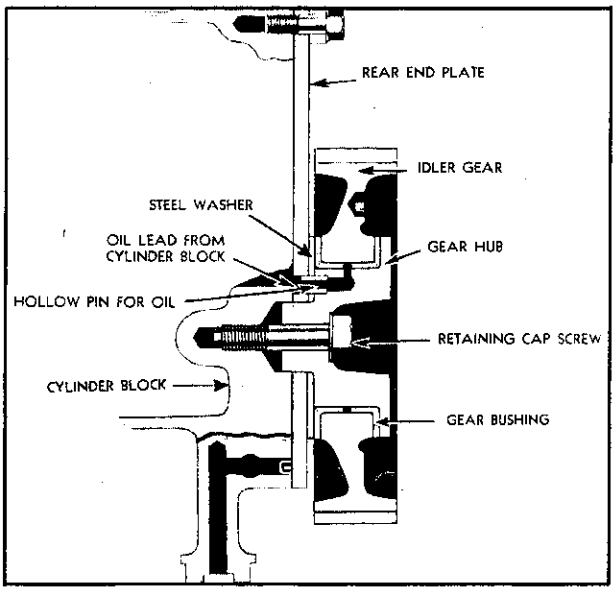


Fig. 5—Idler Gear Mounting.

shaft is inserted into flexible coupling or blower timing gear drive flange, a new shaft should be used.

4. Inspect driving springs and cams of flexible couplings to see that springs are intact and cams not worn.
5. See that all oil holes are open and cavities free from dirt.
6. Install a new rubber grommet around front end of bearing support over which blower drive shaft cover fits.

Assemble Blower Drive—The relative position of all parts constituting the blower drive gear assembly is shown in Fig. 4. All parts having been cleaned and inspected, they may be assembled as follows:

1. Spread some engine oil on outside diameter of drive gear hub "A" and slide hub into bearing support "B" from rear.
2. Install locking ball "C" into gear hub and slide thrust washer "D" in place over ball, with large diameter flat face of washer next to thrust face of bushing.
3. Prevent hub from turning by inserting bolts in two holes in hub and holding with a bar. Install a new lockwasher "E" next to thrust washer and tighten lock nut "F." Bend the ears of lockwasher against flats on nut to prevent nut from loosening.
4. Tap gear "G" into place on hub with flat finished face of gear away from bearing support.
5. The outer end of flexible drive coupling "H" is counterbored for about ¼" on the inside diameter of the hub. With this counterbore away from face of gear, place the retainer "J" against outer face of coupling, with flange at center of shield pointing away from coupling, and lock in place with lockwashers and cap screws.
6. Install shaft locating ring either on shaft or inside coupling "H" and slide shaft into serrations of drive coupling.
7. Apply some engine oil at each thrust shoulder of bushing and again check end clearance, as shown in Fig. 3.

Attach Blower Drive Gear Assembly to Cylinder Block Rear End Plate—The blower drive gear assembly may be attached to front face of cylinder block rear end plate by sliding gear and hub through the hole in end plate with finished face of support up against end plate, and a new paper gasket between end plate and support. Then put oil line from gear bearing to cylinder block into its two connections.

Replace the two cap screws next to engine. The other four through bolts will be put in place when flywheel housing is installed. The two cap screws specified for this position must be used. If the cap screws are too long and project inside gear housing they may interfere with the gears.

The blower may be installed at this time without interfering with any other work to be performed on the gear train. (See "Replace Blower." Page 14, Sec. 14.) Before attempting to install the flywheel housing and gear train cover, the operator should be thoroughly familiar with the following service instructions pertaining to the balance of gear train.

IDLER GEAR ASSEMBLY

Description—The idler gear is mounted on a hardened steel stationary hub on either the right or left side of the engine depending upon either clockwise or counter-clockwise crankshaft rotation, respectively. (See "Model, Serial and Unit Designations," Page 11, Sec. 1.)

The stationary mounting hub is prevented from rotating by a hollow pin, one end of which is driven into the hub; the other end enters the cylinder block and connects with one of the vertical oil passages. (See Fig. 5.)

The gear is bushed with a two-piece combination radial and thrust, steel-backed copper-lead bearing pressed and doweled into the hub from each end. Outer gear thrust is taken between the shoulders of the gear bearing and hardened hub, and inner thrust between the shouldered gear bushing and a stationary hardened-steel washer.

The idler gear bearing is pressure lubricated through the hollow pin leading from the oil passage in the cylinder block, through the hollow stationary gear

CAMSHAFT AND BALANCER SHAFT

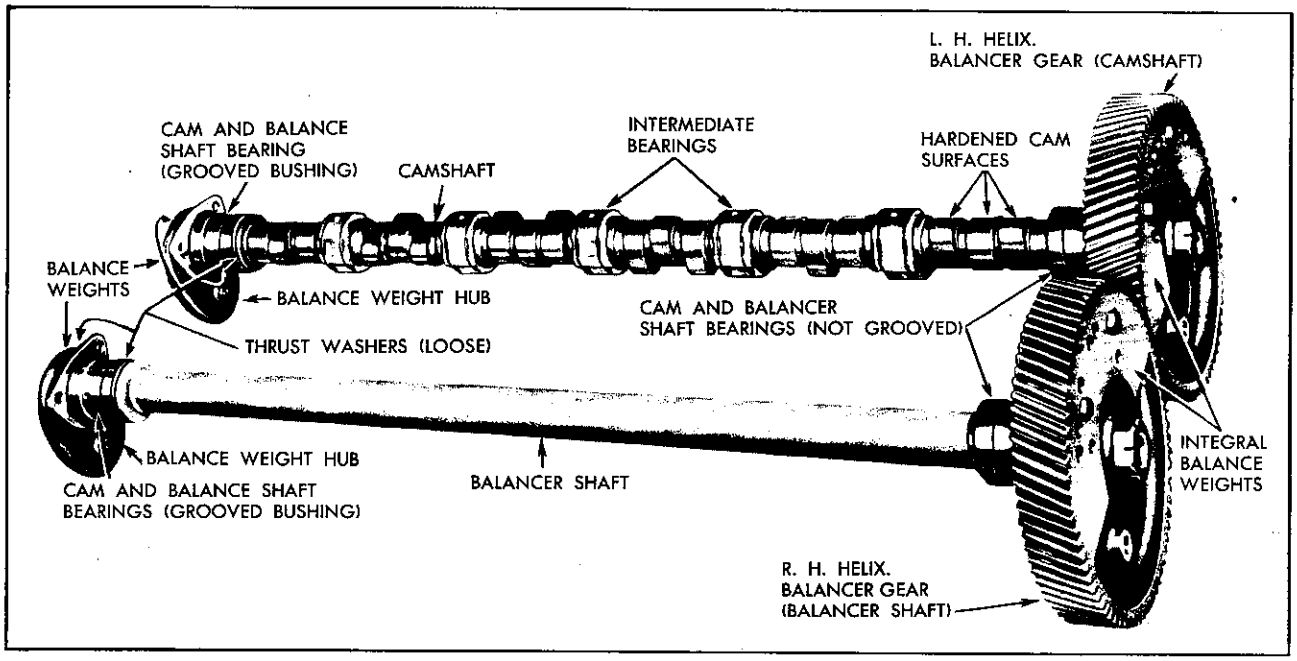


Fig. 1—Cam and Balancer Shaft Assemblies.

Description—The camshaft is a one-piece drop-forging, case-hardened at cams and journal and is located near the top of the cylinder block. A bearing assembly with copper-lead, steel-backed bushings at each end, and intermediate bearings between each set of cams, provide rigid support. ***On the thrust ends of the shafts, the bearing bushings are grooved, while those on the non-thrust ends are not grooved.*** Beginning on engines serially numbered 3714702, 4716608, and 67116791 steel-backed bronze loose thrust washers were added. The new bearings differ from the former bearings in that the bushings project slightly to provide support for the loose thrust washers.

As will be seen from Figs. 1 and 5, the intermediate bearings are two-piece and held together by lock rings, each bearing assembly being located and locked in the cylinder block by a shouldered set-screw sunk into a counterbore at the top of the block.

The cams are ground with parallel surfaces to insure efficient, quiet roller action. Heat-treatment provides hard, wear-resistant cam lobes.

A balancer shaft, running parallel to the camshaft and at the same distance from the crankshaft, is located on the opposite side of the cylinder block. The balancer shaft is supported in the same manner as the camshaft, except no intermediate bearings are used. The end bearings, together with loose thrust washers at the thrust end, are identical with those used on the camshaft.

The function of the balancer shaft, as its name implies, is to counterbalance the rotation of the weighted camshaft and thus effect a stabilizing action upon oscillatory impulses set up within the engine. Eccentrically positioned weights, at the front and rear ends of both shafts, are so designed as to dampen out these forces.

In addition to the counterweighted gears at the rear end, balance weights are used at the front end of both the camshaft and balancer shaft, as shown in Figs. 1 and 5. The front end balance weights are different for the three, four and six cylinder engines

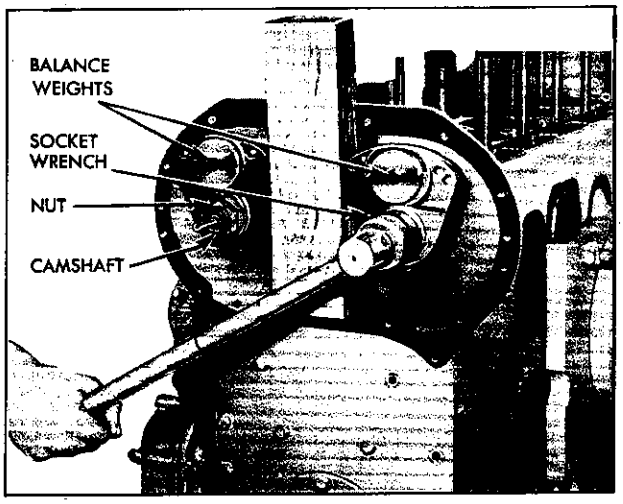


Fig. 2—Loosening Nuts (Camshaft—Balancer Shaft) with Standard 1½" Socket Wrench.

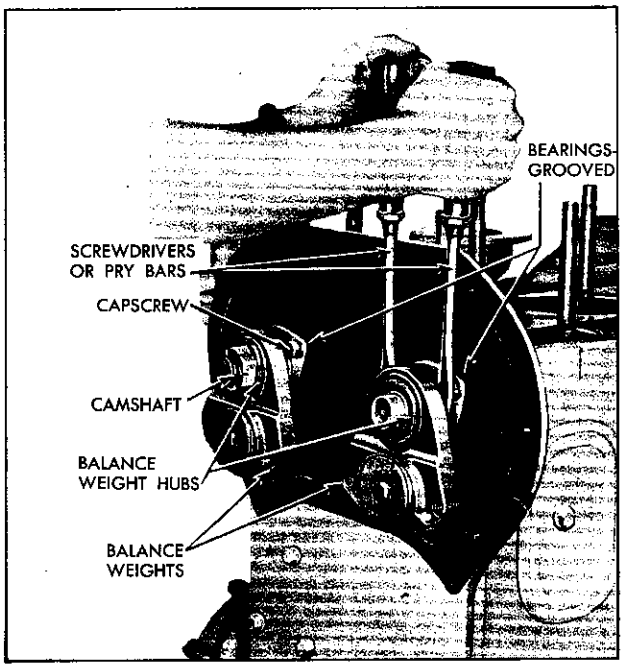
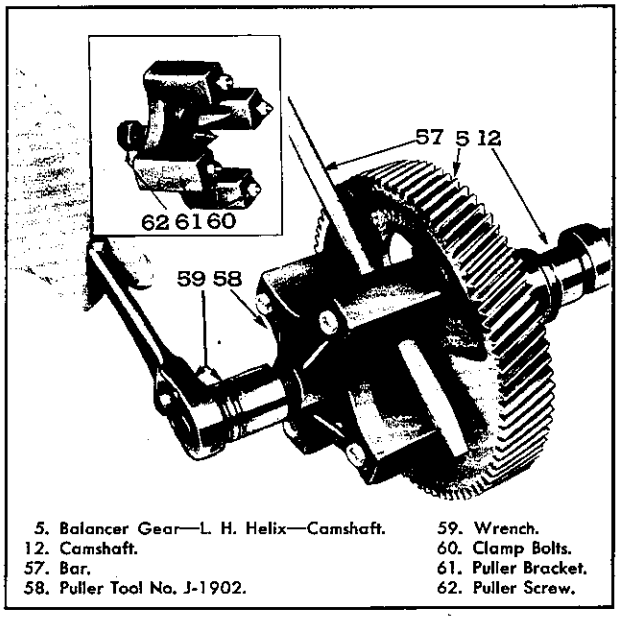


Fig. 3—Removing Balance Weight Assemblies.

in that the weights are lightest for the three cylinder, somewhat heavier for the six cylinder, and still heavier for the four cylinder. The balancing members used on the six cylinder engines are known as balance-weight-and-hub assemblies. The hub of each assembly is securely fastened to the front ends of both camshaft and balancer shaft by means of a Woodruff key and a self-locking nut. All engines except the six cylinder models are equipped with one piece non-adjustable balance weights. They are attached to the cam and balancer shafts in the same manner as the six cylinder weights shown in the illustrations. The six cylinder weight incorporates a bushing, bearing on the hardened surface of the hub, which permits the weight to oscillate (rock) on the hub. Torque variations, developed in the shafts during speed or load changes, are transmitted from the hubs to the weights through the spacers and spring leaves. The bolt, retainer, and nut maintain the correct relation between the weights and hubs.



5. Balancer Gear—L. H. Helix—Camshaft.
12. Camshaft.
57. Bar.
58. Puller Tool No. J-1902.
59. Wrench.
60. Clamp Bolts.
61. Puller Bracket.
62. Puller Screw.

Fig. 4—Removing Camshaft and Balancer Shaft Gears with Tool J-1902.

Lubrication—Ample lubrication is supplied to the camshaft and balancer shaft end bearings from four vertical oil passages in the cylinder block which communicate with the main oil gallery. The camshaft intermediate bearings are lubricated by oil from the hollow camshaft.

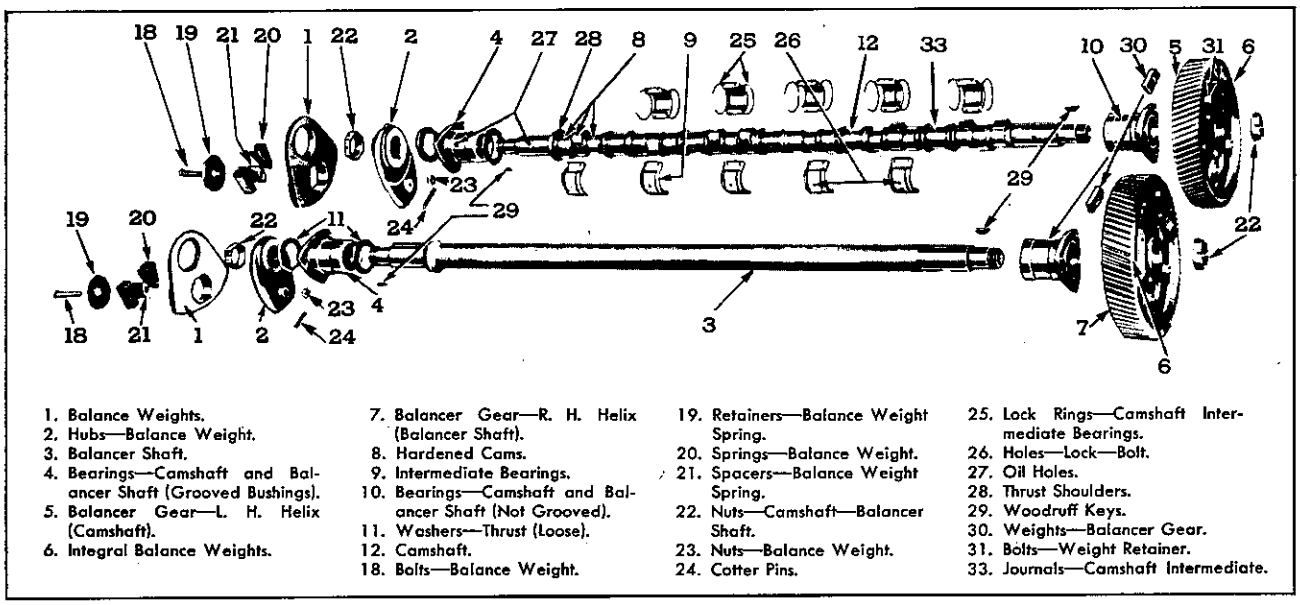
Service—If service on the camshaft gear or balancer shaft gear necessitates removal of gears from the shafts, the work can best be performed by first removing shafts from engine.

Remove Camshaft and Balancer Shaft.

1. Remove cylinder head. See Page 2, Sec. 9.
2. Remove flywheel housing.
3. Remove fifteen capscrews holding balance weight cover to cylinder block and front end plate. Loosen cover from gasketed surface and remove.
4. Wedge a block of wood between balance weights to prevent rotation, then loosen nuts at both ends of shafts with 1½" socket wrench, as shown in Fig. 2.
5. Remove balance weight assemblies by using two heavy screwdrivers, or pry bars, between heads of bearing retainer bolts and balance weight hubs, as shown in Fig. 3. Remove Woodruff keys.
6. Remove the special fillister-head screws from top of cylinder block at each camshaft intermediate bearing.
7. Remove three capscrews from rear end of both camshaft and balancer shaft bearing cages by means of a socket wrench inserted through hole in the web of timing gears.
8. Remove the loose washers, located between the bearing and the balance weight hubs, then withdraw the balancer shaft and camshaft (with balancer gears and bearings assembled) from rear end of cylinder block.

NOTE: If the loose washers, located between the bearings and the thrust shoulders on the shafts, are not removed together with the shafts, they should be removed when removing the bearings as outlined in item 9 below.

9. Remove the three capscrews at the front end of the engine holding each balancer shaft and camshaft bearing to the end plate and remove bear-



1. Balance Weights.
2. Hubs—Balance Weight.
3. Balancer Shaft.
4. Bearings—Camshaft and Balancer Shaft (Grooved Bushings).
5. Balancer Gear—L. H. Helix (Camshaft).
6. Integral Balance Weights.
7. Balancer Gear—R. H. Helix (Balancer Shaft).
8. Hardened Cams.
9. Intermediate Bearings.
10. Bearings—Camshaft and Balancer Shaft (Not Grooved).
11. Washers—Thrust (Loose).
12. Camshaft.
18. Bolts—Balance Weight.
19. Retainers—Balance Weight Spring.
20. Springs—Balance Weight.
21. Spacers—Balance Weight Spring.
22. Nuts—Camshaft—Balancer Shaft.
23. Nuts—Balance Weight.
24. Cotter Pins.
25. Lock Rings—Camshaft Intermediate Bearings.
26. Holes—Lock—Bolt.
27. Oil Holes.
28. Thrust Shoulders.
29. Woodruff Keys.
30. Weights—Balancer Gear.
31. Bolts—Weight Retainer.
33. Journals—Camshaft Intermediate.

Fig. 5—Camshaft and Balancer Shaft Details—Six Cylinder Engines—"B" and "C" Models.

ings and loose washers from cylinder block. See note in item 8 above relative to removal of loose thrust washers with bearings.

Remove Part From Camshaft and Balancer Shaft, as follows:

1. Suitably support camshaft in soft jaws of bench vise, ***being careful not to damage cams,*** and pull gear from shaft, using puller tool J-1902, as shown in Fig. 4. To use the tool:
   (a) Back out puller screw in fixture and attach puller to outer face of gear with the four bolts provided.
   (b) Turn puller screw down against end of shaft and remove gear.
2. After gears are removed, bearings may be withdrawn from shafts.
3. Remove lock rings from camshaft intermediate bearings, also, remove the two halves of each bearing.

Disassemble Balance Weight-and-Hub Assemblies. (See Fig. 6.)

1. Remove cotter pin from nut and remove nut.
2. Remove bolt and retainer.
3. Separate balance weight from hub.
4. Push springs and spacer from balance weight.
5. If bushing is badly worn, press bushing from weight.

Inspection of Camshaft and Balancer Shaft Parts—All parts having been cleaned with gasoline or fuel oil and dried by air, inspect all bearings and journals for good bearing surfaces and wear before replacing the parts.

Examine both faces of the cam and balancer shaft bearing thrust washers and if either face is scored, replace the washers. If both faces are smooth, the washers are satisfactory for further use. Also, examine surfaces against which thrust washers contact and if these surfaces are scratched, but not severely scored, they may be smoothed up with an oil stone. However, score marks too deep to be removed, or parts badly worn, necessitate the use of new parts.

Should the thrust surface (side facing loose thrust washer) of the balance weight hub be damaged, it will be necessary to install an entire new balance weight-and-hub assembly. The close limits of balance maintained in this assembly necessitate the use of mated parts measured and machined as an assembled unit.

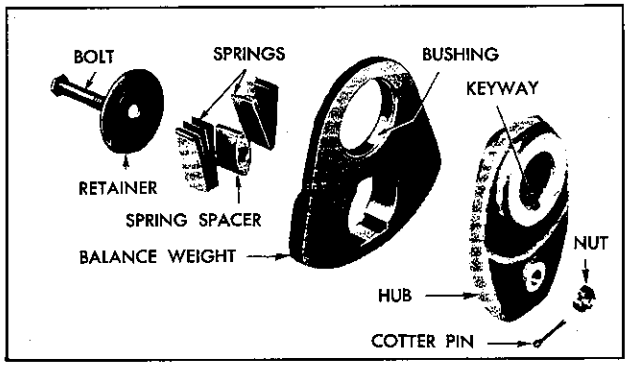


Fig. 6—Details of Front Balance Weight Assemblies for Six Cylinder Engines.

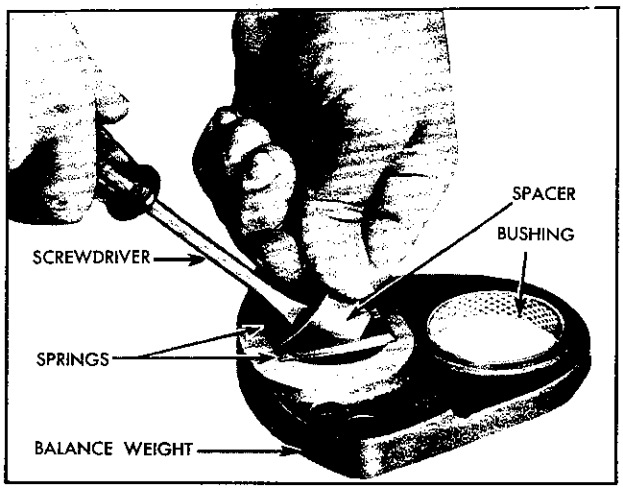


Fig. 7—Installing Spring Spacer in Spring Packs—Six Cylinder.

Radial clearance on camshaft and balancer shaft bearings is from .0015″ to .003″ and should not exceed .006″. End clearance of the loose washer should not be more than .015″ or less than .008″.

Camshaft intermediate bearings have a radial clearance of from .0025″ to .005″. Clearance should not exceed .006″.

Radial clearance between balance weight bushing and balance weight hub is from .001″ to .0035″ and should not exceed .006″. End clearance between weight and hub should be from .010″ to .016″.

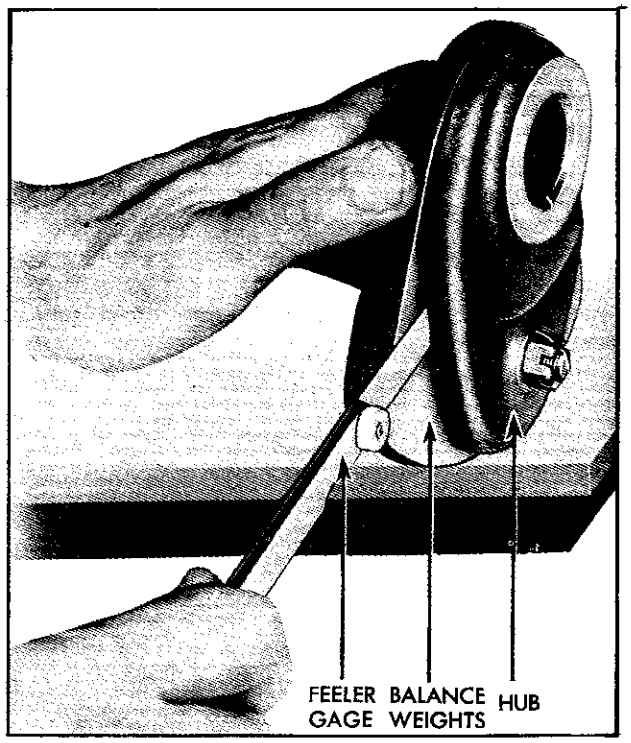


Fig. 8—Measuring Clearance Between Balance Weight and Hub—Six Cylinder.

Should any of the bearings show scoring or be worn so clearances exceed limits given above, install new bearings. Examine cam surfaces for wear or scoring. A shaft with scored cams should not be used.

Oil is fed through the hollow camshaft to its intermediate bearings; therefore, all oil holes should be examined in both the shaft and bearings. Sludge accumulations, which might restrict the oil flow, should be removed.

Assemble Balance Weight and Hub.

1. If old bushing was removed from balance weight, press new split bushing into place, edge of bushing flush with shoulder on drilled (balancing holes) side of weight.
2. Select sufficient springs (17 or 18 per pack) to make four packs, each .253″ to .255″ thick. Springs are available in two thicknesses: .0135″ to .0145″; .015″ to .016″. Pack thickness to be determined while springs are tightly clamped together in vise or arbor press.

CAUTION: Wash springs clean, and dry with compressed air before making above measurements.

3. Place weight, machined face down, flat on clean work bench.
4. Dip spring pack into lubricating oil, completely coating all springs.
5. Arrange the two spring packs, one on each side of spring cavity, in balance weight.
6. Place spacer on blade of screwdriver. Enter spring spacer, tapered end first, between spring packs. As spacer becomes fully enclosed, tilt spacer into upright position, bolt hole up. Press spacer into place against work bench. (See Fig. 7.)
7. Place journal of hub into bushing of balance weight. Weight should swing freely on hub. Burnish bushing if required clearance (.001″ to .0035″) is not present.
8. Place retainer on spring spacer and insert bolt through retainer, spacer, and hub. Fasten with castellated nut.
9. Check clearance between weight and hub, as shown in Fig. 8. Clearance should be from .010″ to .016″. Adjust clearance by tightening or loosening castellated nut. Lock in position with cotter pin.

Install Parts on Camshaft and Balancer Shaft—The camshaft and balancer shaft bearings at the gear end of the shafts, and the timing gears should be installed on the shafts before the shafts are assembled into the cylinder block.

hub, and into a reservoir between the inner ends of the two-piece gear bushing.

Service—Since the idler gear annular and thrust bearings are of ample size and pressure lubricated, necessity for service on the assembly should be very infrequent if engine has not been neglected.

If any of the idler gear parts need inspection or replacement, the assembly may be removed and replaced as follows:

Remove Idler Gear Assembly and Spacer—(Flywheel Housing Removed.)

1. Remove the cap screw and lockwasher from center of idler gear hub and withdraw hub, and gear assembly, from cylinder block rear end plate.
2. If there is any call for doing so, the spacer (dummy hub) may also be removed at this time by removing the one center retaining cap screw and lockwasher.

Inspection of Idler Gear and Hub Assembly Parts—Before the parts of idler gear assembly are put back in position, each part should be washed in clean kerosene, inspected for wear and, if necessary, worn parts replaced.

1. Inspect the journal on gear hub for scoring and also check diameter. Check inside diameter of gear bearing also, for scoring. The clearance between bearing in the gear and the journal should be from .002″ to .0035″ and should not exceed .006″.

   If the clearance exceeds .006″, either the gear and bearing assembly or the gear hub or both should be changed, depending on which part or parts are worn.
2. Examine the face of the steel washer, the wearing face of the gear hub and both thrust faces and inside diameter of the gear bushings for scoring and wear. If necessary, replace worn parts. The end play of the idler gear assembly is from .003″ to .006″ and should not exceed .008″.

NOTE: The idler gear bushings are not removable, therefore in case of bushing failure the idler gear assembly must be replaced.

Install Idler Gear and Spacer—Before installing idler gear, refer to Fig. 6, which shows relative position of each part.

1. Having determined the relative positions of all parts, apply a small amount of cup grease to one face of the steel washer and set against cylinder block end plate, with hole in steel washer in line with oil hole. Grease is used on steel washer to hold it in place until hub and gear is installed.
2. Position crankshaft gear (See Fig. 1), and either balancer shaft gear or camshaft gear so marks

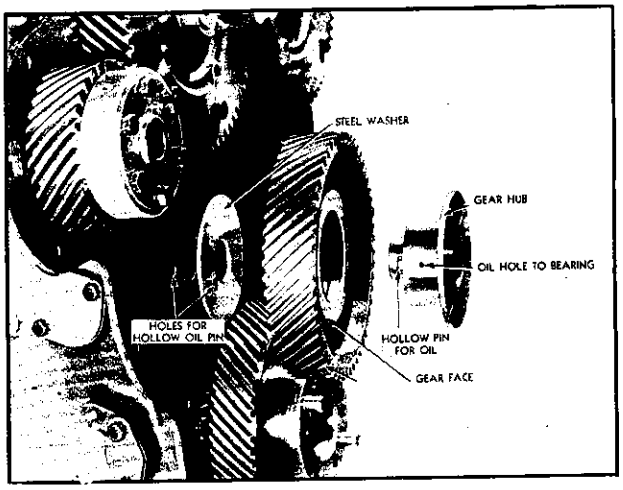


Fig. 6—Idler Gear Mounting Details.

align with those on idler gear, and roll idler gear into position, then slide gear hub into place through bore in gear. ***Special care must be taken to have hollow pin in inner face of gear hub register in hole in end plate which carries oil to idler gear bearing.***

5. Be sure gear hub is tight against end plate and then lock in place with lockwasher and cap screw in center of gear hub.
6. Attach dummy hub (spacer) on side of engine opposite to idler gear.
7. Check backlash between the various mating gears in the train, which should show from .003″ to .008″ between each set of gears.

Remove Crankshaft Timing Gear (Flywheel Housing Removed)—The crankshaft timing gear is attached to crankshaft flange with six cap screws. To remove gear, with flywheel housing removed, remove the six cap screws and slide gear from crankshaft flange. Bolts may be used in the puller holes provided in the gear web.

Replace Crankshaft Timing Gear—To replace crankshaft timing gear:

Slide the timing gear onto the crankshaft, with the flat finished face of the gear toward the cylinder block. Position the gear teeth so timing mark "R" or "L" on gear teeth aligns with the corresponding mark on the idler gear (See Fig. 1), and slide gear up against flange on crankshaft. Due to one offset hole in crankshaft flange, the timing gear can be located in only one position on flange. Turn either the crankshaft or gear train so bolt holes in web of gear align with the six holes in crankshaft flange and install lockwashers and cap screw, drawing gear into place.

Before reinstalling flywheel housing (see Page 2, Sec. 5), liberally lubricate the entire gear train with clean engine oil.

On engine models RA, RD, LA and LD, the camshaft and balancer shaft thrust is taken at the rear of the engine. On Models RB, RC, LB and LC, the thrust is taken at the front of the engine.

The ***thrust*** bearings may be identified from the ***non*** thrust by the oil grooves in the bushings of the former and ***no*** oil grooves in the latter. The thrust washers must be temporarily attached to the ends of the thrust-absorbing bearings before the latter are installed either on the shafts or in the engine. Apply cup grease to steel side of washers and adjoin this face to ends of bearings.

Note that the teeth of one timing gear form a ***right-hand*** and on the other a ***left-hand*** helix. When viewing engine from rear, the gear with right-hand helical teeth is located on left side of engine and carries a timing mark "R". The "L" marked gear has left-hand helical teeth and is located on right side of engine.

The camshaft gears are the same and the balance shaft gears are the same for all engines; but weights are attached to these gears on the four and six-cylinder engines for balancing purposes. No weights are attached to the gears on the three-cylinder engine. Camshaft and balancer shaft gears from a three-cylinder engine, therefore, may be used on either the four or six-cylinder engine, if the necessary specified weights are attached to the gears; by the same token, the gears from either a four or six-cylinder engine may be used on a three-cylinder engine, if the weights are removed from the gears.

1. Select the correct bearing assembly to be used on the gear end of the shafts, lubricate the journals, and place the bearings on shaft journals, with bolting flange of bearing towards outer (gear) end of shafts, as shown in Fig. 5.
2. Install Woodruff keys for balancer gears in both shafts.
3. Rest non-gear end of shaft on wood block and start gear onto shaft by hand so keyway aligns with key and with flat finished face of gear away from bearing. (See Fig. 9.)
4. Using Tool J-1903 in the manner illustrated in Fig. 9, drive gear onto shaft tight against shoulder on shaft. Drive the gear on the balancer shaft, in the same manner.
5. Start nuts on shaft by hand and tighten later after shafts are installed.
6. Install the intermediate bearings on the camshaft and lock the two halves together with two lock rings on each bearing.

Install Balancer Shaft in Cylinder Block (Balancer Gear and Rear Bearing Assembled to Shaft).

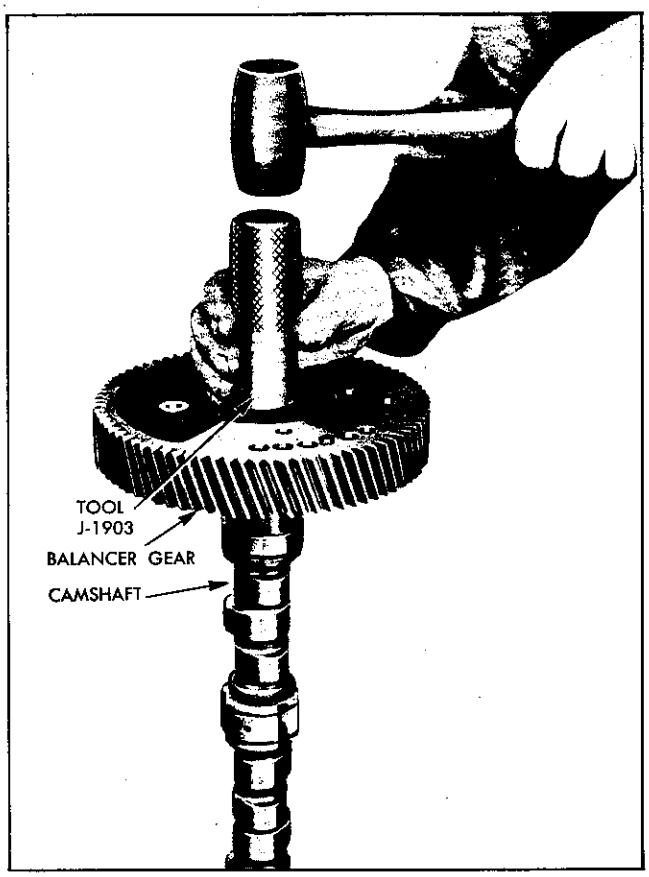


Fig. 9—Replacing Balancer Gears (Camshaft or Balancer Shaft) with Tool J-1903.

1. Install bearings for front end of camshaft and balancer shaft in cylinder block front end plate and secure in place with lockwashers and cap-screws. ***Be careful not to dislodge loose washers on ends of bearings when installing.***
2. Start balancer shaft, including rear bearing and gear assembly, into position at rear end of block. On models having thrust bearing at front, be careful that thrust washer on inner end of front bearing is in position. Continue to push shaft into position to the point where the gear teeth are about to engage.
3. Correctly position crankshaft, idler, and balancer gears so the timing marks ("R" or "L") are adjacent as shown in Fig. 1, Sec. 7; then slide balancer shaft gear into mesh.

   The timing marks "O" on the camshaft and balancer shaft gears must face each other. Looking at engine from rear, the gear on left side of block, which may be either the camshaft gear or balancer shaft gear, always carries the letter "R." The gear on the right side of block always carries the letter "L." The crankshaft gear and the idler gear, which are different for right-hand and left-hand rotation engines, carry the mark-

ing "R" for right-hand rotation and the marking "L" for left-hand rotation. The idler gear has this marking in two places for matching the corresponding markings on the crankshaft gear and either the camshaft gear or balancer shaft gear. If engine is right-hand rotation (viewing engine from rear), the idler gear is located on the left side of cylinder block, and the marking "R" which appears on crankshaft gear must face one of the "R" marks on the idler gear. The other "R" mark on idler gear must face the "R" mark on either the camshaft gear or balancer shaft gear, whichever one of these two gears meshes with the idler gear. If engine is left-hand rotation, the idler gear is located on right side of cylinder block, and the markings "L" on crankshaft gear, idler gear, and either camshaft gear or balancer shaft gear, must face each other. (See Fig. 1, Sec. 7.)

4. Secure balancer shaft rear bearing to engine block end plate with three lockwashers and capscrews. They are accessible through the web of balancer gear.

5. **Install Camshaft in Cylinder Block** (Balancer Gear and Rear Bearing Assembled to Shaft)—After the balancer shaft is assembled in the cylinder block, the camshaft may be assembled as follows:

   (a) Start camshaft and gear assembly into camshaft bore in cylinder block, being careful not to damage cams when installing shaft. When teeth of camshaft gear are about to engage balancer shaft gear, revolve gears, if necessary, so the "O" marks on gears, as shown in Fig. 1, Sec. 7, will match. Slide gears into mesh. ***Be careful not to dislodge loose washer on front end of shaft when installing.***

   (b) Secure camshaft rear bearing to engine block end plate with three lockwashers and capscrews. They are accessible through the web of balancer gear.

   (c) Revolve the camshaft intermediate bearing assembly so locking holes in bearings align with holes in top of cylinder block, and sesure lockscrews in place.

6. **Attach Balance Weights to Camshaft and Balancer Shaft.**

   (a) Install Woodruff keys in keyways at front end of camshaft and balancer shaft.

   (b) Align keyway in hub with key in shaft and place the balance weight-and-hub assembly on the camshaft, with weight and spring retainer facing away from engine.

   On the three and four cylinder engines the balance weight is placed on the end of the shaft, with the overhanging section of the weight facing away from the engine block.

   (c) Similarly place balance weight-and-hub assembly on balancer shaft. Start nuts on both shafts.

   (d) Wedge a block of wood between balance weights, as shown in Fig. 2 and tighten the self-locking nuts, using a 1½" socket wrench.

CAUTION: When tightening retaining nuts for balancer weights and gears, DOUBLE CHECK and MAKE SURE the loose thrust washers are in their proper position over the extended bronze bushings.

   (e) Wedge a clean cloth between the balancer gears, at the rear of the engine, and tighten the self-locking nuts with the same wrench used above.

7. **Replace Flywheel Housing**—The entire gear train having been installed, the flywheel housing may be put in place as outlined on Page 2, Sec. 5.

8. **Replace Balance Weight Cover** (Cylinder Head Removed). The balance weight cover may be replaced by reversing the sequence of operations for removal, as outlined below:

   (a) Remove any traces of the old gasket and affix new gasket on cover-to-front end plate bolting flange.

   (b) Set cover into place and secure with fifteen bolts and lockwashers. Leave top bolts loose to prevent interference when installing cylinder head.

ENGINE TIMING, ENGINE BALANCE

Engine Timing—When the engine is properly timed, the marked teeth on the timing gears will be matched together as shown in Fig. 1, Sec. 7.

The timing diagrams, Figures 10, 11, and 12, show the cycle in which the opening and closing of the air intake ports and exhaust valves takes place, also the period of fuel injection for the different injector models. See Page 3, Sec. 15, for injector model designations.

Firing orders for Series 71 Engines are as follows:

R.H. rotation ("R" in model number)—1-5-3-6-2-4.

L.H. rotation ("L" in model number)—1-4-2-6-3-5.

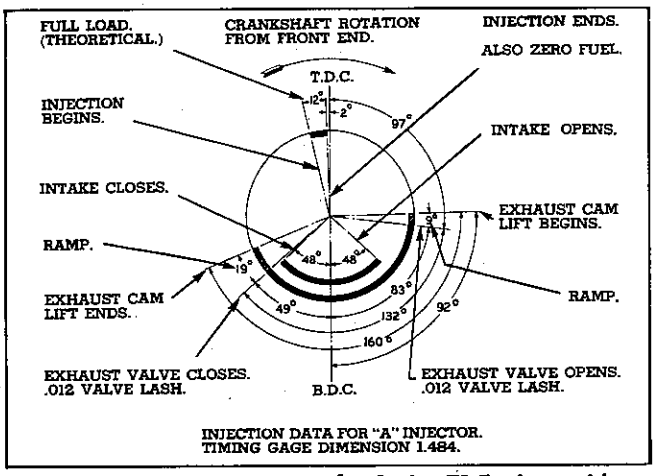


Fig. 10—Timing Diagram for Series 71 Engines with 60 mm. Injectors.

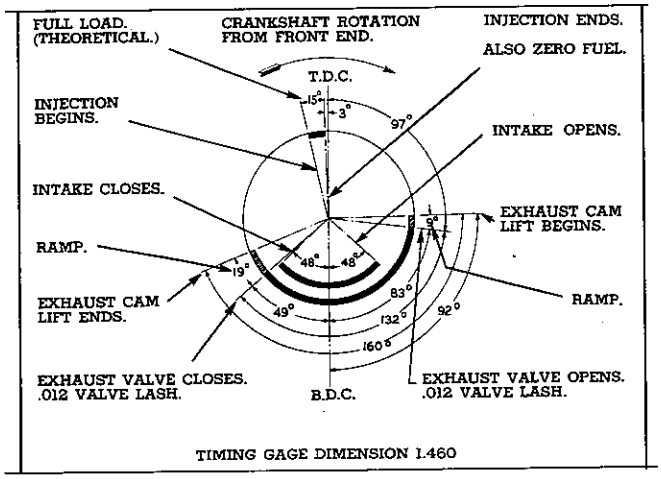


Fig. 11—Timing Diagram for Series 71 Engines with 70 mm. Injectors.

Engine Balance—Both rotating and reciprocating forces are completely balanced in 71 series engines. The eccentric rotating masses of the crankshaft and connecting rod are balanced by counter-weights on the crankshaft cheeks. The reciprocating masses (the piston and part of the rod) produce an unbalanced couple by virtue of an arrangement on the crankshaft in which reciprocating masses, though equal, are not opposite. This unbalanced couple, which tends to rock the engine from end to end, is balanced by an arrangement of rotating counterweights, which produce a couple equal and opposite in magnitude. Consequently, the engine will operate smoothly and in perfect balance throughout the entire speed range. The balance weights consist of two eccentric weights at each end of the engine, as shown in Fig. 1. Each set of weights rotate in opposite directions with respect to each other. When the two weights at either end of the engine are in a vertical plane, their centrifugal forces are in the same direction, and oppose the unbalanced couple. When in a horizontal plane, the centrifugal forces of these balance weights are opposite, and therefore cancelled. The front balance weights are eccentric in a direction opposite to the rear balance weights; therefore rotation will result in the desired couple, effective only in a vertical plane. The balance weights at the rear end of the engine are integral with the camshaft and balancer shaft drive gears. The weights at the front end consist of eccentric slugs. On six cylinder engines only, these weights are flexibly mounted, and spring loaded to serve also as torsional vibration dampers. The weights in the camshaft and balancer shaft gears are an integral part of these gears for the three cylinder engines; one crescent-shaped weight is bolted to each gear for the four cylinder engine, and two small, square weights are attached to each gear for the six cylinder engine.

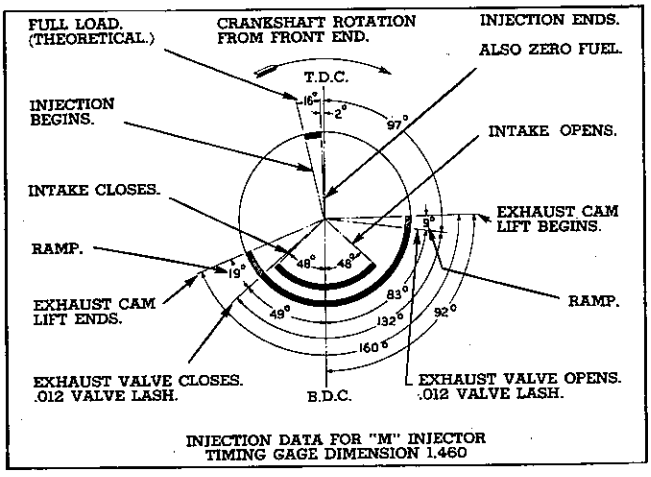


Fig. 12—Timing Diagram for Series 71 Engines with 80 mm. Injectors.

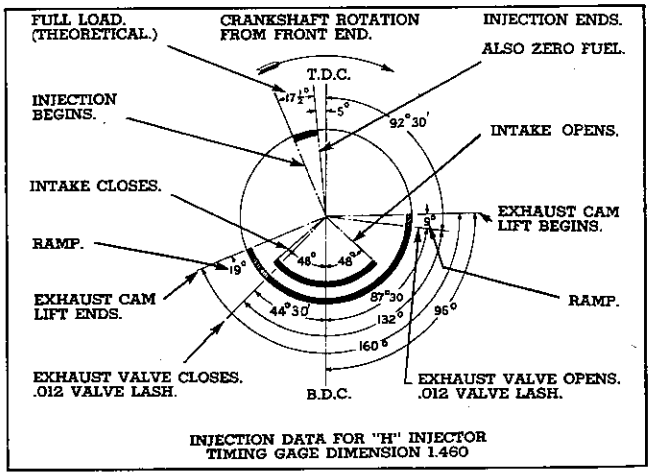


Fig. 13—Timing Diagram for Series 71 Engines with 90 mm. Injectors.

CYLINDER HEAD AND GASKETS

Description—The cylinder head is a one-piece alloy iron casting which can be removed from the engine as an assembly containing cam followers, guides, rocker arms, and valves. The head is securely held to upper deck of cylinder block by heat-treated alloy steel studs.

Located in the head are two exhaust valves, a fuel injector, and three rocker arms, for each cylinder. One rocker arm operates the injector plunger; the other two operate the exhaust valves.

Hardened exhaust valve seats are pressed into the cast iron cylinder head. These seats furnish accurate seating of the valves under variable changes in temperature, as well as materially prolong the life of the cylinder head. The hardened seats are accurately ground to very close limits and their freedom from warpage under ordinary working conditions reduces valve grinding to a minimum.

To insure efficient cooling, each fuel injector is inserted into a thin-walled copper tube passing through the water space in cylinder head. The lower end of the copper tube is pressed into cylinder head and spun over; the upper end is flanged and sealed with a Neoprene seal. The spun-over lower end and sealed upper end prevent any water leaks around the copper tube.

Water nozzles, illustrated in Fig. 2, are pressed into each water inlet on the bottom surface of the cylinder head to direct the flow coming up from the vertical passages in the cylinder block. The nozzles direct the flow of water to the surfaces around valves and exhaust ports.

The four nozzles used in the water passages at the ends of the head are smaller in diameter than the other ten and have but one outlet orifice. The larger nozzles have two outlet orifices 180° apart.

Two exhaust passages from each cylinder lead through a single port to the exhaust manifold. The exhaust passages, exhaust valve seats, and injector tubes are completely surrounded by cooling water.

To seal compression between mating surface of cylinder head and cylinder block, a five sheet laminated steel gasket is provided. Copper grommets around the openings for oil and water provide a non-corrosive seal at these points. A four piece, locked joint, cork oil gasket about ½ inch wide is placed around the entire outside edge of the mating surfaces to keep oil from the cam follower assemblies away from the outside of the engine.

The top of the cylinder head is completely enclosed by an easily removable pressed steel valve rocker cover, which is held in place by two screws fitted with hand knobs. The cover is sealed against leakage by a gasket set into a channel around the flanged edge of the cover.

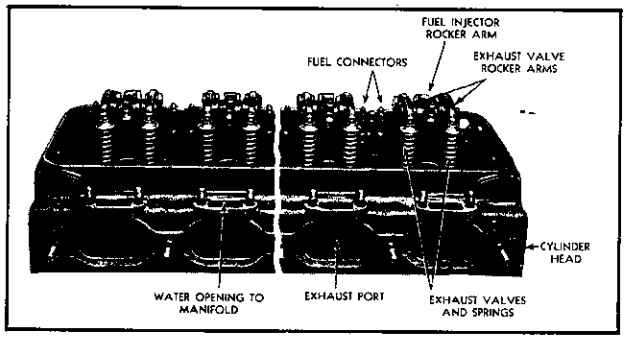


Fig. 1—Cylinder Head Assembly

Service—Since the valves seat into the lower side of the cylinder head, the head must be removed before removing the valves. The cylinder head must be removed before various other major service operations are performed.

Owing to the fact that any one of four different combinations of governors and cooling systems may be used on these engines, the procedure for removing a cylinder head varies somewhat in each case. The four possible combinations of cooling systems and governors are:

1. Radiator and hydraulic governor.
2. Radiator and mechanical governor.
3. Heat exchanger and hydraulic governor.
4. Heat exchanger and mechanical governor.

These four different combinations are treated below in the order shown.

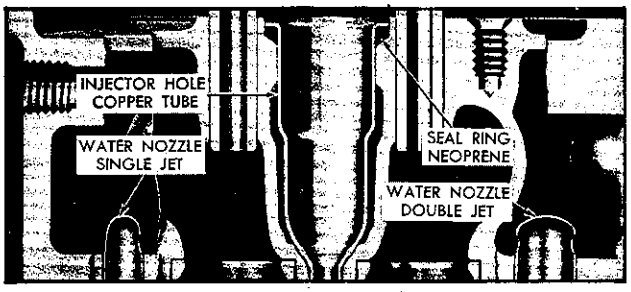


Fig. 2—Sections Through Cylinder Head Showing Water Cooling of Valves and Injector.

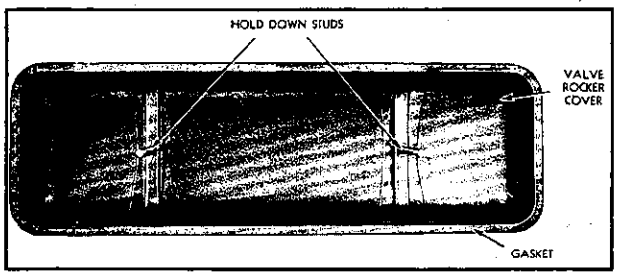


Fig. 3—Valve Rocker Cover and Gasket

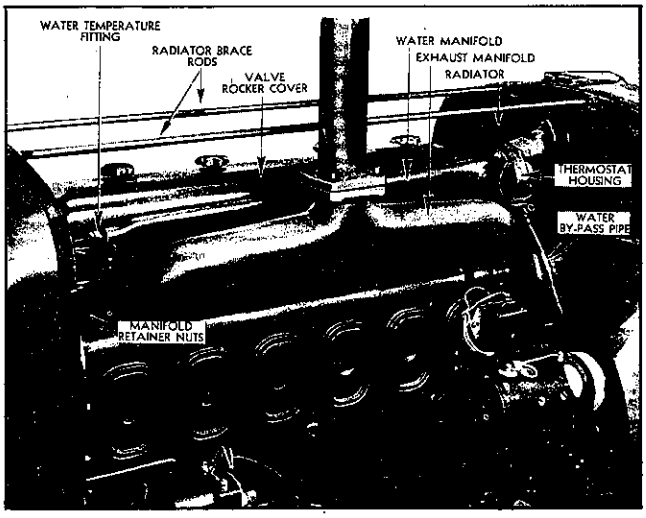


Fig. 4—Water and Exhaust Manifold Connections—Radiator Installation.

Remove Cylinder Head (Radiator and Hydraulic Governor).

1. Drain cooling system below level of cylinder head.
2. Remove retaining nuts and washers and pull exhaust manifold away from cylinder head.
3. Remove air cleaner.
4. Remove radiator brace rods by loosening lock nuts and pulling rods straight up.
5. Remove two cap screws and separate water by-pass pipe from bottom of thermostat housing at front end of water manifold. (See Fig. 4.)
6. Remove three cap screws holding thermostat housing to front end of water manifold and pull housing to one side.

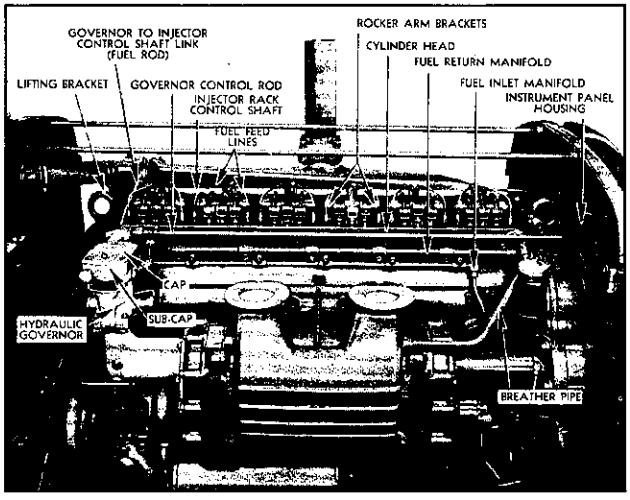


Fig. 5—Hydraulic Governor Mounting and Connections to Injector Rack Control Tube.

7. Loosen and remove water temperature fitting from rear end of water manifold.
8. Remove valve rocker cover.
9. Disconnect governor control link from injector control tube lever.
10. Remove three capscrews at top of governor, holding cap and sub-cap to governor housing and two cap screws at side of cylinder head, holding sub-cap to head, then raise and pull cap, sub-cap, and link, away from governor housing proper. (See Fig. 5.)
11. Remove two cap screws holding governor control rod to instrument panel housing and pull control rod back to clear cylinder head.
12. Remove two cap screws that attach breather pipe to rear end of cylinder head and roll pipe back away from head.
13. Loosen fuel line connections at the intake and return fuel manifolds, on the cylinder head.
14. Remove two cap screws at each end bracket and pick injector rack control tube assembly straight up away from cylinder head.
15. Disconnect fuel feed lines from injectors and fuel connectors, and remove fuel lines. Fuel injector openings should be protected with shipping cap No. 5226414 after disconnecting the fuel lines, to prevent dirt from getting into the injectors.
16. Remove the two cap screws holding rocker arm brackets to cylinder head and remove brackets from shaft and shaft from rocker arms, then fold arms back.

CAUTION: When removing the rocker arm shaft, fold back the three rocker arms and shaft just far enough so shaft can be pulled endwise. DO NOT FORCE THE ROCKER ARMS BACK WITH SHAFT IN PLACE AND IMPOSE A LOAD ON THE ROCKER ARM PUSH ROD WHICH MIGHT BEND THE PUSH ROD.

17. **Remove Injectors:**

NOTE: Removal of injectors is unnecessary unless work is to be done on the cylinder head. If injectors are not removed, protect the spray tips from damage.

(a) Remove injector hold-down bolt, nut, and crab.

(b) Using special tool shown in Fig. 8, Sec. 15, pry the injectors straight up and remove.

After removing the injectors, wash the outside exposed portion in clean gasoline and blow off with compressed air.

If injectors are to be left out of engine any length of time, store them as described on

Page 6, Sec. 22. Test (pop) each injector, as directed on Page 11, Sec. 15, before installing injector in engine.

18. Remove two cap screws at each end of cylinder head that secure cylinder head lifting brackets to the flywheel housing and balance weight cover.

19. Remove nuts from cylinder head studs and, by means of the lifting brackets, raise head away from cylinder block.

NOTE: When resting cylinder head on the work bench, protect cam followers and rollers by resting the valve side of head on a block of wood.

For removing, reconditioning or grinding, and replacing valves after the cylinder head has been removed, refer to "Remove Exhaust Valves," "Recondition Valves and Valve Seats," and "Replace Exhaust Valves," Pages 3, 5, and 6, Sec. 11.

Remove Cylinder Head (Radiator and Mechanical Governor). Items 1 to 8, inclusive, are the same as "Remove Cylinder Head (Radiator and Hydraulic Governor"), Page 2.

9. Remove two cap screws that attach breather pipe to rear end of cylinder head, and roll pipe back away from head.

10. Remove four cap screws from governor control housing cover, and remove cover and gasket. (See Fig. 6.)

11. Detach governor control rack link from governor and control rack tube, and remove link. Remove governor control housing.

12. Remove two cap screws which attach governor control housing to cylinder head.

13. Remove four cap screws holding control housing to governor weight carrier housing, and remove cover and gasket.

    Items 14 to 20, inclusive, are the same as 13 to 19 of "Remove Cylinder Head (Radiator and Hydraulic Governor"), Page 2.

For removing, reconditioning or regrinding, and replacing valves after the cylinder head has been removed, refer to "Remove Exhaust Valves," "Recondition Valves and Valve Seats," and "Replace Exhaust Valves," Pages 3, 5, and 6, Sec. 11.

Remove Cylinder Head (Heat Exchanger and Hydraulic Governor).

1. Drain cooling system below level of cylinder head by removing pipe plug at lower bend in pipe leading from bottom cover of heat exchanger to bottom of oil cooler.

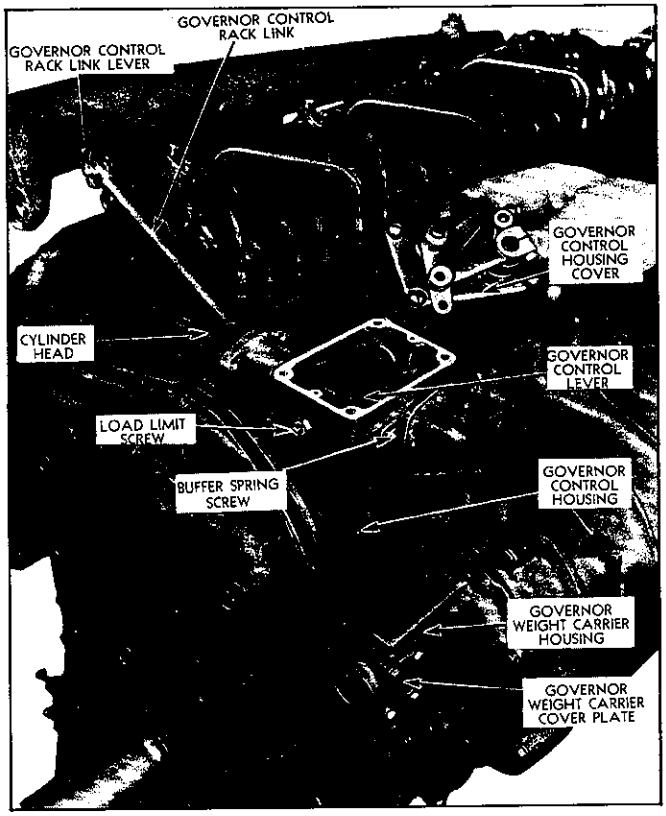


Fig. 6—Mechanical Governor Mounting.

2. Remove retaining nuts and washers and pull exhaust manifold away from cylinder head.

3. Remove air cleaner.

4. Loosen and remove water temperature fitting from rear end of water manifold.

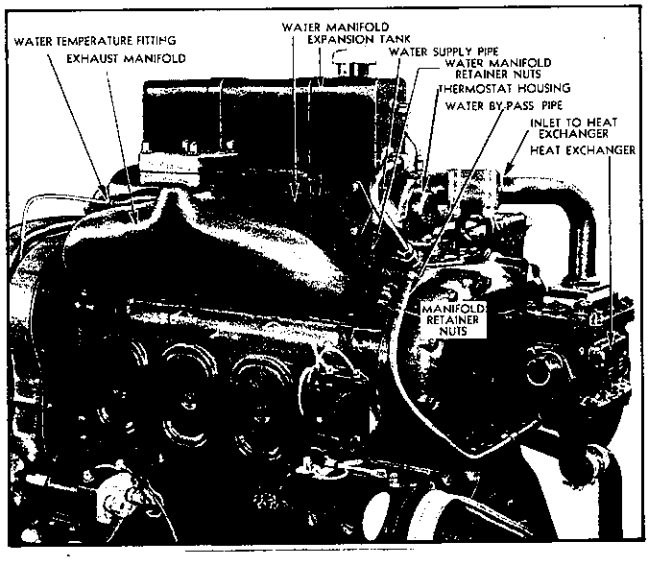


Fig. 7—Water Manifold and Connections—Heat Exchanger Installation.

5. Loosen the two compression coupling nuts and remove the water supply pipe leading from expansion tank to water by-pass pipe. (See Fig. 7.)

6. Remove two cap screws holding water by-pass pipe to lower flange of thermostat housing.

7. Remove two cap screws holding water inlet pipe to top of heat exchanger.

8. Remove nuts from studs holding water manifold to cylinder head, and remove water manifold.

Items 9 to 20, inclusive, are the same as 8 to 19 of "Remove Cylinder Head (Radiator and Hydraulic Governor)," Page 2.

For removing, reconditioning or grinding, and replacing valves after the cylinder head has been re-

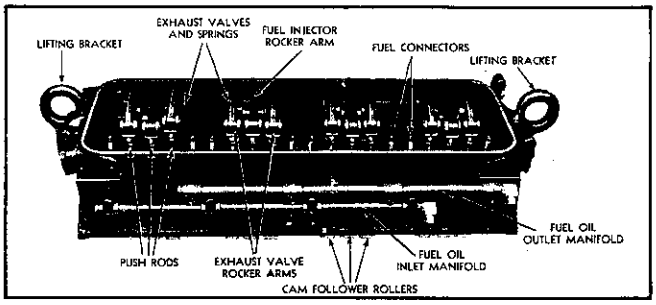


Fig. 8—Cylinder Head Assembly Ready to be Installed.

moved, refer to "Remove Exhaust Valves," "Recondition Valves and Valve Seats," and "Replace Exhaust Valves," Pages 3, 5, and 6, Sec. 11.

Remove Cylinder Head (Heat Exchanger and Mechanical Governor).

1. Items 1 to 8, inclusive, are the same as items 1 to 8, inclusive, for "Remove Cylinder Head (Heat Exchanger and Hydraulic Governor)," above.

2. Items 9 to 13, inclusive, are the same as items 9 to 13, inclusive, for "Remove Cylinder Head (Radiator and Mechanical Governor)," above.

3. Items 14 to 20, inclusive, are the same as items 13 to 19, inclusive, of "Remove Cylinder Head (Radiator and Hydraulic Governor)," Page 2.

For removing, reconditioning or grinding, and replacing valves after the cylinder head has been removed, refer to "Remove Exhaust Valves," "Recondition Valves and Valve Seats," and Replace Exhaust Valves," Pages 3, 5, and 6, Sec. 11.

Remove Parts from Cylinder Head—Conditions will arise when a cylinder head change becomes necessary. For such cases, the removal of all working parts attached to cylinder head is necessary. The parts to be removed from cylinder head after head has been removed from engine are:

1. Fuel oil connectors.
2. Fuel oil manifolds.
3. Valve and injector rocker arms.
4. Cam followers, retainers, push rods, and retainer springs.
5. Valves and valve springs.
6. Cylinder head lifting brackets.
7. Injector control tube assembly.

Items 1 and 2 above are treated under "Fuel System," and items 3, 4, and 5, under "Valve Operating Mechanism."

The cylinder head lifting brackets may be detached by removing the two cap screws that hold each bracket to cylinder head.

Inspection of Cylinder Head Parts—In case of a cylinder head change, the working parts removed from the old cylinder head should be inspected before they are installed in new head.

The proper procedure to be followed and the proper clearances of the working parts will be found under "Service," "Valve Operating Mechanism," Page 2, Sec. 11.

Install Parts in Cylinder Head—New cylinder heads are furnished with valve guides, studs, injector copper tubes, and plugs. When a cylinder head change is made, some of the used parts removed from the old head, or new parts, must be installed in the head before it is attached to cylinder block.

The parts to be so attached are:

1. Valves and valve springs.
2. Cam followers, guides, retainers, push rods, and retainer springs.
3. Valve and injector rocker arms.
4. Fuel oil manifolds.
5. Fuel oil connectors.
6. Cylinder head lifting brackets.
7. Injector control tube assembly.

When attaching cylinder head lifting brackets to head, install a new gasket for each bracket, The gasket at front end fits between the bracket and cylinder head and also between the bracket and balance weight cover. The gasket at rear end fits between the bracket and cylinder head and also between the bracket and gear train cover.

The proper procedure to be followed when replacing valves, valve springs, and valve followers, will be found under "Valve Operating Mechanism," Sec. 11, and for fuel oil manifolds and connectors, under "Fuel System," Page 29, Sec. 15.

Early engines did not use the single and double water nozzles illustrated in Fig. 2. If these nozzles are to be incorporated in the older cylinder heads they may be installed as follows:

1. Clean and remove scale from cylinder head.
2. Size water holes at ends of cylinder head (single jet nozzles) with a $\frac{1}{2}$" diam. drill and break edge of holes slightly.
3. Size water holes inner (double jet nozzles) with a $\frac{13}{16}$" diam. drill and break edge of holes slightly.

Caution: Nozzles must be press fit to maintain proper direction of jets.

If water holes are found to be slightly oversize, preventing a press fit, the nozzles may be coated on the outside diameter with solder before insertion. Care should be exercised to prevent the solder from closing the outlet holes.

Press nozzles in place from flush to $\frac{1}{32}$" below bottom of cylinder head, using care to locate the outlet holes (jets) parallel lengthwise with head.

Attach Cylinder Head to Cylinder Block (Radiator and Hydraulic Governor)—Since the cylinder head was removed for the purpose of grinding or reconditioning valves and these parts were removed from the cylinder head, they must be replaced before the head is installed on the cylinder block. The procedure to follow when replacing valves and valve springs will be found under, "Replace Exhaust Valves," Page 6, Sec. 11.

Even though the procedure has been shown for removing the cylinder head for both methods of engine cooling and both governors, only two will be given for installing the cylinder head; one using a radiator and hydraulic governor, the other using a heat exchanger and mechanical governor. The procedure for the other two installations will be readily apparent after a careful reference to the illustrations and the instructions for cylinder head removal.

Before replacing cylinder head, clean tops of pistons and inspect the cylinder head gasket. It is advisable to use a new cylinder head gasket when replacing the cylinder head.

The necessary steps for replacing a cylinder head on an engine equipped with a radiator and hydraulic governor are given below:

1. Remove the old cork oil seal gasket from top of cylinder block, clean surface well and install a new gasket, using shellac between gasket and block. Do not shellac other side of gasket.

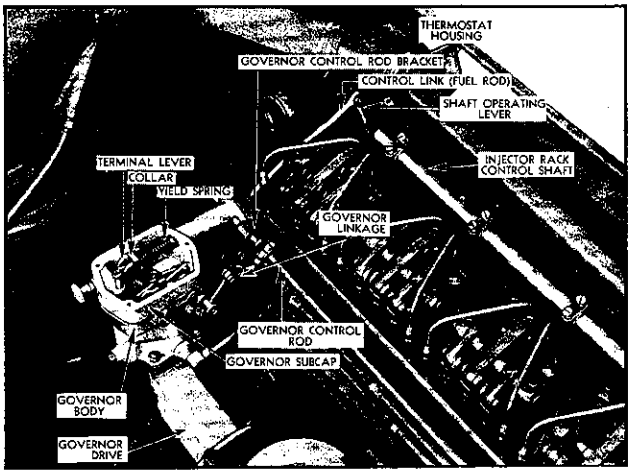


Fig. 9—Hydraulic Governor Control Link and Terminal Lever Positions.

2. Wipe upper surface of cylinder block clean and install cylinder head gasket. The gasket surface next to cylinder head is marked "Top"; also the bead around openings for combustion chambers is toward the cylinder head. Make sure no bolts extend through end plates at ends of cylinder head.
3. Wipe under side of cylinder head clean and, by means of the lifting brackets, set cylinder head in place on block.
4. ***Loosen cap screws that attach lifting brackets to cylinder head so brackets can shift and, starting from center of cylinder head and working toward each end, tighten all cylinder head stud nuts as tight as possible with a 20" wrench.*** (160-170 ft. lbs. torque with engine cold and 180 ft. lbs. after engine is at operating temperature.)
5. Replace and tighten the two cap screws at each end of cylinder head that attach lifting brackets to flywheel housing and balance weight cover. Tighten the two screws that attach lifting brackets to cylinder head.
6. If injectors were not cleaned and tested (popped) when removed, they should be, before installing in the cylinder head. After washing the exposed outside surface of the injectors in clean gasoline and blowing off with compressed air, test each injector as directed under "Testing Injector," Page 11, Sec. 15. If any of the holes are plugged in the spray tips, clean the tips as directed under "Inspecting and Cleaning Injector Spray Tip," Page 6, Sec. 15.

   After cleaning and testing, set each injector in place with locating dowel in injector body

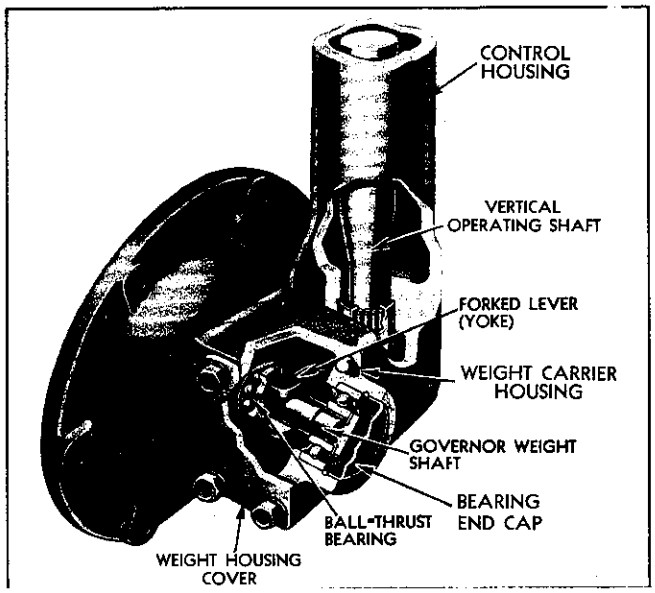


Fig. 10—Correct Relative Positions of Governor Yoke and Thrust Bearing—Mechanical Governor.

registering with hole in cylinder head, and lock in place with crab, washer, and nut. Tighten to 20 to 25 ft. if torque wrench is used.

7. Slide rocker arm shaft through rocker arms and then slide one of the end brackets over each end of shaft, with finished face of the bracket boss next to rocker arm.

8. Put rocker arm bracket bolts in place through brackets and shaft and secure to cylinder head.

9. Attach the two fuel lines to each injector and fuel connectors, making sure all connections are leak proof.

10. Push each injector rack in and out to check for free movement, then with return spring on injector rack control tube at rear end, set tube assembly in place, being sure each control rack is slid over the operating lug on operating shaft lever.

    When attaching tube brackets to cylinder head, be sure the tube works freely in brackets, so the spring returns the tube to the limit of travel of injector racks.

11. Connect fuel lines to intake and return fuel manifolds and draw nuts leak tight.

12. Being sure gasket is not damaged, and that lower end of pipe is inserted in hole at side of air intake pipe to blower, attach breather pipe to flange at rear end of cylinder head.

13. Attach governor control rod to instrument panel housing.

14. Being sure that gaskets are not damaged and are in place between the cylinder head and governor control rod bracket, as well as between this bracket and governor sub-cap, slide the governor control link through hole at side of cylinder head and locate governor sub-cap on governor body.

    When locating governor sub-cap, see that the governor control link (fuel rod) is in the slot of the terminal lever, attached to governor body, and that collar on link is ahead of terminal lever. These conditions must exist in order for the governor to operate the injector control tube. (See Fig. 9.)

15. Connect governor control link to injector control tube operating lever.

16. Replace water temperature fitting in rear end of water manifold.

17. See that gasket is not damaged, and attach thermostat housing to front end of water manifold.

18. See that gasket is not damaged, and attach water by-pass pipe to bottom of thermostat housing.

19. Install radiator brace rods and align radiator so hood panels will fit properly.

20. Using new gaskets, install exhaust manifold, seeing that all retaining washers are in place.

21. Install air cleaner.

22. Refill cooling system with soft water and inspect for leaks.

23. With throttle in "OFF" position, crank engine over to see that all parts function properly.

24. Lash exhaust valves to .015" with engine cold, and relash to .011" ***GO*** — .013" ***NO GO*** with engine hot.

25. Time injectors as outlined under, "Timing Fuel Injectors," Page 12, Sec. 15.

26. Position injector control racks, as outlined on Page 13, Sec. 15.

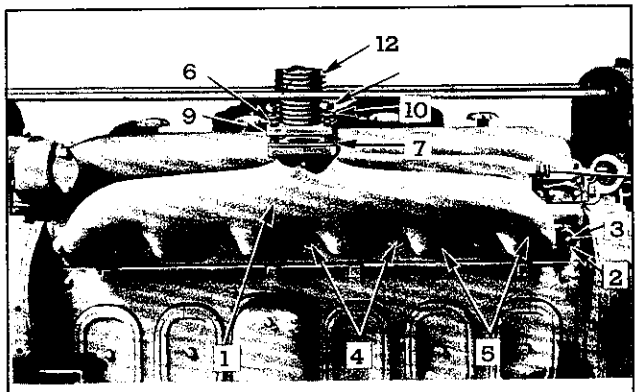
27. ***Before replacing valve cover, open engine throttle to "Idle" position. Start engine by operating starter button and see that all fuel line connections are tight so no fuel oil leaks into cylinder head to dilute the lubricating oil. If lubricating oil is diluted with fuel oil, engine bearings might be seriously damaged.***

28. All connections having been checked for leaks, valve cover and gasket may be installed.

Attach Cylinder Head to Cylinder Block (Heat Exchanger and Mechanical Governor)—Items 1 to 12, inclusive, are the same as items 1 to 12, inclusive, for "Attach Cylinder Head to Cylinder Block (Radiator and Hydraulic Governor)", Page 5.

13. Be sure paper gasket is in place over the two dowel pins, then locate governor control housing assembly in place on governor weight carrier housing, being sure that ball thrust bearing and thrust washer are between the yoke and the sliding sleeve (riser) on governor shaft. (See Fig. 10.)
14. With paper gasket in place, attach the cover on the governor weight carrier housing. Also, insert gasket at top between cylinder head and housing and attach to cylinder head with two cap screws.
15. Attach governor control rack link to governor and control rack shaft and insert cotters in clevis pins.
16. Locate pin on lower end of governor throttle lever into slot in outer end of governor control rod operating lever, locate the dowels of cover into holes in governor control housing and secure cover, with gasket in place, on top of control housing, with four cap screws.
17. See that gaskets are not damaged, and attach water manifold to cylinder head.
18. Using new gasket, attach water intake pipe from manifold to top cover of heat exchanger.
19. Using new gasket, attach water by-pass pipe to lower flange of thermostat housing.
20. Replace water supply pipe leading from expansion tank to water by-pass pipe, and draw nuts tight.
21. Replace water temperature fitting in rear end of water manifold.
22. Using new gaskets, install exhaust manifold, seeing that all retaining washers are in place.
23. Install air cleaner.
24. Refill cooling system with soft water so that water rises to, at least, one inch in the expansion tank.
25. With throttle in "OFF" position, crank engine over to see that all parts function properly.
26. Lash exhaust valves to .015" with engine cold, and relash to .011" ***GO***—.013" ***NO GO*** engine hot.
27. Time injectors as outlined under "Timing Fuel Injectors," Page 12, Sec. 15.
28. Position injector control racks, as outlined on, Page 13, Sec. 15.
29. ***Before replacing valve cover, open engine throttle to "idle" position. Start engine by operating starter button and see that all fuel line connections are tight so no fuel oil leaks into cylinder head to dilute the lubricating oil. If lubricating oil is diluted with fuel oil, engine bearing might be seriously damaged.***
30. All connections having been checked for leaks, valve cover and gasket may be installed.

EXHAUST SYSTEM



1. Exhaust Manifold.
2. Clamp Washer—Special.
3. Stud Nut.
4. Stud—Engine-to-Manifold.
5. Exhaust Leg—From Each Cylinder.
6. Stud—Manifold-to-Flange.
7. Gasket—Manifold Flange-to Flexible Exhaust Pipe.
9. Flange.
10. Lock Washer.
11. Stud Nut.
12. Exhaust Pipe—Flexible.

Fig. 1—Exhaust Manifold Mounting.

EXHAUST MANIFOLD

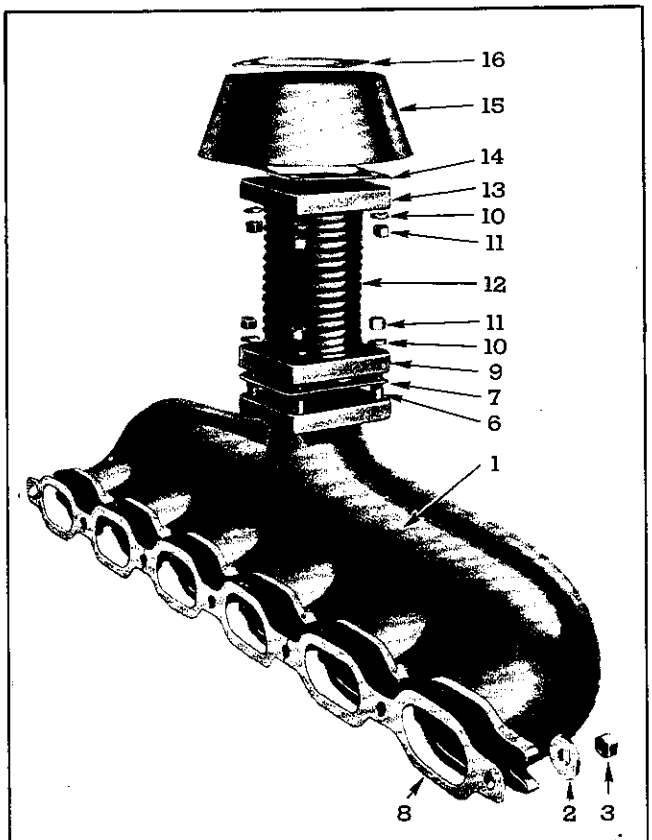
Description—Figure 1 shows the location and mounting arrangement of a typical exhaust manifold on an "A" or a "C" type six cylinder engine. Exhaust manifolds are furnished in several designs to meet a variety of installations. This section treats on one of the more complicated applications—a completely hooded power unit with an exhaust muffler mounted just above the engine and outside of the hood. Refer to Fig. 7, Sec. 1 for manifold locations on the various engine models.

Two exhaust passages from each cylinder lead through a single port in the cylinder head to the exhaust manifold. Studs in the cylinder head, located between each exhaust port and at each end of the two end ports, serve the dual purpose of supporting and securing the manifold to the cylinder head by means of special clamp washers and nuts. As a safeguard against exhaust gas leaks, a two-piece heat-resisting gasket, supported on the studs, is used between the cylinder head and exhaust manifold.

A uniformly circular section at each end of the manifold terminates in a horizontal flange at the mid-section where a flexible exhaust pipe is attached.

Exhaust Manifold Service—Owing to the nature of material from which exhaust manifolds are made, and the method of support, very little service should be required on the parts unless the engine has met with an accident.

Remove Exhaust Manifold—The exhaust manifold will usually be removed along with the cylinder head; however, in case exhaust manifold gaskets are to be replaced, the exhaust manifold may be removed without removing the cylinder head as follows:



1. Exhaust Manifold.
2. Clamp Washer.
3. Stud Nut.
6. Stud.
7. Gasket—Manifold Flange to Flexible Exhaust Pipe.
8. Gasket—Manifold to Engine.
9. Flange—Exhaust Pipe.
10. Lock Washer.
11. Stud Nut.
12. Exhaust Pipe—Flexible.
13. Flange—Exhaust Pipe.
14. Gasket—Flexible Exhaust Pipe to Shield.
15. Shield.
16. Gasket—Shield-to-Muffler.

Fig. 2—Exhaust Manifold Details and Relative Location of Parts.

1. Remove exhaust muffler. (Refer to Page 2.)
2. Remove seven exhaust manifold-to-cylinder head stud nuts (3), special washers (2), and pull exhaust manifold straight out away from engine.
3. Remove manifold gaskets (8) Fig. 2, from cylinder head and manifold flanges.

Replace Exhaust Manifold—When the manifold is removed from the engine along with the cylinder head, it should be separated to facilitate handling of the head during service operations. When replacing, the manifold should not be tightened in place until after the head assembly has been drawn down tight. The manifold location should then be checked to make sure it is resting on the lands at top of cylinder block—if the manifold has corresponding bosses—and then the stud nuts (3) drawn up tight against the conical washers (2).

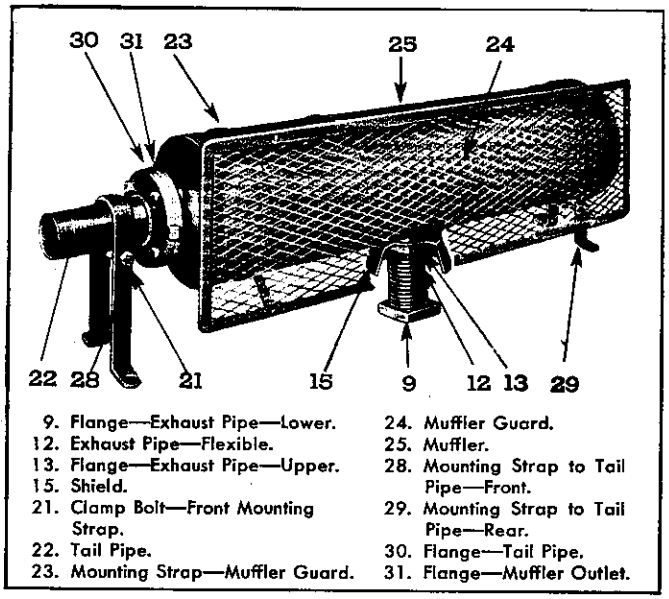
When the manifold has been removed independent of the cylinder head, it may be replaced by reversing the sequence of operations for removal as follows:

1. Place three piece gasket (8) over the studs (4).
2. Set manifold (1) over studs (4) and next to gasket (8).
3. Set a clamp washer (2)—dished side toward manifold—over each stud and next to manifold.
4. Replace nuts (3) and tighten in place.

EXHAUST MUFFLER

Description—On the hooded package power unit, the exhaust muffler is connected to the manifold with a flexible exhaust pipe. A steel shield fastens to the muffler flange offering a protective cover against the hot surface of the flexible pipe. The exhaust muffler is a welded steel tank supported by steel legs located on the top of the unit. The muffler is divided by a baffle into two cylindrical compartments, a large one at the inlet end and a smaller one at the outlet. An outlet pipe is located on the inside of the muffler, extending deep into the large chamber. The exhaust gas is forced out of the manifold into the large chamber and out through the small pipe. A short tail pipe is located on the outlet flange. The muffler, manifold, and exhaust piping are painted with a heat resisting paint as a protective covering. A steel screen is mounted on the outside diameter of the muffler and clamped by means of two straps and bolts. The straps can be loosened to enable the proper positioning of the guard.

Exhaust Muffler Service—The rugged construction of the muffler insures extended periods of trouble-free service. However, if the muffler should be damaged, it may be removed and replaced as described in the following discussion.



9. Flange—Exhaust Pipe—Lower.
12. Exhaust Pipe—Flexible.
13. Flange—Exhaust Pipe—Upper.
15. Shield.
21. Clamp Bolt—Front Mounting Strap.
22. Tail Pipe.
23. Mounting Strap—Muffler Guard.
24. Muffler Guard.
25. Muffler.
28. Mounting Strap to Tail Pipe—Front.
29. Mounting Strap to Tail Pipe—Rear.
30. Flange—Tail Pipe.
31. Flange—Muffler Outlet.

Fig. 3—Exhaust Muffler Assembly.

Remove Exhaust Muffler—The exhaust muffler must be removed to replace the exhaust manifold or when the engine is removed from the base. The procedure is as follows. (See Fig. 3.)

1. Remove from stud (6) four stud nuts and lockwashers holding flange (9) of flexible exhaust pipe (12) to flange of exhaust manifold (1).
2. Remove two bolts (20) and lockwashers (10) holding mounting strap (28) to radiator (18).
3. Remove two bolts (27) holding mounting strap to center hood support (17).
4. Lift muffler (25) and flexible pipe connection (12) through the hole in the hood (19) and place on a suitable bench for further disassembly.

   No further diassembly is necessary unless the muffler or flexible connection is to be replaced. This being the case, proceed as follows:

5. Remove clamp bolt (26) from mounting strap (29) and slide strap off end of muffler.
6. Remove clamp bolt (21) from mounting strap (28) and slip off tail pipe (22).
7. Remove four stud nuts from studs of exhaust muffler flange and pull flexible connection (12) free of muffler.
8. Shield (15) and gaskets (14) and (16) will fall free of studs.
9. Remove two clamp bolts from muffler guard mounting straps (23) and slide off end of muffler.
10. Tail pipe flange can be removed by taking out four bolts holding flange to muffler. Remove gasket.

Replace Exhaust Muffler—The exhaust muffler may be replaced by reversing the sequence of operations for removal as follows:

1. Replace tail pipe flange by aligning four bolt holes and bolt flanges together with gasket in place.
2. Slide muffler guard mounting straps (23) over end of muffler and secure in place with two clamp bolts.
3. Place gasket (16), shield (15), gasket (14), and flange (13) of flexible exhaust pipe (12) in place on studs of muffler flange. Secure in place with four lockwashers and four stud nuts.
4. Place mounting strap (28) on tail pipe (22) and secure in place with clamp bolt (21).

5. Place mounting strap (29) over rear end of muffler and fasten in place with clamp bolt (26).
6. Place gasket (7) on manifold flange. Lift muffler into position and lower flexible pipe (12) through hole in hood (19) and over four studs (6) of exhaust manifold (1). Secure in place with four lockwashers and four nuts.
7. Bolt mounting strap (28) to top of radiator (18) with two bolts (20) and two lockwashers (10).
8. Bolt mounting strap (29) to top of center hood support (17) with two bolts (27) and two lockwashers (10).

VALVE AND INJECTOR OPERATING MECHANISM

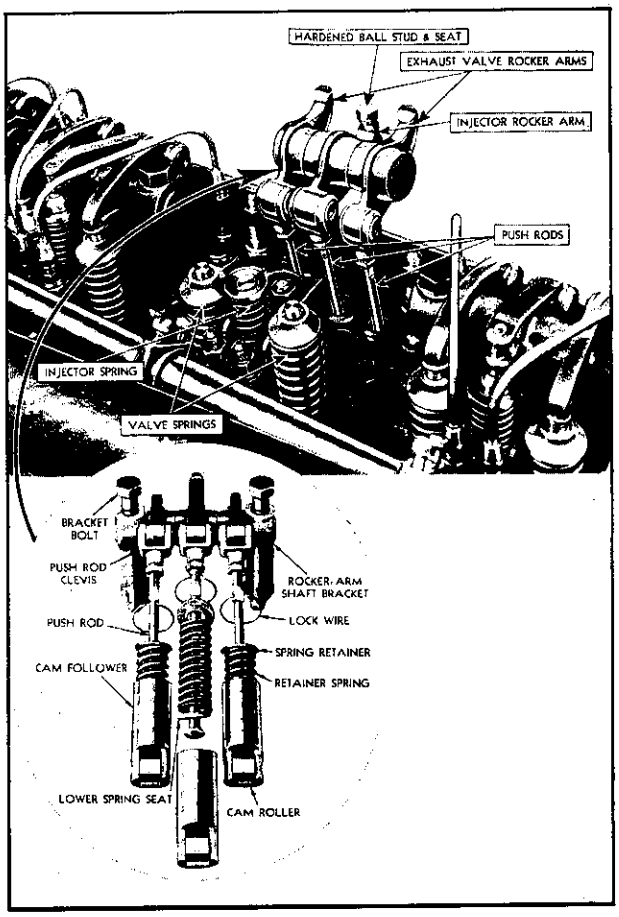


Fig. 1—Valve Operating Mechanism.

Description—Three drop-forged rocker arms are provided for each cylinder, the two outer arms operating the exhaust valves and the center one the fuel injector, as shown in Fig. 1. Each rocker arm assembly operates on a separate shaft supported by two cast iron brackets. A single bolt fastens each bracket securely to the top deck of the cylinder head. Consequently, the removal of these two bolts and the shaft permits raising the rocker arm assembly and gives easy access to the fuel injector and the valve springs.

The injector end of each injector rocker arm is fitted with a hardened ball stud and a ball seat which form a universal joint. The ball seat transmits the rocker arm motion to the fuel injector. The valve end of each valve rocker arm is hardened and ground to a cylindrical surface, which bears directly on the end of the valve stem. The rocker arms are operated from the camshaft through short push rods, which permit high speed.

Contact between the cam follower and the cam is effected by a case-hardened steel roller, equipped

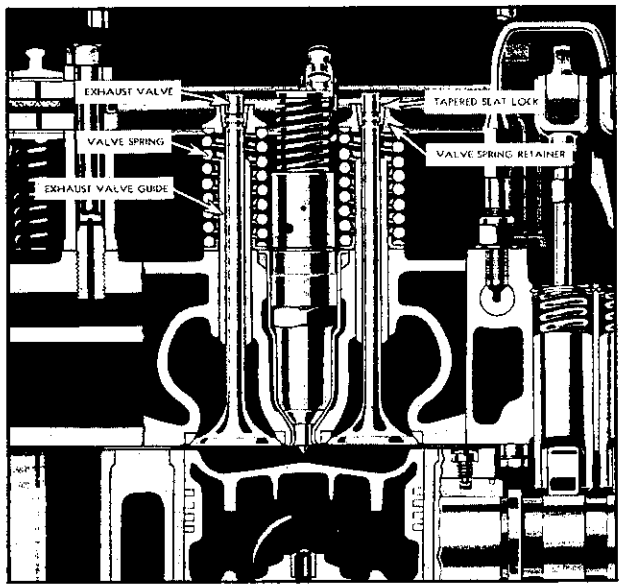


Fig. 2—Exhaust Valves and Guides.

with a roller bearing of the needle type. The 25 accurately lapped needles in this bearing run directly on a pin in the lower end of the cam follower, which operates in a bore in the cylinder head. ***Later model engines are equipped with cam rollers having steel-backed bronze bushings.*** A drop-forged steel guide, shown in Fig. 13, is provided for each set of three cam followers. This guide, located on the bottom of the cylinder head, keeps the follower rollers in line with the cams and also serves as a retainer during assembly and disassembly. A separate coil spring, located inside of the hollow cam follower, is held in place in the cylinder head by a retaining washer (upper spring seat) and wire locking ring. Fig. 2A, Sec. 12, illustrates the method used to lubricate the valve operating mechanism.

Exhaust Valves—Exhaust valves are silchrome steel and carefully heat-treated to develop fully the special properties required for valve service. Each valve stem is accurately ground to size and hardened at the end to provide the extreme hardness needed.

The valve stem guides, made of fine-grained cast iron, are pressed into the cylinder head and then reamed for the desired fit.

A straight cylindrical valve spring, made of alloy steel, is held in place by a retainer (spring cap) and tapered two-piece seat lock.

Lubricating of Valve Operating Mechanism—The valve operating mechanism is lubricated from a longitudinal oil passage on the camshaft side of the cylinder head, which communicates with the main oil gallery in the cylinder block.

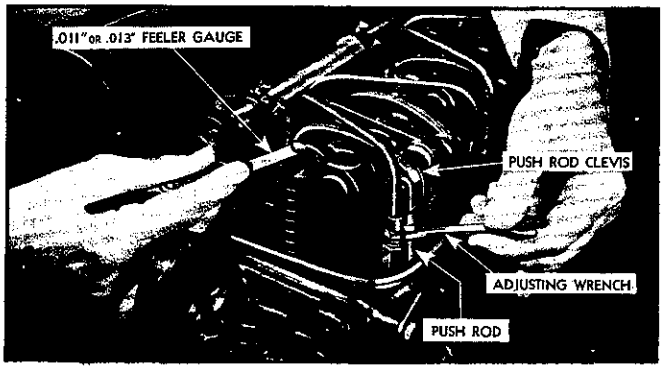


Fig. 3—Adjusting Valve Lash.

Oil from this passage enters the hollow rocker arm shafts through the rocker shaft brackets and hollow cap screws. Excess oil from the rocker arms lubricates the valve ends and push rods, and drains to the cam pockets in the cylinder head, from which the cams are lubricated.

Service—Due to the sweep of air from the blower past the exhaust valves each time the inlet ports are uncovered, the valves in these two-cycle Diesel engines run much cooler than the valves in a conventional gasoline engine; therefore, the attention required by the valves is reduced to a minimum.

Several operations on the valve mechanism may be performed without removing the cylinder head, while the head must be removed for certain other operations. The operations not requiring head removal are:

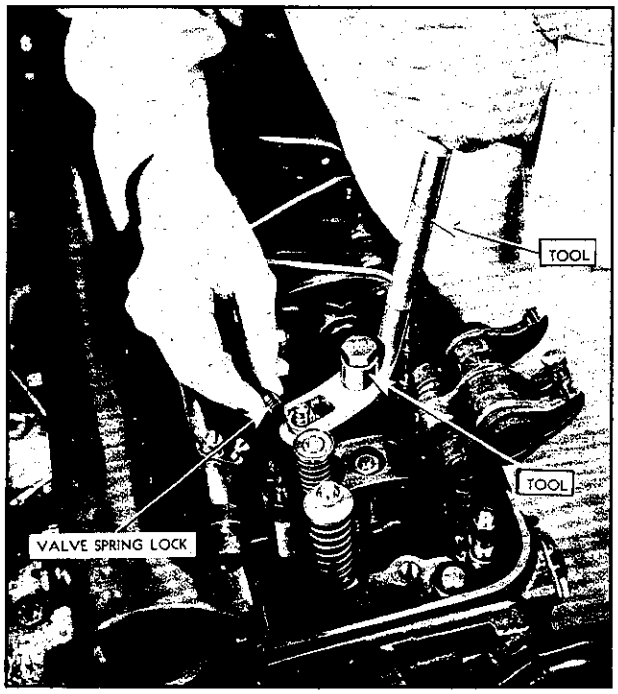


Fig. 4—Compressing Valve Spring to Remove Lock.

1. Adjustment of lash. (Valve clearance.)
2. Remove or replace a valve spring.
3. Remove or replace a rocker arm.
4. Remove or replace a rocker arm shaft or shaft bracket.

It is also possible, if occasion requires, to remove or replace a cam follower retainer spring, a cam follower, or a push rod, without removing the cylinder head. These parts are more easily changed from the lower side of the cylinder head when the head is off the engine. The following discussion explains both methods.

The cylinder head should first be removed to perform the following valve operations.

1. Remove or replace a valve.
2. Remove or replace a valve guide.
3. Grind or reseat valves.

Valve Lash Adjustment—Correct valve lash is important due to the high compression pressure employed in a Diesel engine.

Too little clearance causes a loss of compression, missing cylinder, and eventual burning of valves and valve seats.

Too much clearance between the valve stem and the valve rocker arm results in noisy operation of the engine, especially in the idling range.

The correct lash for all exhaust valves is .011" ***GO*** and .013" ***NO GO*** with engine HOT.

Adjustment of the valve lash can be changed by means of the threaded upper part of the push rod, which is screwed into the push rod clevis and locked by a lock nut. The adjustment is checked as shown in Fig. 3, without the aid of special tools.

The valve lash should be taken on any cylinder when the injector arm is depressing the injector plunger for that particular cylinder.

CAUTION: Whenever a push rod has been disconnected from the push rod clevis, the rod must be screwed back into the clevis flush with the top of the threaded portion of the clevis before the valve lash is checked. If this is not done, the piston may hit the head of the valve when the engine is being turned, owing to the small clearance between the valves and piston head at the piston upper position.

Remove or Replace Exhaust Valve Spring—An exhaust valve spring may be removed as follows without removal of the cylinder head:

1. Remove valve cover.
2. Crank engine until piston is at top of stroke, which is indicated when the injector plunger has traveled approximately 3/16" on the downward stroke.

3. Disconnect and remove fuel feed lines from injector to fuel oil connectors.

4. Remove the two cap screws holding the rocker arm shaft brackets to cylinder head and remove brackets and shaft.

5. Slip one of the cap screws through valve lifter bushing and valve lifter, as shown in Fig. 4, and insert this cap screw into the tapped hole of the cylinder head adjacent to the valve spring to be removed.

6. With slight pressure on the free end of the tool, the valve spring retainer can now be depressed, the locks removed and the spring itself lifted out.

7. The valve spring may be replaced by reversing the sequence of operations for removal.

8. After replacing the valve spring, adjust the valves for .011″ **GO**, .013″ **NO GO** with engine HOT.

NOTE: Connect the fuel feed lines to the injector and the fuel oil connectors, remove the valve cover and after the engine has been started, inspect all fuel oil connections for leaks. Should fuel oil leak into the cylinder head and dilute the lubricating oil, the engine bearings might be seriously damaged.

Remove or Replace Rocker Arm or Shaft—To remove any exhaust valve or injector rocker arm:

1. Remove valve cover.

2. Disconnect and remove fuel feed lines from injector to fuel oil connectors.

3. Remove the two cap screws holding the rocker arm shaft brackets to the cylinder head and remove brackets and shaft.

4. Loosen the lock nut at upper end of push rod, next to clevis, and unscrew the rocker arm from the push rod.

5. Before replacing rocker arms or parts, inspect the bushings inside the rocker arms for excessive wear. Normal clearance is .001″-.0025″ and must not exceed .004″. Clean out oil holes in rocker arms, hollow bracket bolt and rocker shafts with gasoline, small wire, and dry compressed air.

6. Lubricate outside of rocker arm shafts with clean engine oil and install rocker arms and shafts by reversing the sequence of operations for removal.

7. After replacing the rocker arms, adjust valve lash to .015″ cold; .011″ **GO**—.013″ **NO GO**, engine HOT.

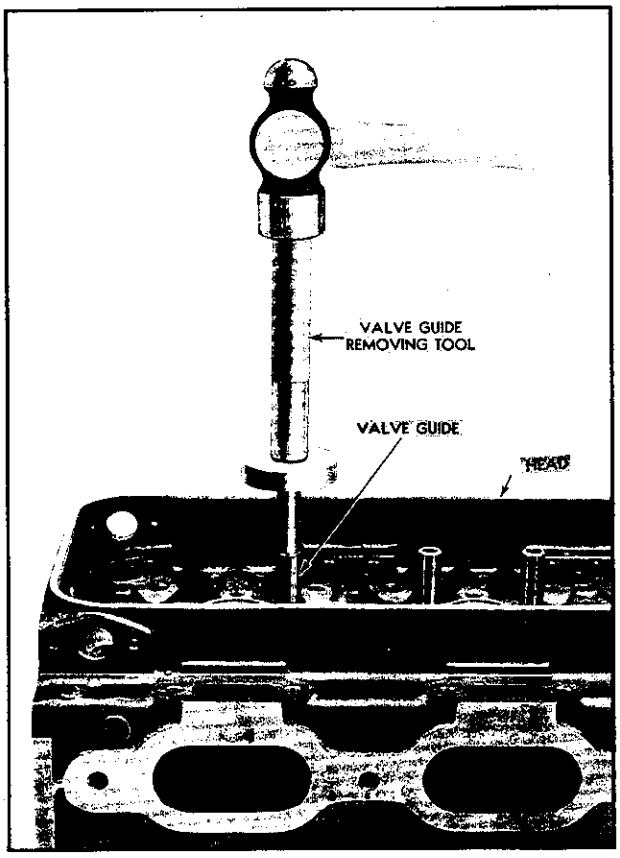


Fig. 5—Removing Valve Guide.

NOTE: Connect the fuel feed lines to the injector and the fuel oil connectors, remove the valve cover and, after the engine has been started, inspect all fuel oil connections for leaks. Should fuel oil leak into the cylinder head and dilute the lubricating oil, the engine bearings might be seriously damaged.

Remove Exhaust Valves—The exhaust valves may be removed as follows:

1. Remove cylinder head. (See Sec. 9, Page 2.)

2. Place the cylinder head on the work bench right side up, with the valve heads resting on a 2″ thick block of wood, and release the valve spring by removing the tapered seat lock with special tool shown in Fig. 4. The 2″ thick block is used to protect the valve followers which project through the lower side of the cylinder head.

3. Turn the cylinder head over and withdraw the valves from the bottom.

Inspect and Remove or Replace Valve Guides (Exhaust Valves Removed).

With the exhaust valves removed, the valve guides may be inspected and, if necessary, changed.

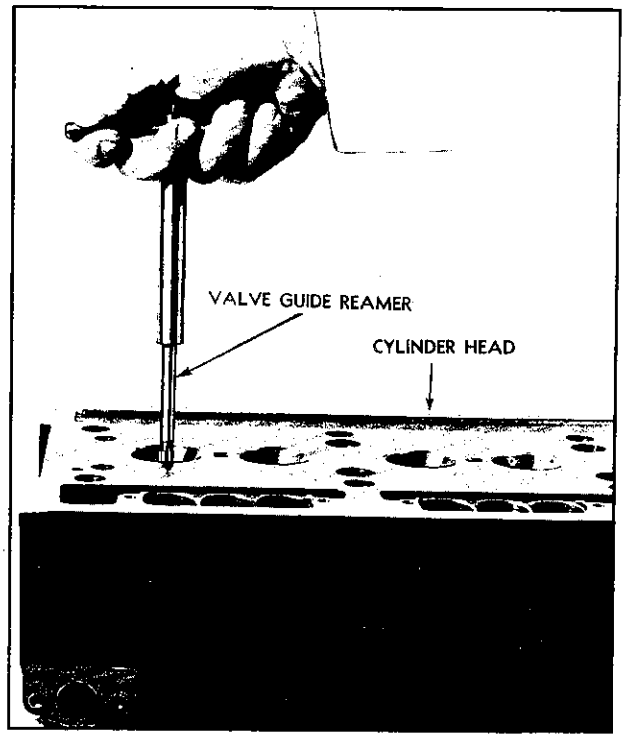


Fig. 6—Reaming Valve Guide.

The valve stem diameter is from .3415″ to .3425″ and the clearance of the stem in the guide is from .001″ to .003″ and should not exceed .006″.

The valve guide may be removed by driving out from the top or bottom of the cylinder head with the special driver shown in Fig. 5.

The valve guide may be installed by driving into place from the bottom of the cylinder head with the same driver shown in Fig. 5.

Reaming Valve Guides—The valve guides must be reamed to size after they have been pressed into the cylinder head. This operation is performed as illustrated in Fig. 6 with the special roughing and finishing reamers, tools .341 and J-129-2.

Valve Seat Inserts—Hardened steel valve seat inserts are shrunk into the cylinder head, and in order not to damage the head, the inserts must be removed with a tool provided for that purpose; also, unless the inserts are installed with care, and according to certain methods, the results will be unsatisfactory.

When reconditioning valves, the inserts in the cylinder head should be inspected and, if unsatisfactory, they may be removed and replaced, then ground for proper valve seating, as outlined below.

Removing Valve Seat Inserts—The valve seat inserts may be removed with the tool illustrated in Fig. 7, in the following manner:

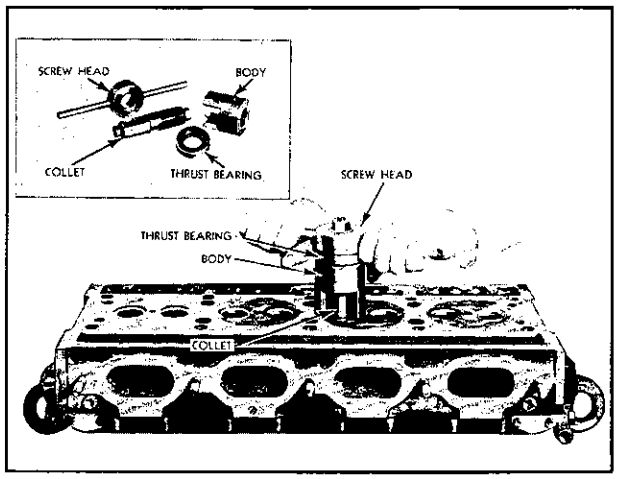


Fig. 7—Removing Valve Seat Insert.

1. With cylinder head removed, wash same in clean gasoline and dry with compressed air.
2. Lay cylinder head on bench and insert the collet inside of valve insert so that lip at bottom of collet flange is flush with bottom side of valve insert. While holding collet in this position, expand same by turning nut at top of tool. ***Be sure that flange of collet is firmly entered just below valve insert.***
3. Slide tool body over top of collet with Allen screw of body in line with slot below threads on collet. Turn Allen screw IN to engage slot and lock screw on collet relative to body.
4. Put thrust bearing over top of collet and on top of body.
5. Start screw thread of tool head onto collet and continue to turn until valve insert is pulled from cylinder head.

Replace Valve Seat Inserts—Particular care must be exercised when replacing valve seat inserts. The inserts are installed into the cylinder head with a .0005″ to .0025″ press fit, and must be started in place true with counterbore in head. The procedure given below is recommended when replacing valve inserts:

1. See that cylinder head is perfectly clean, particularly the counterbore for inserts.
2. Immerse cylinder head for 30 minutes in water at temperature of 180° to 200° F.
3. Place cylinder head bottom-side-up on bench, blow out counterbores for inserts with air, and lay an insert in counterbore—valve side up.
4. Using Tool J-1736, shown in Fig. 8, insert pilot end of drive into valve guide and drive insert down tight into counterbore.

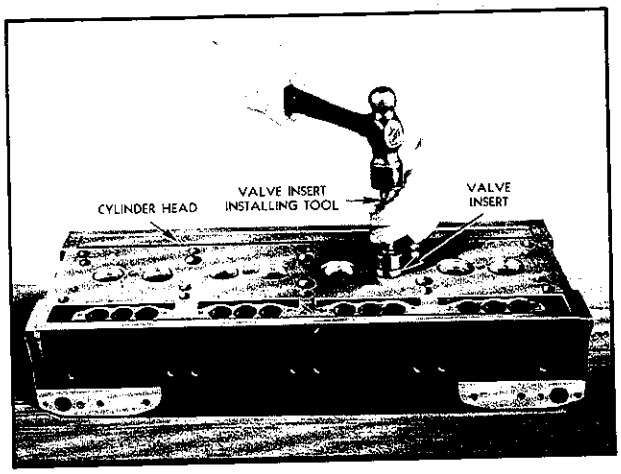


Fig. 8—Driving Valve Seat Insert into Cylinder Head.

This operation must be done quickly, while the valve seat insert is cold.

5. Check valve seat for concentricity with valve guide (see Fig. 10) and, if necessary, recondition seat or seats as directed below.

Recondition Valves and Valve Seats. Before either a new or used valve is installed, the seat in the cylinder head for the valve should be examined for proper valve seating. Furthermore, if valve once used is to be installed again, the valve stem should be cleaned, and the seat reground to the recommended angle of 45 degrees. The valve guide should be thoroughly cleaned with reamer. If bore in valve guide is worn oblong, or if valve heads are warped relative to the stem, the parts should be replaced.

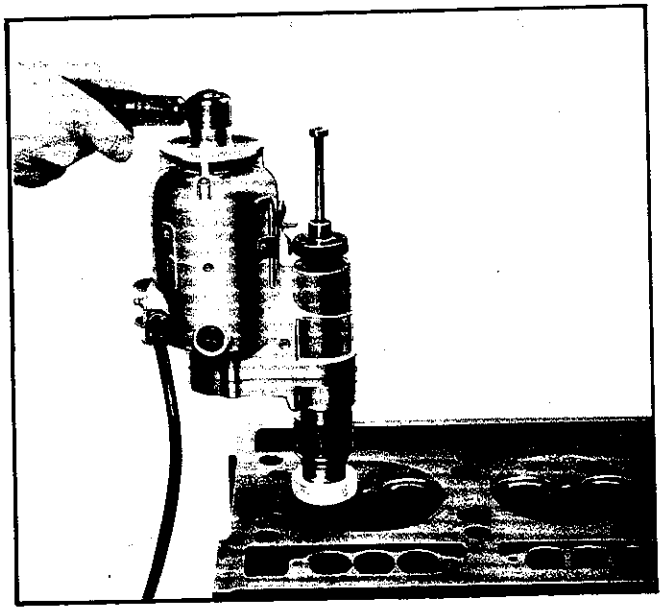


Fig. 9—Grinding Hardened Valve Seats with Tool KMO-167-D.

The width of the valve seat must be between $^{3}/_{64}$" and $^{5}/_{64}$". When new valve inserts are installed, or old inserts refaced, the work must be done with a grinding wheel. The ordinary method of reaming valve seats is ineffective for this operation because of the very hard valve insert material.

The complete equipment furnished with this valve seat grinder set, KMO-167-D includes:

1. Eccentric valve seat grinder.
2. Dial gauge.
3. Pilot.
4. 45 degree grinding wheel.
5. 60 and 30 degree grinding wheels.

The 45° grinding wheel is used for refacing the valve seats, and the other wheels are used for narrowing the seats to the standard $^{3}/_{64}$" to $^{5}/_{64}$" width. After the valve seats have been dressed with the grinding wheel, the dial gauge ,shown in Fig. 10, is used to check the concentricity of the valve seats relative to

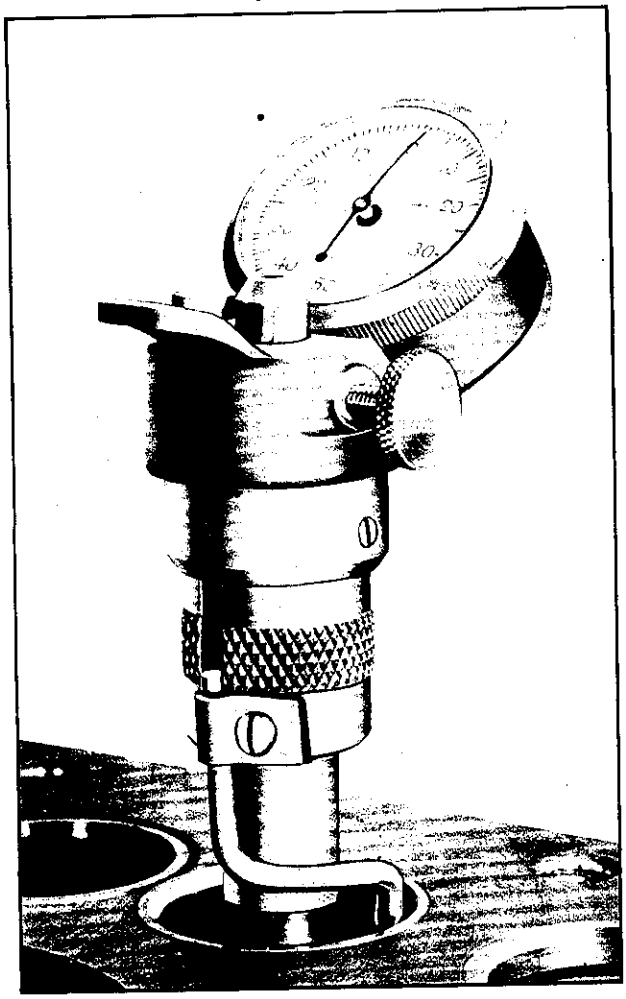


Fig. 10—Determining Concentricity of Valve Seat with Valve Guide.

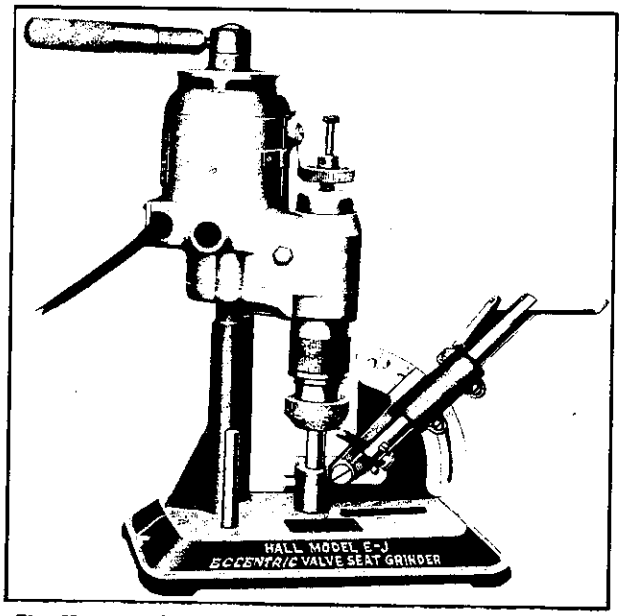


Fig. 11—Grinder and Dresser Tool for Grinding Wheel.

the valve guides. Total runout for a good valve seat should not exceed .002".

When occasion requires, the grinding wheel may be dressed with the special tool shown in Fig. 11.

After the valve seats have been ground with tool shown in Fig. 9, the valves may be put in place and lapped in the regular manner, as shown in Fig. 12. After lapping, contact between valves and seats may be checked by wiping a thin film of Prussian blue on the valve seats, setting valves in place, and bouncing valve on seat.

Replace Exhaust Valves—The valve guides having been checked or replaced and the valves ground, the valves and springs may be replaced by reversing the sequence of operations for removal, as outlined on Pages 2 and 3.

After the valves have been located in their proper positions in the cylinder head, turn the head, valves down, with valve heads resting on a wood block, then compress the valve springs and insert the spring locks, as illustrated in Fig. 4.

A wide piece of masking tape stretched across the valve heads serves to hold the valves in place while inverting the cylinder head.

If further service operations are to be performed on the cylinder head, such as removing cam followers, etc., such work should be carried out before the head is installed on the engine. The cylinder head may be replaced as outlined in Sec. 9.

Remove Cam Followers—The cam followers may be removed from either the top or bottom of the cylinder head. When they are removed from the bottom, the cylinder head must first be removed, and when they are removed from the top, the cylinder head need not be removed. If for any reason the cylinder head is off the engine, the cam followers can best be removed from the bottom of the head as shown in Fig. 13.

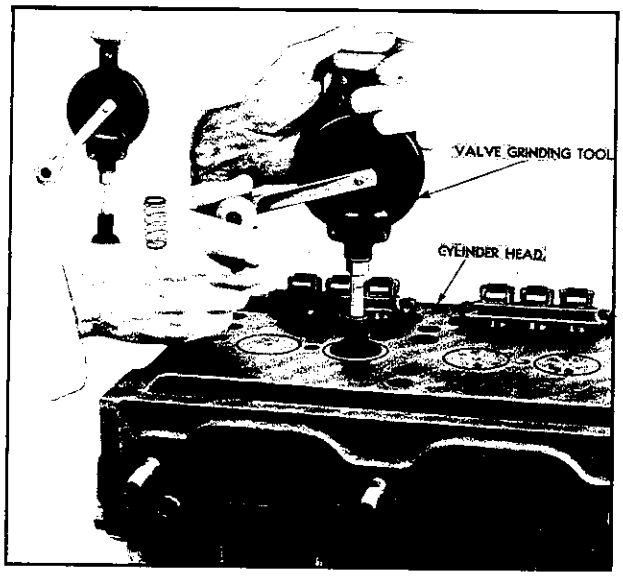


Fig. 12—Lapping Valves.

To Remove the Cam Followers from the Lower Side of the Cylinder Head:

1. Remove cylinder head (See Sec. 9, Page 2).
2. Lay the cylinder head edgewise on the bench, as shown in Fig. 13, and remove the two screws "A" that attach the valve follower guides to cylinder head and remove guides.
3. Loosen lock nuts and unscrew push rods from rocker arms.

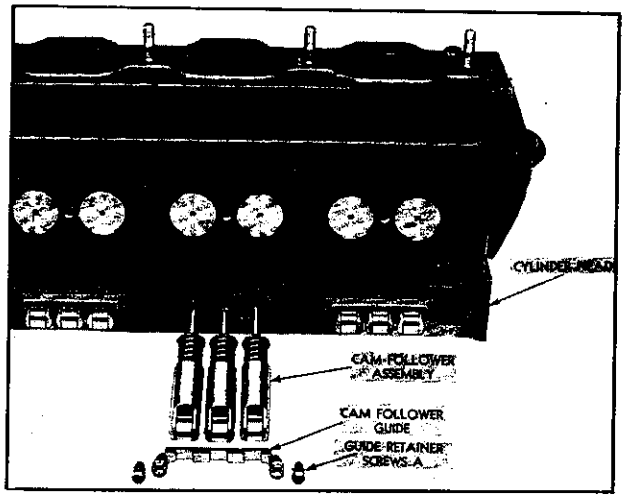


Fig. 13—Cam Followers and Retainer Assembly.

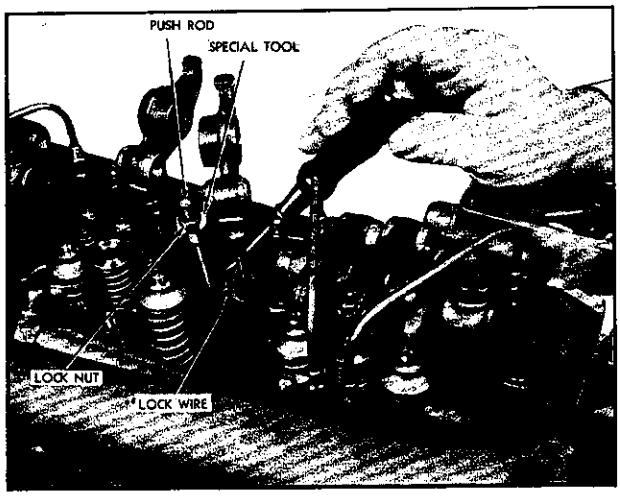


Fig. 14—Removing Push Rod from Upper Side of Cylinder Head.

4. Pull the cam followers, follower springs, spring retainers and push rods as an assembly from lower side of cylinder head.

The valve follower spring retainers (lock wires), shown in Fig. 15, still remain in the cylinder head. If the head is to be changed, these springs must be removed; if not, they may be left in place.

It may be desirable, at times, to change a push rod without removing the cylinder head.

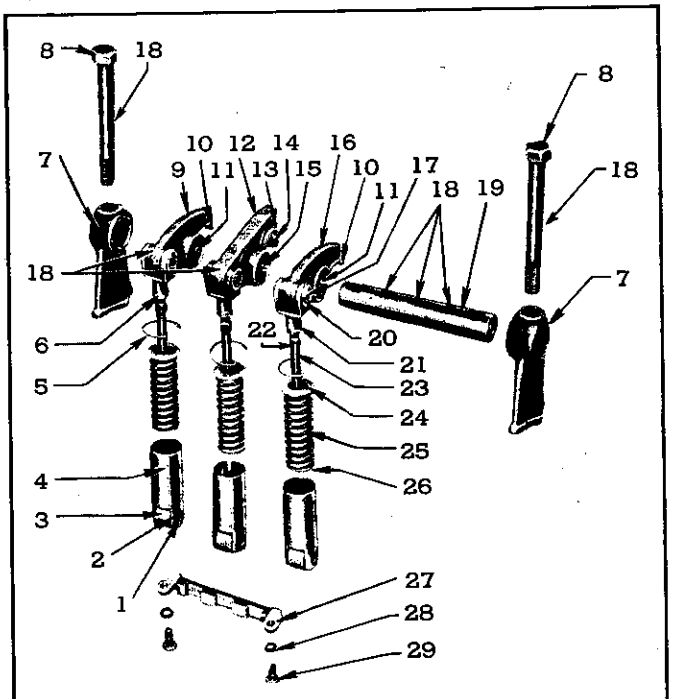
Changing a Push Rod from Upper Side of Cylinder Head—This operation can be done without removing cylinder head from the engine block.

1. Remove both fuel pipe connectors, rocker shaft bolts and rocker shaft.
2. Loosen the push rod lock nut and unscrew the rocker arm.
3. Insert the special tool between the upper surface of the cam follower retainer spring and the lock nut on the push rod (See Fig. 14), then screw the nut down to compress the spring. With spring compressed, use a screw driver or thin nose pliers to dislodge the lock wire from the groove in the cylinder head. With lock wire dislodged, the push rod and cam follower may be pulled out of top of cylinder.

After installing the push rod and replacing the rocker arms and fuel lines, lash the valves to .011" *GO*, .013" *NO GO*—engine HOT.

Inspect Cam Follower Assembly—After the cam followers have been removed they should be cleaned in gasoline, blown off with dry compressed air, and inspected before being assembled into the cylinder head.

The cam rollers must rotate smoothly and freely on the cam roller pins. If cam rollers, bushings, or pins are badly worn, or if pins are loose in the cam followers, the follower assemblies should be renewed. Rollers must be free from flat spots or scuff marks. If these exist, or if rollers have not been rotating freely, examine the cams on which rollers have operated, and if scuffed or noses of cams are worn down, replace camshaft.



1. Cam Roller Pin.
2. Cam Roller Bearing Roller.
3. Cam Roller.
4. Cam Roller Follower.
5. Follower Spring Seat Retainer.
6. Push Rod Lock Nut.
7. Rocker Shaft Bracket.
8. Rocker Shaft Bolt.
9. Valve Rocker Arm—Left.
10. Hardened Surface.
11. Bushing—Large.
12. Injector Rocker Arm.
13. Injector Rocker Arm Ball.
14. Injector Rocker Arm Ball Seat.
15. Injector Rocker Arm Bushing—Large.
16. Valve Rocker Arm—Right.
17. Bushing—Small.
18. Oil Hole.
19. Rocker Shaft.
20. Push Rod Clevis Pin.
21. Push Rod Clevis.
22. Squared Shoulder for Lash Adjustment.
23. Push Rod.
24. Follower Upper Spring Seat.
25. Follower Spring.
26. Follower Spring Seat.
27. Cam Roller Guide.
28. Lockwasher.
29. Bolt.

Fig. 15—Details of Valve and Injector Operating Mechanism.

Rapid change in valve lash, if such condition has existed, may be due to cam follower assemblies because of the above reasons.

Replace Cam Followers from the Bottom Side of Cylinder Head.

To assemble the cam followers and push rod assemblies from the bottom of cylinder head:

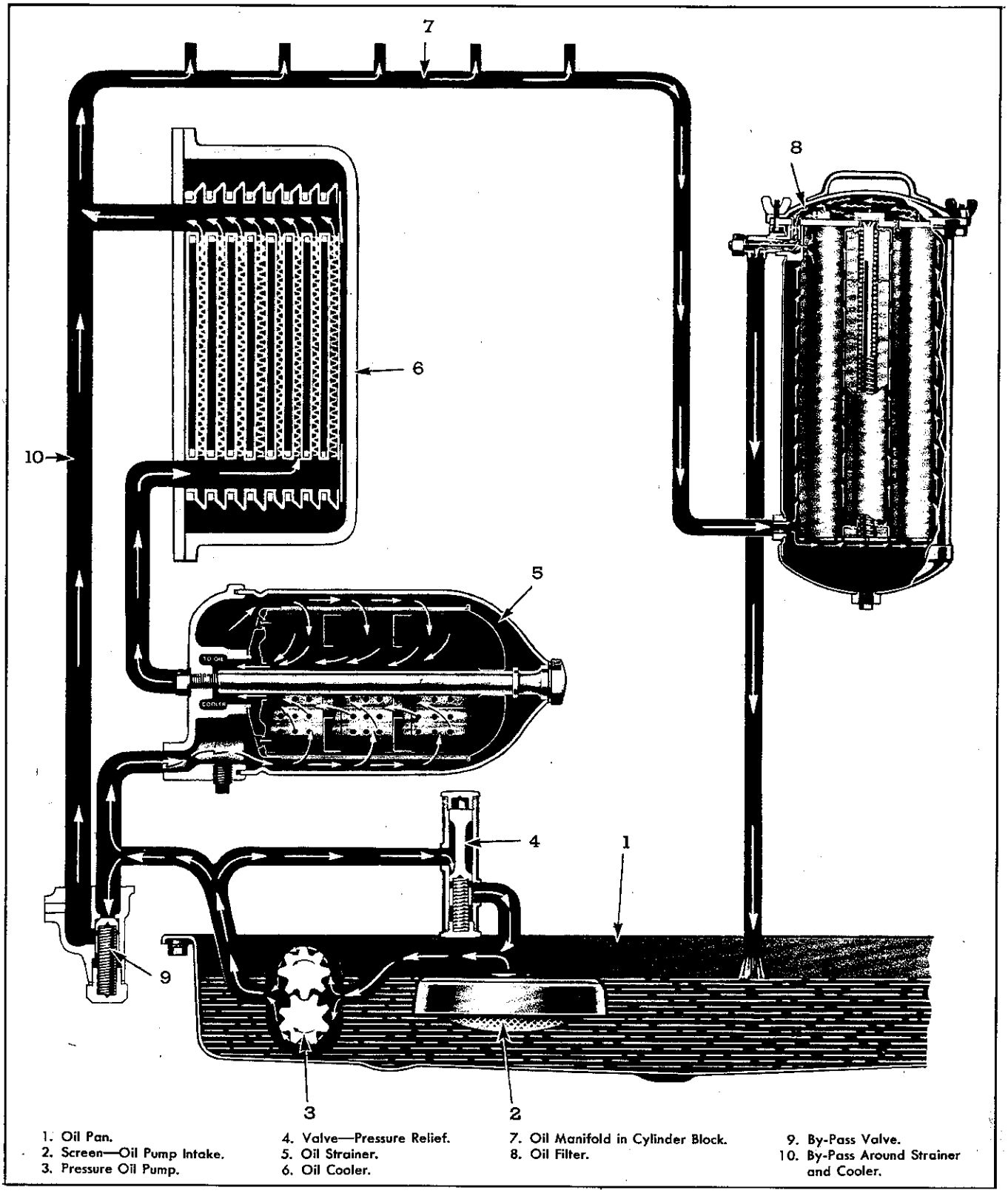
1. See that the spring seats, push rods, and retainer springs, set down into the hollow followers as shown in Fig. 15. Then with the lock wires in place in the cylinder head, slide the follower assemblies into the cylinder head.

When installing the followers, see that the oil holes in the lower end of the followers point away from the valves, so that the holes are not covered with the follower guides.

2. Attach the follower guide retainers to the cylinder head, to hold the followers in place.
3. Provide a 2″ thick strip of wood on which to rest cylinder head and protect valve followers, then reverse the head and run the lock nuts down onto upper end of push rods.
4. Note that the injector rocker arm—the center arm—is different from the exhaust valve rocker arms; also that the boss for the shaft on the valve rocker arm is longer on one side than on the other. The long side of the boss must face the injector rocker arm.

   With the rocker arms selected as above, screw the upper end of each push rod into the rocker arm clevis so the end of the rod is just flush with the top of the threaded portion of the clevis. Do not tighten the lock nuts until cylinder head is attached and valves are lashed.
5. Attach the cylinder head (See Sec. 9).

LUBRICATION SYSTEM



1. Oil Pan.
2. Screen—Oil Pump Intake.
3. Pressure Oil Pump.
4. Valve—Pressure Relief.
5. Oil Strainer.
6. Oil Cooler.
7. Oil Manifold in Cylinder Block.
8. Oil Filter.
9. By-Pass Valve.
10. By-Pass Around Strainer and Cooler.

Fig. 1—Schematic Lubrication Diagram Showing Path of Oil Through System Having Single Pressure Pump, Strainer, Cooler, Cleanable Element Filter and Single Sump Oil Pan.

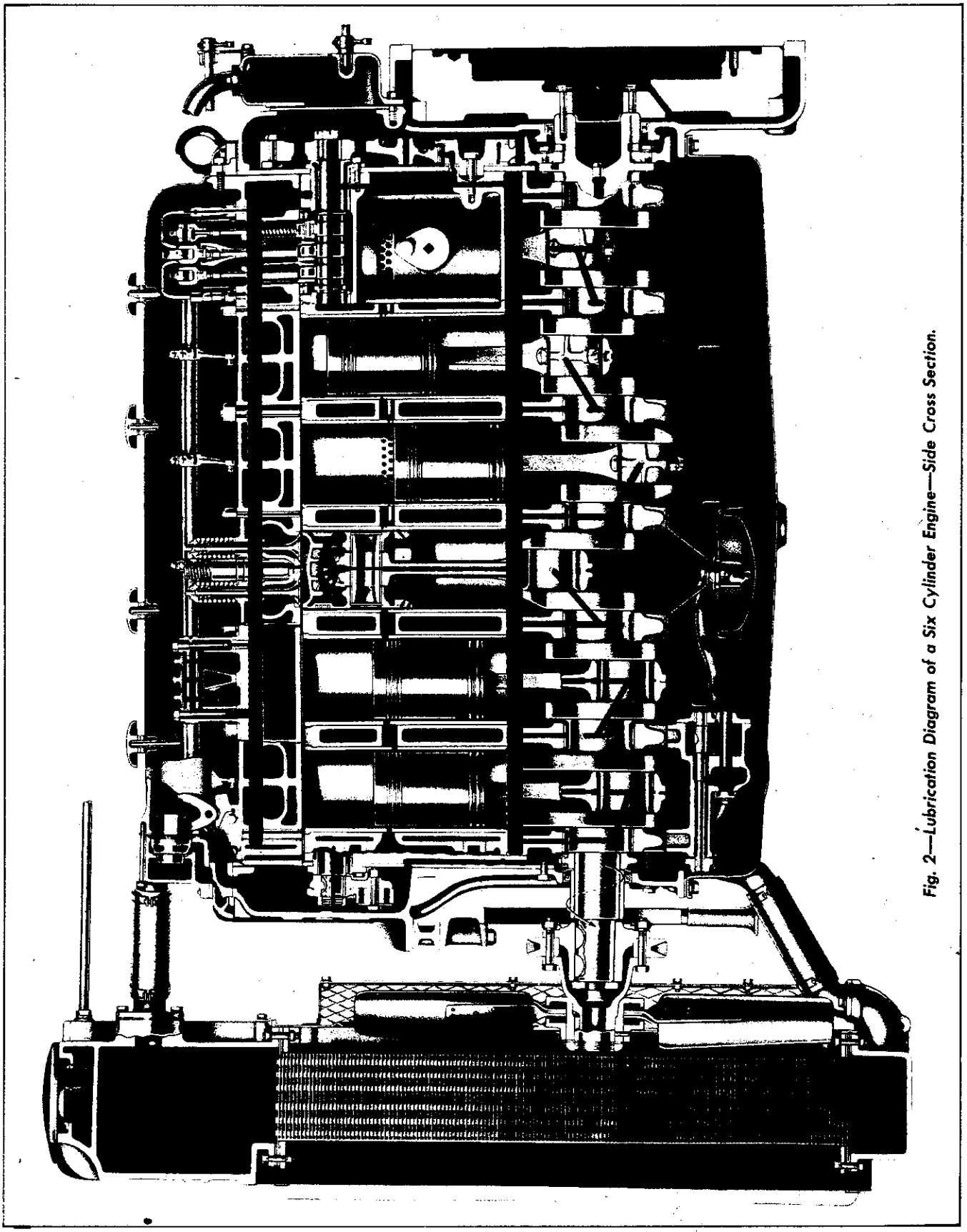


Fig. 2—Lubrication Diagram of a Six Cylinder Engine—Side Cross Section.

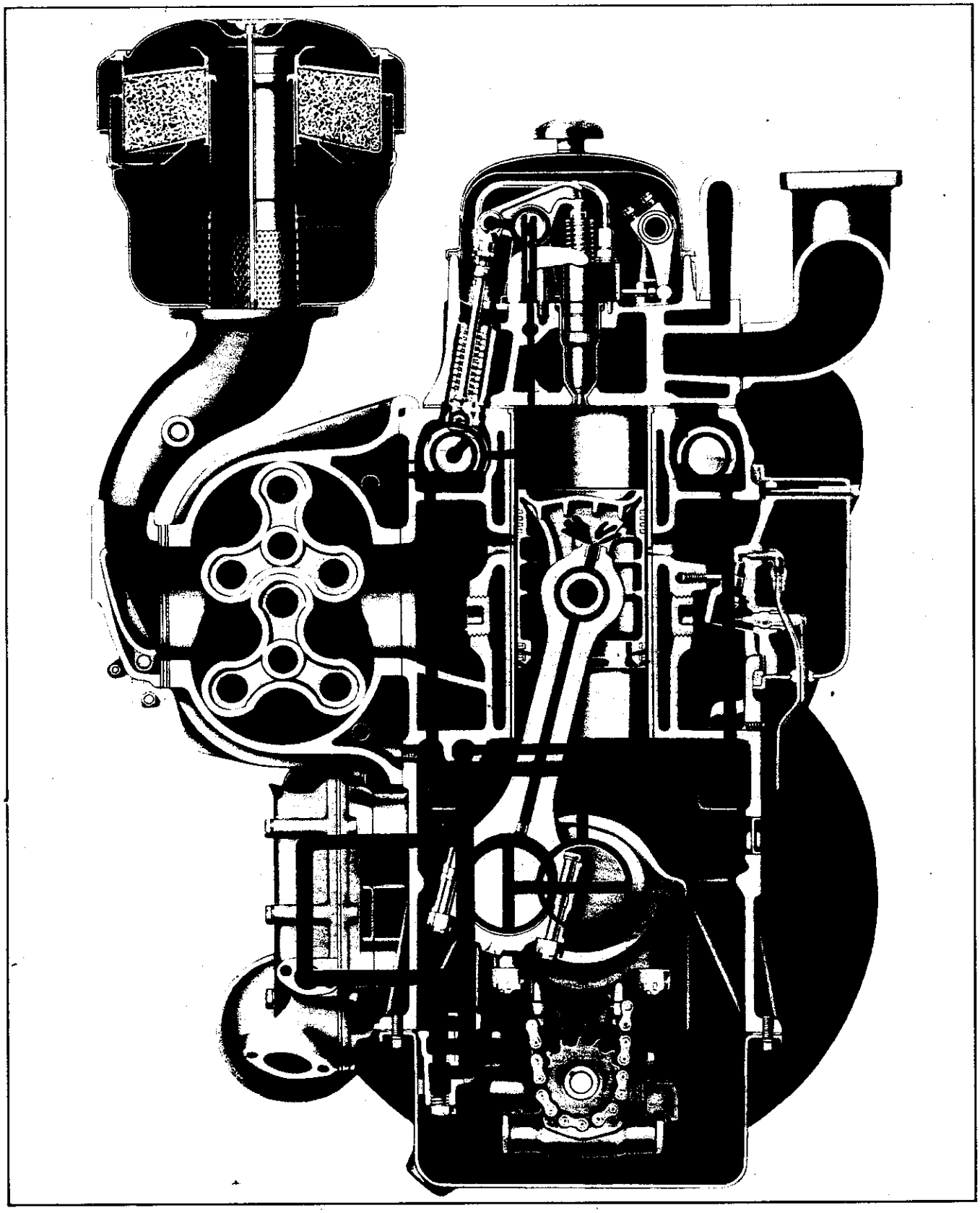


Fig. 2A—Lubrication Diagram—End Cross Section.

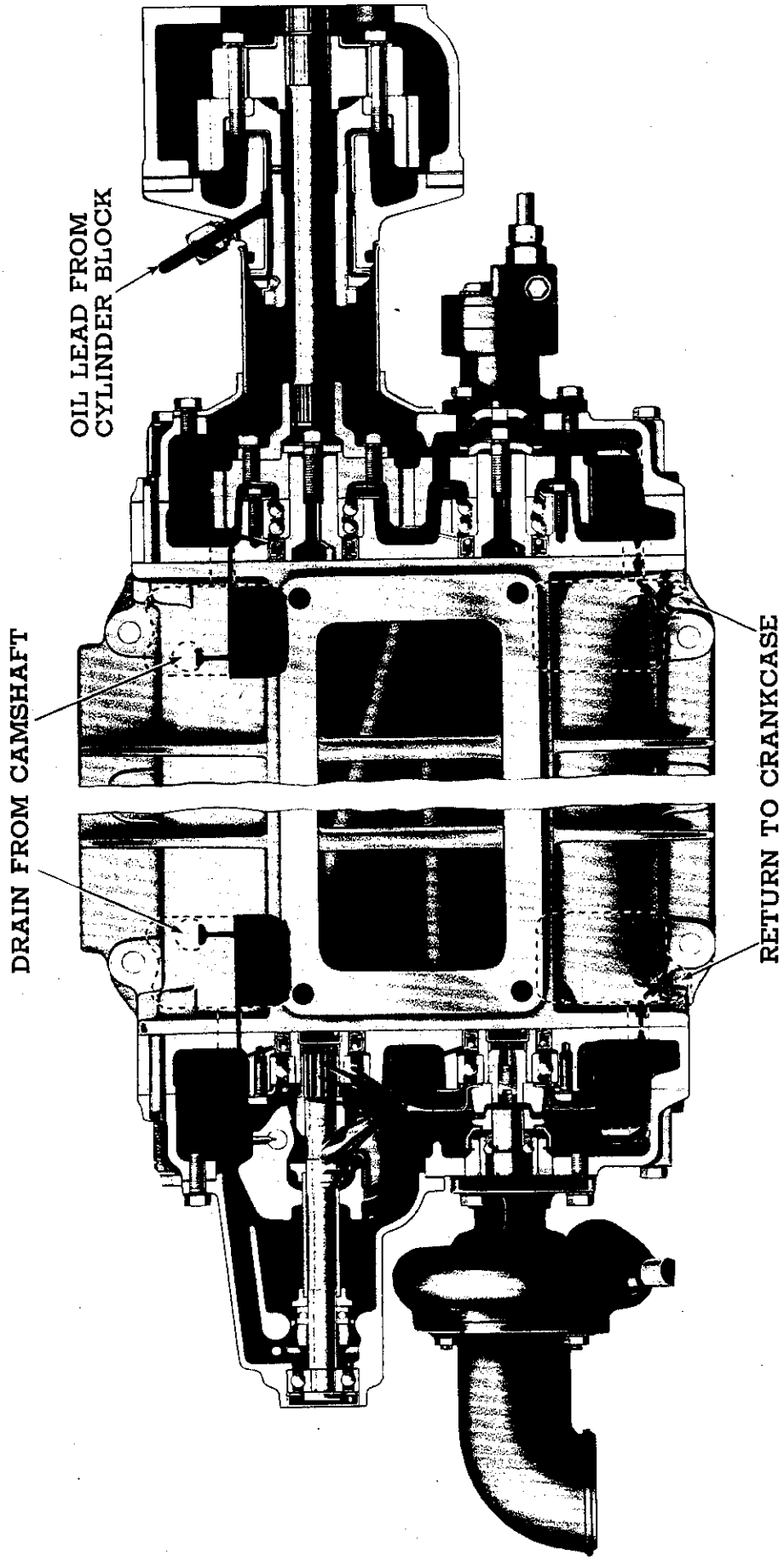
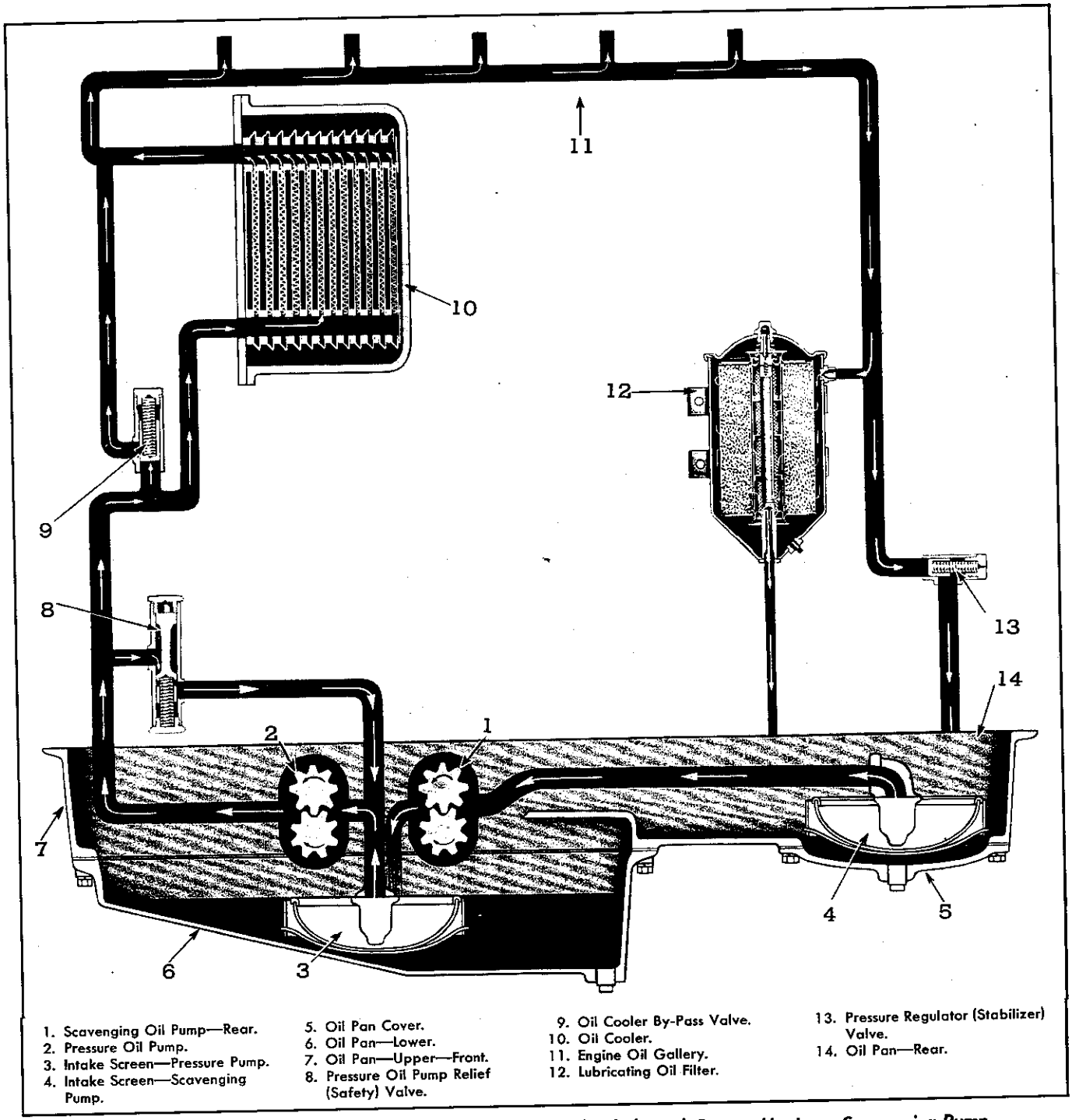


Fig. 28—Lubrication Diagram—Blower and Attached Accessories ("A" and "B" Engine Models).



1. Scavenging Oil Pump—Rear.
2. Pressure Oil Pump.
3. Intake Screen—Pressure Pump.
4. Intake Screen—Scavenging Pump.
5. Oil Pan Cover.
6. Oil Pan—Lower.
7. Oil Pan—Upper—Front.
8. Pressure Oil Pump Relief (Safety) Valve.
9. Oil Cooler By-Pass Valve.
10. Oil Cooler.
11. Engine Oil Gallery.
12. Lubricating Oil Filter.
13. Pressure Regulator (Stabilizer) Valve.
14. Oil Pan—Rear.

Fig. 3—Schematic Lubrication Diagram Showing Path of Oil Through System Having a Scavenging Pump and a Pressure Pump, Cooler, Renewable Element Filter, and a Double Sump Oil Pan.

Lubricating Oil Circulating System—The lubricating system, schematically displayed in Fig. 1, consists of an oil pump, an oil strainer, an oil filter and an oil cooler, with a suitable relief valve in the oil pump, and a by-pass valve between the oil pump and the oil strainer, to insure positive engine lubrication.

The oil strainer is introduced directly into the lubricating system between the oil pump and the oil cooler. All the oil from the pump passes through the strainer.

A spring-loaded by-pass valve, placed in the line between the oil pump and oil strainer, by-passes oil directly from the pump to the lubricating system in

the engine if the pressure at the strainer inlet becomes 25 to 30 pounds greater than the pressure at the cooler outlet.

The oil (sludge) filter, is introduced into the lubricating system beyond the oil cooler, and only a portion of the oil delivered from the pump passes through this unit. Oil entering the filter is bled off one of the oil passages in the cylinder block, forced through the filter packs, and returns directly to the engine crankcase.

Oil circulation is effected by a gear pump which delivers the hot oil through the strainers, then through the oil cooler. After leaving the cooler the stream is delivered directly to the main gallery in the cylinder block. A pipe from the main gallery continuously carries a portion of the oil to the filter for cleaning.

Most engines have a lubricating oil circulation system as described above. However, as shown in Fig. 3, some lubricating systems differ in one or more respects from the preceding description as follows: Some engines do not require an oil strainer, therefore the oil flow is from the pump directly to the oil cooler. On others, the by-pass valve is mounted in the oil cooler cover and a pressure regulator valve, (Fig. 16,) is installed on the lower rear end of the cylinder block at the termination of the oil gallery.

There are also engine models equipped with oil pans which are so constructed that all of the lube oil cannot flow into a main sump. These models have, in addition to the pressure or circulating pump, one or more scavenging pumps. (See Fig. 13.)

The scavenging pump serves as a transfer pump to force the lube oil into an area where it can be picked up by the pressure pump. This type of an assembly consists of separate pumps, each with an individual set of gears in their respective housings and driven from a common shaft. Scavenging pumps do not include a pressure relief valve, but in all other features they are identical with pressure pumps and are serviced alike.

Lubricating Oil Distribution Through Cylinder Block and Bearings—Oil from the cooler is conducted by a vertical passage to a longitudinal main gallery on the blower side of the crankcase. As shown in Fig. 2, this gallery distributes the oil, under pressure, to the main bearings, and to a horizontal, transverse passage at each end of the cylinder block. From these two horizontal passages, two vertical bores at each end of the cylinder block carry the oil to the end bearings of the camshaft and balance shaft, as well as to the oil passage in the camshaft, which conducts the oil to the camshaft intermediate bearings.

Oil for the lubrication of the connecting rod bearings, piston pins, and the cooling of the piston head, is provided through the drilled crankshaft from the adjacent forward main bearings. The gear train is lubricated by the overflow of oil from the camshaft pocket through a communicating passage into the gear train cover. A certain amount of oil spills into the gear cover from the camshaft, balancer shaft, and idler gear bearings. The blower drive gear bearing is lubricated through an external pipe from the rear horizontal oil passage of the cylinder block.

A second longitudinal gallery is arranged on camshaft side of cylinder head and supplied with oil from one of the vertical bores at each end of the cylinder block. Oil from this gallery enters the hollow rocker arm shafts through the rocker shaft brackets, hollow capscrews, and lubricates the rocker arm bearings and push rod clevis bearings.

Excess oil from rocker arms lubricates the valve ends and push rods and drains to cam pockets in cylinder head from which cams are lubricated. As shown in Fig. 2, after reaching a certain level, this oil overflows through two holes at each end of the blower housing, providing lubrication for blower drive gears at rear end and governor drive gear at the front. A dam in the blower housing cover maintains an oil level which submerges the teeth of the lower blower rotor timing gear. A slinger on the opposite end of lower rotor throws oil into the governor weight assembly. Surplus oil passes from the blower to the oil pan through drilled holes in cylinder block.

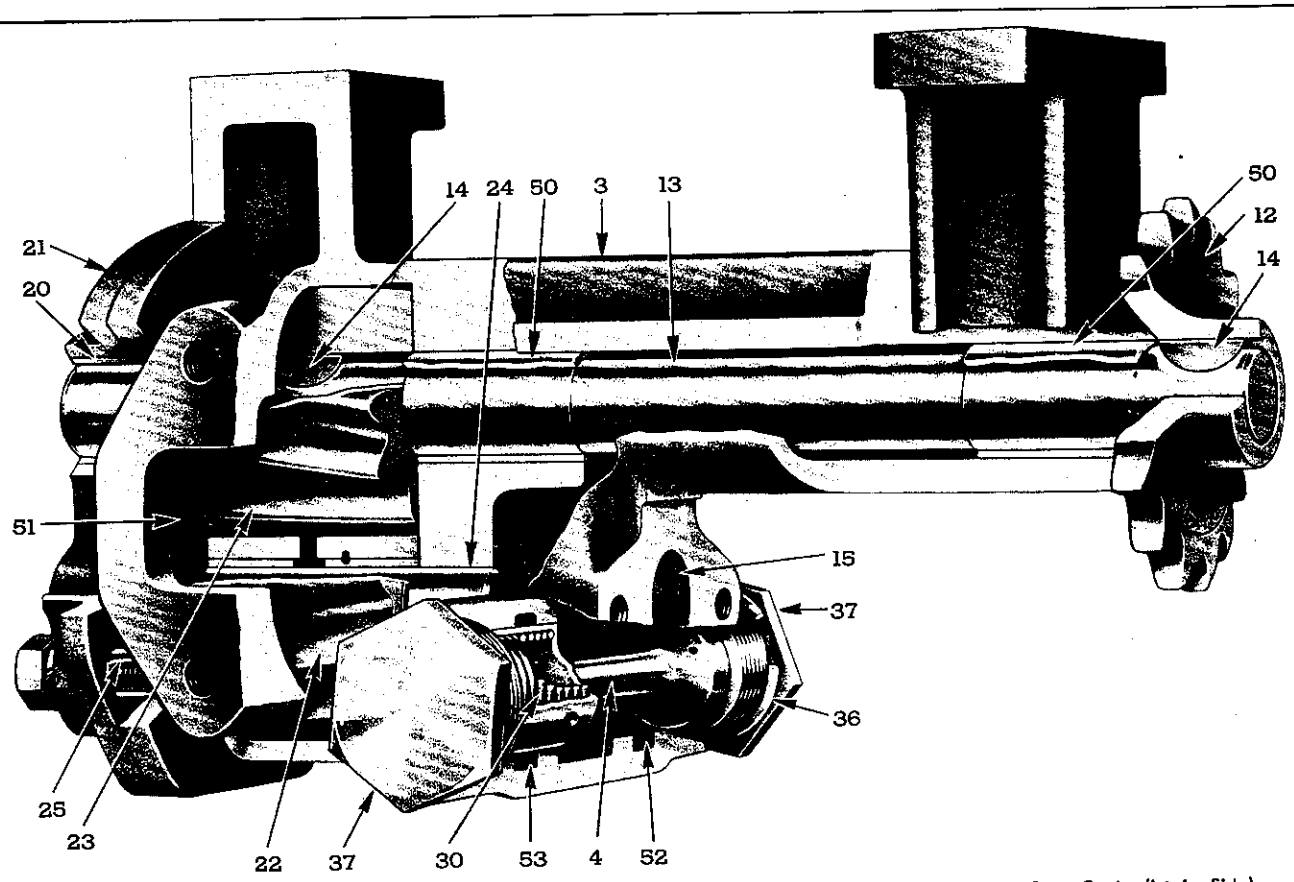
LUBRICATING OIL PUMP

Description—Gear type lubricating oil pumps are used on all engines. All three and four (and some six) cylinder oil pumps are driven by a roller chain from a sprocket on the crankshaft.

On other six cylinder engines the pumps are gear driven. Gears are used instead of sprockets on the pump and crankshaft. A third gear, an idler gear, which rotates on a stub shaft bolted to the crankshaft front cover is installed between and in mesh with the drive and driven gears.

On three and four cylinder engines the drive sprocket is keyed to a sprocket shaft. This shaft is coupled to the oil pump shaft with a self-aligning sleeve with a bearing in a sprocket support. The support is separate from the oil pump proper and is attached to the front main bearing cap. On six cylinder engines the sprocket or gear, whichever is used, is keyed directly to the oil pump shaft.

A plunger type relief valve in the pump body bypasses excess oil to the inlet side of pump when dis-



3. Pump Body.
4. Valve—Pressure Relief.
12. Sprocket—Driven.
13. Drive Shaft.
14. Woodruff Keys.
15. Passage—Oil Pump Outlet.
20. Bushing—Short Drive Shaft.
21. Cover—Oil Pump.
22. Driven Gear and Bushing Assembly.
23. Drive Gear.
24. Shaft—Driven Gear.
25. Hollow Dowel—Cover-to-Body.
30. Spring—Pressure Relief Valve.
36. Copper Gasket.
37. Plug—Relief Valve Retaining.
50. Bushings—Long Drive Shaft.
51. Gear Cavity (Intake Side).
52. Oil Passage (Gear Cavity-to-Pump Outlet).
53. Oil Passage (By-Pass to Intake Side of Gear Cavity).

Fig. 4—Chain Driven Six Cylinder Lubricating Oil Pump Assembly Used in RA, RB, RC and RD Engines.

charge pressure exceeds 100 pounds per square inch approximately.

To accommodate either direction of engine rotation and have the flow of oil through the pump in the proper direction, the relief valve assembly may be changed from one side of the pump housing to the opposite side. When this change is made on the three and four cylinder engines, the pump cover is inverted in order to locate the pump intake on the correct side of the pump.

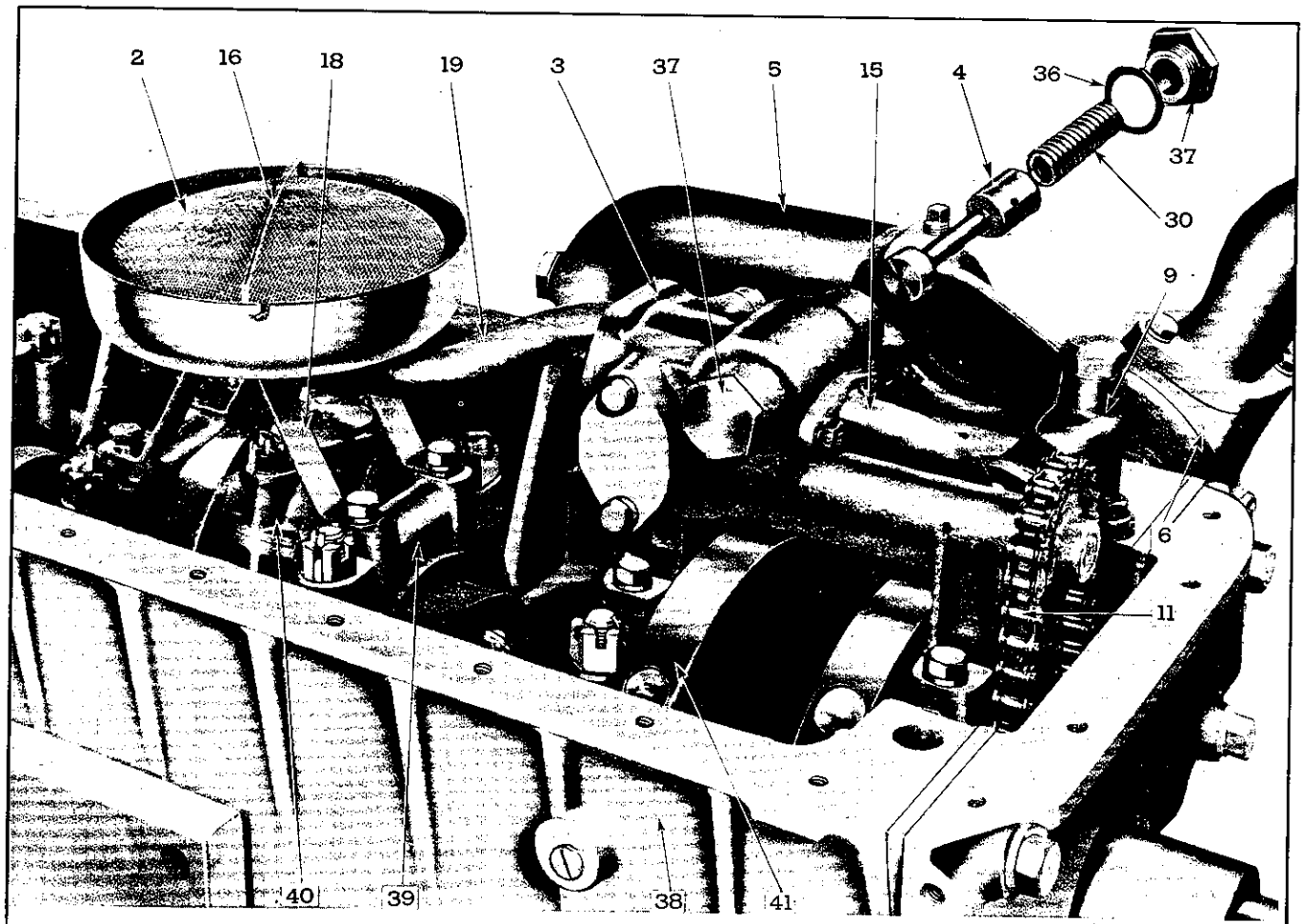
Since the pump intake is attached to the pump body rather than the cover on the pump used with the six cylinder engine, no pump cover change is necessary when transferring the relief valve and pump inlet from one to the opposite side of the pump body. (See Figs. 4, 11, and 12.)

By reference to Fig. 7, it will be noted that the oil pump covers for the three and four cylinder engines are marked "R.H.—TOP" and "L.H.—TOP," indicating the position the cover is assembled to the pump body for either right or left-hand crankshaft. rotation. When the cover is assembled with "R.H.—TOP" at top of pump, it is for use on engine models RA, RB, RC and RD. If assembled with "L.H.—TOP" at top of pump, it is for use on engine models LA, LB, LC and LD.

To protect the oil pump gears, and as an insurance against pump losing its prime, a screen of ample size is attached to the oil pump suction pipe, and partially immersed in the lubricating oil contained in the oil pan.

The oil pump screen, oil strainer, and oil filter all serve to clean the lubricating oil of foreign particles and impurities which might be harmful to the engine bearings. Clean oil and an occasional overhaul of the oil pump if oil becomes sludged, are essential to long engine life.

Service—Due to the simplicity and ruggedness of the lubricating oil pump, service operations on the pump should seldom be necessary. However, for certain connecting rod and main bearing service operations, the lubricating oil pump and inlet screen must be removed from the main bearing caps.



2. Screen—Pump Intake.
3. Pump Body.
4. Valve—Oil Pressure Relief.
5. Strainer—Lubricating Oil.
6. Housing—Oil Cooler.
9. Valve—By-Pass.
11. Chain—Oil Pump Drive.
15. Pipe—Oil Pump Outlet.
16. Retainer—Intake Screen.
18. Bracket—Intake Screen Support.
19. Pipe—Oil Pump Inlet.
30. Spring—Pressure Relief Valve.
36. Gasket—Copper.
37. Plug—Pressure Relief Valve.
38. Cylinder Block.
39. Main Bearing Caps.
40. Connecting Rod.
41. Crankshaft.

Fig. 5—Six Cylinder Lubricating Oil Pump Mounting—With Chain Drive.

Remove Lubricating Oil Pump—To remove the lubricating oil pump from either the three and four or six cylinder engines:

1. Drain oil from oil pan and remove pan.
2. Unfasten oil pump screen retainer and remove screen from cover.
3. Loosen nuts from two bolts holding screen cover to supports and pump inlet pipe and two cap-screws holding inlet pipe to pump body. Remove screen cover, intake pipe and gasket at pump body.
4. Remove two bolts and lockwashers retaining by-pass valve housing to cylinder block, also two bolts and lockwashers retaining oil outlet pipe to pump body. Remove oil outlet pipe and by-pass valve assembly, together with two gaskets.

NOTE: When the by-pass valve is located at some point other than the base of the cylinder block the oil pump outlet is attached directly to the cylinder block.

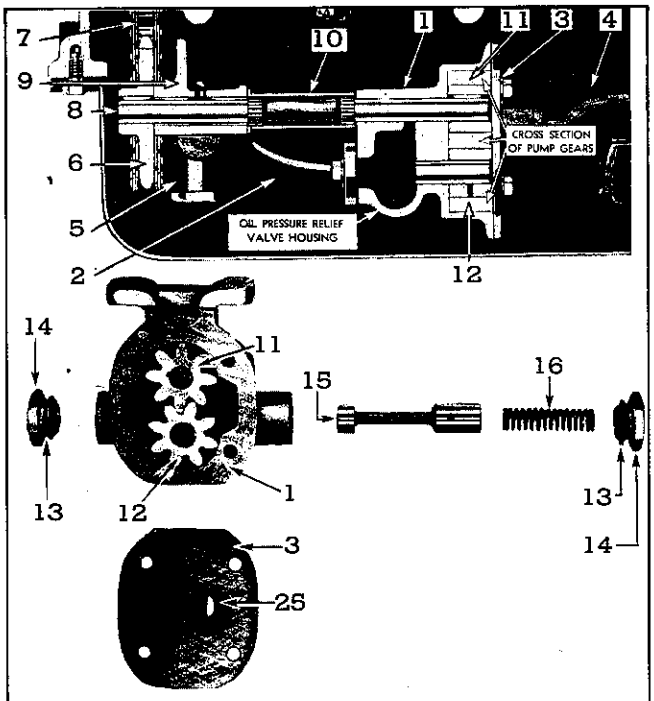
5. On the six cylinder engine, remove four bolts and lockwashers holding pump assembly to main bearing caps, and slip pump shaft sprocket from beneath drive chain. If engine is bottom-side up, support chain to prevent its dropping down inside crankshaft front cover.

   Six-cylinder gear-driven pump is separated from engine by removing four bolts holding pump to main bearing caps.

   On the three and four-cylinder engines, loosen pump assembly from main bearing cap, and slip pump straight back off of shaft drive coupling. Remove coupling with pump.

NOTE: Observe and replace the shims used beneath pump and/or sprocket support. If occasion demands, sprocket support may be released from front main bearing cap and released from chain.

6. Remove screen supports from main bearing caps.



1. Pump Body.
2. Oil Outlet Pipe.
3. Pump Cover.
4. Oil Inlet Pipe.
5. By-pass Valve Assembly.
6. Pump Drive Sprocket.
7. Pump Drive Chain.
8. Sprocket Shaft.
9. Oil Pump Drive Sprocket Support.
10. Oil Pump Shaft Sleeve.
11. Oil Pump Drive Gear.
12. Oil Pump Driven Gear.
13. Copper Gasket.
14. Plug.
15. Relief Valve.
16. Relief Valve Spring.
25. Inlet Port.

Fig. 6—Three and Four Cylinder Lubricating Oil Pump Assembly and Mounting.

Disassemble Oil Pump—Six Cylinder—If the six cylinder oil pump is to be disassembled for inspection or repairs, the work may be carried out as follows:

NOTE: Time will be saved when assembling the oil pump if careful observation is made of the relative location of all pump parts when disassembling.

1. Remove the two retaining nuts and copper gaskets from each side of pump body, and jar relief valve assembly from body.

2. Remove four bolts and lockwashers, and separate pump cover from body.

3. Remove pump idler gear from stub shaft.

4. Support pump body and driveshaft assembly, including sprocket, or gear, in bench vise; then by means of a gear puller, pull sprocket, or gear, from pump shaft, as shown in Fig. 9. Remove Woodruff key from shaft, and withdraw shaft and gear assembly from pump body.

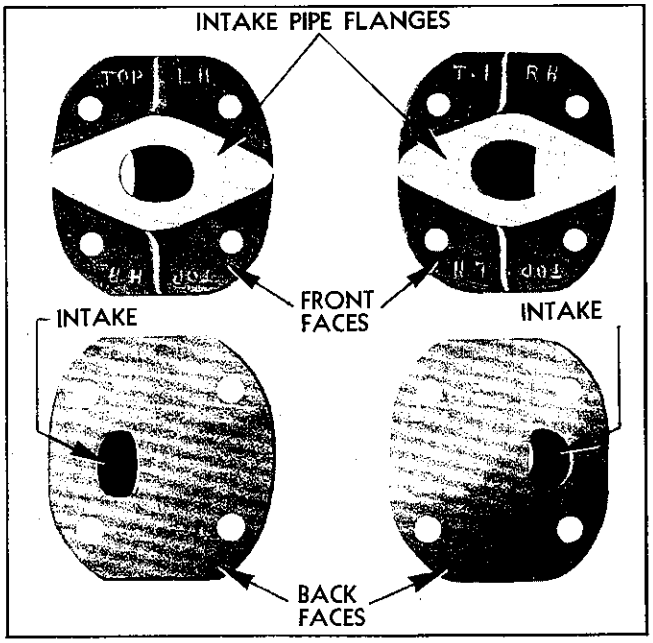


Fig. 7—Oil Pump Covers for Three and Four Cylinder—Left-Hand Views for LA, LB, LC and LD, Right-Hand Views for RA, RB, RC and RD Engines.

5. If gear is to be removed from shaft, place gear and shaft assembly on bed of arbor press with long end of shaft through slot in bed plate and face of gear resting on plate. With arbor on gear end of shaft and under ram of press, press shaft from gear. (See Fig. 10.)

Disassemble Oil Pump—Three and Four Cylinder Engines.

Items 1 to 3 are the same as for the six cylinder engine.

4. Support pump body and drive gear assembly on bed of arbor press—cover side up—and by means of arbor on gear end of pump shaft, press shaft through gear, thus removing gear and feather key from shaft.

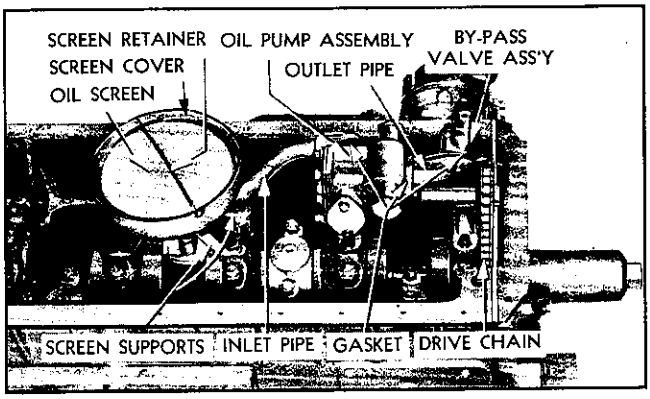


Fig. 8—Three and Four Cylinder Lubricating Oil Pump Mounting.

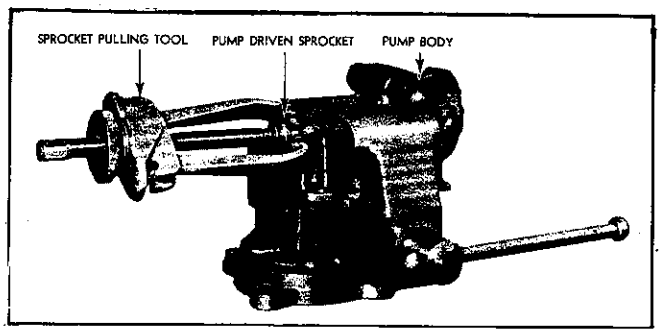
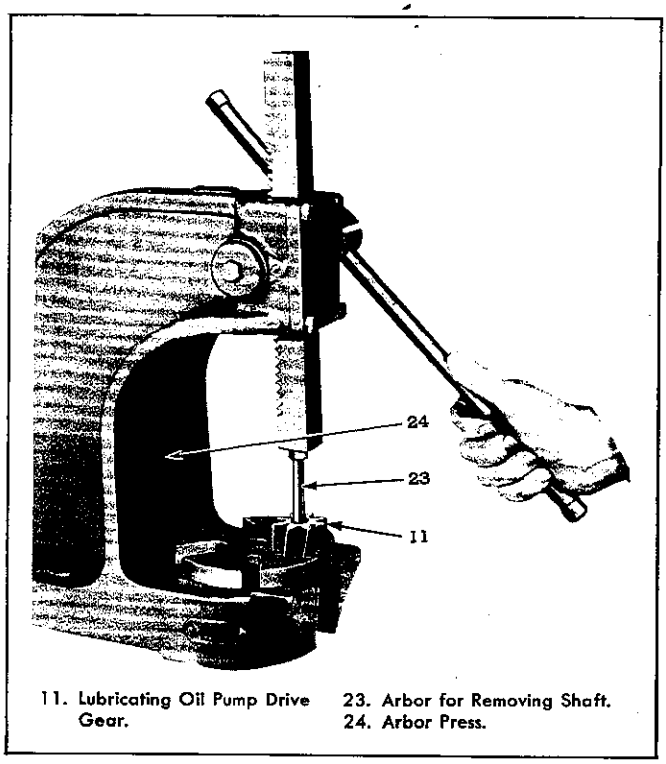


Fig. 9—Pulling Drive Sprocket from Oil Pump Shaft.

NOTE: Be careful not to cover key-way with arbor when removing gear, thereby preventing key from being removed with gear.

Inspection of Lubricating Oil Pump Parts—After washing all lubricating oil pump parts in clean gasoline, all parts may be inspected before re-assembly.

The principal wearing parts of the lubricating oil pump are the gears. If the oil has been kept clean the wear of these parts will be very slow. If, however, dirt and sludge have been allowed to accumulate in the lubricating system, oil pump gear wear may be rather pronounced in a comparatively short time. The oil pump, as well as the other wearing parts of the engine, should be protected against abuse by diligent attention to "Oil Filter Service," as outlined on Pages 16 and 19.



11. Lubricating Oil Pump Drive Gear.
23. Arbor for Removing Shaft.
24. Arbor Press.

Fig. 10—Removing Lubricating Oil Pump Drive Gear from Shaft.

Before assembling pump examine gear teeth, inside of gear housing, and shaft bearings for wear. If gear teeth are scored, or apparently much worn, replace. If gear housing is scored, the pump body and cover should be replaced.

Oil pump gears should be smooth, and without scratches or score marks on their sides. Also, teeth must be smooth without nicks or rough spots. Radial clearance between gears and housing should not exceed .0045″ or be less than .002″. Endwise gear to housing clearance should be between .002″ and .0045″.

Inspect seat and plunger of by-pass valve, and change if necessary.

Assemble Lubricating Oil Pump—Six Cylinder—Since the crankshaft rotation in these engines may be either right-hand or left-hand, this fact must be taken into consideration when assembling the oil pump. The oil pumps for right and left-hand crankshaft rotation differ in two respects:

(a) The location of the pump intake.

(b) The position of the relief valve relative to the pump intake.

When viewing the oil pump from the drive (sprocket or gear) end, the shaft revolves ***clockwise*** on RA, RB, RC and RD engines, and ***counterclockwise*** on LA, LB, LC and LD engines. (See Basic Engine Arrangement, Fig. 7, Sec. 1.)

Again, as viewed from the drive end, the intake will be positioned on left side, and the relief valve spring on same side of the pump for RA, RB, RC and RD engines, and on the right side of the pump for LA, LB, LC and LD engines. (See Figs. 11 and 12.)

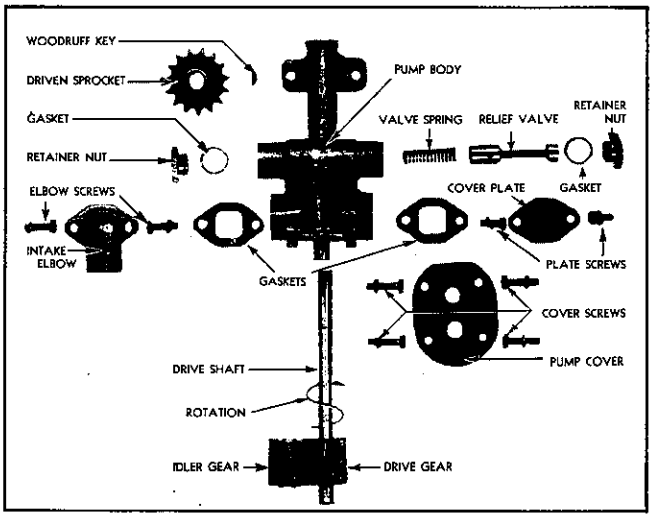


Fig. 11—Six Cylinder Lubricating Oil Pump Details—for RA, RB, RC, and RD Models.

With these identification features in mind, and by reference to Figs. 11 and 12, this Sec., assemble the lubricating oil pump, as follows:

1. The pump gear end of drive shaft has a key-way about 1 5/8" from end of shaft. If gear was removed, install Woodruff key at this position and start gear onto shaft in line with key. Press gear onto shaft with arbor press until inner end of gear is 6 15/32" from drive end of shaft.
2. Lubricate shaft with engine oil, and insert into pump body.
3. Install Woodruff key at sprocket (or drive gear) location, align key-way with key and start sprocket (or gear) onto shaft with flat face facing pump body. Support pump gear end of shaft on bed or arbor press and press sprocket (or gear) onto shaft to within .005" of pump body.
4. Lubricate and position idler gear onto stub shaft.

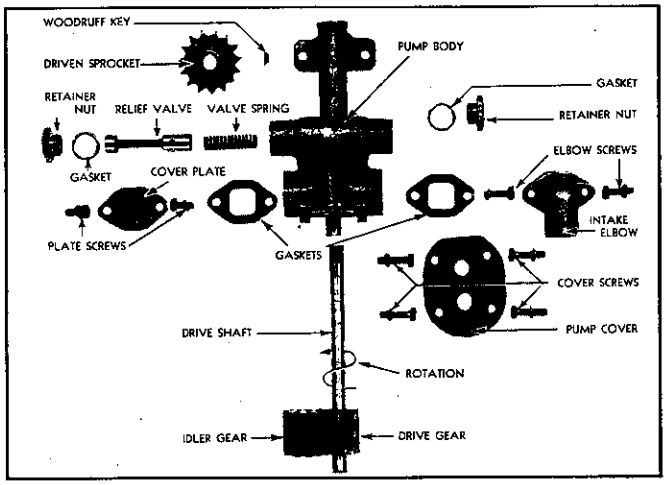
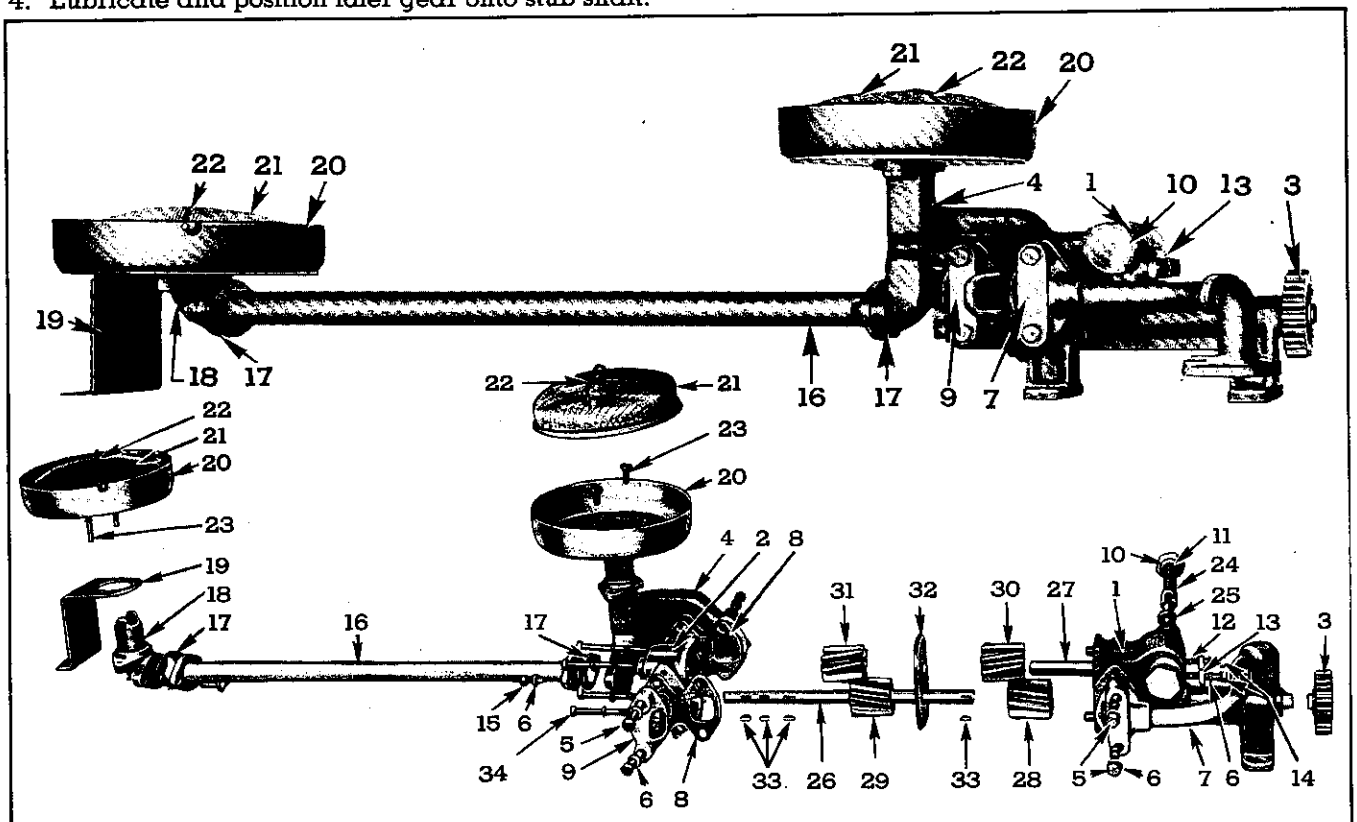
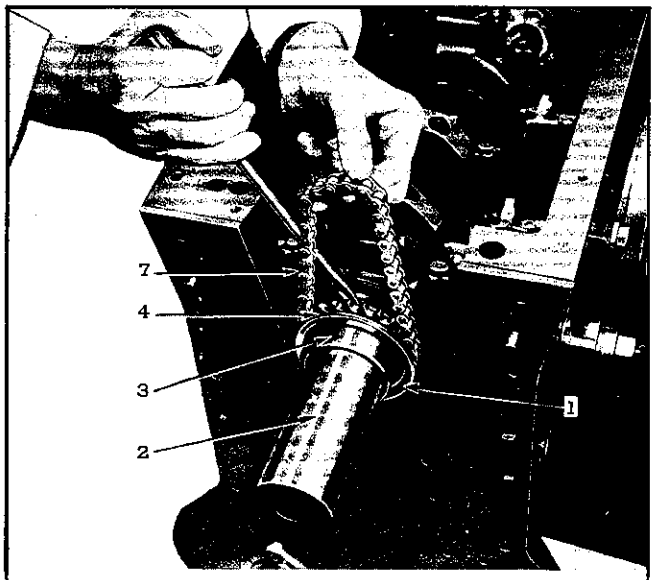


Fig. 12—Six Cylinder Lubricating Oil Pump Details—for LA, LB, LC, and LD Models.



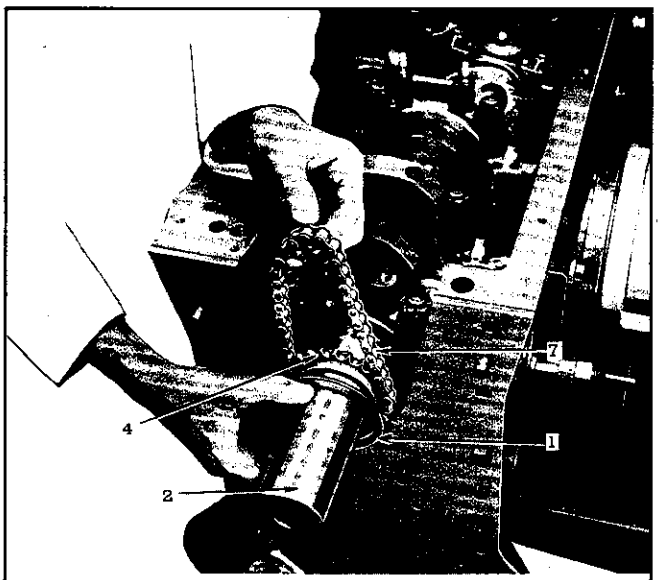
1. Oil Pump Body Assembly—Pressure Pump.
2. Oil Pump Body Assembly—Scavenging Pump.
3. Oil Pump Drive, Driven Gear.
4. Oil Pump Inlet.
5. Bolts.
6. Lock Washers.
7. Oil Pump Outlet Pipe.
8. Gasket.
9. Scavenging Oil Pump Outlet.
10. Relief Valve Plug.
11. Relief Valve Plug Gasket.
12. Oil Pump Pad Cover Gasket.
13. Oil Pump Pad Cover.
14. Bolts.
15. Bolts.
16. Scavenging Oil Pump Inlet Tube.
17. Gasket.
18. Scavenging Pump Screen Support (Inlet Elbow).
19. Scavenging Pump Screen Bracket.
20. Pump Screen Cover
21. Pump Inlet Screen.
22. Screen Retainer.
23. Bolts—Special—5/16-18 x 1 1/16
24. Relief Valve Spring.
25. Relief Valve.
26. Oil Pump Drive Shaft.
27. Idler Gear Shaft.
28. Drive Gear—Pressure Pump
29. Drive Gear—Scavenging Pump.
30. Driven Gear—Pressure Pump.
31. Driven Gear—Scavenging Pump.
32. Spacer.
33. Woodruff Keys.
34. Bolt.

Fig. 13—Details and Relative Location of Parts of a Six Cylinder Lubricating Oil Pump consisting of Pressure and Scavenging Pumps.



1. Oil Slinger.
2. Crankshaft.
3. Spacer.
4. Pump Driving Sprocket (Crankshaft).
7. Pump Drive Chain.

Fig. 14—Removing Lubricating Oil Pump Driving Sprocket from Crankshaft.



1. Oil Slinger.
2. Crankshaft.
4. Pump Driving Sprocket (Crankshaft).
7. Pump Drive Chain.

Fig. 15—Replacing Lubricating Oil Pump Driving Sprocket on Crankshaft.

5. See that finished face of pump cover is perfectly flat to make tight joint between cover and pump body and bolt cover in place with four lockwashers and capscrews.

NOTE: No gasket is used at this joint.

6. Note on what engine model the pump is to be used, then refer to Figs. 11 and 12, and assemble the relief valve in the pump body. As viewed from sprocket (or gear) end of pump, the intake and relief valve spring will both be on left side of pump for RA, RB, RC and RD model engines, and on right side of pump for LA, LB, LC and LD model engines.

CAUTION: After pump is assembled, revolve shaft by hand for any bind. Pump shaft must turn freely when pump is completely assembled.

Assemble Lubricating Oil Pump—Three and Four Cylinder Engines.

1. Lubricate pump shaft with engine oil and slide shaft into pump body. Install feather key in shaft and place drive gear on shaft with key-way in line with key; then support splined end of pump shaft on bed of arbor press, and press gear into position just flush with end of shaft.

2. Position idler gear on stub shaft.

   By reference to Figs. 6 and 7, it will be noted that the oil pump covers for the three and four cylinder engines are marked "R.H.—TOP" and "L.H.—TOP," indicating the position the cover is assembled to the pump body for either right or left hand crankshaft rotation. When the cover is assembled with "R.H.—TOP" at top of pump, it is for use on engine models RA, RB, RC and RD. If assembled with "L.H.—TOP" at top of pump, it is for use on engine models LA, LB, LC and LD. With this identification in mind, attach pump cover with four lockwashers and capscrews. Be sure finished face of cover is perfectly flat and smooth before attaching to pump.

3. Bear in mind that spring and relief valve assembly is always on same side of pump as the intake; then lubricate piston and install relief valve assembly, being sure that copper gaskets are next to heads of both retaining nuts.

CAUTION: After pump is assembled, revolve shaft by hand for any bind. Pump shaft must turn freely when pump is completely assembled.

Replace Lubricating Oil Pump—With main bearing caps in place and the pump drive chain in position on the crankshaft sprocket, the lubricating oil pump may be installed as follows:

1. On the six cylinder, work sprocket on pump shaft under drive chain, install capscrews, and lock in position. Measure side movement (tension) of chain, one side only, at a point in line with the bottom face of cylinder block. This side movement should be $\frac{7}{16}'' \pm \frac{1}{16}''$. If necessary to adjust the chain tension, remove attaching capscrews and remove or install an equal number of .005" shims under both legs of oil pump. When tension is cor-

rectly set, re-install attaching bolts but do not lock in position until inlet and outlet pipes have been connected.

NOTE: On gear driven pumps, back lash between the pump gear and the idler gear is .005" to .012". Removing or adding a .005" shim between pump feet and bearing caps changes the back lash .0035".

CAUTION: The above clearance measurements are always to be taken with the pump locked securely in its normal operating position.

On the three and four cylinder, if driven sprocket and bearing assembly was removed, slip drive coupling onto end of sprocket shaft and work sprocket under drive chain. Insert .005" shims under bracket feet to give proper chain tension, as described above. Secure assembly to front main bearing cap with two lockwashers and bolts. Insert an equal number of .005" shims under pump feet to align pump shaft with sprocket shaft. Secure pump to main bearing cap. Move coupling endwise to check alignment of shafts. Coupling must be free on both shafts when assemblies are tightened in place.

2. If by-pass is to be reinstalled, using new gasket, attach by-pass valve housing to cylinder block with two lockwashers and bolts.
3. Using new gasket at each end, attach oil outlet pipe to by-pass valve housing (or cylinder block) and oil pump body, with two lockwashers and bolts at each end.

CAUTION: The two bolts for oil outlet pipe to pump body must not exceed 7/8" in length. Longer bolts will extend into housing and damage gears.

When tightening bolts on oil outlet pipe, shift drive coupling endwise at the same time. If coupling binds on shafts, loosen and shift sprocket bearing assembly, or perhaps outlet pipe, then retighten so coupling is free.

4. Position screen supports on the two correct main bearing caps and with lockwashers on bolts, start bolts in place. Do not tighten.
5. Using new gasket at pump end, secure oil inlet pipe to pump body for six cylinder or pump cover for three and four cylinder.
6. Set screen cover—screen side facing oil pan—over casting at outer end of oil inlet pipe and bolt to outlet pipe casting and screen supports. Tighten screen supports to bearing caps.
7. Attach oil screen and lock in place with wire retainer.
8. Re-check all bolts for tightness to make sure there will be no oil leaks in connection with the pump installation.
9. Replace oil pan and supply the proper viscosity oil to the prescribed oil level as indicated on oil gauge stick.

Remove Lubricating Oil Pump Drive Sprocket and Chain (or Gear) from Crankshaft (Oil Pan Removed).

1. Remove crankshaft cap and any accessories—pulleys or vibration dampers) from front end of crankshaft (see Sec. 5, Page 6, for vibration damper removal instructions).
2. Remove the bolts which attach crankshaft front cover to cylinder block. Note different sizes and lengths of bolts supporting this cover.
3. For the three and four-cylinder engines, disconnect oil outlet pipe from pump, and sprocket bearing assembly. Also loosen sprocket bearing assembly from front main bearing cap.

   For the six cylinder engine remove lubricating oil pump. (See "Remove Lubricating Oil Pump," Page 8.)
4. Place screwdriver back of drive sprocket, as shown in Fig. 14, or use suitable puller on gear, and remove drive from crankshaft. Slide oil slinger "F" and spacer "G" off end of crankshaft.

Replace Lubricating Oil Pump Drive (Sprocket and Chain or Gear) on Crankshaft.

1. The chamfered side of sprocket, or raised-hub side of gear, faces the main bearing cap. Place Woodruff key in crankshaft. Slide sprocket and chain, as shown in Fig. 15, or gear, on crankshaft and up against main bearing cap.
2. Slide the oil slinger over crankshaft with dished outer diameter away from sprocket or gear. (See Fig. 15.)

Do not put spacer or cone next to oil slinger until after the front cover has been put in place. The oil seal in front cover may be damaged if slid over the spacer or cone.

NOTE: The spacer is not included on engines equipped with vibration dampers because the damper rear cone serves the same purpose.

3. For the three and four cylinder engine, install the pump driven sprocket and bearing assembly to front main bearing cap. On the six cylinder engine, install lubricating oil pump. (See "Replace Lubricating Oil Pump," Page 12.)
4. Slide the crankshaft front cover into position over dowel pins and secure with lockwashers and bolts. Note different sizes and different lengths of bolts are used in the cover.
5. Slide the spacer (or vibration rear cone) over crankshaft, through the oil seal in cover, and up against the oil slinger, as shown in Fig. 2, Sec. 5.

See that the outer diameter of the spacer (or cone) is smooth, as this surface rubs on the oil seal to prevent oil leaks through the cover.

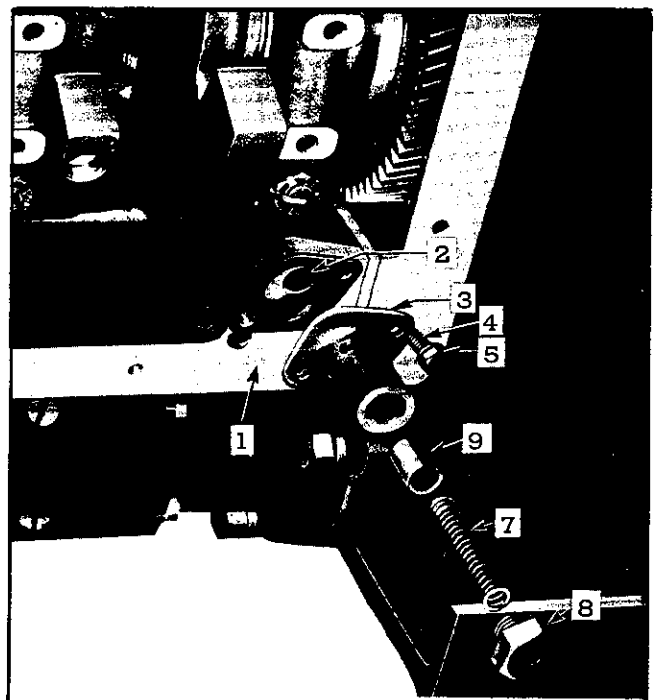
6. If accessories such as pulleys or vibration dampers have been previously removed, reinstall these parts, followed by the crankshaft cap and attaching bolt. (See Sec. 5, Page 7, for vibration damper installation instructions.)

LUBRICATING OIL PRESSURE REGULATOR VALVE

Description—Stabilized lubricating oil pressure is maintained within the engine at all speeds, regardless of oil temperature, by means of a regulator valve located at the rear end of the cylinder block and at the termination of the oil gallery, as shown in Fig. 16.

The regulator valve assembly consists of a hollow piston-type valve, a compression spring, a plug to retain the spring and a valve body.

The valve is held on its seat by the spring, which is held in compression by the plug screwed into the valve opening in the valve body. The entire assembly is bolted to the lower flange of the cylinder block and sealed against oil leaks by a gasket between the two members. When conditions are such that the oil pressure at the valve exceeds 45 pounds per square inch, the valve is lifted from its seat and oil from the engine gallery is by-passed to the engine crankcase. Thus stabilized lubricating oil pressure is maintained at all times regardless of oil temperature.



1. Cylinder Block.
2. Gasket—Cylinder Block-to-Valve Body.
3. Regulator Valve Body.
4. Cap Screw.
5. Lockwasher.
6. Regulator Valve.
7. Spring—Regulator Valve
8. Plug—Valve Body.

Fig. 16—Lubricating Oil Pressure Regulator Valve and Relative Position of Parts.

Service—Under normal conditions, the pressure regulator valve should require very little attention. If the lubricating system has been allowed to sludge up, the regulator valve may not work freely, thereby remaining open or failing to open at the normal operating pressure.

Whenever the lubricating oil pump is removed for inspection, the regulator valve and spring assembly should be removed also, thoroughly cleaned in fuel oil and inspected for fits.

The valve assembly may be removed from the cylinder block and the valve from the body as outlined below.

Remove Oil Regulator Valve Assembly from Cylinder Block—To remove the regulator valve assembly from the cylinder block:

1. Remove the two valve body-to-cylinder block bolts and lockwashers.
2. Strike lower end of valve body lightly to separate body from gasket and cylinder block. Remove gasket.

Disassemble Oil Regulator Valve The regulator valve may be disassembled as follows:

1. Clamp flange of valve body in bench vise and remove plug from valve body.
2. Remove spring and valve from valve body.

Inspection—After removal and before assembly, the regulator valve body and parts should be thoroughly cleaned in fuel oil, oil passages cleaned, parts and passages dried with compressed air, then parts inspected before assembly.

All oil passages must be open and the valve free from score marks. The valve must move freely in the valve body.

Assemble Oil Regulator Valve—All parts having been cleaned and inspected, refer to Fig. 16 for relative location and position of parts and assemble the lubricating oil regulator valve as follows:

1. Apply some clean engine oil to outside of valve (6) and position valve in valve body (3) with open end of valve towards threaded end of valve opening.
2. Put spring (7) inside valve (6), and while compressing spring, start plug (8) into valve body. Tighten plug.

Attach Oil Regulator Valve Assembly to Cylinder Block—After assembly, and by reference to Fig. 16, the lubricating oil regulator valve may be attached to the cylinder block as follows:

1. Remove all traces of old gasket from valve body and cylinder block.
2. Affix new gasket (2) to regulator valve body so that opening in gasket registers with hole in body.
3. Attach body to cylinder block with two bolts (4) and lockwashers (5). Draw body tight against gasket.

LUBRICATING OIL FILTERS

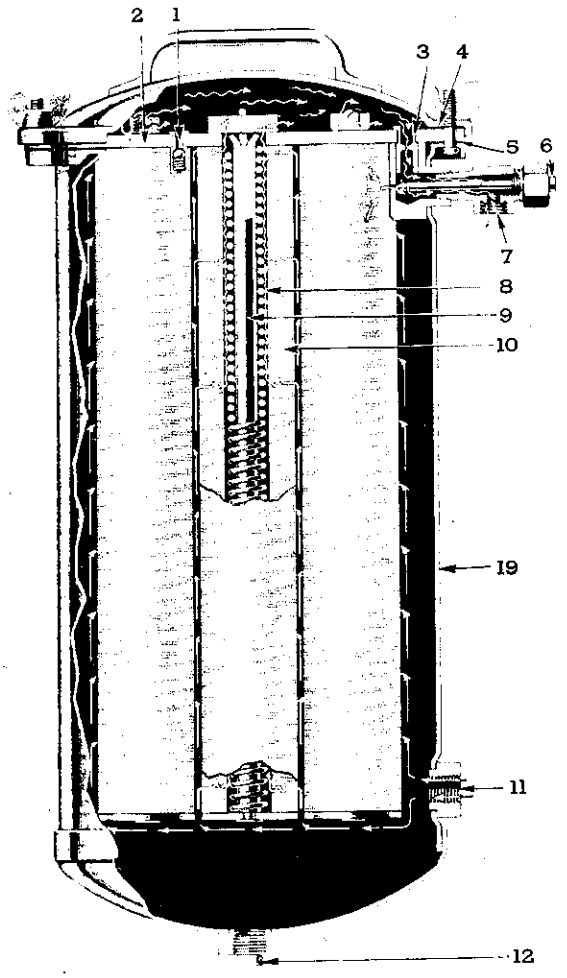
Description—Each engine is equipped with a sludge filter which is introduced into the lubricating system as shown in Fig. 1. The filter elements or cartridges are not the same for all model engines, some being the cleanable type and others the replaceable type. However, regardless of the type of filter element used, all filters are introduced into the lubricating system as illustrated and in such a manner that a portion of the lube oil flowing in the oil galleries passes through the filter before returning to the engine crankcase. Continuous filtering of the lubricating oil is thus maintained as long as the filter is properly serviced.

Filters are bolted to the side of the engine crankcase and connected on the intake side from the engine oil gallery and on discharge side to the engine crankcase. Filter elements are contained inside a steel body and mounted to the filter cover. A portion of the oil from the engine oil galleries enters the steel body and passes through the element to the head of the filter. From the space in the head, oil passes through a connection and tube when it is returned to the engine crankcase. The extremely fine filtration, which is largely mechanical, causes the solids and moisture to be deposited on the outer edge of the filter element.

Cleanable Type Lubricating Oil Filter—In order to insure proper oil temperature in the filter, a small amount of oil short-circuits the filter element so that the oil in the filter is kept at substantially the same temperature as that in the engine. The quantity of oil necessary to maintain this temperature is, in this type, controlled by an adjustable valve in the outlet of the filter element.

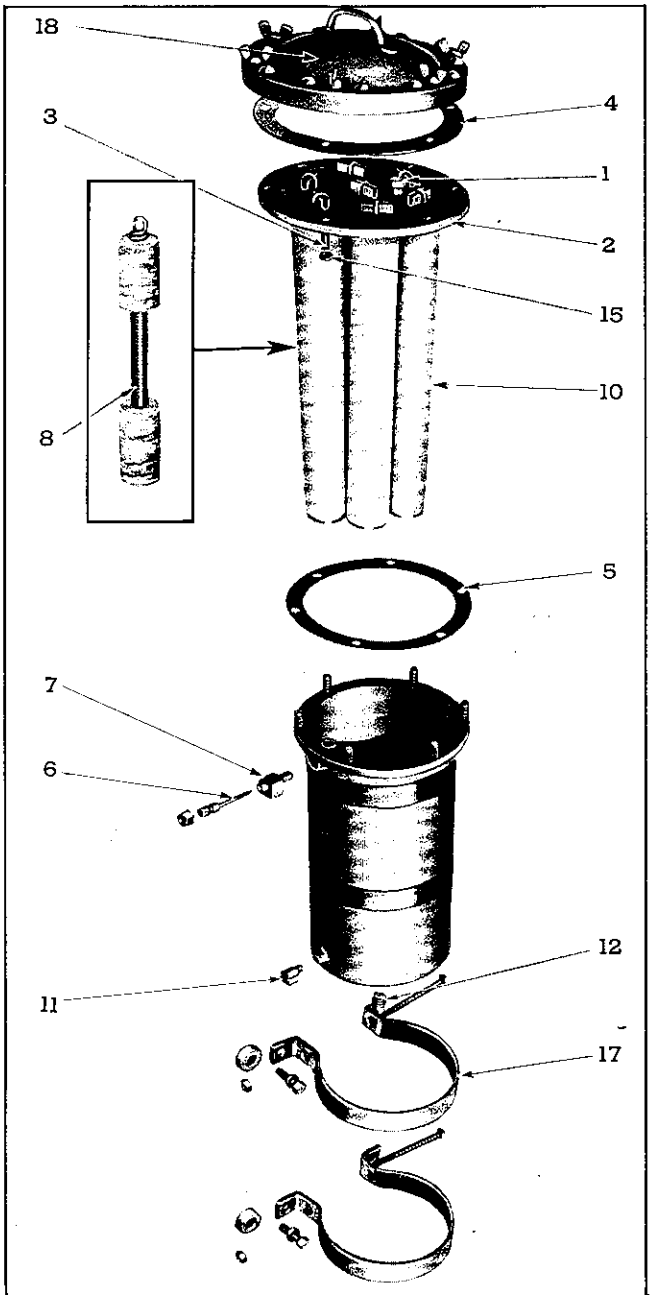
This by-pass type filter (continuously filtering a small portion of the lubricating oil during engine operation) has a cleaning element consisting of a group of circular filter packs as shown in Fig. 16. Each pack is made up of a quantity of thin paper discs stacked on coiled springs fastened to the division plate. The springs retain the discs under compression, restricting the flow of oil to the extent that only the clean oil passes between the discs, the impurities being deposited on the outer edges of the discs.

Operation—Oil from the engine oil gallery enters the steel body, passes between the thin paper discs, up the hollow center of the packs and through the division plate. From the space between the cover and the division plate, the clean oil passes through oil outlet nipple, control valve, oil outlet, and the outlet tube and into the crankcase.



1. Valve—Air Relief.
2. Division Plate.
3. Nipple—Oil Outlet.
4. Gasket—Plate-to-Cover.
5. Gasket—Plate-to-Body.
6. Control Valve.
7. Oil Outlet.
8. Spring—Pack Compression.
9. Holder—Compression Spring.
10. Filter Pack.
11. Oil Inlet.
12. Plug—Oil Drain.
19. Steel Body.

Fig. 17—Cleanable Type Lubricating Oil Filter Assembly.



1. Valve—Air Relief.
2. Division Plate.
3. Nipple—Oil Outlet.
4. Gasket—Plate-to-Cover.
5. Gasket—Plate-to-Tank.
6. Control Valve.
7. Oil Outlet.
8. Spring—Pack Compression.
10. Filter Pack.
11. Oil Inlet.
12. Plug—Oil Drain.
15. Felt Seal.
17. Mounting Bracket.
18. Cover.

Fig. 18—Details of Cleanable Type Lubricating Oil Filter.

A small amount of oil, the flow of which is regulated by the control valve, is permitted to by-pass the filter packs after entering the steel body. The regulated flow determines the operating temperature of the filter, and this temperature should be as close as possible to that of the oil in the engine. Hot oil is more effectively filtered than cool oil, the contaminating solids being more readily separated from the thinner liquid. Under ordinary conditions, the needle valve should be open ½ turn. Lower filter operating temperatures indicate that the valve by-pass opening is clogged. In this event close valve, then open ½ turn.

The filter is bolted to the side of the engine crankcase, and connected, on the intake side, from the engine oil gallery and, on the discharge side, to the engine crankcase.

Service—Due to the impurities collecting on the edges of the filter, the rate of oil flow slows up gradually and it becomes necessary to remove the collected impurities from the edges of the paper discs. The slowing up or time between cleaning is determined entirely by the condition of the engine and the service under which the engine is operated. Normally, cleaning is advised every 128 hours of engine operation.

The normal life of the flexible paper filter discs or pack is a year or more. If when the packs are being cleaned by compressed air or when cleaning with a brush, a crack in the pack is noticed, which might be due to a torn flexible disc, the complete pack unit should be changed. If the oil is not properly cleaned during the normal operation of the engine, and when frequent cleaning or blowing does not restore the filter to its original filtering capacity, the packs should be renewed.

Cleaning Lubricating Oil Filter—Cleanable Pack (Sludge) Type—To clean the sludge filter:

1. Shut off the oil intake valve at the bottom of the filtering unit. (If one is used.)
2. Remove wing nuts at the top of the filter and lift the complete assembly out of the steel body.
3. (a) When air pressure is available, attach Schrader connection with a clip to the small oil outlet on the underside of the pack head. which is located between the filtering packs. Allow the air to blow through the filtering packs at least five or ten minutes. The cake of impurities will slide off the packs. When white foam appears the entire length of the packs, they are clean, and have been subjected to blowing for a sufficient length of time. (See Fig. 19.)

   (b) If compressed air is not available, use scraper and brush furnished with the equipment. Scrape off the heavy cake of solids and other contaminations that have collected on the outer edge of the flexible paper discs. Then using fuel oil, or kerosene, clean the outside of the packs, with the circular brush supplied so that the edge of the flexible paper discs are clean and free from any contaminations. (See Figs. 20 and 21.)

4. Replace filter pack head assembly to filter.

NOTE: Be sure oil inlet valve is turned on. If this valve is closed, no filtering of the oil takes place.

Due to the impurities collecting on the edges of the filter, the rate of oil flow slows up gradually. It is necessary to remove the collected impurities from the edges of the paper discs. The slowing up or time between cleaning is determined entirely by the condition of the engine and the service under which the engine is operated. Clean filter when oil color begins to darken.

Changing Filter Packs (Cleanable Pack Type Filter)—The normal life of the flexible paper filter discs or pack is a year or more. If when the packs are being cleaned by compressed air or when cleaning with a brush, a crack in the pack is noticed, which might be due to a torn flexible disc, the complete pack unit should be changed. If the oil is not properly cleaned during the normal operation of the engine, and when frequent cleaning or blowing does not restore the filter to its original filtering capacity, the packs should be renewed.

1. Remove the wing nuts on top of the filter and lift the complete assembly out of the steel body.
2. Remove the screws holding the plate assembly to the filter cover and hold the plate assembly in a vise. Using the special hook provided with the replacement pack, pull the spring to release the tension on the holding pin and remove the pin. All the packs are removed in this manner. Remove the old filter flexible paper discs from the springs and wash springs thoroughly in kerosene, gasoline, carbon tetrachloride or fuel oil.
3. Place the new filter pack assembly in the special V blocks which are supplied with each replacement pack. Insert the spring through the center hole in the paper discs, then place a second V block on the pack assembly, and line this complete unit up with one of the holes in the plate assembly. Push the special hook through the hole in the plate assembly, hook it to the eye of the spring, then pull the pack assembly against the plate so pin can be inserted in eye of spring. Hold the V blocks around the packs firmly while doing this to keep the discs in line. The rest of the packs may be assembled in the same manner.

NOTE: Be sure that the outer edges of the packs are absolutely smooth and in perfect alignment, as it aids in the cleaning of the packs and giving proper filtration.

4. After the packs are all assembled on the plate, screw the center plate assembly to the filter cover and replace the complete assembly in the steel body, the same as when cleaning the filter.

NOTE: Be sure that the oil inlet valve is turned on. If this valve is closed, no filtering of the oil takes place.

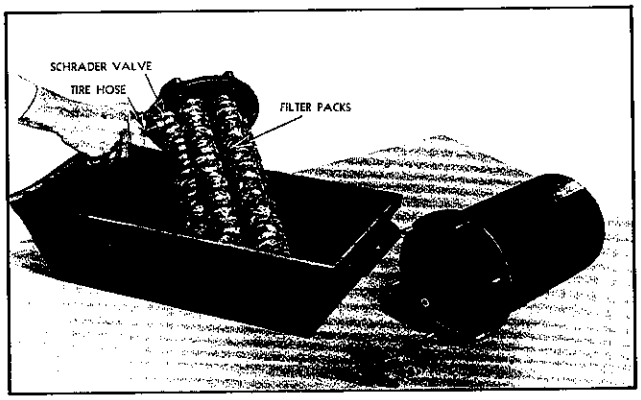


Fig. 19—Cleaning Lubricating Oil Filter Packs with Schrader Connection.

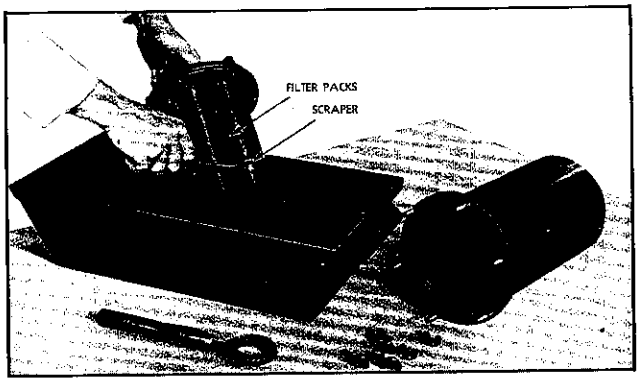


Fig. 20—Cleaning Lubricating Oil Filter Packs with Scraper (Operation 1).

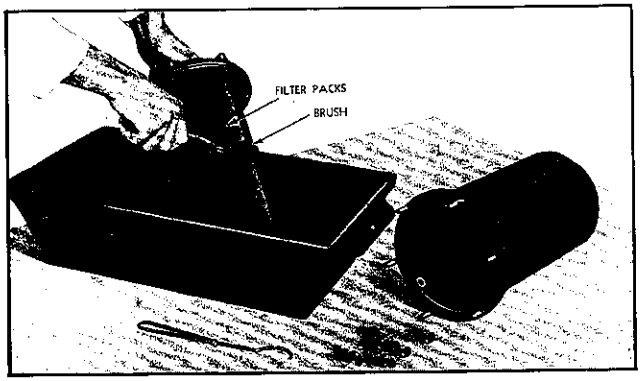
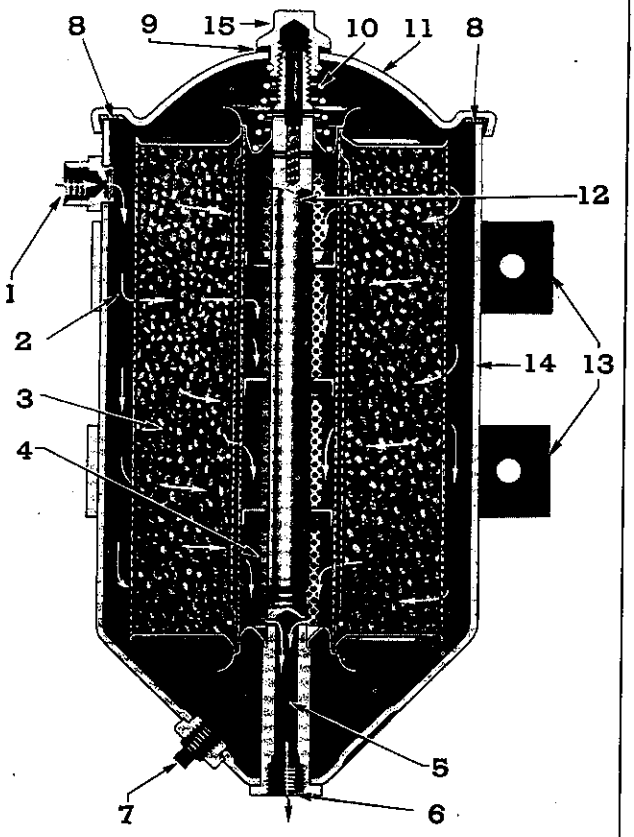


Fig. 21—Cleaning Lubricating Oil Filter Packs with Brush (Operation 2).

Replaceable Element Type Lubricating Oil Filter—A steel housing and a stamped steel cover constitute the main structural part of this filter. A readily replaceable filtering element is carried inside the housing and held in position with a coil spring at the top. To provide maximum cleaning, the element is composed of a fabric-sheathed, perforated metal cylinder, surrounded by a thick layer of special absorbent material. This element slides over and is positioned by a shoulder on a center tube within the steel housing. When the cover is in place, the filter

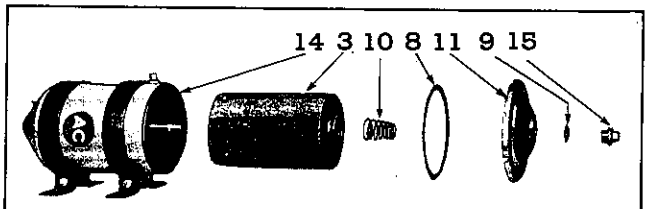


1. Oil Inlet.
2. Space Between Filter Housing and Filter Element—Filled with Unclean Lub. Oil.
3. Filter Element.
4. Passage for Clean Lub. Oil.
5. Passage for Clean Lub. Oil.
6. Clean Oil Discharge—To Crankcase.
7. Drain Plug.
8. Housing Cover Gasket.
9. Retainer Nut Gasket.
10. Element Seating Spring.
11. Housing Cover
12. Center Stud.
13. Support Bracket.
14. Filter Housing.
15. Retainer Nut.

Fig. 22—Replaceable Element Type Lubricating Oil Filter Assembly.

element is restrained from movement by the coil spring at the top, which is attached to the cover nut and bears against the element.

Operation—A shown in Fig. 22, lubricating oil to be filtered is forced, by the pressure lubricating oil pump, through the restricted filter inlet (1), and into the annular space (2), surrounding the filter element. Impurities are absorbed within the element (3) as the oil is forced through and into the metal cylinder (4). The passages in the central tube permit filtered oil to flow into the hollow passage (5) and through the outlet passage (6) to the engine crankcase. Because of this continuous flow through the filter, the lubricating oil is kept free of harmful impurities as long as the filter is properly serviced.



3. Filter Element.
8. Cover Gasket.
9. Retainer Nut Gasket.
10. Spring.
11. Housing Cover.
14. Filter Housing.
15. Retainer Nut.

Fig. 23—Details of Replaceable Type Lubricating Oil Filter Assembly.

Service—Replaceable Element Type Lubricating Oil Filter—Sludge filters are equipped with absorption type filter elements which must be replaced at periodic intervals. Used elements cannot be cleaned by a solvent wash or reverse flow. Because the life of a filter will depend upon engine operating conditions, and characteristics of the lubricant, the time interval between element renewals cannot be arbitrarily specified.

Filter elements should be replaced when the color of the lubricant begins to darken from sludge. Filter element should always be renewed at the time the crankcase is drained. This will be after approximately 100 hours of operation or every 2000 miles.

Replace Filter Elements—To replace the filter element (engine not running): Refer to Figs. 22 and 23.

1. Remove filter cover (11) by backing-out on screw at center of cover. Withdraw element (3) from filter housing (14).
2. Remove drain plug (7) at bottom of housing and flush out with fuel oil or carbon tetrachloride.
3. Install a new element on center stud (12), replace the old with a new cover gasket (8).
4. Being sure that seating spring (10) is in place to properly position the filter element replace cover (11) and tighten retaining nut (15); being sure gasket (8) is in place under head of nut.

   Retaining nut should be drawn snug against the gasket, but not tight enough to bend the cover.
5. Start engine and observe for oil leaks at cover gasket.

LUBRICATING OIL STRAINER

Some engines operate in areas or under conditions which are more severe than others. For those engines operating under the more severe conditions additional filtering equipment is provided in the form of an oil strainer. When strainers are used they are introduced into the oil system as shown in Fig. 1.

Description—As shown in Fig. 24, the oil strainer, when used, is attached to the lubricating oil cooler adaptor. The strainer is introduced in the lubricating system between the oil pressure pump and the cooler so that all the warm oil delivered by the pump passes through the strainer, before it passes through the cooler.

The strainer assembly consists of a housing inside of which is carried a double strainer element (cleaner). These are held in position by a retainer tube passing through the end of the housing, through the center of the strainer elements and screwing into the short retaining bolt which passes through the adaptor.

Sealing washers are assembled under the heads of bolt and tube.

Operation—Oil discharged from the pressure pump is introduced inside the housing and surrounds the strainer. The .005" openings in the strainers permit the clean oil to pass to the inside of the elements while any particles larger than the openings in the strainers are retained on the outer surfaces. Clean oil, leaving the chamber inside the screens, passes out the opening at the lower end from where it is forced through the oil cooler by the pump pressure.

Service—The main purpose of the oil strainer is to trap any particles that might pass through the screen in the oil filler spout before such particles reach the engine bearings and cause trouble. In addition to being a collector of foreign particles, it is also a reliable indicator of the suitability of the oil used in the Diesel engines. Whenever the strainer coats up rapidly with carbon and sludge deposits, such coating usually indicates that unsatisfactory lubricating oil is being used.

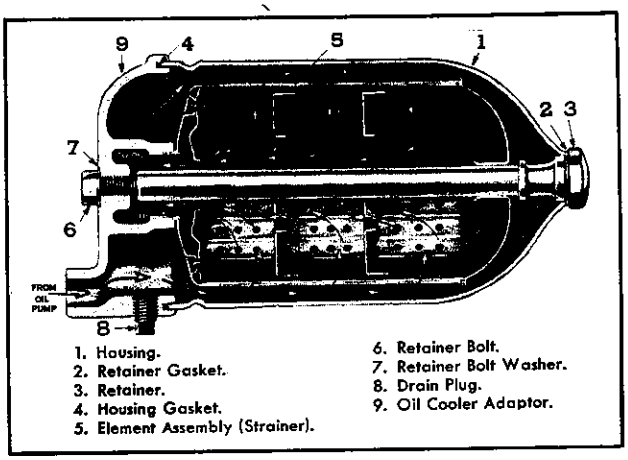


Fig. 24—Lubricating Oil Strainer Assembly.

Cleaning Lubricating Oil Strainer—Lubricating oil strainer should be reconditioned at each lubricating oil renewal period. This will be approximately 100 hours or 2000 miles of operation. ***To clean the strainer refer to Fig. 25 and:***

1. Remove plug (8) and drain oil from strainer housing (1).
2. Loosen retainer tube (3) at the small end of the strainer housing by turning counter-clockwise on the acorn head.
3. Pull housing (1), strainer (5), retainer tube (3) and retainer gasket (2) away from oil cooler adaptor (9).

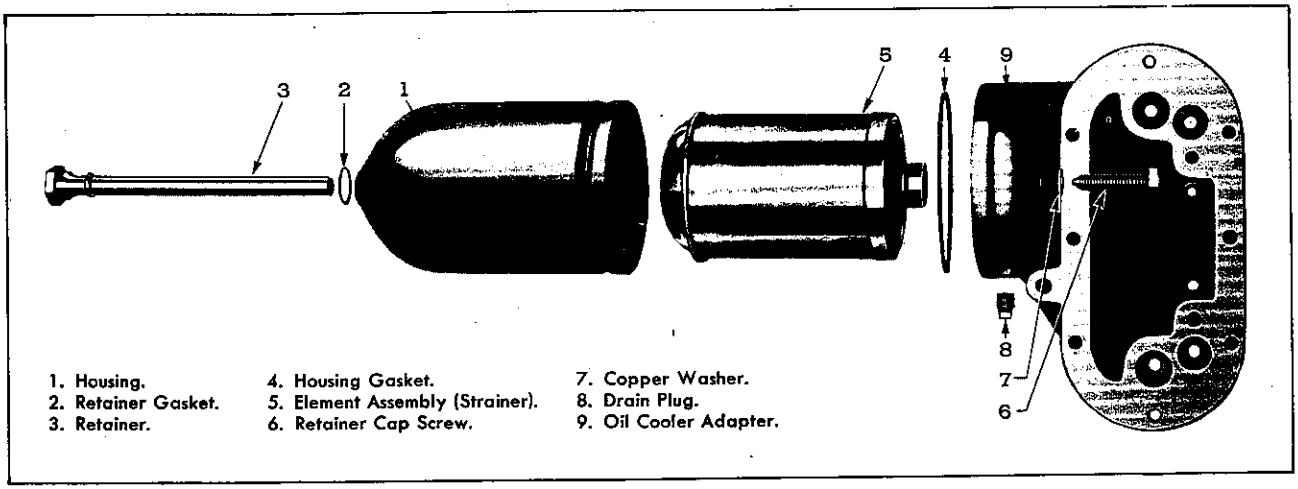


Fig. 25—Lubrication Oil Strainer Details and Relative Location of Parts.

4. Remove strainer element from retainer and thoroughly wash inner and outer surfaces by rinsing in clean fuel oil. ***Do not use stiff wire brush for cleaning.*** Fine wire or bristle brush will be satisfactory. ***Be sure strainer is clean before replacing.***

5. Remove all sludge from inside of housing (1).

6. Examine large circular composition gasket (4) —embedded in oil cooler adaptor—against which the strainer housing seats. If gasket is damaged so that tight seal cannot be maintained between gasket and housing, replace gasket.

7. Position strainer collar into oil cooler adaptor (9).

8. Install new gasket (2) under head of retainer tube (3) and insert tube through small end of housing (1).

9. Set housing against adaptor and tighten retainer tube against gasket by turning acorn nut at small end of housing in clockwise direction.

   Be sure retaining cap screw (6) is tight against copper washer (7).

10. Replace oil drain plug (8).

11. After starting engine, check for oil leaks.

LUBRICATING OIL COOLER

Description—Series 71 engines are equipped with an oil cooler which not only cools the hot engine oil, but, by means of the cooling water temperature control, provides a means of rapidly raising the oil temperature during the warm-up period. (See "Water Temperature Control," Page 2, Sec. 13.)

The oil cooler is the single-pass, multiple-type, with a corrosion-resistant steel cooling unit contained in a cast iron housing. Cooling water drawn through the housing by the water pump completely surrounds the cooling unit. (See Fig. 26.)

The hot oil enters the cooling unit at the bottom, flows through the inside passages and is discharged at the top into a vertical passage in the cylinder block.

A water by-pass pipe is attached to the thermostat housing at the upper end, and to the oil cooler housing at the lower end. During the warm-up period, and while the thermostats are still closed, water circulates through the by-pass pipe, around the oil cooler element, and returns to the cylinder block; thus quickly raising the engine oil temperature during the engine warm-up period.

To insure engine lubrication, should the cooler element become clogged, a by-pass valve located in the pump outlet pipe, by-passes oil around the cooler and directly to the oil gallery in the cylinder block.

Service—If occasion requires, the cooling unit may be removed from the cooler housing or the entire cooler assembly may be removed from the cylinder block. Since the element through which the oil passes, while being cooled, is surrounded by water inside a cast iron housing, the cooling element must be well sealed against water getting into the oil or oil getting into the cooling water. Whenever, therefore, the oil cooler is disassembled, special care must be taken at assembly to have the proper gaskets in place and the retaining cap screws tight.

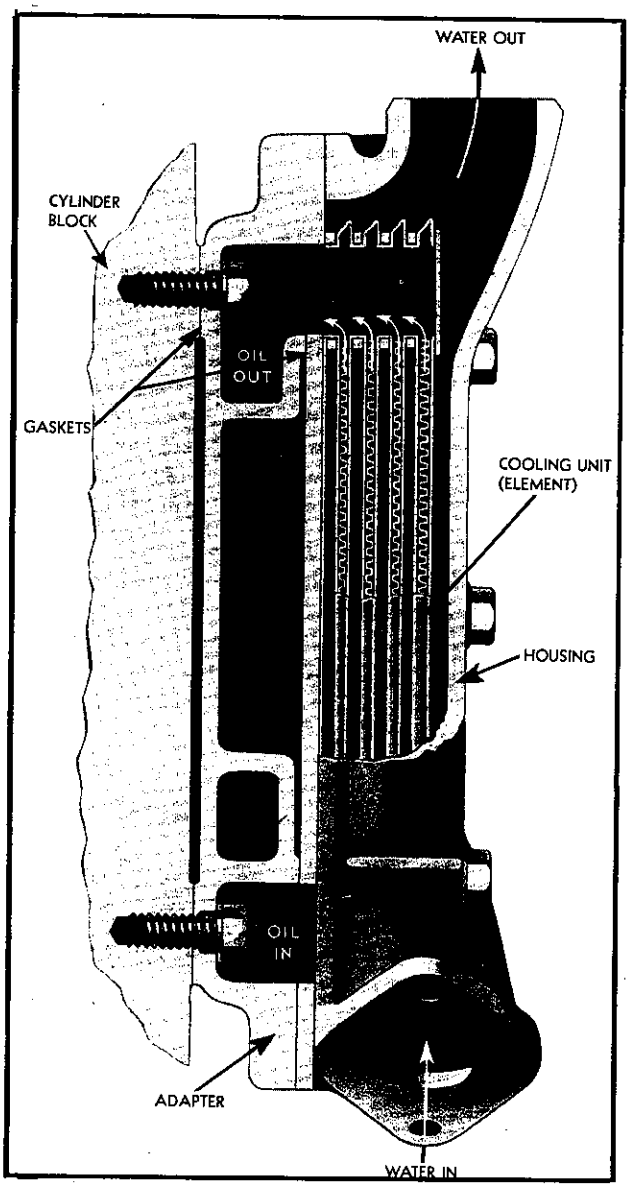


Fig. 26—Lubricating Oil Cooler Assembly.

Remove Lubricating Oil Cooler—To remove the lubricating oil cooler:

1. Drain cooling system and oil strainer.
2. Disconnect water connection from radiator to lower end of oil cooler, at oil cooler.
3. Break hose clamp connections between the water pump and oil cooler.
4. Disconnect water tube from water manifold to oil cooler, at cooler.
5. Remove the eight cap screws which attach the oil cooler cover casting to the combination adapter and oil strainer header, and remove the cover and oil strainer as an assembly. Be careful when withdrawing the assembly not to drop and pamage the cooling element.

   The above is all the work necessary to remove the oil cooler element; if the combination adapter and oil strainer is to be removed, then continue as follows:

6. Back out the cap screw at the center of the oil strainer housing and the seven cap screws that hold the adapter to the cylinder block, and remove adapter.

Cleaning Oil Cooler—The function of the lubricating oil cooler is to lower the oil temperature by the surrounding water during the time the oil travels through the small passages within the cooling unit. If these passages are allowed to become choked with sludge, the oil flow will be restricted, or stopped, and the oil temperature will rise. When this happens the viscosity of the oil decreases, with a resulting drop in oil pressure. IT IS ABSOLUTELY NECESSARY THAT THE OIL COOLER UNIT BE KEPT CLEAN FOR PROPER OIL COOLING.

(a) If live steam is available, a jet of steam, mixed with a soapy substance, is a very effective cleaner. After cleaning, remove all traces of water by heating the cooler unit.

(b) If steam is not available, place the cooler unit in a vessel and fill with carbon tetrachloride, or with other suitable cleaner, to a level of at least one inch above openings in the unit plate. A force pump is suggested as a means of forcing the cleaning solution back and forth through the plates. This operation should be continued until unit is cleaned.

CAUTION: Cleaning with carbon tetrachloride is to be done in the open air or with adequate ventilation due to the toxic qualities of the chemical.

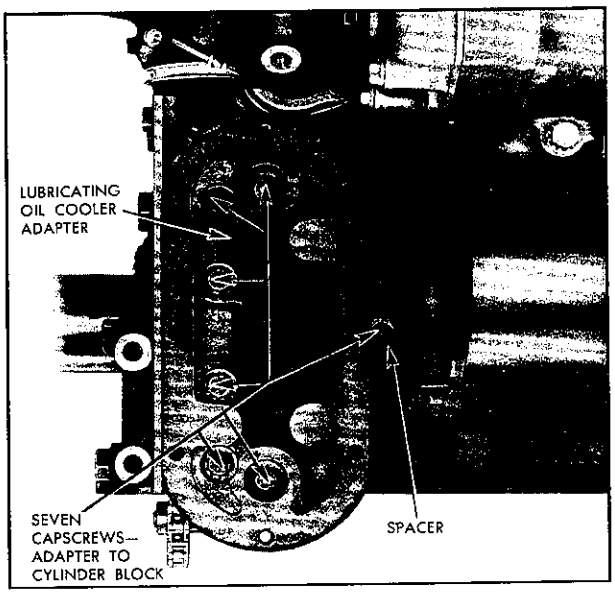


Fig. 27—Mounting of Lubricating Oil Cooler Adapter.

Assembly and Mounting of Lubricating Oil Cooler—The lubricating oil cooler is assembled and mounted by reversing the sequence of operations for removal. The order of the operation is:

1. Clean the old gaskets from the bosses where the oil cooler adapter sets against the crankcase, and affix gaskets to these bosses with shellac.
2. With the circular rubber gasket in place in the adapter, to receive the end of the oil strainer steel housing, slide the adapter into place and attach to cylinder block with the seven cap screws. Put copper washer and cap screw in place at center of oil strainer. Use spacer between adapter and block, to rear of cover bolting flange.
3. Clean the old gasket from both sides of the flange on the cooler element—from the finished face of the adapter and the finished face of the oil cooler cover, and shellac a new gasket to each flange of the cooler element.
4. Put the cooler element into position inside the cover, then set cover with element against adapter and secure with lockwashers and cap screws.
5. Replace water connections to oil cooler and fill cooling system.

CRANKCASE VENTILATION

The crankcase and valve compartment are continually cleaned of harmful vapors by an automatic crankcase ventilating system.

A small vent pipe either connects the cylinder head to the blower intake or runs down the side of the engine and vents to the atmosphere, depending upon the type of installation. This pipe keeps the air inside the valve chamber and crankcase slightly below the normal outside atmospheric pressure.

In one case, the oil fumes and water vapors caused by condensation are sucked into the blower, burned in the engine and expelled through the exhaust system.

In the other case, oil fumes and water vapors caused by condensation are discharged to the atmosphere.

A slight amount of scavenging air is forced past the oil control rings, keeping the drain holes free from sludge accumulations and providing clean ventilating air for the crankcase.

As soon as the piston on its downstroke uncovers the ports, these fumes or fuel particles are blown back into the combustion chamber.

OIL CAPACITY

A bayonet type oil gauge at the side of the engine block is used to determine the quantity of oil in the engine oil pan. As will be seen from Fig. 28, this gauge is marked with the two designations, "Low" and "Full". The oil should never be allowed to drop below the Low mark, and no advantage is gained by having the oil above the Full mark. The oil level should be checked in the engine crankcase after the engine has been started, then stopped for three or four minutes. If the level is taken before starting the engine which has stood for some time, some oil will drain back into the crankcase from the engine parts and filters, raise the level in the oil pan, and the gauge will show a false high reading.

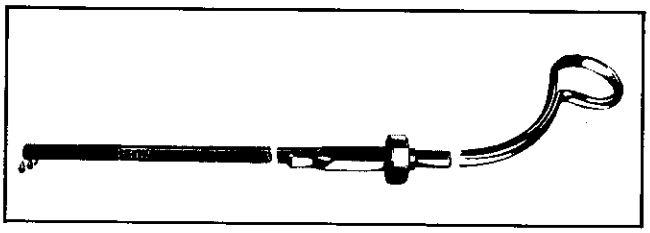


Fig. 28—Lubricating Oil Level Gauge.

LUBRICATING OIL SPECIFICATIONS

Quality—Lubricating oils for Series "71" Diesel engines must possess high oxidation resistance, low tendency towards formation of carbon deposits and noncorrosiveness to copper-lead bearings.

Commonly quoted oil inspection data, such as Gravity, Flash Point, and Carbon Residue, bear little significance on the performance of the lubricant in an engine under actual service conditions.

The operator is, therefore, entirely dependent on the experience and reliability of his oil supplier.

Satisfactory operation of heavy-duty engines for long periods of time, requires use of the specially compounded "Heavy-Duty Lubricants."

These superior oils provide better lubrication, possess more heat resistance, and counteract sludge formation more effectively than ordinary motor oils. Their higher initial cost is more than offset by greatly increased life.

Heavy-Duty Lubricants are marketed, by most oil companies, for use in high-speed Diesel and Gasoline engines.

Viscosity—The recommended viscosity grade for all operating conditions is SAE-30.

Only when prolonged engine exposure to temperatures below freezing is unavoidable, use of the following lighter grades of oil is permissible to facilitate cold starting.

Atmospheric Temperature	Viscosity Grade
+32°F to 0°F	SAE-20W
Below 0°F	SAE-10W

Filtration—Satisfactory engine lubrication requires continuous cleaning of the oil.

Heavy-Duty Lubricants will always appear dark-colored on account of their exceptional ability to keep fine carbon particles in suspension.

Since the color of the oil can no longer be used as an indicator for proper filter action, removal of abrasive dust, metal and carbon must be insured by periodic replacement of the absorption filter elements.

Filter elements must be changed at every oil change.

Engines equipped with full-flow oil strainers require additional cleaning of the edge-type strainer elements at every third oil change.

Renewal—All mineral oils deteriorate in service. To remove the acidic and resinous materials thus formed, the crankcase content must be renewed at regular intervals. No flushing oils or other solvents should be used.
(See flushing crankcase below.)

The frequency of these oil changes depends on the quality of the lubricant, the efficiency of filtration, and the severity of engine service.

The following maximum oil change intervals are suggested when using recognized oils of the "Heavy-Duty" type:

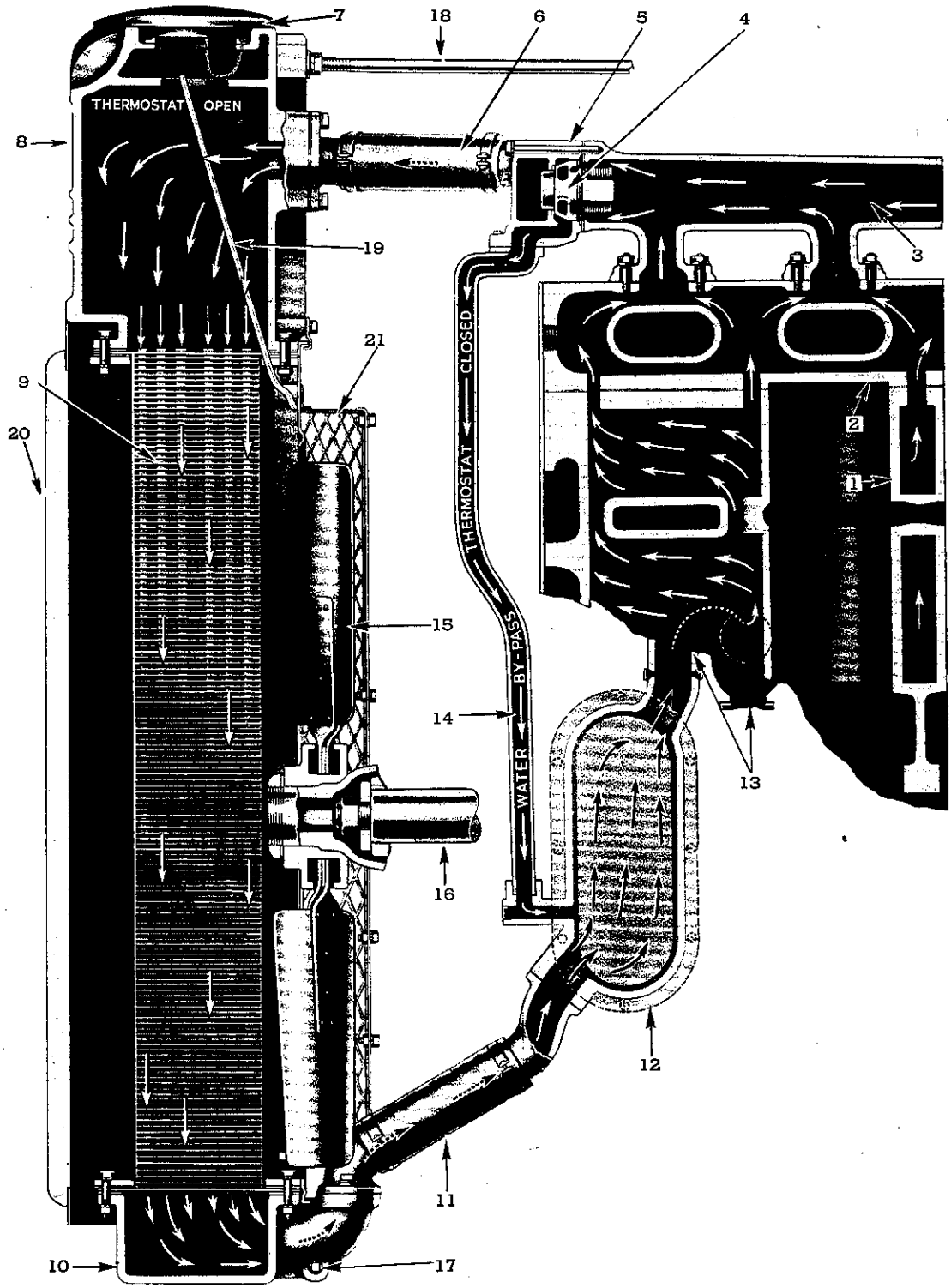
Engine Installation	Oil Change Intervals
Marine	200 hours
Industrial	300 hours

Selection of a reliable oil supplier, strict observation of his oil change recommendations and proper filter maintenance serve best to insure trouble-free lubrication.

Flushing Crankcase—After long periods of operation, a flushing of the complete engine is advisable. For this purpose, the crankcase should be filled with No. 20W viscosity oil to the low mark on the oil level gauge. After running the engine idle for a few minutes, this oil should be drained out. ***No special flushing oils or compounds should be used because they may prove harmful to the copper-lead bearings.***

When a compounded type of oil is used for the first time to replace a straight mineral oil, the compounded oil should be drained out of the crankcase after running not more than 24 hours. This prevents any dangerous obstruction of the oil pump intake screen and the strainer by any previously formed oxidation deposits which might be loosened by the purging action of the oil. The second crankcase filling of compounded oil should be drained out after running 30 to 40 hours, at which time the strainer should be cleaned, and the by-pass filter element should be renewed. Following these two oil changes, the recommended crankcase draining interval for the engine can be resumed and continued for as long as compounded oil is used thereafter.

COOLING SYSTEM



1. Cylinder Block.
2. Cylinder Head.
3. Water Manifold.
4. Thermostat.
5. Thermostat Housing.
6. Hose—Thermostat Housing to Radiator.
7. Filler Cap—Radiator.
8. Upper Tank.
9. Core.
10. Lower Tank.
11. Hose—Radiator to Oil Cooler.
12. Oil Cooler.
13. Water Pump.
14. By-Pass—Thermostat Housing to Oil Cooler.
15. Fan.
16. Crankshaft.
17. Drain Plug.
18. Tie Rod.
19. Overflow Pipe.
20. Grill.
21. Guard—Fan.

Fig. 1—Typical Cooling Arrangement with Radiator and Fan.

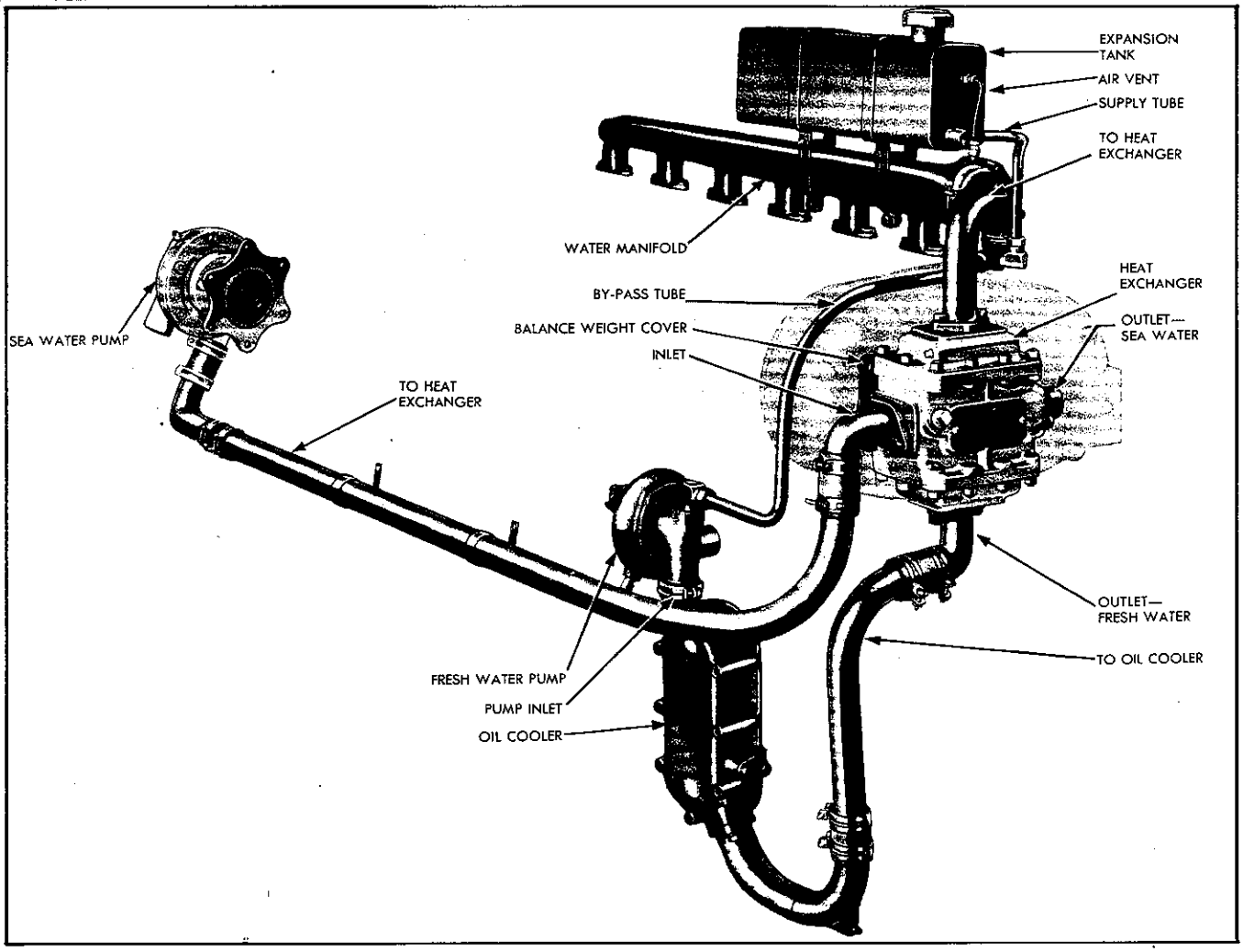


Fig. 2—Typical Cooling Arrangement with Heat Exchanger.

Cooling of the engine is accomplished by means of water circulation through the cylinder block and cylinder head by a centrifugal pump mounted on the front end of the blower and driven by the lower blower rotor shaft through a coupling.

The water pump works in conjunction with either a radiator or heat exchanger, through which the water passes in the process of cooling. With a radiator, a cooling fan is provided which either draws or forces air through the radiator core, thus lowering the water temperature while passing from the top to the bottom of the core. The temperature of the cooling liquid in the heat exchanger is reduced while passing through the heat exchanger core, by cold water forced around the outside of the core by an auxiliary (raw) water pump. In both the radiator and heat exchanger methods, the water pump draws the cooling liquid through the oil cooler and discharges it into the lower part of the cylinder block as shown in Fig. 1. Openings in the water jacket around the cylinder bores connect with corresponding openings in the cylinder head, where the liquid circulates around the valves and fuel injectors. A water manifold bolted to the cylinder head discharges the cooling water back into either the radiator or heat exchanger.

Water Temperature Control—The water temperature in the engine cooling system is automatically controlled by a by-pass-type thermostat mounted in the water manifold, as shown in Fig. 1. The thermostat starts opening at approximately 158°F. and is fully open at 185°F. Before the thermostat starts opening, water circulation takes place in the cylinder block, cylinder head and oil cooler only, through a water by-pass tube connecting the water outlet manifold to the water inlet. After the thermostat starts opening and up until it is fully open (185°F.) water circulation takes place through both the by-pass tube and through the radiator or heat exchanger. After the thermostat has fully opened, water circulation takes place through the radiator or heat exchanger and engine only—no circulation taking place through the by-pass tube.

Before the thermostat starts opening, therefore (during the warm-up period of the engine), the lubricating oil passing through the oil cooler is rapidly warmed due to the warm water circulation through the by-pass tube, thus insuring positive engine lubrication at all times, regardless of the outside temperature at which the engine is being operated. Also, by means of by-pass circulation, engine normal operating temperatures are reached with a minimum warm-up period.

WATER PUMP

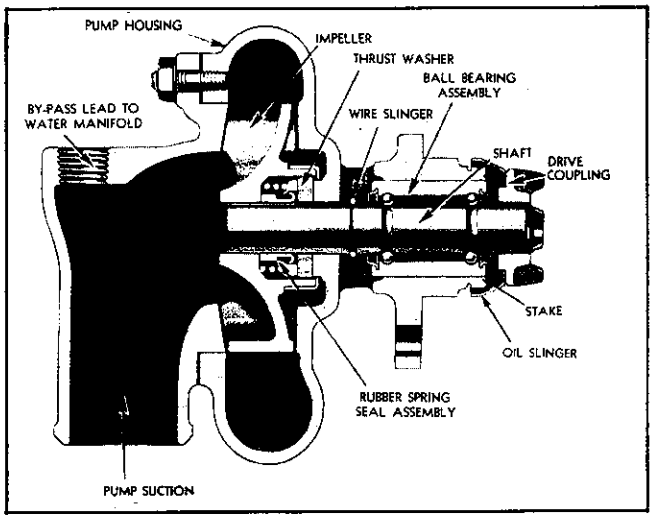


Fig. 3—Water Pump Assembly.

Description—A centrifugal type water pump is used for circulating the cooling liquid through the cylinder block, cylinder head and the radiator. A bronze impeller with straight blades is pressed onto one end of the case-hardened steel shaft and a pump drive coupling with an oil thrower is pressed onto the opposite end. The oil thrower shrouds the inner end of the pump body flange to prevent oil from creeping along the shaft and through the shaft bearing. The shaft is supported at the drive end on a sealed double-row combination radial and thrust ball bearing, and prevented from moving endwise by peening the pump housing at the inner end of the bearing as shown in Fig. 3.

Water is prevented from creeping along the shaft from the impeller end by means of a spring loaded Neoprene seal, retained in the impeller by a steel stamping. A wire slinger is fitted on the shaft between the pump housing and ball bearing to prevent moisture from creeping along the shaft to the bearing. The pump shaft and bearing constitute one assembly and are serviced as such, inasmuch as the shaft serves as the inner race of the ball bearing.

Water Pump Lubrication—As the water pump ball bearing is the "shielded" type and filled with lubricant when assembled, no further lubrication is necessary.

1. Body—Water Pump.
15. Cover—Body.
20. Plug.
30. Blower End Plate Cover
31. Inlet Seal.
32. Housing—Oil Cooler.
33. Bolts—Water Pump-to-Blower.
36. Hose Clamp.
37. Drain Cock
38. Governor Drive Housing
39. Wrench—Tool No KMO-326-A

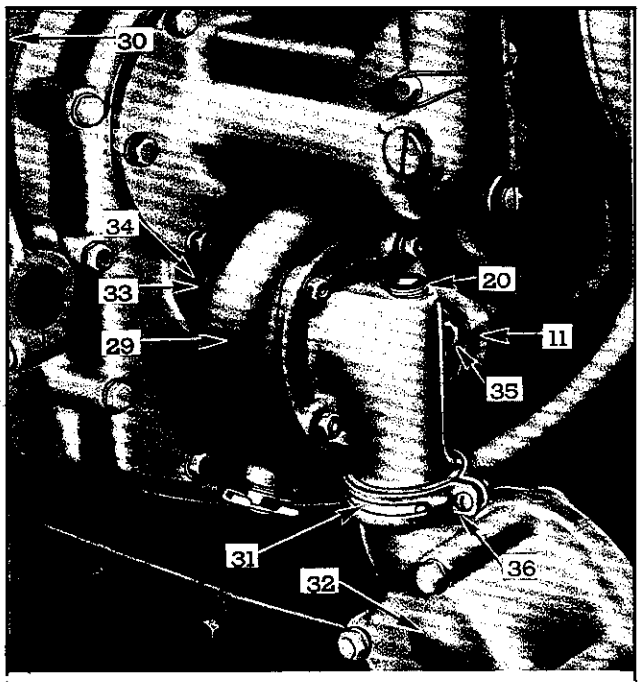
Fig. 4—Loosening Inner Bolt from Water Pump Mounting Flange with Tool No. KMO-326-A.

Service—The rugged construction of the water pump and the care taken to prevent water getting from the pump into the ball bearing are conducive to long life with minimum attention. However, when wear does occur, or if it becomes necessary to replace parts in the water pump, the pump may be removed from the engine and completely overhauled as follows:

Remove Water Pump from Engine—

1. Drain Cooling System.

NOTE: When draining or filling cooling system, remove vent plug (8) in thermostat housing, as shown in Fig. 10.



11. Flange—Outlet Packing.
20. Plug.
29. Body—Water Pump.
30. Blower End Plate
31. Inlet Seal.
32. Housing—Oil Cooler.
33. Bolt—Water Pump-to-Blower.
34. Lock Washer.
35. Bolt—Packing Flange-to-Cylinder Block.
36. Hose Clamp.

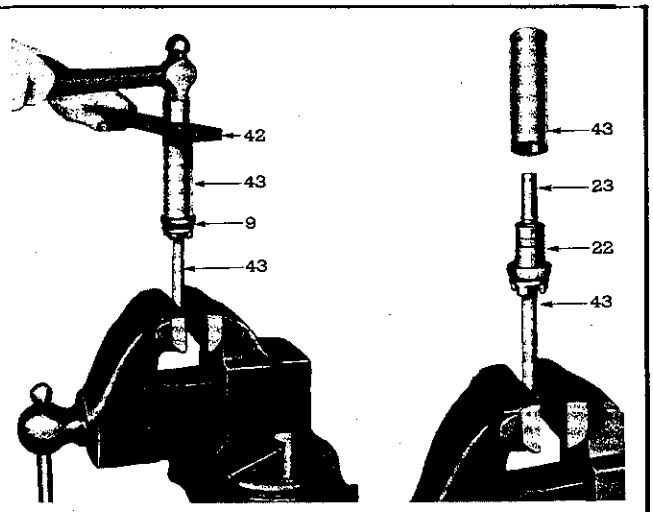
Fig. 5—Water Pump Mounting.

2. Loosen clamp (36) (see Fig. 5 above) and slip inlet seal (31) down on oil cooler neck.
3. Remove two bolts (35) and flange (11) holding pump outlet to cylinder block. Move flange and packing towards pump body.
4. Remove three bolts (33) holding pump to blower. The inner bolt can be removed by using a half moon wrench as shown in Fig. 4.
5. Free pump by jarring with palm of hand and turn until the pump will clear the governor drive housing (38) and oil cooler housing neck (32).

Disassemble Water Pump—The water pump is made up of the shaft and double-row bearing assembly, the seal assembly, seal washer, pump body, pump cover, and drive coupling.

If removal of the spring seal assembly or the impeller is necessary, the following sequence of operations will apply:

1. Remove pump cover.
2. Support the water pump in an arbor press flange down, as shown in Fig. 7, and press the shaft through the impeller. Shaft and bearing assembly will also be removed from the body during this operation. If the water seal only is to be inspected or changed, no further disassembly is necessary and the new seal may be installed and pump reassembled. The water seal is an assembly and sold with or without impeller.
3. If further disassembly is necessary, the pump drive coupling and oil thrower assembly (9) may be forced from the shaft with Tool J-1930, as shown in Fig. 6.



9. Assembly—Pump Drive Coupling and Oil Thrower.
22. Ball Bearing.
23. Shaft—Water Pump Drive.
42. Steel Bar.
43. Tool No. J-1930—Water Pump Drive Coupling and Oil Thrower Assembly Removing.

Fig. 6—Removing Water Pump Drive Coupling from Impeller Shaft with Tool J-1930.

Assemble Water Pump—The water pump may be assembled by reversing the sequence of operations for disassembly. One feature in connection with impeller and drive coupling is that these pieces are pressed on the shaft and drive solely through the press fits. The metal stretches when being pressed onto the shafts, and if repeatedly used, may not result in a satisfactory drive. This feature should be checked after either the impeller or drive coupling has been removed from the shaft. If necessary, install new coupling or impeller to insure water circulation.

Before starting the pump assembly, study Fig. 8, which shows the relative location of all parts in the pump, and then carry out the assembly as follows:

1. Support body-to-cover bolting flange of pump on bench, and drive bearing of shaft assembly (7) into inner end of bearing bore so that inner end of bearing is flush with inner face of flange for bearing bore as shown in Fig. 3. Stake pump body flange at junction of bearing outer race in three or four places to prevent bearing from moving endwise.
2. Refer to Fig. 8 and assemble spring guide (8), seal (5), clamp ring (10), and seal washer (4) together. Insert spring (6) into impeller hub (3);

then set seal assembly items (8), (10), (5) and (4), next to spring and lock the assembly in the impeller by driving retaining cup (12) down over hub of impeller.

3. Set impeller and seal assembly onto outer end of shaft; then support outer end of shaft on bed of arbor press and press impeller onto and flush with end of shaft. This operation is similar to removal of impeller as illustrated in Fig. 7.
4. Support impeller end of pump shaft on suitable arbor, and using brass hammer, drive coupling and oil thrower assembly (9) onto inner end of shaft, flush with end of shaft.
5. Rotate shaft by hand for clearance between impeller and pump body. A clearance of .005" to .0045" is satisfactory. (See Fig. 3).
6. Affix gasket (13) to pump body at bolting flange for combination cover and elbow (15). Set cover over studs and up against body, so that elbow points down when the pump outlet can be attached to the cylinder block. Tighten cover in place with four nuts (16), and lockwashers (17). Again turn pump shaft by hand for bind between impeller and cover.
7. If pump coupling and thrower assembly was removed from the blower shaft, insert splined end of coupling (19) into mating splines of blower shaft and insert the 3/16" Allen screw to expand inner end of coupling. Be sure coupling is fully in place before tightening Allen head screw; otherwise, a preloading of the water pump bearing may cause damage.

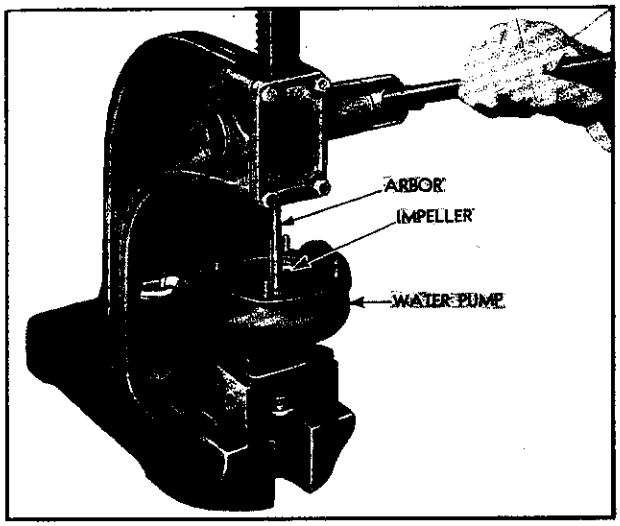
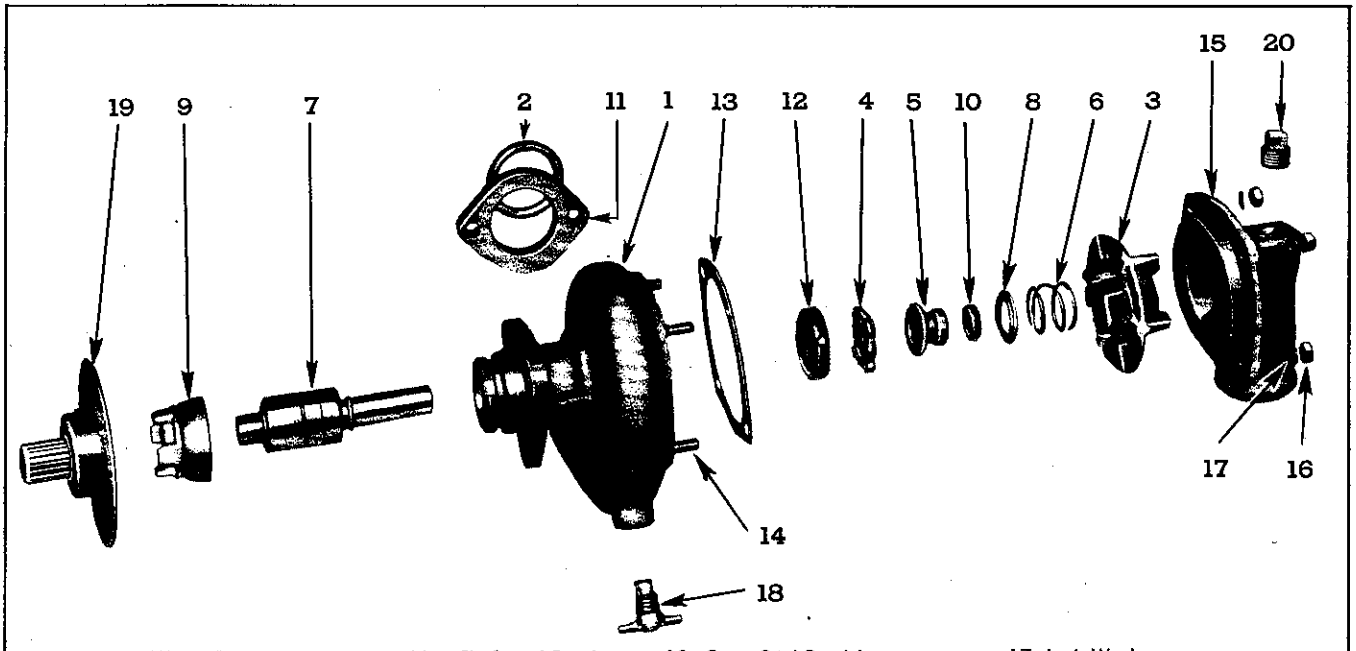


Fig. 7—Pressing Water Pump Impeller from Shaft.

Install Water Pump to Engine—The water pump may be installed to the engine by reversing the sequence of operations for removal, as follows:

1. See that water pump coupling and thrower assembly—item (4), Fig. 8, Sec. 14—is locked in



1. Body—Water Pump.
2. Outlet Packing.
3. Impeller.
4. Seal Washer.
5. Seal.
6. Seal Spring.
7. Assembly—Shaft and Bearing.
8. Guide—Seal Spring.
9. Assembly—Pump Drive Coupling and Oil Thrower.
10. Ring—Seal Clamp.
11. Flange—Outlet Packing
12. Cup—Seal Retaining
13. Gasket—Water Pump Body-to-Cover.
14. Stud.
15. Cover—Body.
16. Nut.
17. Lock Washer.
18. Drain Cock.
19. Assembly—Intermediate Shaft Coupling and Slinger.
20. Plug.

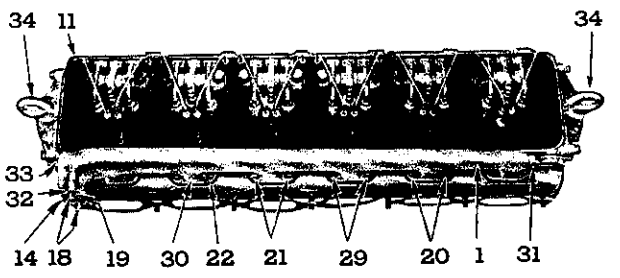
Fig. 8—Water Pump Details and Relative Location of Parts.

place with a 3/16" Allen screw (3) in end of blower shaft.

2. Slip water outlet packing flange (11), Fig. 8, over pump outlet, with flat machined face away from pump body. Slip packing (2) over outlet next to flange.
3. Slip hose clamp (36) and water pump inlet seal (31) over inlet elbow to pump. (See Fig. 4).
4. Set pump assembly in place at end of blower cover so that lugs register on the two drive couplings when pump inlet elbow points down. Secure with three bolts and lockwashers.
5. Slide water outlet packing and packing flange up against cylinder block and secure with two bolts (35) and lockwashers. (See Fig. 5).
6. Slide pump inlet seal and hose clamp in place at junction of oil cooler and pump inlet elbow, and tighten clamp screw.
7. Fill cooling system and check for water leaks.

NOTE: When filling or draining cooling system, remove plug (8), shown in Fig. 10, to vent system.

WATER MANIFOLD AND THERMOSTAT



1. Water Manifold.
11. Cylinder Head.
14. Cover Plate—Water Manifold.
18. Bolts—Cover Plate-to-Manifold.
19. Lock Washers.
20. Nuts—Manifold-to-Cylinder Head.
21. Lock Washers.
22. Gaskets—Manifold-to-Cylinder Head.
29. Studs—Water Manifold Mounting.
30. Riser—Water Passage from Each Cylinder.
31. Adapter—Water Temperature Gage-to-Manifold.
32. Gasket—Cover Plate-to-Manifold.
33. Flange—Thermostat Housing Mounting.
34. Lifter Brackets.

Fig. 9—Water Manifold Mounting.

Description—Cooling water leaving the cylinder head through openings directly over each exhaust port, enters the water manifold, which is attached to the head with two nuts and lockwashers at each end of the six water openings, as shown in Fig. 9. A separate gasket is used at each attaching flange between the manifold and cylinder head.

A gradually increasing area in the cast manifold from the rear end, terminates in a flange at the front, where a thermostat housing is attached.

Unrestricted water flow through the circulating system is accomplished by the use of a blocking-type thermostat, so positioned that when the thermostat is closed free flow of water from the manifold takes place through the sides of the thermostat cages and to the by-pass pipe. (See Fig. 1.)

A water by-pass pipe leads from the thermostat housing, in front of the engine, and connects to a water opening at the front face of the oil cooler housing. Before the thermostat starts opening (below water temperature of approximately 158°F.), water circulation takes place through the engine circulating system only. After the thermostat starts opening and until it is fully open (at approximately 185°F.), water circulation takes place through the by-pass pipe and through the entire circulating system. When the thermostat is fully open, water circulation is through engine and radiator, or heat exchanger, no circulation taking place through the by-pass pipe.

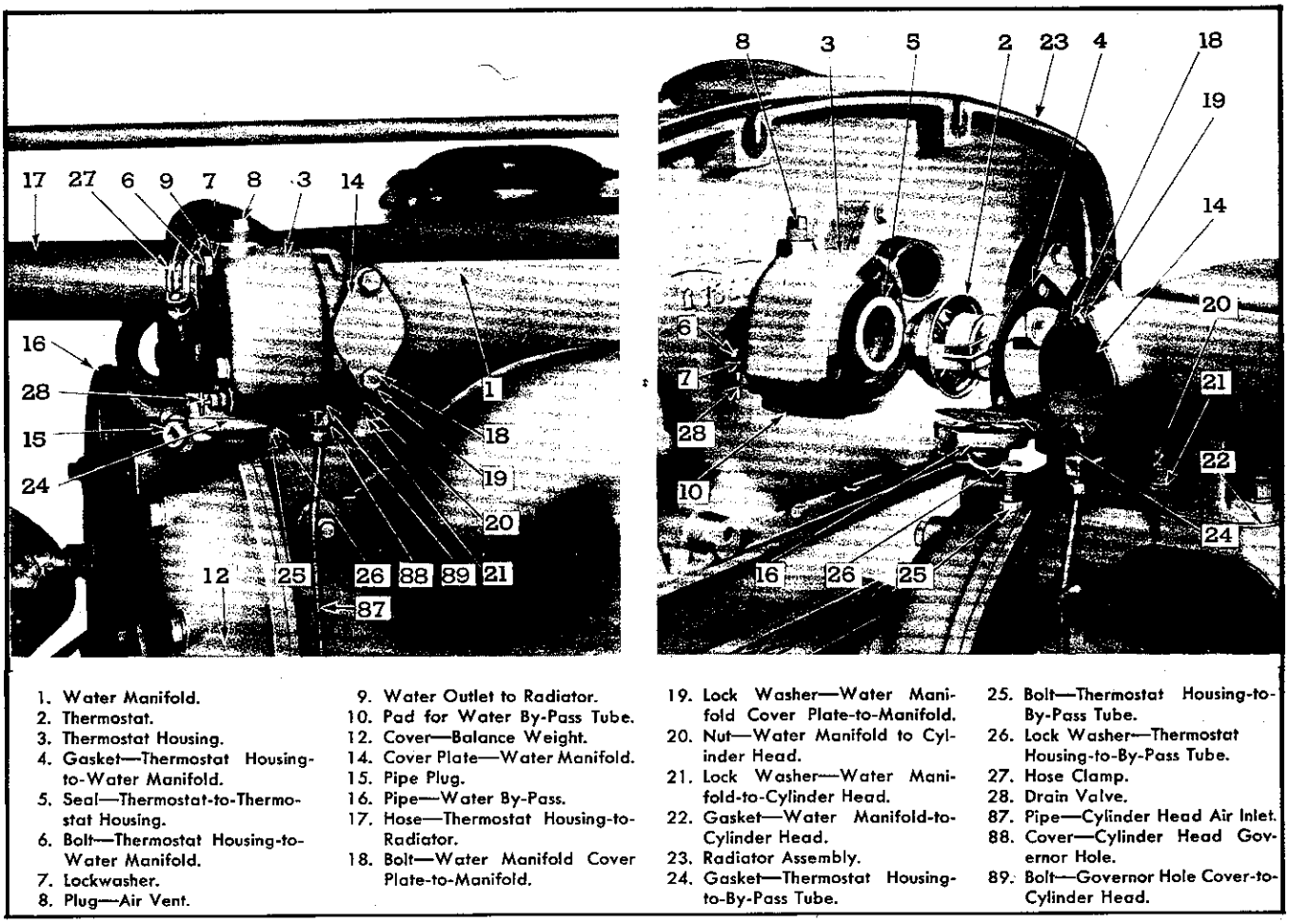
Service—Thermostats and Water Manifolds—No service should be required on the water manifold unless due to accident or at engine overhaul. Occasions may arise, however, when the thermostat may require changing. In this event, it may be removed and replaced as follows:

Remove and Replace Thermostat:

1. Drain cooling system to level necessary.

NOTE: When filling or draining cooling system, remove plug (8), shown in Fig. 10, to vent system.

2. Disconnect radiator hose to radiator or seal to heat exchanger at thermostat housing.
3. Remove two bolts holding water by-pass pipe (16) to thermostat housing (3). See Fig. 10.
4. Remove three bolts (6) and thermostat housing (3). Remove thermostat (2).
5. Clean seat in water manifold for thermostat cage (2) and set thermostat (bellows in) into manifold. (See Fig. 10).
6. Remove thermostat seal (5) from thermostat housing. Clean seat and install new seal.



1. Water Manifold.
2. Thermostat.
3. Thermostat Housing.
4. Gasket—Thermostat Housing-to-Water Manifold.
5. Seal—Thermostat-to-Thermostat Housing.
6. Bolt—Thermostat Housing-to-Water Manifold.
7. Lockwasher.
8. Plug—Air Vent.
9. Water Outlet to Radiator.
10. Pad for Water By-Pass Tube.
12. Cover—Balance Weight.
14. Cover Plate—Water Manifold.
15. Pipe Plug.
16. Pipe—Water By-Pass.
17. Hose—Thermostat Housing-to-Radiator.
18. Bolt—Water Manifold Cover Plate-to-Manifold.
19. Lock Washer—Water Manifold Cover Plate-to-Manifold.
20. Nut—Water Manifold to Cylinder Head.
21. Lock Washer—Water Manifold-to-Cylinder Head.
22. Gasket—Water Manifold-to-Cylinder Head.
23. Radiator Assembly.
24. Gasket—Thermostat Housing-to-By-Pass Tube.
25. Bolt—Thermostat Housing-to-By-Pass Tube.
26. Lock Washer—Thermostat Housing-to-By-Pass Tube.
27. Hose Clamp.
28. Drain Valve.
87. Pipe—Cylinder Head Air Inlet.
88. Cover—Cylinder Head Governor Hole.
89. Bolt—Governor Hole Cover-to-Cylinder Head.

Fig. 10—Thermostat Housing Mounting and Details.

7. Affix new gasket (4) to manifold side of thermostat housing, and install housing, using three bolts (6) and lockwashers (7).
8. Connect water by-pass tube (16) and use new gasket, if necessary.
9. Connect radiator or heat exchanger hose to thermostat housing with hose clamps. Fill cooling system and check for leaks.

Remove Water Manifold.

1. Drain cooling system.

NOTE: When draining or filling cooling system, remove vent plug (8), shown in Fig. 10, to vent system.

2. Disconnect hose leading from thermostat housing to radiator or heat exchanger.
3. Remove thermostat housing, as described above
4. Remove two bolts (18) and water manifold cover plate (14) from water manifold. Remove gasket
5. Remove two bolts (25) holding water by-pass pipe (16) to bottom side of thermostat housing (3).
6. Remove water temperature gauge bulb from adaptor at rear of manifold.
7. Remove stud nuts (20) and washers (21) holding water manifold to cylinder head.
8. Raise water manifold straight up off of studs. Remove manifold-to-cylinder head gaskets.

Replace Water Manifold—The water manifold may be replaced by reversing the sequence of operation for removal and referring to Figs. 9 and 10 for relative location of parts.

1. Remove all traces of old gaskets from the manifold, as well as the cylinder head.
2. Place one gasket (22) on cylinder head at each water opening to manifold and set manifold in place on gaskets. Replace lockwashers (21) and nuts (20) and tighten nuts.
3. Using new gasket, replace water manifold cover plate (14).
4. Install thermostat housing, with thermostat, on water manifold as described under Thermostat Service, Page 6.

5. Replace gasket if necessary, and connect water by-pass pipe (16) to lower side of thermostat housing (3).
6. Attach radiator connection to thermostat housing.
7. Replace water temperature gauge bulb in adaptor at rear of manifold.
8. Fill the cooling system and check for leaks.

NOTE: When filling or draining cooling system, remove plug (8), shown in Fig. 10, to vent system.

NOTE: When draining cooling system for storage or for winter anti-freeze, be sure to open shut off valve (28) at thermostat housing and drain remaining water from system

RADIATOR

Description—Effective engine cooling is insured either by a large radiator and fan or by a heat exchanger. Description of the heat exchanger cooling system appears on Page 2.

The radiator core and side members are bolted between the upper and lower tanks with gaskets at both top and bottom to prevent leaks. In order that the fan may pull all air used for cooling through the radiator core, a shroud is provided back of the core. A grille in front of the core helps keep the radiator fins free from obstructions, protects the core, and adds to the finished appearance of the unit. Water loss is prevented in the large upper tank by carrying the discharge from the cylinder head under a baffle plate.

Located within the upper tank is a seamless copper overflow tube. This tube serves as an overflow for all excess water above the baffle plate in the tank. The overflow tube goes through the inside of the tank and out the bottom, around the shroud, and down the side of the radiator core, and then to waste. It is supported on the side member by a metal clip. The overflow tube is of one piece construction and soldered into place where it passes through the bottom of the upper tank.

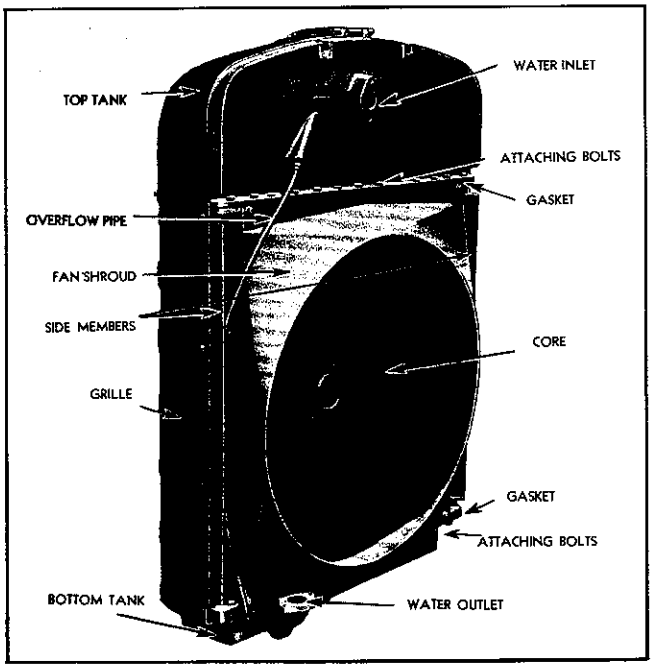


Fig. 11—Radiator Assembly.

Service—Only clean soft water should be used in the radiator and cooling system of the engine. Hard water will form scale, not only in the radiator core, but in the engine block and head. This lime deposit causes hot spots within the engine and plugs the tubes in the radiator core. Dirty water also will close the tubes in the core and restrict the water flow, and in extreme cases, will collect in the engine and cause overheating and eventual engine failure.

In the event the engine overheats and the fan belt, fan, and water level in upper tank are found to be satisfactory, it will be necessary to clean and flush the entire cooling system to correct this undesirable condition. In addition, all grease, oil, dirt, and any other obstructions must be removed from the fins of the radiator core so that the entire cooling area of the core can readily transmit the heat of the cooling water to the air stream.

A very effective and safe scale (and other foreign deposit) solvent is Sal Soda. It should be used in the proportions indicated and according to the directions printed on the solvent container. After the solvent has acted within the cooling system the prescribed length of time, the engine and radiator should be completely drained. Drains are provided on the lower tank of the radiator, at the water pump, and on the thermostat housing (air vent plug and drain valve, shown in Fig. 10). Following this, the system should be filled, slowly, to avoid rapid cooling and distortion, with clean soft water, and the engine operated for 15 minutes. Completely drain entire system again, then fill with clean soft water, as described above.

After filling system, closely inspect radiator and engine for water leaks. The cleaning of the fins is accomplished by means of an air blast carrying a

grease solvent, such as oleum spirits or carbon tetracholoride—never use gasoline, fuel oil, or kerosene—directed at the front (grille) side of the core and passing through to the back, or fan, side. The grille, upper and lower fan guards, fan guard, and shroud must be removed and the front end of the engine covered before performing this operation.

NOTE: Secure adequate ventilation of the working area to avoid possible toxic effects of the cleaning spray. Replace fan shroud, guards, and grille before resuming engine operation.

As will be noted in the preceding paragraphs, it has not been necessary to remove or disassemble the radiator for any of the above operations. However, there may be occasions, other than complete teardown of package power unit, when it is desirable to disassemble the radiator. Full instructions, arranged in proper sequence, are contained in the following paragraphs.

Remove Radiator—The radiator may be removed from the engine base in the following manner:

1. Drain cooling system.
2. Disconnect upper water hose at radiator flange and remove the elbow from the flange at the lower tank, leaving the hose attached to the elbow.
3. Loosen stay rods at radiator upper tank.
4. Remove radiator grille.
5. Remove drain cock that projects through engine base at lower water connection.
6. Remove radiator hold-down cap screws at each outside flange of lower tank.
7. On the six cylinder engine, loosen the fan assembly from crankshaft flange and push fan forward inside of shroud. On the three and four cylinder engines, loosen the fan shroud and slide shroud back over fan.
8. Lift radiator assembly; at the same time pull forward.

Remove Radiator Core—With the radiator removed from the engine base, the core may be removed as follows:

1. Remove fan shroud.
2. Remove the through bolts that retain the upper and lower tanks to the side members and core.
3. Loosen overflow pipe from upper tank and separate both tanks from core.

Install Radiator Core—The radiator core may be installed by reversing the sequence of operations for removal. Before installing the core in connection with other radiator parts, remove all traces of the old gaskets from the core and tank flanges.

1. Shellac a gasket to both the upper and lower tank flanges.
2. The hole to expose end of crankshaft is closer to the bottom than the top of the radiator core. The radiator side members are assembled with hood ledge toward the engine. Water outlet in the bottom tank is at the rear of the radiator.

   With these identification marks in mind, place the core on lower tank; set one side member each side of the core with flanges to the rear and the upper tank down on the side members and core, with water inlet opening toward rear.
3. Place the metal straps on the core flange gaskets between the flanges of the side members, then put all through bolts in place, a lockwasher on each bolt, and screw nuts finger tight. ***Do not tighten any nuts until after all bolts are in place, then tighten all nuts securely.***
4. Install fan shroud.
5. Attach overflow pipe to upper tank.

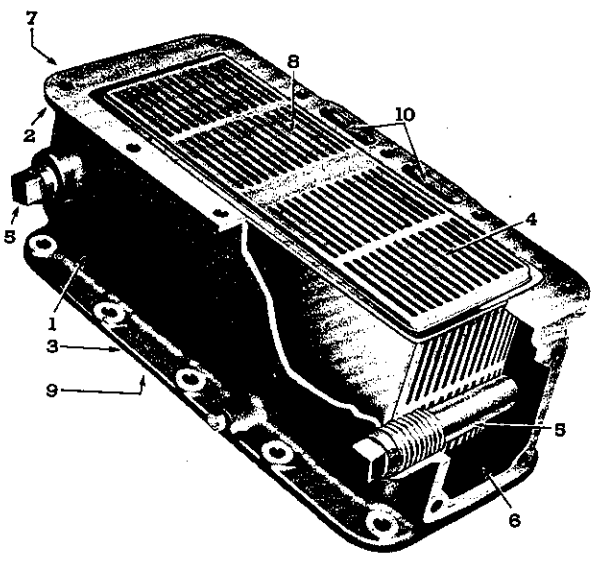
Install Radiator to Engine Base—A somewhat different procedure is followed on the three and four cylinder engines than on the six cylinder engine when installing the radiator to the engine base. When making this installation on a six cylinder engine, with the fan shroud in place, the fan and hub extension assembly, see Fig. 13, must be removed from the crankshaft flange and slid inside the radiator shroud. The radiator on the six cylinder engine cannot be set with the cooling fan in place, because the fan blades will interfere with the fan shroud. When setting the radiator on the three and four cylinder engines, the fan hub extension, including the blades, may be attached to the crankshaft driving flange, providing the radiator shroud is removed from the assembly and slid over the fan blades before setting radiator in place.

Fan blades may be designed for either the pusher or puller type; that is, forcing the air through the radiator from the back, or pulling the air through the radiator from the front. When fan blades are removed, and before they are again assembled, observe to see whether a pusher or puller type fan is used, and locate the blade assembly accordingly. With the above cautions in mind, the radiator assembly may be set on the engine base as follows:

1. Set radiator assembly down onto engine base, at the same time pull top of radiator away from engine.
2. Slide stay rods into position at radiator upper tank and start hold-down bolts into position at lower tank flanges.

3. Align radiator with nuts on stay rods so hood panels will fit, then turn hold-down bolts tight.
4. Install drain cock at lower water connection.
5. Attach water connections at upper and lower tanks.
6. Attach grille.
7. Fill cooling system before starting engine and inspect for leaks.

HEAT EXCHANGER



1. Heat Exchanger Housing.
2. Upper Flange—Water Tank Mounting.
3. Lower Flange—Oil Cooler Mounting.
4. Heat Exchanger Core—Cooling Element.
5. Zinc Electrodes.
6. Sea Water Inlet.
7. Sea Water Outlet.
8. Coolant Inlet from Water Tank.
9. Coolant Outlet to Oil Cooler.
10. By-Pass Passages.

Fig. 12—Heat Exchanger Assembly.

Cooling of the engine is accomplished by means of coolant circulation through the cylinder block and cylinder head by a centrifugal pump mounted on the front end of the blower and driven by the lower blower rotor shaft through a coupling (see page 3). The coolant pump operates in conjunction with a heat exchanger, through which the coolant passes in the process of cooling. A pump is also provided which forces raw water around the heat exchanger core, thus lowering the temperature of the coolant while passing through the core. The coolant pump draws the coolant from the oil cooler, and discharges it into the lower portion of the cylinder block as shown in Fig. 1. Openings in the water jacket around the cylinder bores connect with corresponding openings in the cylinder head, where the liquid circulates around the valves and fuel injectors. The water manifold, bolted to the cylinder head, discharges the cooling water past thermostats and into the water tank.

Description—The heat exchanger is known as the liquid-to-liquid cooling type.

The unit consists of a tubular core which forms the cooling element, and the housing for the core, as shown in Fig. 12. The exchanger is mounted to the balance weight cover with a water tank attached to water manifold, in some installations as shown in Fig. 2 and in others to the upper flange and the oil cooler housing attached to the lower flange.

In this system of engine cooling, the hot coolant, leaving the engine manifold, passes through the core of the heat exchanger. This core is surrounded by a supply of raw water which does not circulate in the engine cooling system, but is forced around the core of the heat exchanger and serves only to lower the temperature of the coolant coming from the water manifold.

Engines Used in Marine Service—To protect the heat exchanger core from the electrolytic action of the sea water, a zinc electrode is screwed into the housing at both the inlet and outlet openings and extends into the raw water passages. Zinc electrodes should be examined thirty days after installation. Under normal operating conditions, the electrodes will last much longer and need only be examined at intervals and replaced when necessary.

Operation—The water to be cooled in the heat exchanger enters the core from the water tank and circulates through the tubes, which are surrounded by raw water.

After leaving the heat exchanger core, the coolant is picked up by the pump and circulated through the cylinder block and cylinder head.

The coolant is lowered in temperature while passing through the core of the heat exchanger by the raw water, which is forced around the core by the raw water pump. The raw water enters the heat exchanger from the blower side of the engine and is discharged at the opposite side.

The water tank, which is located above the heat exchanger, is one of the essentials in connection with the heat exchanger installation. This tank provides a means of filling the engine cooling system, as well as space for expansion of the coolant as the

temperature rises. An overflow pipe near the top of the tank vents the water tank to atmosphere.

Service—The length of time a heat exchanger will function satisfactorily as a cooling unit will be governed largely by the kind of cooling liquid used in the engine and the cooling water passed around the heat exchanger core by the raw water pump. Soft water should be used as the engine cooling liquid, to prevent lime deposits in the heat exchanger core as well as in the engine.

Enough cooling liquid should be maintained in the engine to fill the cylinder block and head, and partially fill the water tank. Enough space should be maintained in the water tank to allow for the increase in volume as the temperature of the cooling liquid rises.

Whenever the heat exchanger fails to cool the engine properly and the sea water pump is circulating a normal amount of cooling water around the exchanger core, the core should be examined for foreign deposits.

Deposits may be removed from the heat exchanger core, if such deposits consist of dirt or like material, by running live steam through the core. If the deposits consist of lime or similar scale, this material may be removed by immersing the core in a scale solvent composed of one-third (⅓) muriatic acid and two-thirds (⅔) water, to which has been added one-half (½) pound of oxalic acid, to each two and one-half (2½) gallons of solution.

Remove core when foaming and bubbling stops. This usually takes from thirty (30) to sixty (60) seconds. ***Pressure flush thoroughly with clean hot water.*** To prevent hardening and drying of accumulated foreign substance, the core should be cleaned as soon as possible after removing from service.

No attempt should be made to remove the core from the heat exchanger body, as the two are serviced as one assembly. The covers and cover gaskets may be purchased separately.

Anti-Freeze Solutions—The same permanent anti-freeze solutions that are recommended for conventional gasoline engines are suitable for the G. M. 71 Diesel Engines.

When operating engines at outside temperatures below 32°F., a suitable anti-freeze solution should be used in the cooling system. As the Series 71 engines are equipped with a high temperature thermostat (158° F. opening temperature) a permanent anti-freeze must be used. ***Alcohol cannot be used successfully with the high-temperature thermostat*** as the alcohol will evaporate off and the engine will run hot. When operating an engine under certain conditions, it will be advisable, at times, to drain the cooling system even though an anti-freeze solution is used. This is particularly true when operating the engine at very cold temperatures, when it is advisable to warm the cooling solution for easy starting, before pouring back into the circulating system. If an inflammable anti-freeze is used, the solution should not be exposed to an open flame, where it is apt to catch fire. This procedure is unnecessary if the engine is equipped with an air heater as described on Page 7, Sec. 22.

COOLING FAN

Description—The cooling fan used on the industrial application is mounted directly to the front end of the crankshaft. The cooling fan used with automotive applications is mounted on a bracket supported on the front of the balance weight cover. Both fans are the six-blade suction type.

The fan for industrial applications, shown in Fig. 13, is mounted to a fan hub. This hub is bolted to a flange which in turn is keyed on the front end of the crankshaft. The driving inner diameter of the fan blades proper is retained between two rubber washers, one on either side of the fan blades. Each of these rubber washers is in turn bonded to a metal clamp, one of which sets inside the fan blades and is keyed to the fan hub extension; the other is pinned to the inner metal clamp. The entire fan blade assembly, including rubber mounting, is retained on the fan hub extension with a special nut and lockwasher. The fan is the same size and capacity on the three, four and six cylinder engines.

Fans for automotive applications, shown in Fig. 14, are bolted to a fan pulley (2), which is carried on two annular ball bearings. A slotted bracket supports the fan shaft at the inner end. This construction permits vertical motion of the fan assembly and fan belt adjustment by means of the adjusting lock screw.

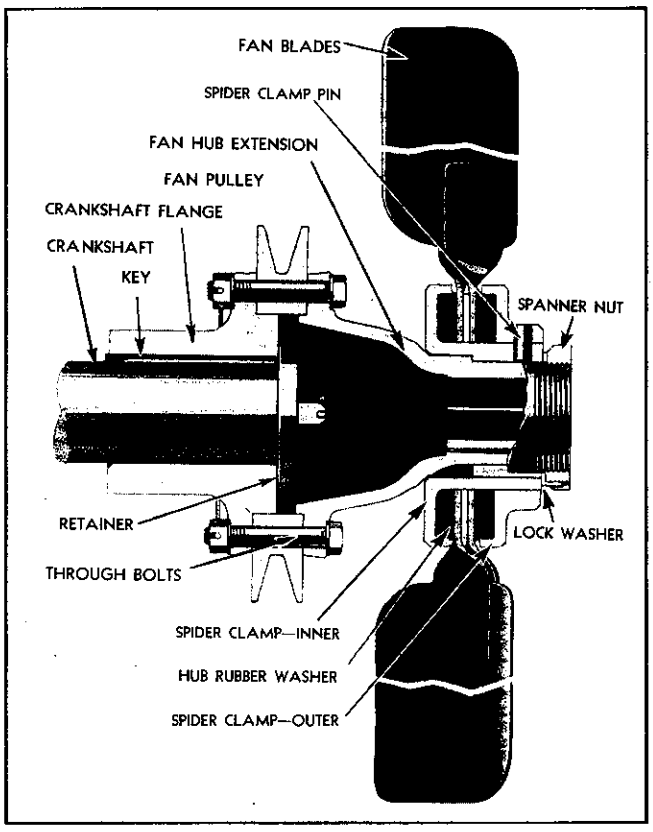
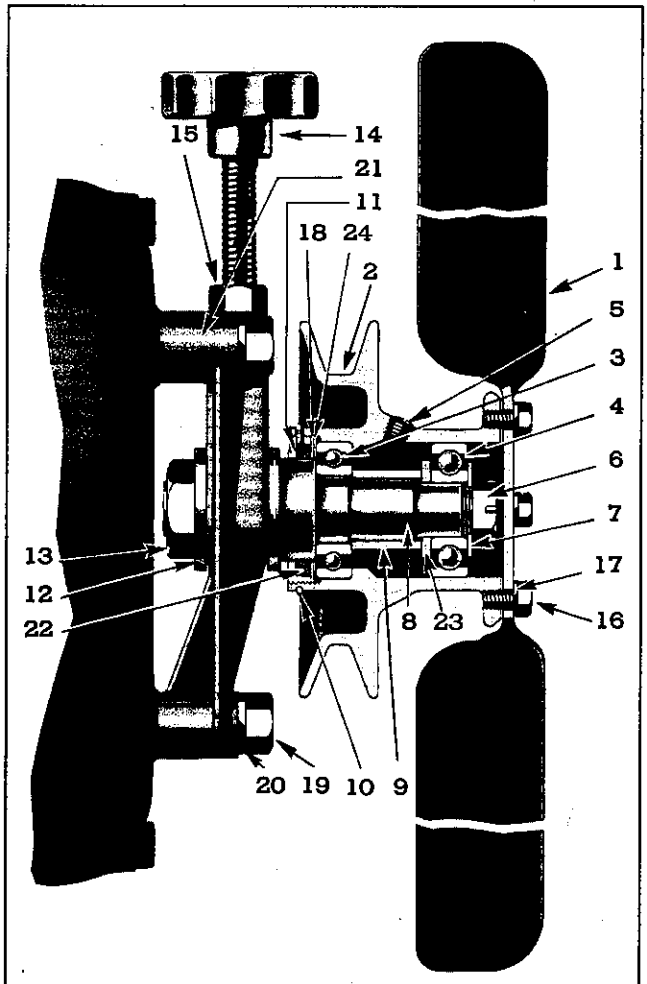


Fig. 13—Fan and Hub Assembly—Industrial.

Lubrication—The two fan bearings on the automotive fan are packed with grease when assembled and should need no further lubrication for the life of the bearings. The plug should be removed from the fan hub, however, before the engine is started to see that the bearings have been properly packed. If not, a good grade of fibre grease, such as is used in front wheel automobile bearings, should be introduced into the fan hub to completely fill the cavity between the two bearings.

Service—The cooling fan blades should run true with the rear face of the radiator core. Bent fan blades are not only conducive to inefficient cooling but may throw the fan out of balance and, if badly bent, are apt to damage the radiator core. DO NOT ATTEMPT TO TURN THE ENGINE BY PULLING ON THE FAN BLADES.

Fan Belt Adjustment—The V-type fan belt should be neither too tight nor too loose. Too tight a belt imposes undue load on the fan bearings and shortens the life of the belt. Too loose a belt allows slippage and lowers the fan speed. The belt may be adjusted on the automotive applications by means of the adjusting screw at the front of the engine. To adjust the belt, loosen the large nut (13) at the rear end of the fan shaft and the lock nut (15) on the adjusting



1. Fan Blades.
2. Fan Pulley.
3. Ball Bearing—Inner—Large.
4. Ball Bearing—Outer—Small.
5. Grease Plug—Removable.
6. Castle Nut.
7. Washer—Bearing Retaining.
8. Fan Shaft.
9. Bearing Spacer.
10. Lock Wire.
11. Lock Nut.
12. Washer—Shaft Retaining.
13. Nut—Shaft Retaining.
14. Belt Adjusting Screw.
15. Lock Nut.
16. Bolt—Fan Blade-to-Hub.
17. Lockwasher—Fan Blade-to-Hub.
18. Washer.
19. Bolt—Fan Bracket-to-Balance Weight Cover.
20. Lockwasher—Fan Bracket-to-Balance Weight Cover.
21. Fan Bracket.
22. Oil Seal.
23. Washer—Outer Bearing.
24. Shim—Inner Bearing.

Fig. 14—Fan and Hub Assembly—Automotive.

screw (14) and turn the adjusting screw clockwise to tighten or counter-clockwise to loosen the belt. Lock both nuts tight after belt has been adjusted.

The belt should have enough slack so it can be pushed in approximately 1¼" from a straight line between the rims of the two pulleys, midway between the pulleys. This straight line can be determined by placing a straight edge on the rims of the pulleys.

Remove Fan Blades—Industrial—The radiator must be removed along with the removal of the fan blades. This is accomplished by taking out the six bolts at the generator drive pulley and sliding the fan and hub extension into the fan shroud.

To remove the fan blades from the fan hub extension:

1. Support fan and hub extension assembly in a vise.
2. Straighten ears of lockwasher and remove nut at outer end of hub extension.
3. Tap fan blade assembly, including spider clamps, from hub extension.

The fan hub extension, including generator drive pulley, may then be removed from end of crankshaft by removing nuts and lockwashers from the six through bolts.

To remove the crankshaft flange to which the fan hub extension was bolted, back out cap screw in center of crankshaft and remove plain washer. Crankshaft flange may be pulled from position with gear puller, or driven from crankshaft with heavy bar and hammer.

Replace Cooling Fan—Industrial—Before the cooling fan is attached to the engine crankshaft flange, the blades should be assembled to the hub and hub extension in the manner shown in Fig. 13.

When replacing the fan blades, the support to which the blades are riveted will face the radiator core; in other words, the support will be between the radiator core and the fan blades proper.

With radiator off the engine base, slide the fan and hub assembly inside the fan shroud. Then set radiator in place, and attach the fan assembly to the crankshaft flange, with the belt pulley between the two members. After drawing nuts tight, on the through bolts at the belt pulley, install the lock wire through each bolt to keep bolts from backing off.

Remove and Replace Fan Blades—Automotive—The fan blades on the automotive type engines may be removed from the combination fan pulley and hub by first removing the cap screws which attach the blades to the hub, providing enough clearance exists between the fan blades and the inner face of the radiator core. If blades cannot be removed in this manner, then the entire fan bracket may be removed from the engine balance weight cover, and the blades removed from the hub. The fan blades may be installed by reversing the sequence of operations for removal.

AIR INTAKE SYSTEM

In the scavenging process employed in these two-cycle engines, a charge of air, which is forced into the cylinders by the blower, thoroughly sweeps out all of the burnt gases through the exhaust valve ports, and also helps to cool the internal engine parts, particularly the exhaust valves. (See Fig. 1.) At the beginning of the compression stroke, therefore, each cylinder is filled with fresh, clean air, which permits highly efficient combustion.

BLOWER

Description—The Blower, designed especially for efficient Diesel operation, supplies the fresh air needed for combustion and scavenging. Its operation is similar to that of a gear-type oil pump. Two hollow rotors, each with three lobes, revolve with very close clearances in a housing bolted to the side of the engine. To provide continuous and uniform displacement of air, the rotor lobes are made with a twisted or helical form. (See Fig. 2.)

The air entering the blower inlet from the air cleaner is picked up by the lobes and carried to the discharge side of the blower as indicated by the arrow in Fig. 1. The continuous discharge of fresh air from the blower creates an air pressure of about seven pounds per square inch in the air chamber of the cylinder block at maximum engine speed. This air sweeps through the intake ports, which start to open at 48° before bottom dead center, and close at 48° after bottom dead center.

The angle of the intake ports imparts a rotational motion to the intake air as it enters the cylinder. This rotation persists throughout the compression stroke and improves the combustion.

Two timing gears on the drive end of the rotor shafts space the rotor lobes with a slight clearance. Consequently, due to the fact that the rotors do not touch each other at any time, they require no lubrication. Highly effective seals prevent air leakage at the ends of the lobes, and also keep the oil used for lubricating the timing gears and rotor shaft bearings from entering the rotor compartment. The upper rotor is driven at 1.95 times engine speed by the blower driveshaft and the lower rotor is driven from the upper rotor through the timing gears. The flexible coupling which prevents the transmission of torque fluctuations to the blower is formed by an elliptical cam driven by two bundles of leaf springs, which ride on four semi-cylindrical supports. Each rotor is supported in the doweled end plates of the blower housing by a single-row radial ball bearing at the front, and a two-row pre-loaded radial and thrust ball bearing at the gear end.

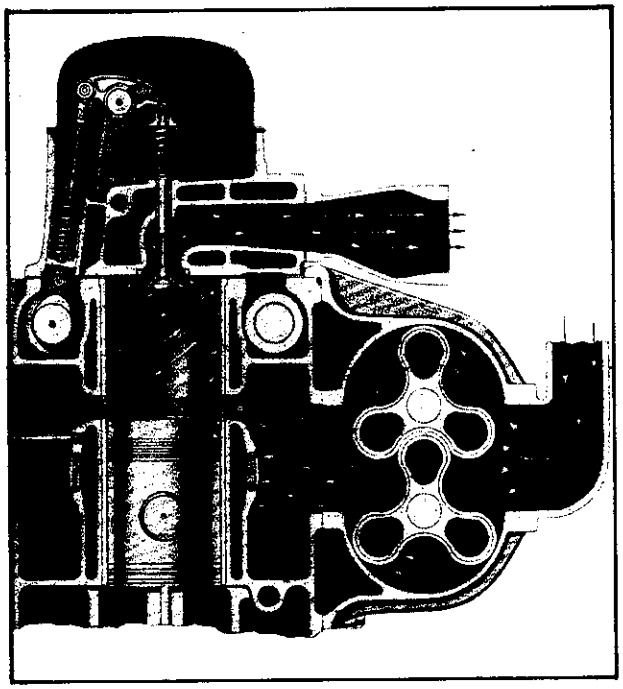


Fig. 1—Air Intake System Through Blower and Engine.

With the exception of the housing, rotors, and housing to cylinder block, and air inlet gaskets, which differ in length, the blower parts are identical for all 3, 4 and 6 cylinder engines and are completely interchangeable.

Blower Lubrication—The blower gears and bearings are lubricated from the oil which drains from the valve operating mechanism on the cylinder head and into the camshaft or balancer shaft gallery pockets. After this oil reaches a certain level in the pockets, it overflows through two holes at each end of the blower housing, providing lubrication for the blower drive gears at rear end and governor and water-pump drives at the front. A dam in the blower housing cover maintains an oil level which submerges the teeth of the blower lower rotor timing gear. A slinger on the opposite end of the lower rotor throws oil into the governor weight assembly. Surplus oil passes from the blower to the oil pan through drilled holes in the cylinder block.

Service—The blower is not a delicate device. Nevertheless, great care is taken when the unit is assembled at the factory. The same care must be exercised when the blower is serviced by the field mechanic.

As pointed out in the foregoing description, the blower rotors revolve with a slight clearance between the lobes and also between the lobes and the blower housing. Amply large bearings are used at

BLOWER

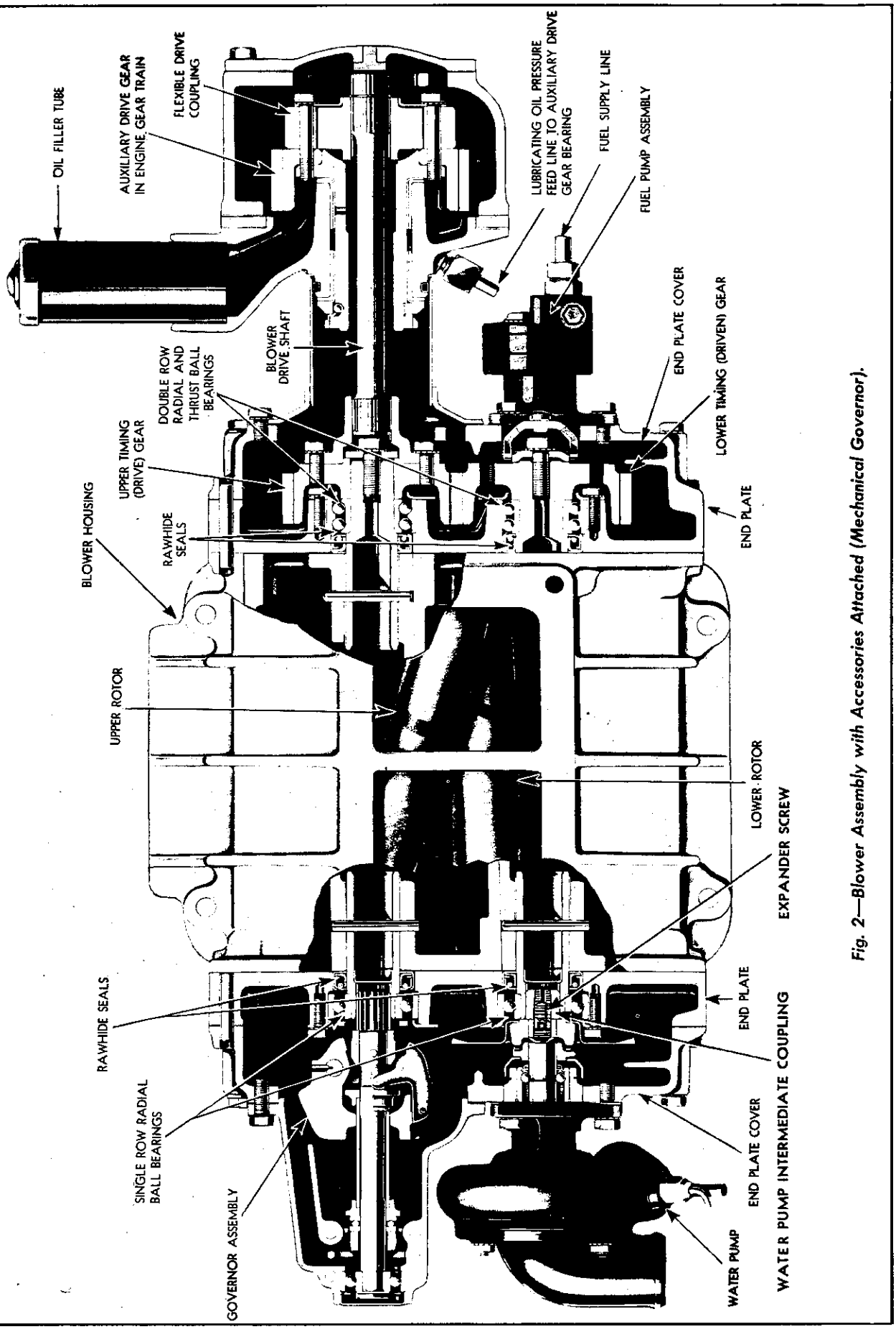


Fig. 2—Blower Assembly with Accessories Attached (Mechanical Governor).

each end of the rotor shafts and suitable oil seals are used back of each bearing to prevent engine oil entering the rotor compartment.

The blower rotors are timed by the two gears at the rear end of the rotor shafts. This timing must be correct, otherwise the required clearance between rotor lobes will not be maintained.

Normal gear wear causes a decrease of rotor-to-rotor clearance between the leading flanks of the upper rotor lobes and the trailing flanks of the lower rotor lobes. Clearance between the opposite sides of the rotor lobes is increased correspondingly.

While rotor lobe clearances may be changed by adjustment, gear back-lash cannot. When gears have worn to the point, therefore, where the back-lash exceeds .004" the gears should be changed. The procedure for timing blower rotors for proper clearance between lobes is outlined under "Blower Timing," Page 11.

Blower Inspection—Because of the important part the blower plays in the efficient operation of the Diesel engine, an inspection of the unit at regular intervals is recommended. Inspection periods will vary according to the application. When engines are used in dusty surroundings with improper service of air cleaners, blower inspection must be more frequent. Generally, 1000 hours of operation on tractor and industrial applications and 15,000 miles on automotive applications, is a fair index of when blowers should be inspected. If this practice is followed minor irregularities can usually be detected and corrected before more serious difficulties develop. A blower may fail to function properly because of any one, or a combination of the following reasons:

1. Dirt or foreign matter having been drawn through the blower, thereby scoring the rotor lobes and housing.
2. Worn oil seals permitting lubricating oil to be drawn into rotor compartment.
3. Worn blower drive causing rattling noise inside blower.
4. Loose rotor shafts or unsatisfactory bearings causing contact between rotor lobes, rotors and end plates and between rotors and housing.
5. Out of time—that is, due to timing gear wear, the mating rotor lobes may not have sufficient clearance at one side and too much clearance on the opposite side. (See "Blower Rotor Timing," Page 11.)

A blower may be inspected for any of these conditions without being removed from the engine. If, however, inspection reveals that the blower has been damaged or worn, sufficiently to impair its efficiency, then it should be removed from the engine and either overhauled or replaced.

Before examination of blower on the engine for any unusual conditions, remove air cleaners, blower air inlet housing, or any other parts interfering with the air inlet system.

CAUTION!

(1) ***When blower rotors are exposed and engine is in operation, keep fingers, clothing, and any loose parts away from the blower air inlet. Severe bodily injury, or damage to the blower may result.***

(2) ***Always disconnect starting battery cable to render engine starting equipment inoperative before starting work on a blower that involves use of the hands on blower rotors.***

An inspection to determine if any of the four above conditions exists in a used blower may be carried out thus:

1. **Dirt or Chips** drawn through the blower will cause deep scratches in the rotors and housing and throw up burrs around such abrasions. If burrs cause interference between rotors, or rotors and housing, the blower should be removed from the engine and parts dressed down to eliminate interference, or rotors changed if too badly scored.
2. **Leaky Oil Seals** are usually manifest by the presence of oil on the blower rotors or inside the housing. Oil on rotors is sometimes a result of pull-over from air cleaner or ventilator; therefore, the two conditions should not be confused. For a sure check for oil seal leak:
   (a) Start and operate engine at approximately 1000 r.p.m.
   (b) With strong light directed into rotor compartment, observe end plate for thin film which will radiate away from a leaky oil seal. (See Fig. 3, for location of blower oil seals.)
3. **Inspect for Worn Blower Drive:**
   (a) Start and operate engine at approximately 300 r.p.m. by manual control of injector control tube. Worn drive coupling will cause loose, rattling sound within blower.

NOTE: Do not confuse this sound with a loose water pump drive coupling, which causes a similar noise.

   (b) Stop engine. ***Disconnect starting system.*** Grasp top rotor firmly and attempt to rotate. Rotors should move from 3/8" to 5/8", measured at lobe crown, with a springing action. When released, rotors should move back at least 1/4". Coupling should be inspected if rotors cannot be moved as above, or if rotors move freely or can be rattled.

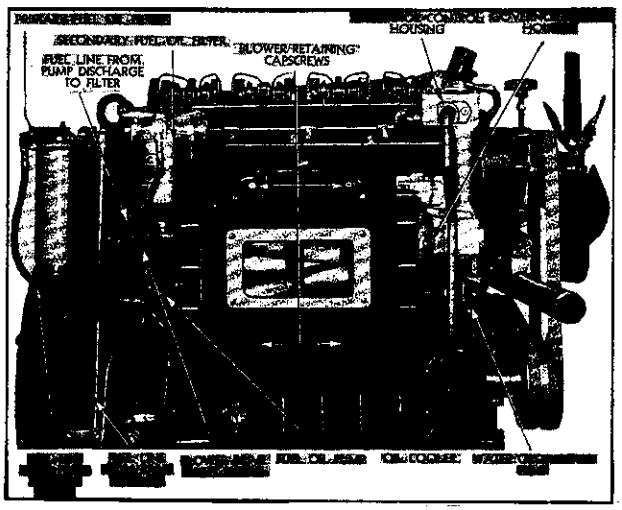


Fig. 3—Blower Mounting—Shown with Mechanical Governor.

If check shows drive coupling to be worn it may be removed for reconditioning or changing by first removing the combination flywheel housing and gear train cover, and then loosening coupling from the blower drive gear.

4. **If Loose Rotor Shafts or Defective Bearings** are causing blower difficulties, such a condition will be manifest by rubbing and scoring between crowns of rotor lobes and mating rotor roots, between rotors and end plates, or between rotors and housing. Generally a combination of these conditions exist.

A loose shaft usually causes rubbing between rotors and end plates. Worn or unsatisfactory bearings will cause rubbing between mating rotor lobes at some point or perhaps allow rotor assemblies to rub blower housing. This condition will usually show up at end of rotors at which bearing has failed.

Excessive back-lash in blower timing gears usually results in rotor lobes rubbing throughout their entire length.

To correct any one of these conditions the blower must be removed from the engine and either repaired or replaced.

Timing of blower rotors is described in detail on Page 11. As mentioned previously, blower rotors may be retimed to compensate for timing gear wear. However, correction cannot be made in the gears themselves. When, therefore, gear wear develops to the point that mating rotor lobes are apt to strike (more than .004" total gear back-lash), the gears should be changed.

The procedure for checking rotor-to-rotor and rotor-to-housing clearances is described under "Blower Timing," Page 11. Obviously, if rotor lobes or blower housing are scored so as to require a blower overhaul or change, a check for clearance would be not only misleading, but unnecessary.

If the above checks indicate that the blower must be removed from the engine, or if removal is required for any other reason, a guide to the various operations will be found below.

Remove Blower Assembly From Cylinder Block—In most cases the removal of the blower assembly together with the governor drive, the water pump, the fuel oil pump, and the blower drive shaft cover, will be found most advantageous. For removal of this assembly the following may be used as a guide:

1. Drain water from cooling system.
2. If mechanical governor is used, remove the control housing assembly as directed in the first six items, "Remove Governor from Engine," Page 5, Sec. 16. If hydraulic governor is used, remove the unit as directed under "Remove Governor from Engine," Page 27, Sec. 16.
3. Disconnect fuel lines at fuel pump.
4. Break water pump connections at oil cooler and cylinder block.
5. If engine is equipped with the hand control over-speed trip, disconnect Bowden wire control at valve shaft lever located at lower rear corner of blower air inlet housing.

   If engine is equipped with automatic, over-speed trip, disconnect drive shaft at over-speed trip governor.
6. Remove air cleaners and blower air inlet housing, including striker plate and blower screen which are mounted between inlet housing and blower.
7. Remove retaining cap screws at top and bottom of blower housing.
8. Raise front end of blower slightly to clear water pump to oil cooler connection, and pull blower assembly (including accessories) forward, withdrawing blower drive shaft cover from grommet on drive gear housing and drive shaft from coupling attached to blower upper rotor timing gear.

Remove Accessories From Blower—After the blower assembly has been removed from the engine, the various accessories may be removed as follows before the blower itself is disassembled:

1. Remove three cap screws attaching fuel pump to blower rear end cover plate, and remove fuel pump and drive coupling.

2. Remove six cap screws attaching blower drive shaft cover to the blower rear cover plate, and remove sleeve.
3. Remove three cap screws attaching water pump to blower front cover plate, and remove pump by tapping pump housing lightly with copper hammer.
4. Remove six cap screws attaching either governor drive or governor weight housing to blower front cover plate and withdraw governor drive shaft from blower rotor shaft.

Disassemble Blower—After blower is removed from the engine and accessories removed therefrom, it may be cleaned with gasoline and compressed air, then disassembled. ***Do not clean in hot solvents, as such practice will destroy the leather oil seals.***

To Disassemble:

1. Remove ten cap screws in each end cover and pull cover off dowels at top and bottom of bolt flange. Do not pry between cover and end plate or gasket surfaces will be damaged.
2. Using a 3/16" Allen wrench, loosen expander screw, if one is provided, at center and front end of blower lower rotor shaft, and withdraw water pump intermediate coupling from shaft. (See Fig. 2.)
3. Remove six cap screws attaching blower drive shaft flange to rear face of blower upper rotor timing gear, and tap flange free of gear.
4. Remove the cap screws and washers at center of rear end timing gears that lock the gears in place.
5. **Pull Rotor Timing Gears.** ***The two timing gears must be pulled from the rotor shafts at the same time.*** This may be done with tool set J-1682-C, shown below, as follows:
   (a) Back out puller studs (A) in puller plates (B) as far as possible.
   (b) Install two anchor bolts (C) in diametrically opposite holes of puller plates and screw anchor bolts into gears as far as possible so faces of plates are parallel with face of blower.
   (c) Turn the two puller studs (A) ***uniformly*** clockwise and withdraw gears from rotor shafts.

   Note number and thickness of shims on each rotor shaft, if any are used, remove from shafts and replace accordingly when assembling blower.
6. Back out three cap screws at each bearing and remove rotor shaft bearing retainers at both ends of blower.

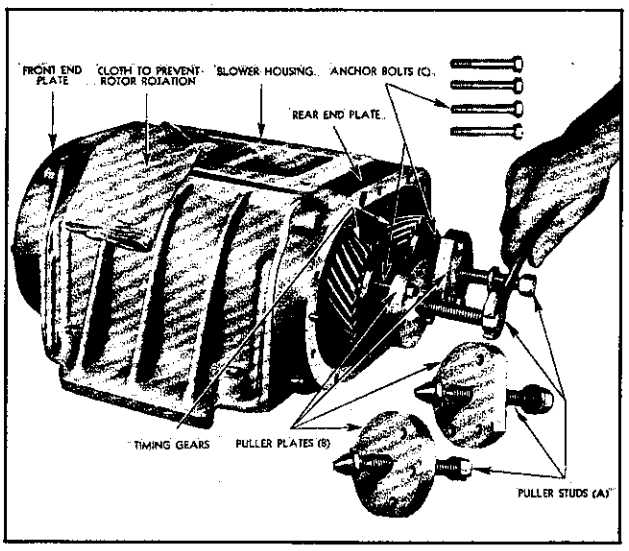


Fig. 4—Pulling Rotor Timing Gears.

7. **Remove Rotor Shafts From Rear Bearings and Front End Plate From Blower Housing.** This procedure applies to blowers on which the rotors and housing have not been scored to the extent that withdrawal of rotors assembled to the front end plate will not further damage rotors. If rotors and blower housing are badly scored, rotor shafts should be pushed from bearings in front end plate before withdrawal, as outlined in item (8) below.
   (a) Remove two countersunk fillister head screws from ***front end*** plate, and loosen about three turns the two countersunk fillister head screws in ***rear*** end plate.
   (b) Back out puller studs (A) in puller plate (B) as far as possible. (See Fig. 5.)
   (c) Install the three anchor bolts (D) in the three equally spaced holes of each puller plate and screw anchor bolts in holes from which

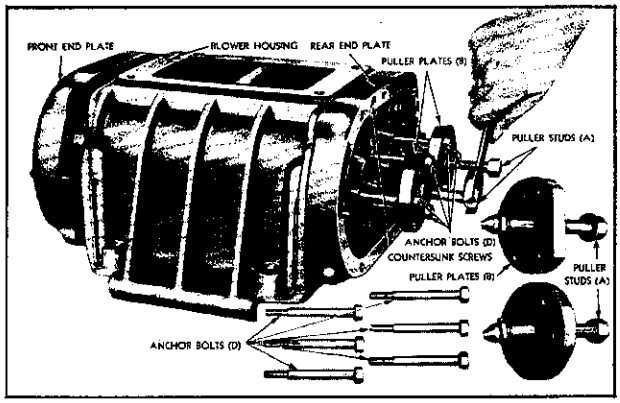


Fig. 5—Pressing Rotor Shafts from Rear Bearings and Front End Plate from Housing.

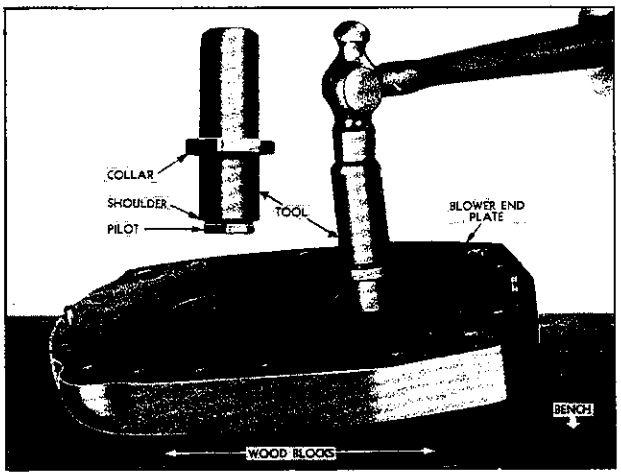


Fig. 6—Removing Rotor Shaft Bearings, also Oil Seals from Blower End Plates.

bearing retainer screws were removed so faces of plates are parallel with face of blower.

(d) Turn the two puller studs (A) uniformly clockwise and push rotor shafts from bearings in *rear* plate. *Front* plate, with rotor shafts still assembled in bearings, will be pushed away from blower housing simultaneously.

(e) Remove tool from rear end plate and the two fillister head retaining screws, then pull plate from position by hand. Withdraw rotors and front end plate assembly from blower housing, *if rotors are not scored.* If rotors are scored, remove front end plate from rotor bearings before withdrawing rotors; as outlined in item (8) below.

8. **Remove Rotor Shafts From Front End Plate Bearings**—The rotor shafts are removed from the *front* end plate bearings with the same tool and in exactly the same manner as from the *rear* plate, as follows:

(a) Attach puller plates (B) to blower front end plate with anchor bolts (D) screwed into holes from which bearing retainer bolts were removed—the same as in 6-c above.

(b) Turn the two puller studs (A) *uniformly* clockwise and push rotor shafts from bearings.

9. **Remove Rotor Shaft Bearings From Blower End Plates.** To remove bearings from end plates:

(a) Insert bearing removing tool through oil seal from inner face of blower end plate, as shown in Fig. 6, so pilot of tool enters bore in inner race of bearing and shoulder of tool rests against face of bearing inner race. Support end plate approximately two inches off bench and drive bearing from position. Follow this same method on all four bearings.

10. **Remove Bearing Oil Seals From Blower End Plates**—Inspection of oil seals for leaks while the blower was running on the engine largely determined if they should be changed. A further inspection may be conducted after blower has been disassembled. If the leather is scored so that a tight seal on shafts is impossible or the leathers have become charred and hard, the seals should be changed. If change is necessary, the seals may be removed from the end plates at the same time the individual bearings are removed. This is done by continuing to drive down on the tool, shown in Fig. 6, until collar on tool rests on and forces seal down and out of plate.

Inspect Blower Parts—After the blower has been disassembled all parts should be washed in clean gasoline, blown off with dry compressed air and inspected before assembly.

1. **Ball Bearing Inspection.**

(a) Wash the ball bearings by rotating the bearings by hand in clean kerosene or fuel oil until free from grease and oil.

(b) Clean the balls and races by directing air through the bearing, at the same time rotating the bearing by hand. Do not spin the bearing with air pressure.

(c) If necessary, repeat cleaning operation to be sure all foreign substance is removed.

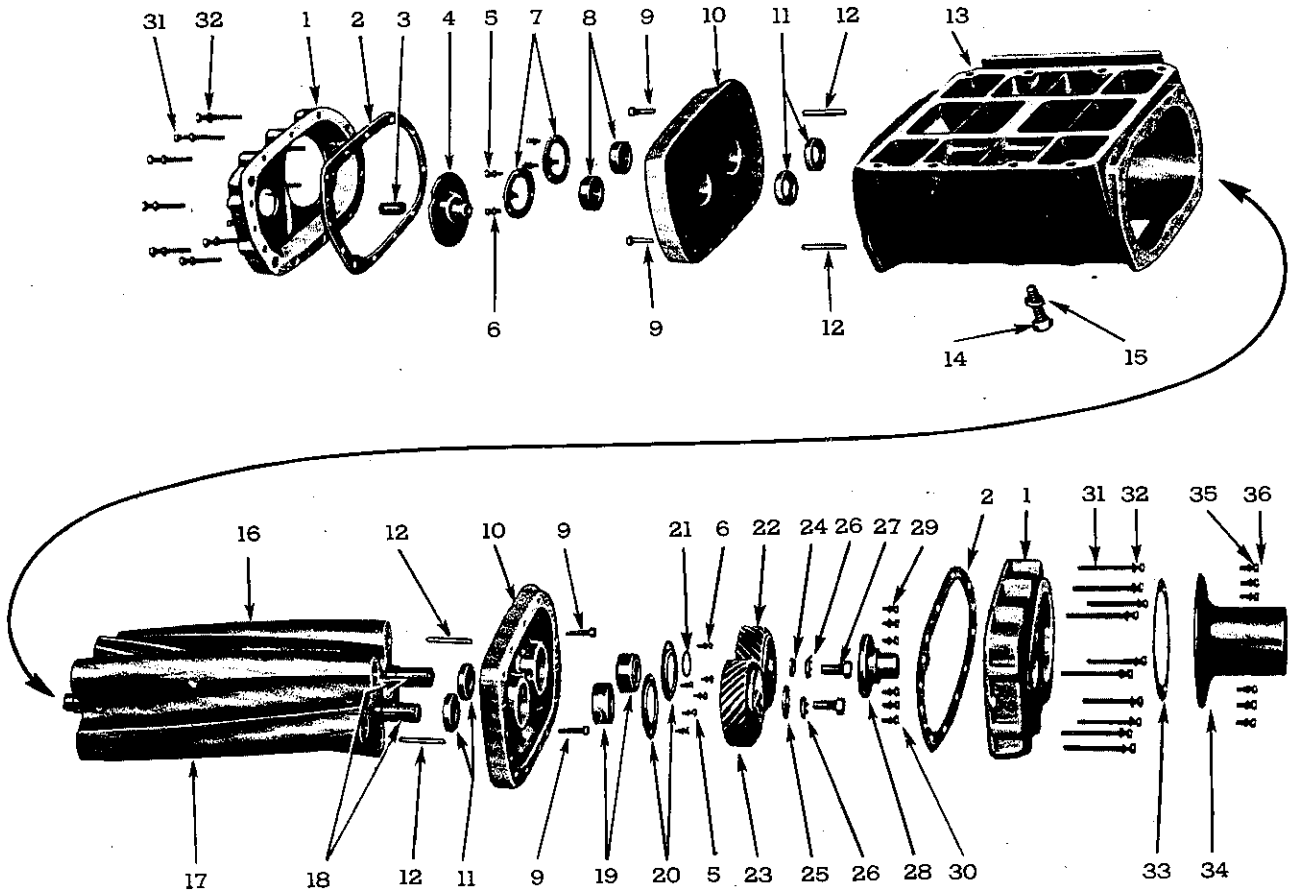
(d) After cleaning thoroughly, lubricate with clean engine oil and rotate by hand and inspect for rough spots. The bearing should run free and show no indication of roughness. The double-row bearings are pre-loaded and have no end play; in fact, a new double-row bearing will seem to have considerable resistance to motion when revolved by hand.

2. Check the oil seals in the end plates and, if necessary, replace. Oil seals should be lubricated with clean engine oil, or light grease, at time of assembling blower.

3. Inspect blower rotor lobes for smoothness, and shaft serrations and bearing surfaces for wear or burrs.

4. See that end plate finished faces are smooth and flat.

5. See that finished ends of of blower housing, which receive the end plates, are flat and free from burrs. The end plates must set flat against the blower housing.



1. Cover—End Plate.
2. Gasket—End Plate-to-Cover.
3. Expanding Screw—Water Pump Intermediate Shaft.
4. Assembly Water Pump Intermediate Shaft Coupling and Oil Slinger.
5. Bolt.
6. Lock Washer.
7. Bearing Retainer—Front.
8. Ball Bearing—Front.
9. Screw—End Plate Retainer.
10. End Plate.
11. Oil Seal.
12. Dowel—End Plate.
13. Blower Housing.
14. Bolt—Housing Mounting.
15. Lock Washer.
16. Upper Rotor—R. H. Helix.
17. Lower Rotar—L. H. Helix.
18. Rear Shaft—Blower Rotor—Serrated.
19. Ball Bearing—Rear—Double Row—Thrust.
20. Bearing Retainer—Rear.
21. Shim—Placed Between Gear and Bearing for Timing of Rotors.
22. Rotor Gear—R. H. Helix.
23. Rotor Gear—L. H. Helix.
24. Washer—Gear Retaining.
25. Disc—Fuel Pump Coupling.
26. Lock Washer.
27. Bolt.
28. Hub—Blower Rotor Gear.
29. Lock Washer.
30. Bolt.
31. Bolt—End Plate Cover-to-Housing.
32. Lock Washer.
33. Gasket—Drive Shaft Cover to End Plate Cover.
34. Cover—Drive Shaft.
35. Lock Washer.
36. Bolts.

Fig. 7—Blower Details and Relative Location of Parts.

6. Check blower gears for wear. If teeth show excessive wear or back lash exceeds .005", gear should be replaced.
7. As will be seen from Fig. 17, the rotors must revolve inside the blower housing with a specified clearance between the housing and rotor lobes. Inspect the inside of the housing to see that the surfaces are smooth, also the rotor lobes to see that lobes do not contact. Follow the clearances shown in the above chart when assembling blower.

Blower Assembly—All blower parts having been inspected, assemble blower by reversing sequence of operations for disassembly and using tools shown, as follows:

1. **Install Oil Seals in Blower End Plates**—The oil seals should be assembled into the end plates with flat face of seals flush with inner, finished face of plates and sealing edge of leather pointing toward rotor bearings, as shown in Fig. 2. The seals may be installed properly with the tools shown in Fig. 8, as follows:

   (a) Support end plate between soft jaws in bench vise. Back out puller stud (A) as far as possible and push stud through bore for bearing in end plate from the outer face (rib side with puller plate [B]) resting against outer face of blower end plate.

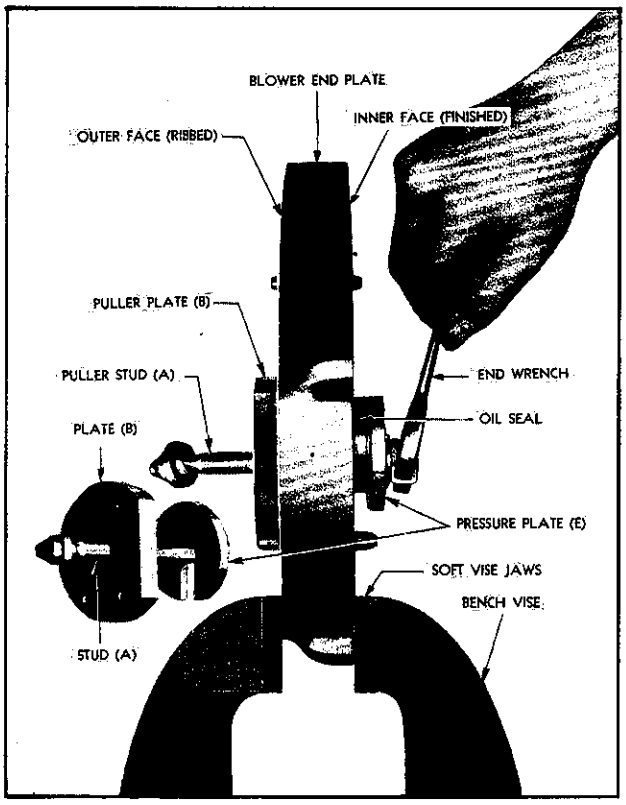


Fig. 8—Installing Oil Seals into Blower End Plates.

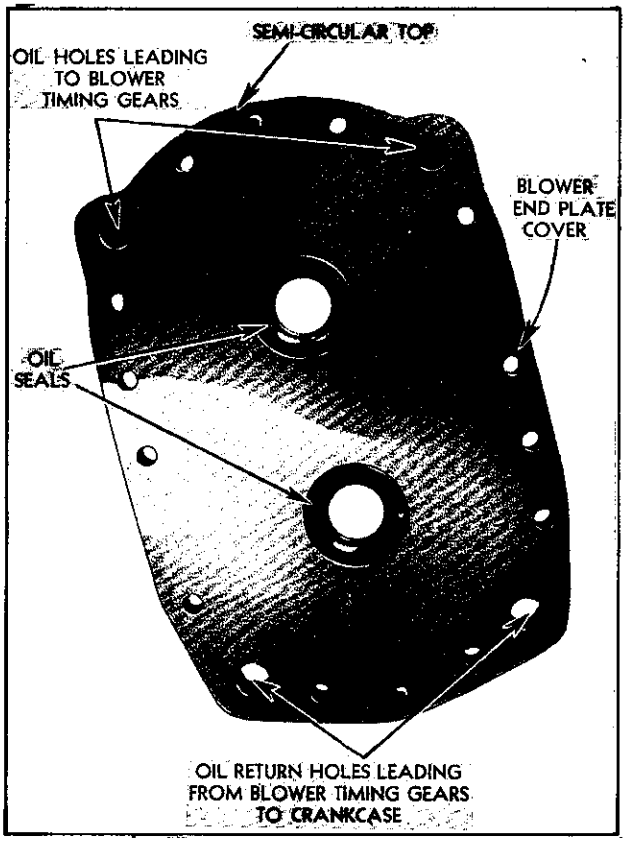


Fig. 9—Blower End Plate.

(b) With flat face of oil seal facing head of puller stud, slide seal over head of stud and start into bearing bore by hand.

(c) Slip pressure plate (E) over body and next to head of puller stud and turn puller stud (A) clockwise forcing oil seal into seat until pressure plate (E) sets tight against inner face of blower end plate. Remove tool and install remainder of seals in the same manner.

2. **Install Blower Front End Plate**—The top of the blower may be identified by the flange which carries the entire length of the housing and provides a rest on top of the cylinder block. The end plate is semi-circular at the top, as shown in Fig. 9, and is also marked "TOP" on outer, ribbed side.

   Even though the blower end plate is interchangeable front and rear, the plate at the front end of the blower should be assembled to the blower housing before the rear plate is assembled.

   When viewing blower housing from cylinder block side, the end plate for the front will be assembled to the right-hand end of the housing for RA, RB, LA and LB model engines, and to the left-hand end for RC, RD, LC and LD model engines, as shown in Figs. 10 and 11.

   With these identifications clearly in mind, attach end plate to front end of blower housing, as follows:

   (a) Start end plate dowels in dowel holes of blower housing. Rap dowels and end plate lightly with babbitt hammer to fit end plate to housing.

   Note that no gaskets are used between end plates and housing, therefore mating surfaces must be perfectly flat and smooth.

   (b) Lock end plate securely to housing with two fillister head screws. ***No lockwashers.***

   (c) Inspect and see that dowels project $\frac{3}{8}$" beyond outer face of end plate.

3. Before further assembly of the blower, certain checking operations are necessary to insure the proper relation of parts. The lobes on one of the blower rotors and the teeth on one of the timing gears form a right-hand helix and on the mating parts a left-hand helix. The rotor with the right-hand helix must be used with gear having right-hand helical teeth and vice-versa. Rotor and gear with ***right-hand*** helices are the upper units in the blower; and those parts with ***left-hand*** helices the lower units. On later engines rotors and gears are marked with the words "Upper" and "Lower." The Identification marks are on the rear face of the gears and on the top of one

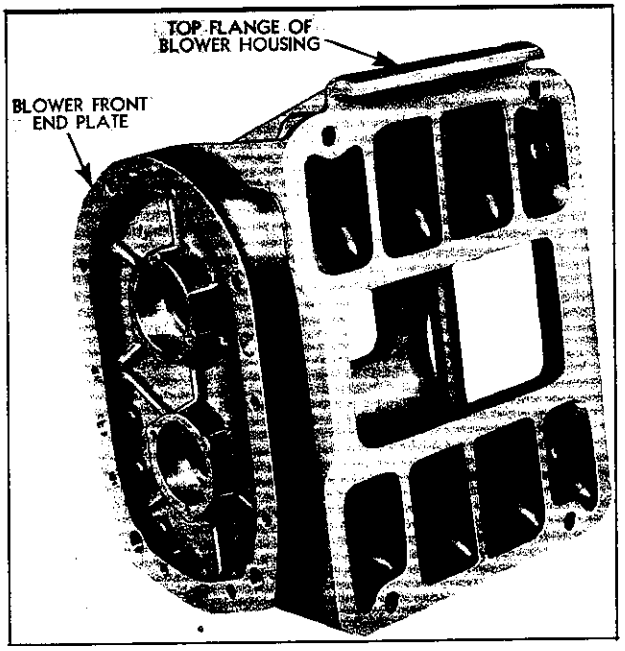


Fig. 10—Position of Blower Front End Plate for Engine Models RC, RD, LC, and LD.

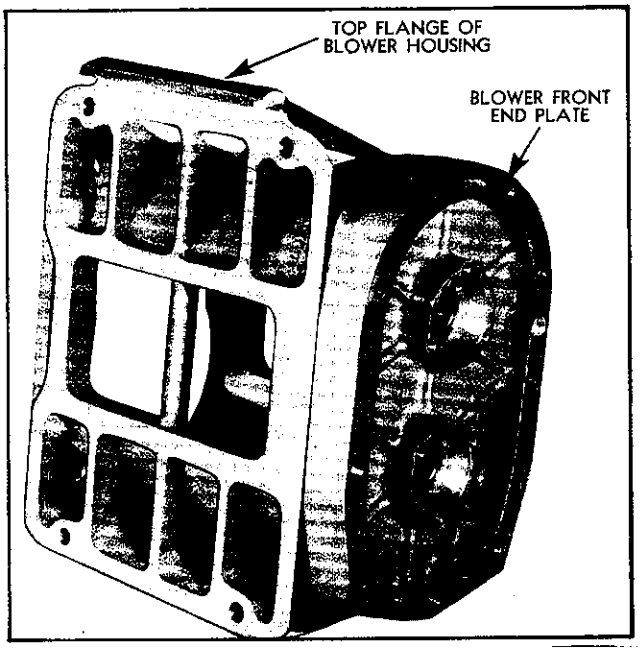


Fig. 11—Position of Blower Front End Plate for Engine Models RA, RB, LA, and LB.

of the lobes of each rotor. Furthermore, for convenience in blower timing, one serration is omitted on the drive end of each blower shaft with corresponding omissions in the gear hubs. Gears must be placed on the shafts with the serrations in registration. ***Rotors must be assembled with the omitted serrations toward top on both rotor shafts.***

To avoid confusion when assembling, place the right-hand rotor and right-hand gear together on the bench; likewise the left-hand rotor and gear, as shown in Fig. 12.

4. **Assemble Rotors into Housing**—With checks in mind, as outlined in item (3) above:
   (a) Install one oil seal pilot (F) over short end (non-splined) of each rotor shaft and with rotors in mesh and omitted serrations toward top of blower housing, slip rotors into housing. (See Fig. 13.)
   (b) Remove oil seal pilots.
5. **Install Blower Rear End Plate.** With rotors positioned in housing as per item (4) above:
   (a) Install one oil seal pilot (F) over serrated end of each rotor shaft. (See Fig. 14.)
   (b) Identify top and bottom of end plate as described in item (2) above, and shown in Fig. 9, and start end plate dowels into dowel holes in blower housing. Tap dowels lightly to fit end plate to housing.
   (c) Lock end plates securely to housing with two fillister head screws. ***No lockwashers.***
   (d) Inspect and see that dowels project $\frac{3}{8}$" beyond outer face of end plate.
   (e) Remove oil seal pilots.
6. **Install Rotor Shaft Front Bearings**—Single-row ball bearings are used at the front end of the blower rotor shafts and double-row ball bearings at the rear (serrated) end. The bearing number is stamped at one end of the ball race only. ***When assembled, the markings are toward the outside face of the end plate. With these identifications in mind:***
   (a) Start the single-row bearings onto front end of rotor shafts (short end with internal splines).

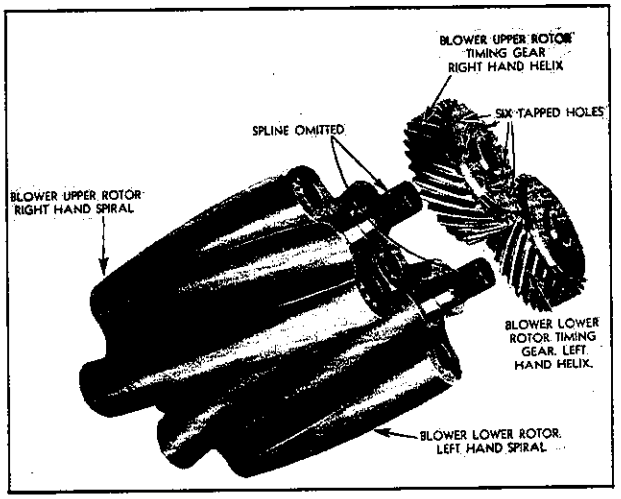


Fig. 12—Upper Vs. Lower Rotors and Gears.

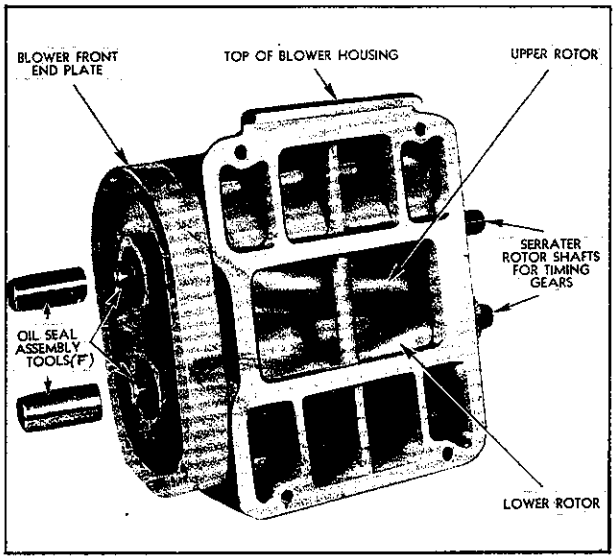


Fig. 13—Assembling Blower Rotors into Housing—Front End Plate Attached.

(b) Using tool (G) shown in Fig. 15, tap bearings into end plates.

NOTE: Bearing retainers for single-row bearings have 1 13/16" inside diameter and for double-row bearings 1 9/16" inside diameter.

(c) Install front bearing retainers with flange at inner diameter of retainer directed toward bearing. Lock each retainer with three cap screws and lockwashers. (See Fig. 2.)

7. **Install Rotor Shaft Rear Bearings**—Install the rear rotor shaft bearings exactly the same way the fronts were installed and using the same tool, except, flange at inner diameter of retainer is directed away from bearing. (See Fig. 2.) Be sure markings on bearing race are toward blower end plate.

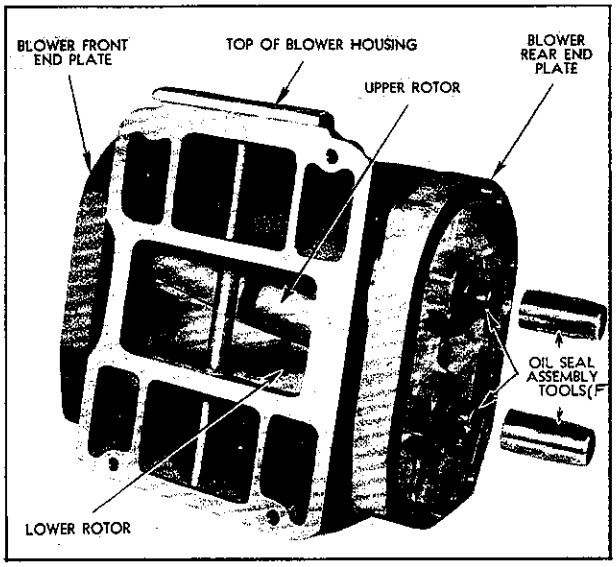


Fig. 14—Installing Blower Rear End Plate.

8. Rotor to housing and rotor to end plate clearances may be checked at this time, as described under "Blower Timing," Page 11.

9. **Press Timing Gears Onto Roller Shafts**—If blower once used is being reassembled—shims were no doubt used back of one, or perhaps both blower timing gears—they should be installed in their original positions before pressing gears onto shafts. If new gears or shafts are used, install without shims, and use later if necessary, when timing rotors.

NOTE: Timing gears are matched. When replacement is necessary they must be replaced as a set. (See Blower Timing, Page 11.)

Being sure that both rotor shafts with the omitted serrations, as shown in Fig. 12, point toward top of blower; that the drive gear (timing gear) with six tapped holes in hub, is located on the upper rotor shaft; that original shims are placed on their respective shafts, start both gears onto shafts with omitted serrations on shafts and gears registering. An "O" mark is indented into end of shaft at omitted serration to assist in locating gears properly.

Apply some engine oil at shaft serrations and proceed to press gears onto shafts with tool, shown in Fig. 16, as follows:

(a) If blower is equipped with 3/8" diameter timing gear retainer bolts, put thrust washers (J) on puller studs (H), insert short threaded end of studs through holes in gear hubs and screw into rotor shafts as far as possible.

(b) Turn puller nuts (K) uniformly clockwise and press gears tight against shoulders or shims on shafts.

CAUTION: Gears must be pressed to position at the same time to avoid damage to gears and rotors. Do not pull gears up tight if rotors are in contact.

(c) If blower is equipped with 1/2" diameter timing gear retainer bolts, use these bolts, together with the small washer at upper shaft and large washer with driving lugs at lower shaft, to press the gears uniformly onto shafts.

(d) If 3/8" timing gear retainer bolts are used, lock gears in place with cap screws and lockwashers, noting that small flat washer is located on upper shaft, and large washer, with driving lugs for fuel pump, is located on lower shaft. See that locking ears on fuel pump coupling engage slots in gear hub.

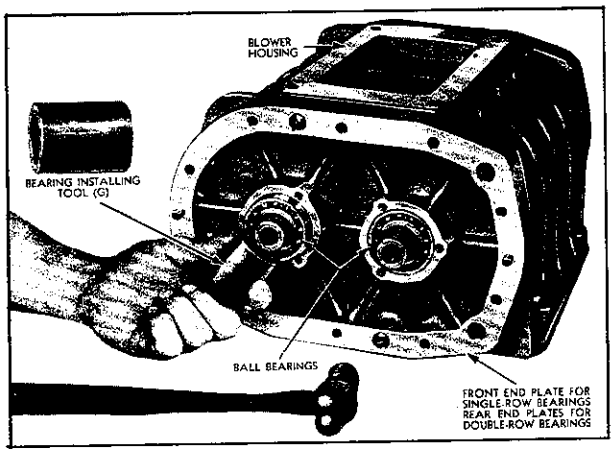


Fig. 15—Installing Blower Rotor Shaft Bearings into End Plates.

(e) If ½" timing gear retainer bolts are used, install special lockwasher and pierced retaining washer on bolt for upper gear so that retaining washer pierced lugs engage slots in gear hub, and lockwasher ear engages slot in retaining washer.

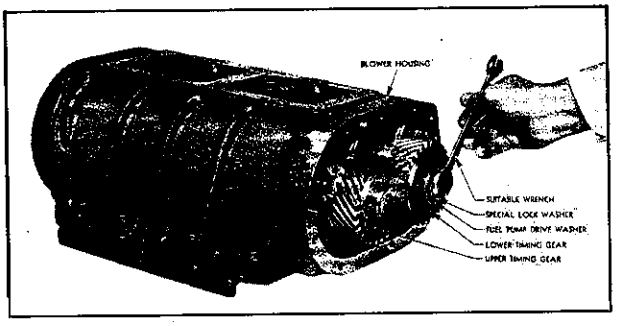
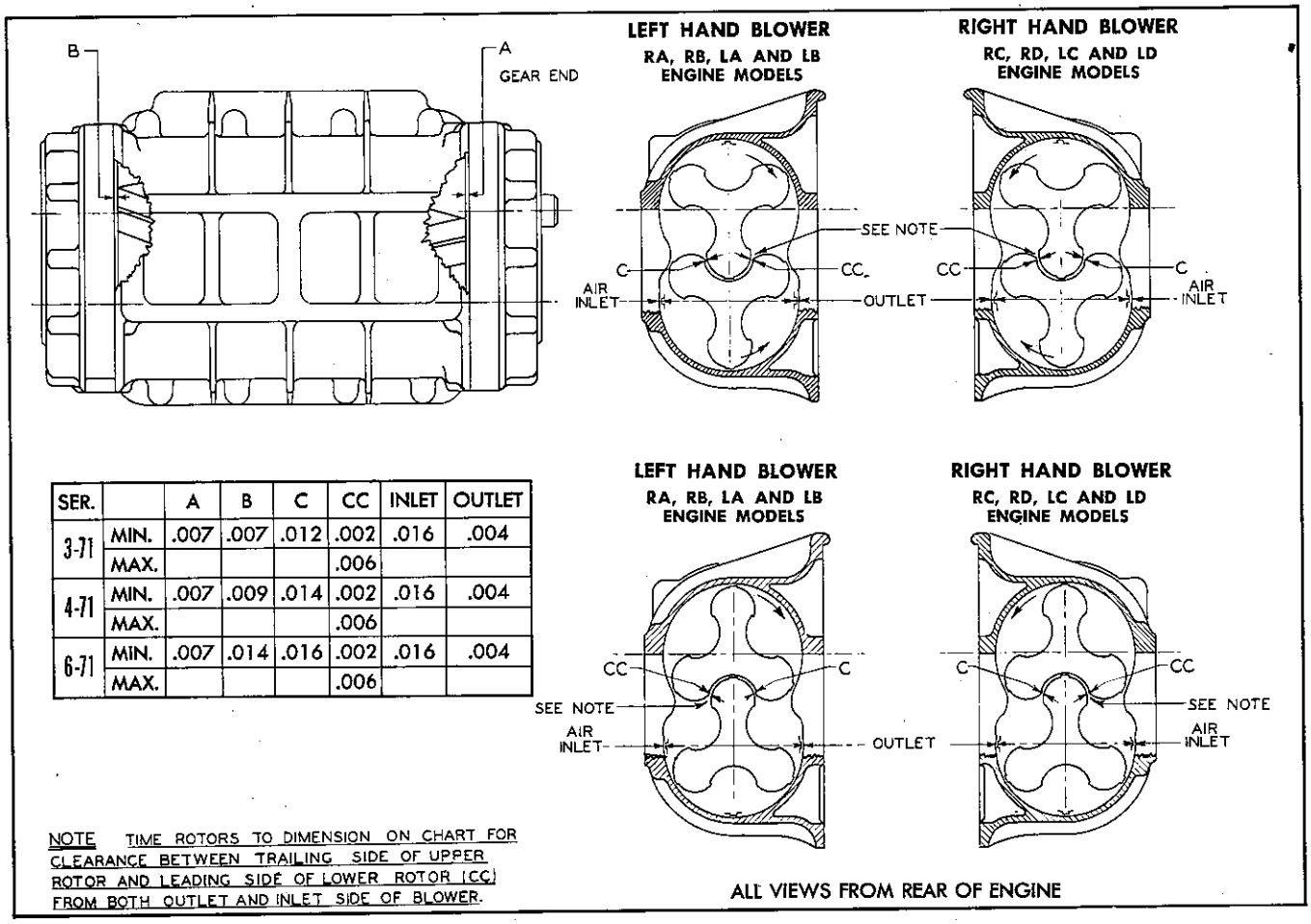


Fig. 16—Pressing Blower Timing Gears onto Rotor Shafts

For lower gear lock, install special lockwasher and fuel pump coupling disc on retainer bolt so lock tangs of disc engage slots in gear hub and lockwasher ear engages slot in coupling disc. Draw retainer bolts reasonably tight but not enough to bend fuel pump coupling disc.

10. **Blower Rotor Timing**—At this stage of the blower assembly, the blower rotors must be "timed."



SER.		A	B	C	CC	INLET	OUTLET
3-71	MIN.	.007	.007	.012	.002	.016	.004
	MAX.				.006		
4-71	MIN.	.007	.009	.014	.002	.016	.004
	MAX.				.006		
6-71	MIN.	.007	.014	.016	.002	.016	.004
	MAX.				.006		

NOTE TIME ROTORS TO DIMENSION ON CHART FOR CLEARANCE BETWEEN TRAILING SIDE OF UPPER ROTOR AND LEADING SIDE OF LOWER ROTOR (CC) FROM BOTH OUTLET AND INLET SIDE OF BLOWER.

Fig. 17—Diagram of Blower Clearances.

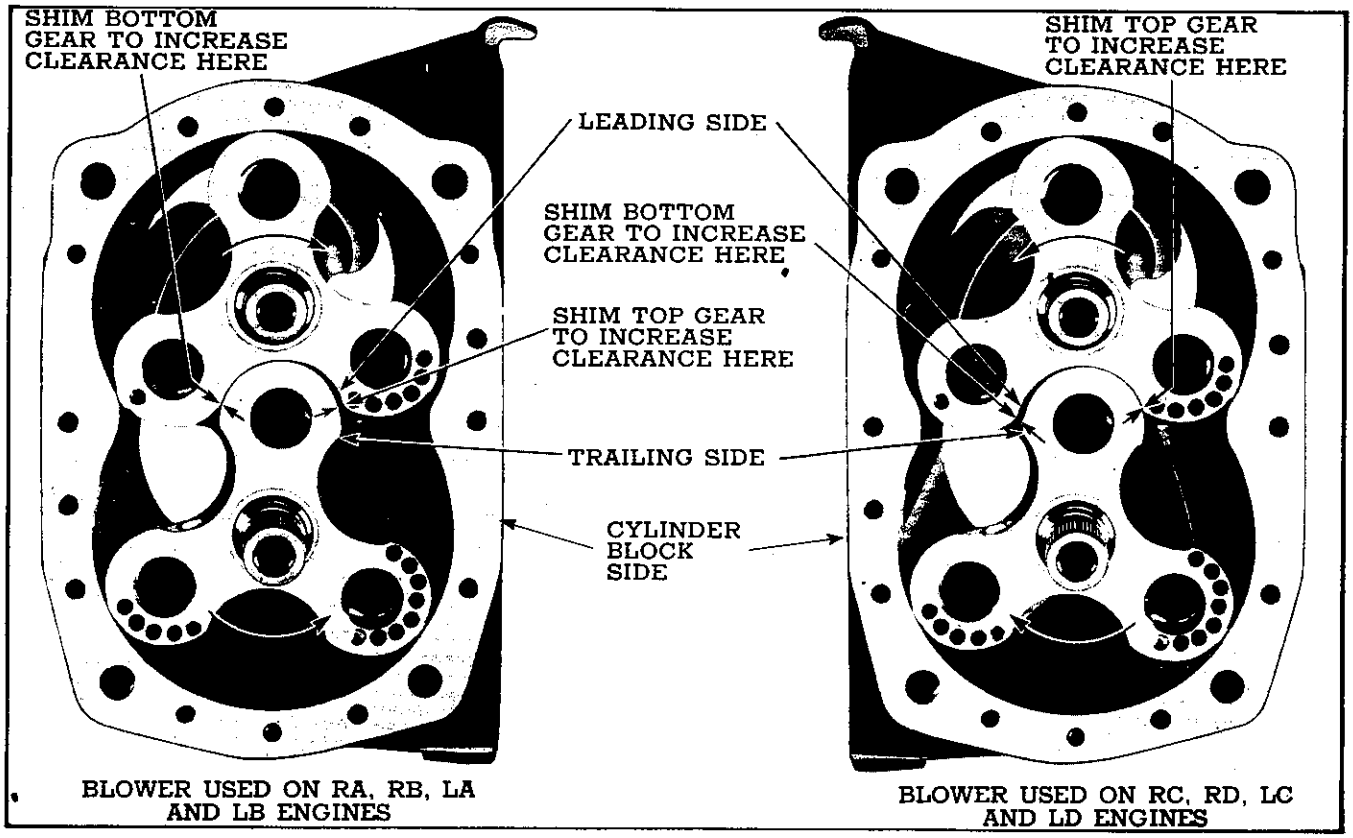


Fig. 18—Diagram Showing Proper Location of Shims for Correct Rotor Lobe Clearances.

The three lobes on each blower rotor are located spirally (helical) relative to the center line of the rotor shaft. The teeth on the timing gears are also helical, and, as previously stated, the rotor with the right-hand helical lobe is driven with a gear having right-hand helical teeth. (See Fig. 12.)

The blower rotors, when properly positioned in the housing, run with a slight clearance between the lobes. This clearance may be varied by moving one of the helical gears in or out on the shaft relative to the other gear.

If the ***upper*** gear is moved ***out,*** the ***upper*** rotor will turn ***counter-clockwise*** when viewed from the gear end. If the ***lower*** gear is moved ***out,*** the ***lower*** rotor will turn ***clockwise*** when viewed from the gear end. This positioning of the gear, to obtain the proper clearance between the rotor lobes, is known as ***Blower Timing.***

Moving the gears OUT and IN on the rotors is accomplished by adding or removing shims between the gear hub and the bearing back of the gears.

Check Rotor Lobe Clearance—The clearance between rotor lobes may be checked with various thickness feeler ribbons ½" wide. When measuring clearances more than .005", laminated feelers made up of .002", .003" or .005" are more practical and suitable than one single thick feeler.

The clearance between rotor lobes must be taken between two of the lobes at one end of the blower while revolving the rotors to the right, and also between the same two lobes at the same end while revolving the rotors to the left. This double check must be made between each pair of mating lobes at each end and at the mid-section for the three and four-cylinder engines, and at several intermediate points on blowers for the six cylinder engine. ***Always determine point of minimum clearance and adjust for that point.***

NOTE: Recent developments have resulted in the change of blower rotor timing gear helix angle from 45° to 19°. With the new 19° gears (interchangeable with the 45° gears in sets only), three .002" shims are required to revolve the rotor .002". Therefore, when timing rotors, first determine that the gear helix angle is either 45° or 19°, then proceed accordingly as directed above.

Having determined the amount one rotor must be revolved to produce the proper clearance, observe engine model on which the blower is to

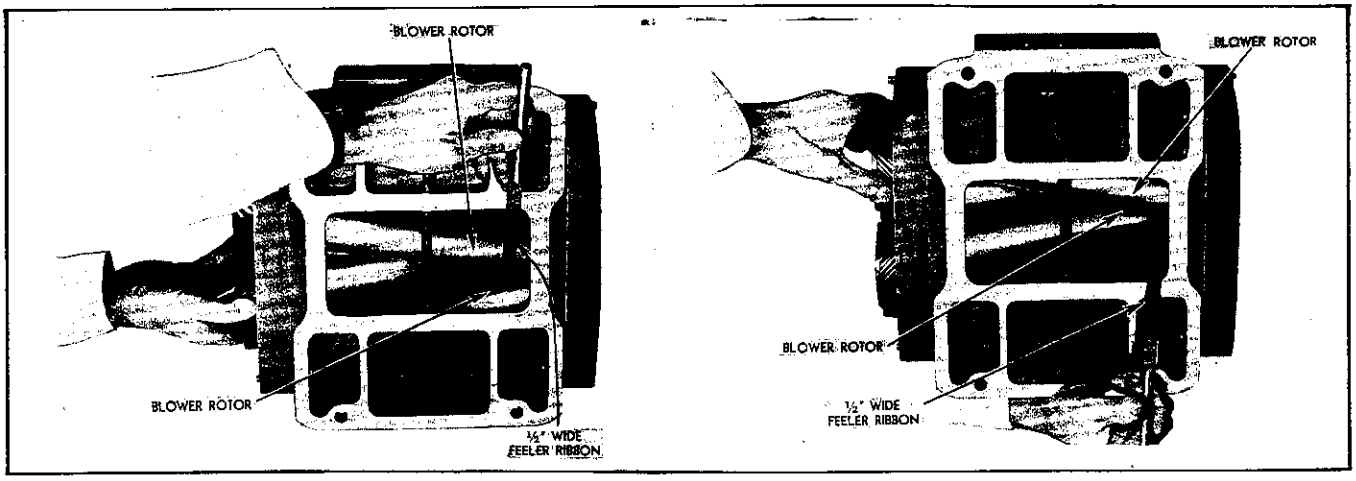


Fig. 19—Measuring Clearance Between Blower Rotor Lobes.

be used and add shims back of either the upper or lower gears, as shown in Fig. 18, to produce the desired result. Note that adding shims back of the ***lower*** gear will increase the clearance between the leading side of the lower and trailing side of the upper rotor lobes in blowers used on RA, RB, LA and LB engines; and adding shims back of the ***upper*** gear will increase the clearance between the leading side of the lower and trailing side of the upper rotor lobes in blowers used on RC, RD, LC and LD engines.

When additional shims are required, both gears must be pulled from the rotors, as directed in item 5 under "Disassembly of Blower," Page 5.

Install the required thickness of shims back of the proper gear and next to the bearing inner race, and again press the gears tight in place. Re-check clearances between rotor lobes.

Check Rotor End Clearance—Insert feelers between end of rotors and end plates. Determine minimum distance. This operation must be performed at the ends of each lobe, making 12 measurements in all. (See Fig. 17 for permissible dimensions.)

If checks were carefully made, shims correctly installed, and gears tight in place, the clearances should be correct; if work was done carelessly, the operation may have to be repeated.

After correct clearances are obtained lock gears in place as directed in either item 9d or 9e under, "Press Timing Gears Onto Rotor Shafts," Page 10.

11. Using the six cap screws and lockwashers, attach blower drive shaft flange to outer face of upper rotor timing gear.

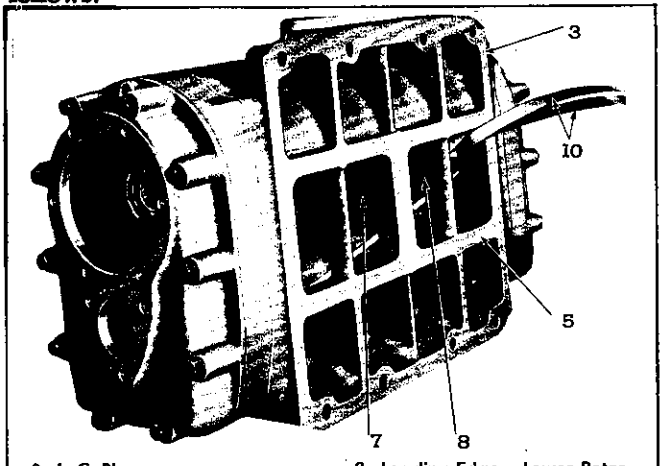
12. Insert splined end of water pump intermediate shaft and coupling into front end of lower rotor shaft and hold coupling tight against end of shaft while tightening Allen screw securely with 3/16" wrench.

    Some water pump couplings are not provided with expander screw, in which case, simply insert coupling into engagement with rotor shaft inner serrations.

13. If gasket is unsatisfactory in any way, shellac a new gasket to each blower end plate cover, supply a lockwasher and plain washer, in turn, on the ten cap screws and attach both end plate covers.

NOTE: Foreign matter inside the blower is apt to ruin the unit. After blower has been assembled, attach the gasket and cover over the air inlet on the outer face of the blower housing to prevent foreign matter entering housing.

Attach Accessories to Blower—Time may be saved and operations simplified if the various accessories are assembled to the blower before the latter is attached to the engine. This may be done, as follows:



3. L. C. Blower.
5. Exhaust Side of Blower.
7. Trailing Edge—Upper Rotor.
8. Leading Edge—Lower Rotor.
10. Feeler Ribbon—.007" Thick. (Min.).

Fig. 20—Measuring End Clearance Between Blower Rotors and Housing.

1. If necessary, shellac a new gasket to bolting flange of the governor weight housing, and slip governor shaft straight into serrations at front end of blower, upper rotor shaft. Secure finger tight only to front cover with six lockwashers and cap screws.
2. If necessary, shellac new gasket to water pump bolt flange and, with intake for pump pointing toward bottom of blower, slide water pump into position at *front* of blower lower rotor shaft with driving lugs on pump shaft registering with driving lugs on rotor shaft. Lock securely to cover with three lockwashers and cap screws.
3. Using new gasket if necessary, and six lockwashers with cap screws, attach blower driveshaft cover to blower *rear* cover at upper rotor shaft.
4. The fuel pump is driven by a "U" coupling from the squared-end of the pump shaft. The pump cover is marked at the pump intake. The markings shown should always set next to the cylinder block.

NOTE: Reduction of helix angle of blower rotor timing gears may necessitate use of sufficient shims to eliminate proper clearance between lower gear and fuel pump drive fork. Check for clearance by installing pump (minus bolting-flange gasket) and drive-fork in place. If pump bolting flange contacts end plate cover, clearance is satisfactory. If pump flange does not contact end plate cover, carefully grind small amount from ends of fork or head of rotor timing gear cap screw.

CAUTION: Be sure driving fork is fully on fuel pump shaft.

If necessary, shellac a new gasket to pump bolting flange, then with pump drive coupling on pump shaft so that arms are directed away from pump, with intake and discharge openings at bottom and markings on pump cover toward cylinder block, attach pump to blower *rear* cover at lower rotor shaft, using three lockwashers and cap screws. ***Do not force pump into place.*** Such treatment is not necessary if the drive coupling registers with mating member on rotor shaft.

Attach Blower Assembly to Cylinder Block (includes blower, fuel pump, blower drive shaft sleeve, water pump and governor weight housing).

1. Before attaching to engine, examine inside of blower for any foreign material and revolve the rotors by hand for smooth operation. Rough particles in the blower may score the rotors and impair blower efficiency. Shellac a new gasket to the cylinder block at the blower pad.
2. Install a new rubber grommet in the groove of the blower drive gear housing, which acts as an oil seal for the blower drive shaft cover. Apply some soap to the rubber. Slip water pump outlet packing flange—flat face out—and packing over pump discharge, also hose clamp and seal over pump inlet.
3. Use of increased number of shims, due to 19° helix angle of blower rotor timing gears, may bring about interference of blower drive shaft with upper rotor capscrew and lock ring in blower drive cam. (Cam is part of blower drive gear assembly. See Fig. 2, Sec. 7.) Therefore, before installing blower, remove flywheel housing plug and install capscrew of sufficient length in end of blower drive shaft. After attaching blower to engine as directed below, check end clearance of blower drive shaft with cap screw in end of shaft. If shaft has no end clearance, remove blower and carefully grind small amount from blower end of drive shaft.

NOTE: On engine models having a removable cover on the flywheel housing just behind the blower drive gear, the cover may be taken off and the blower drive shaft removed and replaced from the rear. This procedure will simplify taking the blower off the engine and replacing it and will also simplify fitting the drive shaft when 19° gears have replaced worn out 45° gears.

CAUTION: Do not damage serrations. Install blower and again check for shaft end clearance.

4. See that blower drive shaft is in position inside of blower drive flexible coupling. Avoid damage to gasket at blower pad on cylinder block, and slide the blower assembly into position with blower driveshaft registering with serrations in driveshaft flange and shaft sleeve sliding over rubber grommet in blower drive gear housing. Attach blower housing securely to cylinder block with washers and cap screws.

CAUTION: The blower will slide into position easily if the blower driveshaft serrations are lined up with the mating serrations in the blower rotor shaft. Do not force the blower assembly into position and damage the serrations on the blower shaft.

5. Connect water pump intake to oil cooler housing.
6. Connect water pump discharge to cylinder block.
7. The fuel line from the primary filter connects to the intake (opening nearest to cylinder block) of the fuel pump and the discharge from the pump leads to the intake of the secondary filter. With these features in mind, attach fuel lines to pump.
8. If hydraulic governor is used, install governor as directed under "Install Governor to Engine," Page 36, Sec. 16, or for mechanical, as directed on Page 13, Sec. 16.

9. **Attach Blower Air Inlet Housing with Emergency Engine Shut-down**—Since the function of the shut-down device is to choke off the air to the blower completely when the flap valve or valves are closed, the valves must set tight against the striker plate gasket when the Bowden wire control is pulled all the way OUT to close the valves.

   Before attaching the shut-down assembly to the blower, therefore, lay a straight-edge lengthwise of the finished bolt housing flange and close the valves against same. The finished pads at both ends of both valves must set flat against the straight edge when the latter is moved from top to bottom of inlet housing pad. Now, turn straight edge crosswise of pad and draw from end-to-end. Both the upper and lower finished pads of valves must rest against straight edge throughout length of valves. Furthermore, when the lock ball within lever indexes with hole in lock plate or Bowden wire is pushed way IN, the valves must recess back into the inlet housing so not to restrict air passage to the blower.

   When attaching inlet housing:

   (a) Shellac new gasket to striker plate, if necessary. Install lockwasher and plain washer, in turn, on each housing retainer cap screw and position screws in blower housing. With gasket facing valves, slide striker plate, then screen over inner ends of cap screws and set housing in place.
   (b) Push Bowden wire control button way IN, throw valve shaft lever to open position and attach Bowden wire to lever.

10. Service air cleaners as directed on Page 17, and install.
11. If engine is equipped with automatic over-speed trip, connect drive shaft at over-speed trip governor.
12. Fill cooling system with soft water or suitable anti-freeze, and check for leaks.

EMERGENCY ENGINE SHUT-DOWN

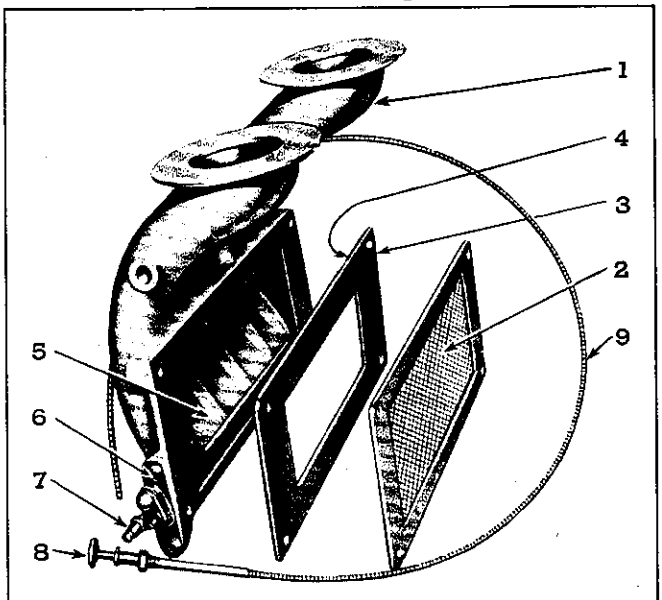
Description—Occasionally when combustible liquids are introduced accidentally into the combustion chamber by way of the air box, an emergency engine shut-down device is desirable. The speed governor has no control over an engine in such instances; therefore, a shut-down valve at the air inlet housing operated either manually or by an overspeed trip governor is sometimes provided for use only in case of emergency. The manually operated valve is discussed in this text.

The emergency engine shut-down consists of one flap valve for the three and four cylinder engines, and two valves for the six cylinder, which are attached to a shaft and incorporated within the air inlet housing. A valve shaft lever outside the air inlet housing, is operated by a Bowden wire, with suitable clips to support the Bowden wire control.

The flap valve is rigidly supported to the valve shaft and, when the valve is open for the running position, fits back into the outer wall of the air inlet housing and out of the air stream. When the valve is closed for the shut-down position, it seats firmly against a gasket which is backed up by a striker plate held between the blower and blower inlet housings.

The valve shaft lever is provided with a swivel connection at one end for attaching to the Bowden wire control and a spring loaded ball at the other end, which indexes with a notch in the lock plate to definitely position the flap valve in the wide open position.

The lower end of the Bowden wire control is fastened to the valve shaft lever and the upper end terminates at the engine instrument panel where it is readily accessible to the engine operator. The button on the Bowden wire at the instrument panel should be all



1. Air Inlet Housing.
2. Blower Screen.
3. Striker Plate.
4. Gasket—Striker Plate-to-Valve.
5. Shut-down Valve.
6. Lock Plate.
7. Valve Shaft Lever.
8. Control Button to Instrument Panel.
9. Bowden Wire Control.

Fig. 21—Manually Operated Emergency Engine Shut-Down Assembly.

the way IN when the engine is operating. The button must be pulled all the way OUT to stop the engine. The Bowden wire control may be lengthened, if necessary, to suit special installations.

Service — Emergency Engine Shut-down — Manual—The emergency shut-down is properly adjusted before leaving the factory and should need no further attention unless the device has met with accident or becomes otherwise inoperative. Should it become necessary to disassemble the shut-down device, note the relative position of each part, as shown in Fig. 22, so parts may be reassembled correctly.

In order to stop the engine with the shut-down device, the flap valve must close tight. To provide a perfectly flat surface for the valve to close against, a striker plate is mounted between the blower and air inlet housing with a gasket on the valve side of the plate. The valve closes against the gasket. When the shut-down is assembled, therefore, the striker plate must be perfectly flat and the gasket in place, as shown in Fig. 21.

Disassembly of Emergency Engine Shut-down Device—If occasion requires, the emergency shut-down may be disassembled as outlined below after the air inlet housing assembly is removed from the blower:

1. Using a small punch, remove locking pin for valve shaft lever and valve, or valves (two valves used on six cylinder engine).
2. Remove lever and withdraw shaft from housing and valve.

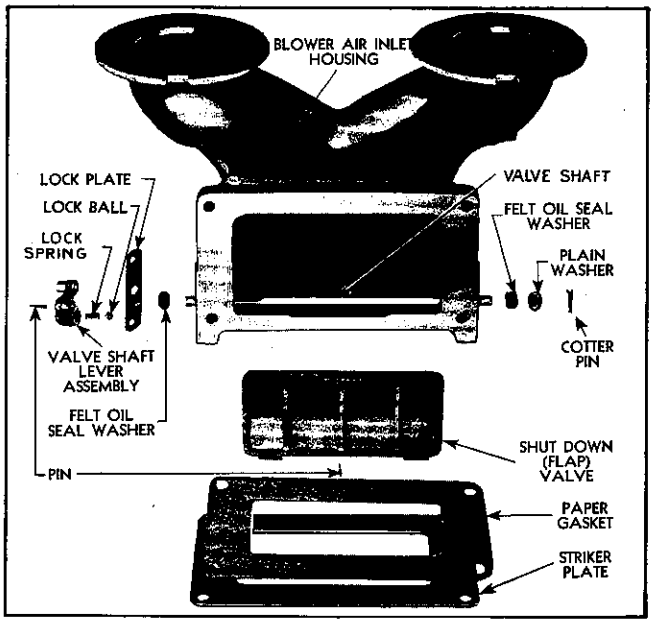


Fig. 22—Manually Operated Emergency Engine Shut-Down Details.

3. Remove two cap screws, lock plate, and felt seal washer in counter-bore at shaft beneath plate. Also, remove felt seal washer in counter-bore of housing at opposite end of shaft.

Inspection—Before assembly inspect parts. See that striker plate is perfectly flat and that gasket on plate for valve is in good condition.

Inspect finished face of valve, which must be perfectly flat for a tight seal against gasket.

If felt seal washers do not form a tight fit on shaft, replace.

Assembly—All parts having been cleaned and inspected, the shut-down device may be assembled into the blower air inlet housing, as outlined below. Bear in mind that both ends of the air inlet housing are machined for the lock plate at the valve shaft. This is to make the housing interchangeable for a blower used on either the right or left side of the engine. The valve shaft lever for the shut-down will be located at the rear end of the air inlet housing in all cases.

1. Put a felt seal washer in counter-bore at each end of housing for shaft bearing.
2. Determine the correct end of inlet housing to attach the lock plate so that shaft lever will be at rear housing when assembled, then with hole in lock plate for lock ball toward top of housing and so positioned that ball will seat in hole when valve is open, attach plate with two lock washers and cap screws.
3. Note that small hole is drilled near to, but further from one end of the valve shaft than the opposite end. The one of these holes farthest from the end is for locking the valve shaft lever at the rear end of the air inlet housing. With this identification in mind, lock lever to shaft with pin, then insert from rear end of housing and through bore in flap valve. Put plain washer over front end of shaft next to felt seal and lock with cotter pin.
4. Turn shaft and lever assembly so that seat for spring and lock ball is toward top of housing and lock valve or valves to shaft with pin.
5. Install spring and lock ball and observe if valve assembly works freely.

Attach Air Inlet Housing with Emergency Shut-Down to Blower—See Item 9, Page 15, for attaching air inlet housing to blower.

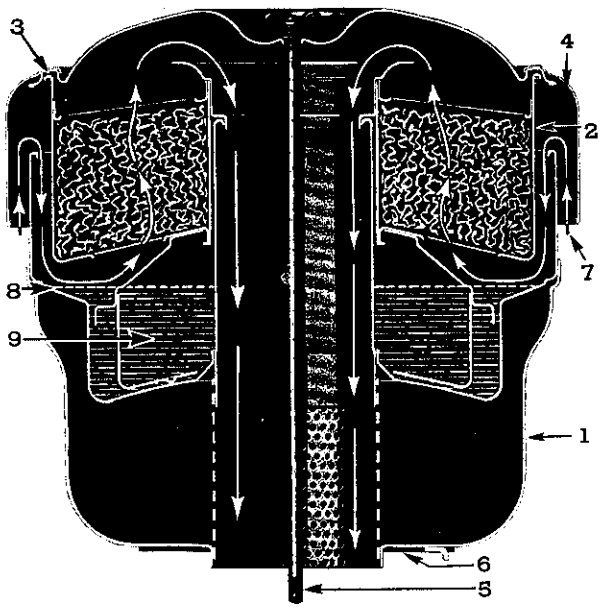
AIR CLEANER AND SILENCER

One or more oil bath air cleaner and silencer of the type shown in Fig. 23 is used as standard equipment on all 3, 4 and 6 cylinder engines.

The cleaner and silencer consists of a metal wool cleaning element supported inside a housing beneath which is contained a bath of oil. The lower portion of the device is a hollow chamber which serves as a silencer for the incoming air to the blower. Air drawn into the cleaner by the blower passes over the top of the oil bath, where a major portion of the dirt is trapped, then up through the metal wool, where the finer particles are removed, thence down the central duct to the blower.

Oil of a viscosity which compares with 50 SAE should be used in the reservoir. The oil level should not be above that indicated, which is just flush with the top of the reservoir itself. If too much oil is used, it will be pulled up into the metal wool, down into the blower, thence forced into the air box, and may cause excessive engine speeds.

Service—Air Cleaner—The air cleaner should be reconditioned as directed on the cleaner housing; that is, every 100 hours (more frequently under severe working conditions), wash the metallic wool elements in fuel oil to remove the dirt. Drain dirty oil from oil reservoir and clean sludge from bottom of reservoir. ***Refill with 50 SAE auto engine oil up to oil level.*** Reassemble after filter element has ***thoroughly drained.***



1. Air Cleaner Bowl.
2. Element Assembly.
3. Gasket—Cover-to-Element.
4. Cover.
5. Bolt.
6. Gasket—Bowl-to-Air Intake Housing.
7. Air Inlet.
8. Oil Level.
9. Oil Reservoir.

Fig. 23—Oil Bath Air Cleaner and Silencer Assembly.

NOTE: For extreme dusty conditions, a special, large air cleaner can be obtained.

AIR BOX DRAINS

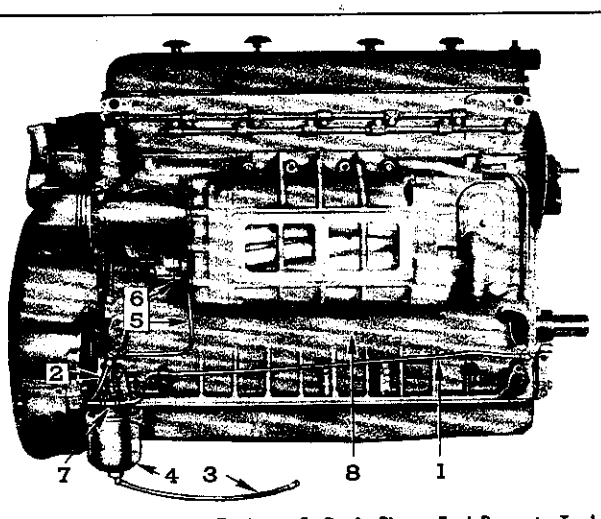
Description—In normal operation, a slight amount of vapor from the air charge condenses and settles on the floor of the air box. This condensation is drawn off through cored passages in the ends of the block and openings in the side of the engine block below the air box floor, on the blower side of the engine.

On some engines these openings are vented to the atmosphere. Other engines are equipped with a drain tank, as shown in Fig. 25, to receive the condensate.

Pipes from the air box drain openings lead to the drain tank mounted on the cylinder block, as shown in Fig. 24.

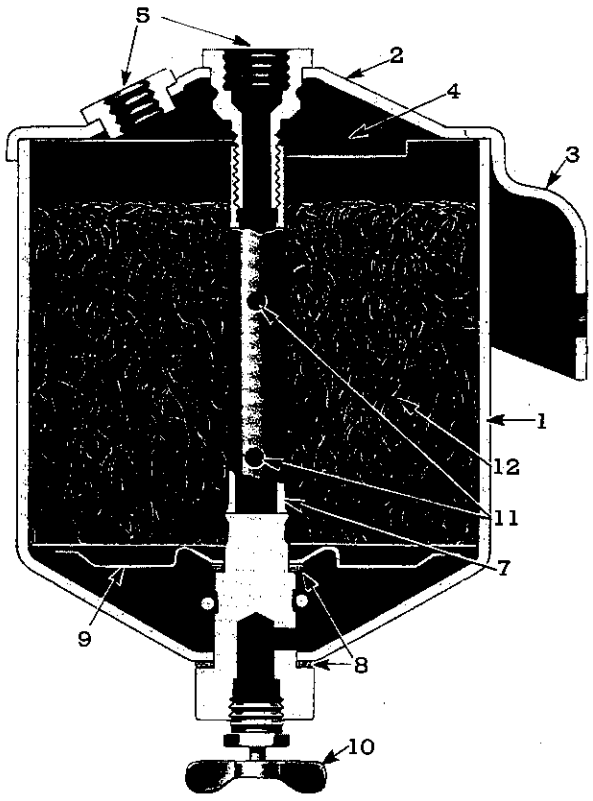
Should a fuel leak develop past the oil seals in the fuel pump, such waste is also carried to the drain tank through a small pipe leading from the pump to the tank.

The tank illustrated in Fig. 25 consists of a vented steel shell, a cover, a metal wool filtering element,



1. Drain Pipe—Front to Tank.
2. Drain Pipe—Rear to Tank.
3. Tee Connection.
4. Drain Tank.
5. Drain Pipe—Fuel Pump to Tank.
6. Fuel Pump.
7. Drain Hose—Tank to Supply.
8. Cylinder Block.

Fig. 24—Air Box Drain System.



1. Steel Shell.
2. Cover.
3. Attaching Flange.
4. Vent.
5. Inlet from Air Box Drains.
6. Inlet from Fuel Pump Drain.
7. Retainer Stud.
8. Gaskets.
9. Retainer—Filtering Element.
10. Drain Cock.
11. Drain Holes.
12. Filtering Element.

Fig. 25—Air Box Drain Tank Assembly.

a removable retainer stud, which holds the shell and filtering element to the cover, and an elbow.

If occasion requires, the unit may be disassembled by removing the drain hose from the elbow at the bottom of the tank and by removing the stud holding the shell to the cover.

Two inlet openings are provided in the cover of the filter and one outlet from the bottom of the tank to the fuel supply tank.

Service—Air box drains should be open at all times. A wise practice is to examine the openings occasionally, and if necessary, clean the passages. An indication of plugged vents is liquid accumulation on the air box floor. Such accumulations can be seen when removing hand hole cover plates on the side of the engine block. If accumulations appear, thoroughly wipe out air box with rags, or blow out with compressed air; then remove tube connectors from vents and clean connectors and tubes thoroughly, blowing out vents with compressed air.

Under normal conditions, only a small amount of waste drains into the tank.

If removal of the shell becomes necessary, back out stud by turning on head at bottom of tank.

Before replacing the stud and assembling the tank, replace the filtering element and see that the gaskets are between the head of the retainer stud and on the stud and beneath the filtering element retainer, respectively.

After some liquid has drained into tank, check for leaks at gasket. If not leak-tight, replace gasket.

There is no gasket between shell and cover. On the other hand, four slots are provided at top of shell to afford a suitable vent for the tank.

FUEL SYSTEM

Description—Included in the fuel system are the injectors, fuel oil pump, fuel oil filters, and the fuel oil manifolds. Fuel is drawn from the supply tank, through the primary filter by the fuel pump, which is driven from the rear end of the blower lower rotor shaft. From the pump, fuel is forced through the secondary filter and to the fuel intake manifold, which supplies the injectors. Surplus fuel, flowing through the injectors, is returned through the fuel outlet manifold to the supply tank.

To secure combustion, a small quantity of accurately metered, finely atomized fuel must be mixed, at the end of the compression stroke, with the charge of air which has been forced into the cylinder by the blower. This is accomplished by a high-pressure fuel injection device.

Before injection can be effected, the fuel pressure must be higher than that of the air charge in the combustion chamber. Consequently, the fuel in-

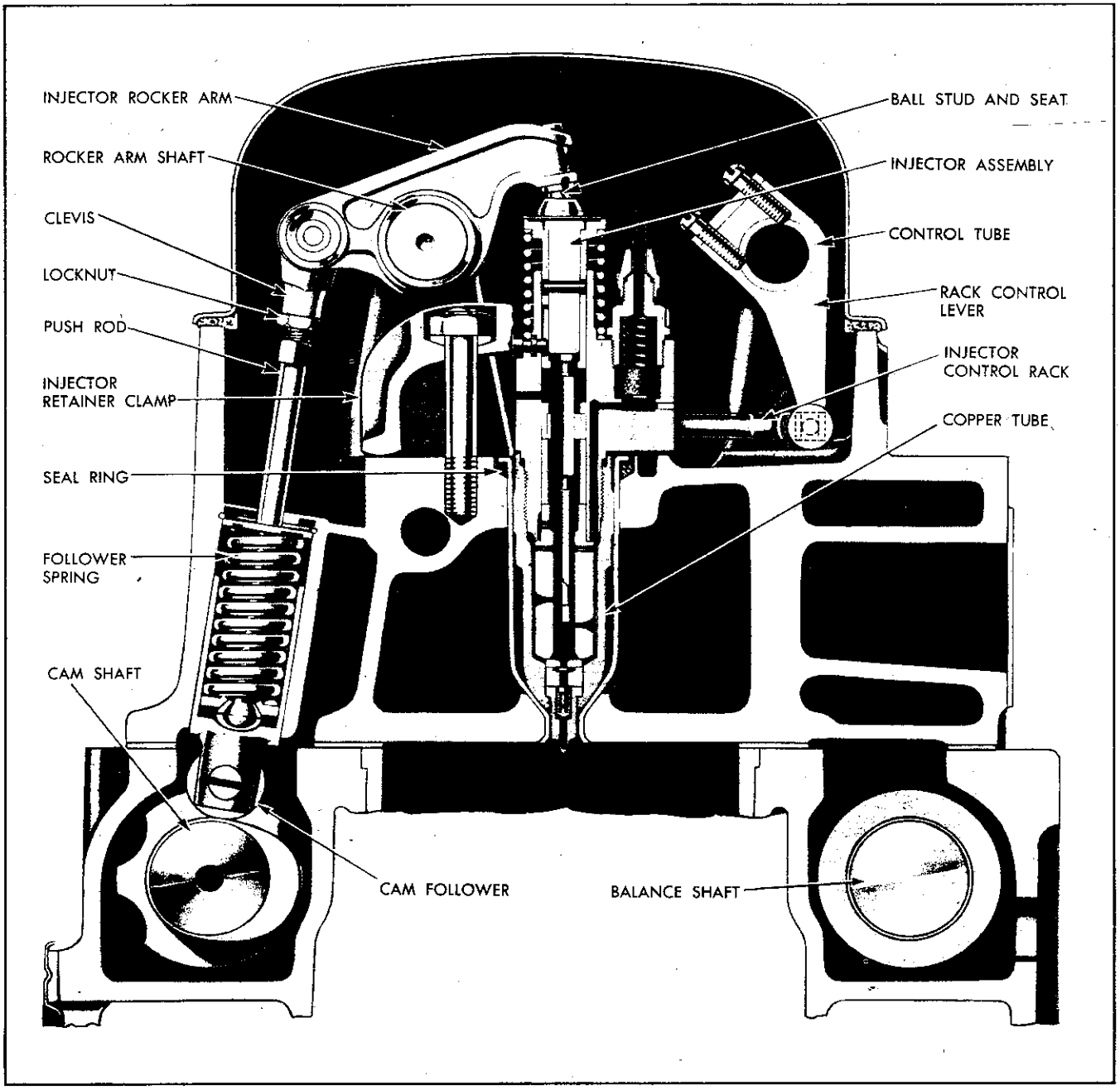


Fig. 1—Fuel Injector Mounting.

jector, shown in Fig. 2, performs a quadruple duty: 1st, metering and injecting fuel; 2nd, creating high fuel pressure; 3rd, atomization; and 4th, continuous by-pass of fuel through the injector body which acts as a coolant and also eliminates air pockets. The unit fuel injector, developed by General Motors and used in these engines, combines in a single unit all of the parts necessary to perform the above functions, thus providing a complete and independent injection system for each engine cylinder.

Fuel Injector Mounting—The injectors are mounted in the cylinder head, with their spray tips projecting slightly below the top of the inside surface of the combustion chambers. A clamp, bolted to the cylinder head and fitting into a machined recess in each side of the injector body, holds the injector in place in a water-cooled copper tube which passes through the cylinder head. A dowel pin in the injector body registers with a hole in the cylinder head for accurately locating the injector assembly.

A copper tube is installed in the cylinder head with a seal ring at flanged upper end. The lower end is peened into a recess of the cylinder head. The tapered lower end of the injector seats in the copper tube, forming a tight seal to withstand the high pressures inside the combustion chamber.

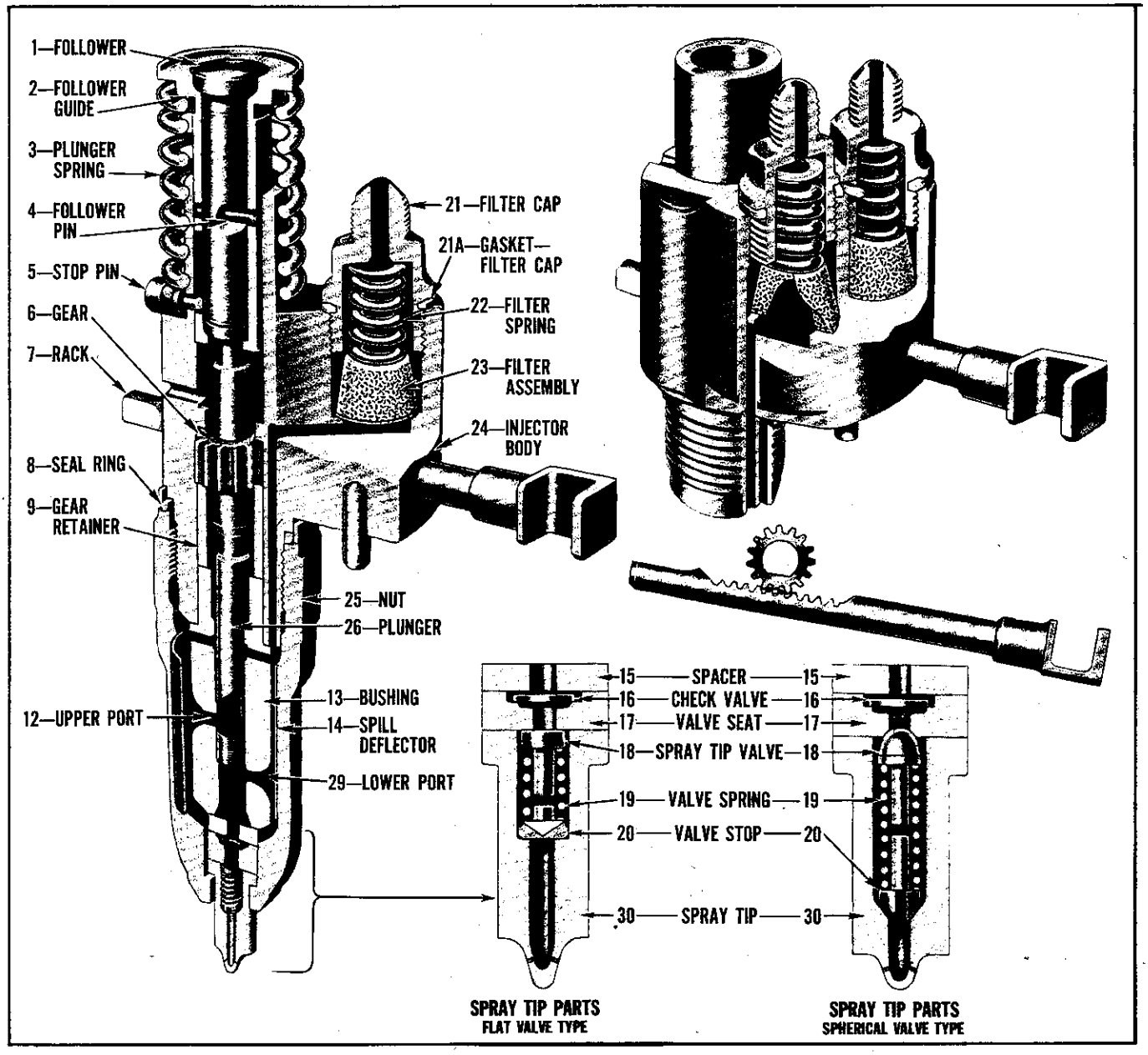


Fig. 2—Fuel Injector Assembly.

FUEL INJECTOR

Description—The cross section of the Model 71 Injector, illustrated in Fig. 2, shows the various fuel injector parts. Fuel oil is supplied to the injector at a pressure of about twenty pounds per square inch and enters the drop-forged steel body (24) at the top through the filter cap (21). After passing through the fine-grained filter element (23) in the inlet passage, the fuel oil fills the annular supply chamber between the bushing (13) and the spill deflector (14). The plunger (26) operates up and down in this bushing, the bore of which is connected to the fuel supply in the annular chamber by two funnel-shaped ports.

The motion of the injector rocker arm is transmitted to the plunger (26) by the follower (1) which bears against the return spring (3). In addition to this reciprocating motion, the plunger can be rotated, in operation, around its axis by the gear (6), which is in mesh with the control rack (7). An upper helix and lower helix or cut-off are machined into the lower end of the plunger for metering purposes. The relation of this helix and cut-off to the two ports changes with the rotation of the plunger. As the plunger moves downward, the fuel oil in the high-pressure cylinder or bushing is first displaced through the ports back into the supply chamber until the lower edge of the plunger closes the lower port. The remaining oil is then forced upward through the center passage in the plunger into the recess between the upper helix and the lower cut-off from which it can still flow back into the supply chamber until the helix closes the upper port. The rotation of the plunger, by changing the position of the helix, retards or advances the closing of the ports and the beginning and ending of the injection period, at the same time increasing or decreasing the desired amount of fuel which remains under the plunger for injection into the cylinder.

Fig. 3 shows the various plunger positions from NO INJECTION to FULL INJECTION. With the control rack pulled OUT completely (no injection), the upper port is not closed by the helix until after the lower port is uncovered. Consequently, with the control rack in this position, all of the fuel charge is forced back into the supply chamber, and no injection of fuel takes place. With the control rack pushed IN completely (full injection), the upper port is closed shortly after the lower port has been covered, thus producing a full effective stroke and maximum injection. From this NO INJECTION position to FULL INJECTION position (full rack movement) the contour of the helix advances the closing of the ports and the beginning of injection.

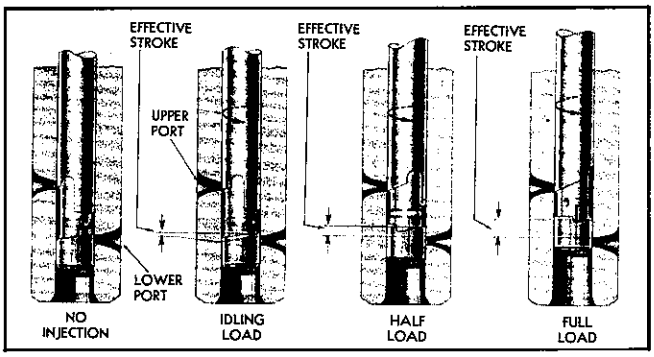


Fig. 3—Fuel Metering from NO INJECTION to FULL INJECTION, Produced by Rotating Plunger with Control Rack.

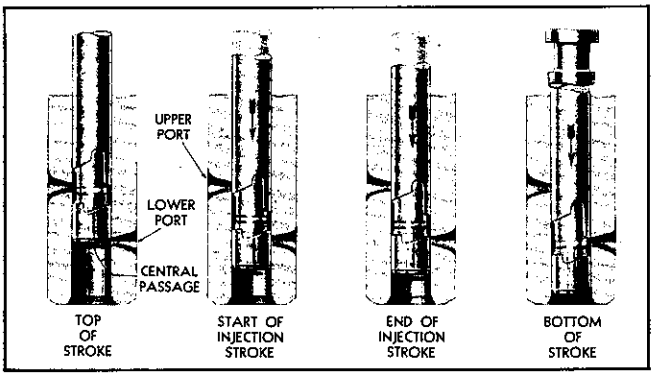


Fig. 4 – Phases of Injector Operation by Vertical Travel of Plunger.

Fig. 4 shows four positions for downward travel of the plunger, rack fixed. On the downward travel of the plunger, the metered amount of fuel is forced through

Model	Injector and Case Assembly	Identification on Body		Timing Gauge	
		Old	New	Part No.	Tool No.
50 cu.mm.	5226817	5226746 S	50 on Red Tag	2114371	J-1242
60 cu.mm.	5226710	5226556 A	60 on Blue Tag	2114371	J-1242
70 cu.mm.	5227935		70 on Black Tag	5164385	J-1853
80 cu.mm.	5227231	5227226 M	80 on Green Tag	5164385	J-1853

Chart 5—Identification Chart for Injectors Used in 71 Series Engines.

the center passage of the valve assembly, through the check valve (16), shown in Fig. 2, and against the spray tip valve (18). When sufficient fuel pressure is built up, the valve (18) is lifted off its seat and fuel is forced through seven small orifices in the spray tip (30) and atomized in the combustion chamber.

The check valve (16) prevents air leakage from the combustion chamber into the fuel system in case the valve (18) is accidentally held open by a small particle of dirt, thus allowing the injector to continue to operate until the particle works through the valve.

On the return upward movement of the plunger, the high-pressure cylinder is again filled with fuel oil through the ports. The constant circulation of fresh, cool fuel through the injectors, which renews the fuel supply in the chamber, helps to maintain even operating temperatures of the injectors, and also effectively removes all traces of air which might otherwise accumulate in the system and interfere with the accurate metering of the fuel.

The fuel injector outlet opening, which returns the excess fuel oil supplied by the fuel pump, is directly adjacent to the inlet opening, and is protected against dirt or other foreign matter by a fine-grained filter element, exactly like the one on the inlet side.

Four types of injectors are used in the 71 series engines as shown in Chart 5, each designed for a specific requirement. The correct injector must be used and type can be determined by obtaining suffix letter to engine model number located on identification plate riveted to side of cylinder block. Type may also be determined by checking injector in engine for assembly number die stamped on body or model number which appears on color tag pressed into body as illustrated in Fig. 6.

The injector plunger is marked with a letter or number to identify its type and both plunger and bushing are marked with corresponding serial numbers so that they may be associated as mating parts. Replacement plungers and bushings must have markings identical to those of parts removed to insure proper metering of fuel. Spray tips used in limited (71S) and standard (71 or 71A) output injectors have six holes or orifices; those used in medium (71M) and high (71H) output injectors have seven holes.

Early injectors were equipped with a spherical spray tip valve and valve stop as shown in Fig. 7; while late injectors, starting with those incorporating model identification color tag, have the flat type valve and valve stop. Spray tip assembly No. 5227324, which includes spray tip, valve seat, valve spring and flat spray tip valve and valve stop, is used to fill service requirements of early injectors; individual parts of tip assembly are available for late injectors.

Injector Control—Each injector control rack is connected by an easily detachable joint to a lever on a common control tube, which, in turn, is linked to the governor and throttle. These levers can be rotated independently on the control tube by the adjustment of two screws which permit a uniform setting of all injector racks. (See Fig. 1, Sec. 16, for governor to injector linkage.)

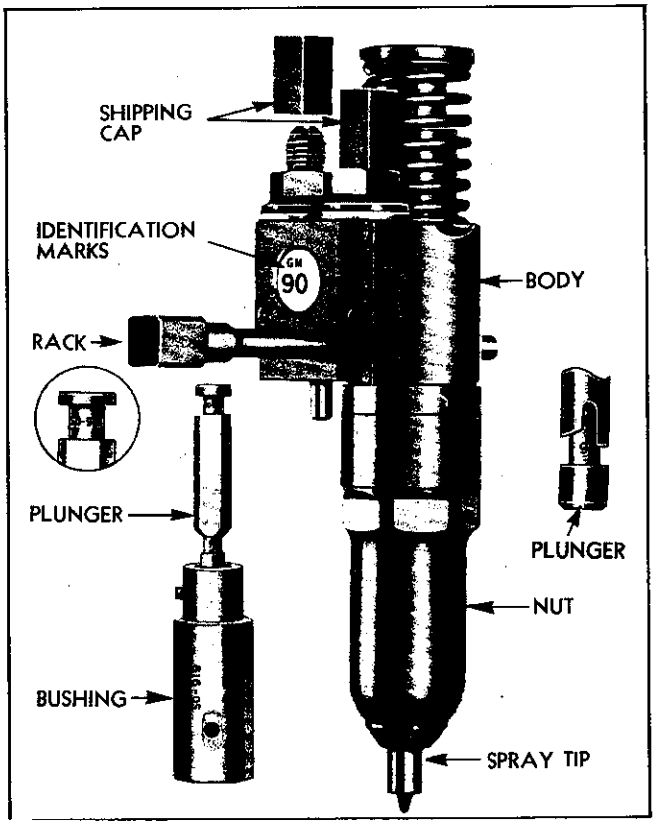


Fig. 6—Injector Body, Plunger, and Bushing Identification Markings.

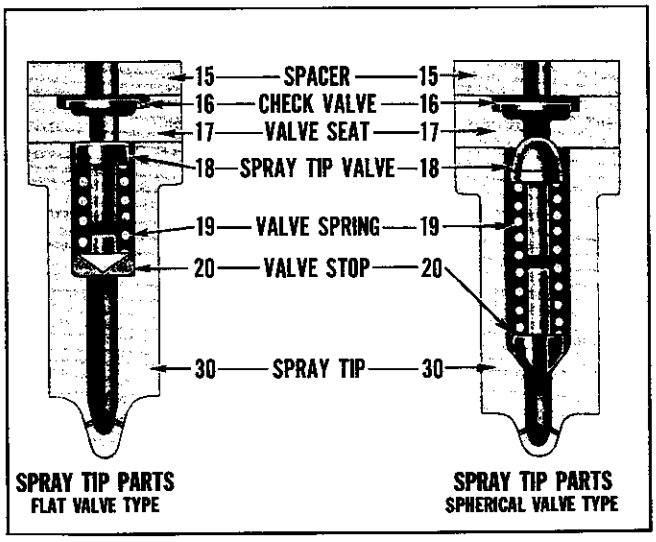


Fig. 7—Comparison of Spherical with Flat Valve in Spray Tip Assembly.

Injector Service—The injector is one of the most important and carefully constructed parts of the engine. On this unit depends the injection of the correct amount of fuel at exactly the right time into the combustion chamber. Due to the fact that the injector works against high compression in the combustion chamber, efficient operation demands that all injector parts be maintained in clean, first-class condition at all times. This will necessitate the use of ***only clean fuel*** in the injector, and intelligent care when servicing the unit. A mechanic should not attempt any service operations on the injector without first acquiring a complete understanding of its construction and operation. This section of the text thoroughly describes the working principle, shows the construction, and explains how to service the unit.

While a skilled mechanic may intelligently service the injectors, using the instructions in this section as a guide, time and expense may be saved by changing the unit rather than attempting repairs, especially in dirty surroundings.

Before starting to dismantle an injector, it is necessary to have an extremely clean workbench on which to work and to store the parts. ***Cleanliness*** for the injector and its parts is emphasized because practically all injector service troubles are directly traceable to dirt, loose particles, grit, or any other foreign matter.

When preparing to assemble an injector, it is absolutely essential to wash the hands thoroughly and to clean all the injector parts in either clean fuel oil or carbon tetrachloride. Parts should then be blown dry by compressed air (filtered—free of dust and moisture), making sure to blow through all the passages in the injector body and all the drilled holes, slots, etc., in the injector parts. ***Waste or rags should never be used for cleaning the injector parts,*** since this would leave lint and other particles which could collect and clog parts of the injector when assembled.

Toilet tissue is a good and inexpensive material for wiping any injector part, or on which to place injector parts after cleaning with liquid and blowing dry with air. After the liquid wash and subsequent blowing dry with air, it is essential that the parts are placed in a clean place until assembled. Clean, light oil should be used liberally on injector parts during assembly to protect them from rust in case the injector is not used immediately and to provide initial lubrication when the engine is started.

Care of Injectors—Because of the important part the injector plays in the operation of the engine, the necessity for proper care and cleanliness of these units cannot be over-emphasized. The instructions below should be carefully followed in connection with injector service:

1. Whenever the fuel lines are removed from an injector which is installed in the engine, protect the two fuel fittings with the shipping cap, part No. 5226414, to exclude dirt from the injector.
2. Do not dismantle an injector in dirty surroundings or on a dirty workbench. Use clean paper on the bench and, after the parts have been removed from the injector, store the loose parts in clean fuel oil as a protection against dirt and corrosion.
3. With more than one injector disassembled, it is not only good practice, but necessary, to keep the parts of each injector separate. ***The plunger must be fitted, always, with the same bushing.*** It is advisable to keep the parts of the tip assembly—the spring, stop, spray tip valve and seat, as a unit, as it insures that the "pop" pressure and calibration built into the injector will remain essentially the same as when it was first tested and assembled.
4. After injectors have operated in an engine, the filter caps or filters should not be removed from the injector when the injector is in the engine. If filter caps or filters are to be removed, the injector must be completely disassembled and cleaned.
5. Whenever an injector has been removed and reinstalled, or a new injector installed in the engine, the injectors must be:

   (a) Timed.

   (b) Racks positioned.

   (See "Timing Fuel Injectors," Page 12, "Positioning Injector Control Racks," Page 13.)
6. Whenever an engine is to be out of service for an extended period, the fuel system should be purged, as outlined under "Storing," Page 6, Sec. 22.
7. When a repaired injector is to be placed in stock, it should be primed with special oil, the properties of which agree with those for purging the fuel system, and described under "Storing," Page 6, Sec. 22.
8. Before installing any used or rebuilt injectors in an engine, test each injector. (See "Testing Injector," Page 11.)

Remove Injector—If it becomes necessary to remove one of the fuel injectors for inspection or replacement, follow the procedure given below:

1. Remove valve rocker cover.
2. Remove fuel lines from both the injector and the fuel connectors.

   Immediately after removal of the fuel lines from an injector, the two fuel feed fittings should be protected with the shipping cap, part number 5226414, to prevent dirt entering the injector.

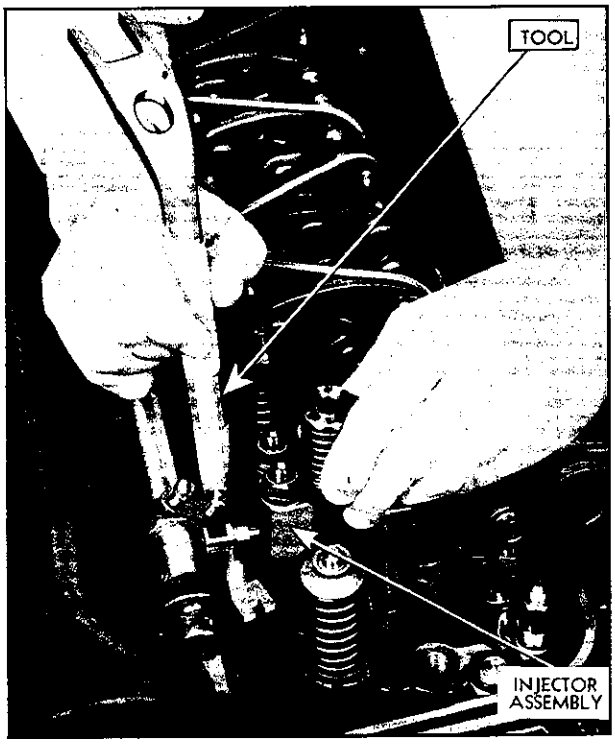


Fig. 8—Removing Injector with Tool as Shown.

3. If necessary, crank the engine with the starter or a bar at the flywheel ring gear until the three rocker arm clevis pins—at outer end of arms—are in line.
4. Loosen the two rocker arm bracket bolts holding the brackets to the cylinder head and swing the rocker arm assembly over away from valves and injector.
5. Remove injector hold-down stud nut, special washer, and injector clamp.
6. Using Tool J-1227-1, as illustrated in Fig. 8, pry injector from its seat.
7. Lift injector from seat; at the same time disengage the control rack linkage.

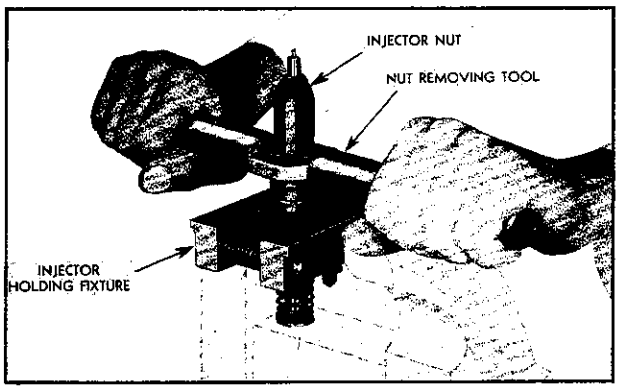


Fig. 9—Removing Injector Nut with Tool J-1238 and J-1261.

Inspecting and Cleaning Injector Spray Tip—With the injector removed from the engine, the injector spray tip and allied parts may be removed, cleaned, and replaced without disassembling the entire injector. Before removing the spray tip, check to see if the plunger works freely in the bushing, and that the control rack moves back and forth freely. Free movement of plunger may be checked by depressing the plunger follower with the thumbs and forefingers.

If these parts stick or bind in operation, the injector should be completely overhauled and cleaned. The purpose of depressing the plunger and follower with the hands is because any binding or sticking can be more easily detected than if tools were used.

If plunger follower and control rack are in good working order, the failure of an injector may be due to one or more of three causes:

1. Plugged fuel passages in spray tip.
2. Inoperative spray tip valve.
3. Plugged injector filters.

These parts may be inspected and cleaned as follows after the injector has been removed from the cylinder head:

1. Clamp the injector in the holding fixture, J-1261, and using wrench J-1238, as illustrated in Fig. 9, loosen nut from injector body.
2. Finish removing injector nut by hand. When nut is removed, the spray tip, valves, valve seats, and spring will be released. Retain these parts in a clean receptacle until ready for reassembly.
3. **Removing Injector Spray Tip from Nut**—After the injector has been in use for some time, the spray tip, even though clean on the outside, may not be pushed readily from the nut with the fingers. In this event the nut may be supported on a wood block, and the tip driven down through the nut with a hollow steel rod or, if available, Tool J-1291-A may be used.

   After removal, the seat in the nut for the spray tip should be thoroughly cleaned with one of the brushes provided in the injector cleaning tool set, J-1241-AS.
4. Thoroughly wash and inspect the check valve and spacer for smooth, flat surfaces and the spray tip valve and valve stop for smoothness and chips. (See Fig. 7 for identification of parts.)

   If the check valve or its seat on the spacer are scored or damaged, or the spray tip valve and valve seat are chipped, pitted, or otherwise damaged, the parts must be replaced. However, spray tip valves and valve seats with surfaces showing discoloration only may be lapped, using carborundum H-40 medium lapping cream or its equivalent.

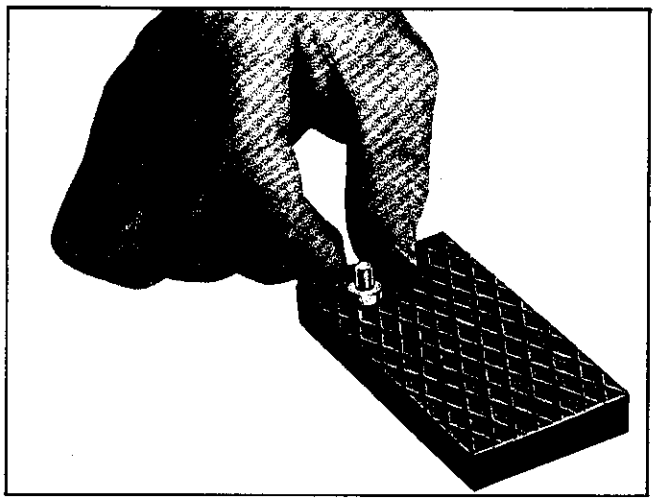


Fig. 10—Lapping Flat Surfaces of Spray Tip Valve.

When a spherical type spray tip valve or its seat becomes scored or damaged, both must be replaced by service tip assembly. (See Page 3.) However, if valve is flat type, the valve and valve seat can be lapped on a lapping block as illustrated in Fig. 10. Spread lapping cream on the block, then grasp stem of valve firmly with thumb and forefinger and lap valve, using figure eight motion. Always exercise care to keep valve head flat on lapping block.

In some instances it has been found that the use of a 4" square piece of kraft or heavy wrapping paper with stem of valve protruding through one corner and heel of hand resting on opposite corner, eliminates tendency to tip valve which would result in convex surface. To obtain a flat mirror finish and thus high popping pressure of injector, finish lap parts on block after it has been cleaned with a bristle brush, rinsed in fuel oil or kerosene and dried with compressed air.

As frequent refacing of blocks will produce top quality work it is advisable to have two grooved lapping blocks on hand and maintain their surfaces flat and free from worn or low spots. To remove these spots hand-lap one block on another, using fine grain lapping compound. Protect blocks when not in use against dust and damage by enclosing in close fitting, wooden container.

5. Reconditioning Spray Tip and Assembly.

(a) Holding injector spray tip in the fingers, as illustrated in Fig. 11, ream tip with Tool J-1243.

While reaming, hold spray tip in fingers, insert reamer down into tip, press lightly and turn with fingers to remove any carbon or foreign matter. After thoroughly reaming, blow out tip with compressed air to remove any loose particles.

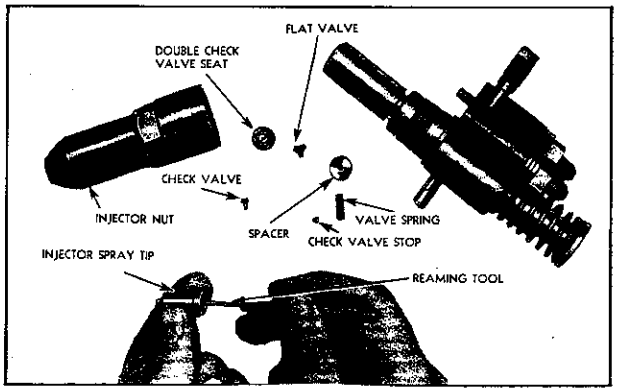


Fig. 11—Reaming Injector Spray Tip.

(b) Holding spray tip in fingers, as illustrated in Fig. 12, clean the seven spray tip orifices with Tool KMO-235.

Before using the tool, the sharp burrs should be removed from the wire on a honing stone furnished with cleaning set J-1241-AS.

NOTE: The spray tips are marked (6-.006-155) and (7-.006-155), the first digit indicating number of orifices in tip. Always use tips with correct number of orifices when servicing injectors.

After reaming, cleaning the spray tip holes with the .006" wire, and blowing out with compressed air; re-ream the tip, again clean the holes, then wash with carbon tetrachloride or fuel oil and again blow out with compressed air.

Observe the cautions on cleanliness at the beginning of this chapter, then assemble the valves and spray tip into the injector nut and onto the injector, as described in Item 3, Page 10.

(c) Test injector as outlined on Page 11.

(d) Install injector as outlined on Page 12, providing tests described on Page 11 are satisfactory. If the injector requires further reconditioning, including complete overhaul, the unit may be disassembled, cleaned, and reassembled, as outlined below.

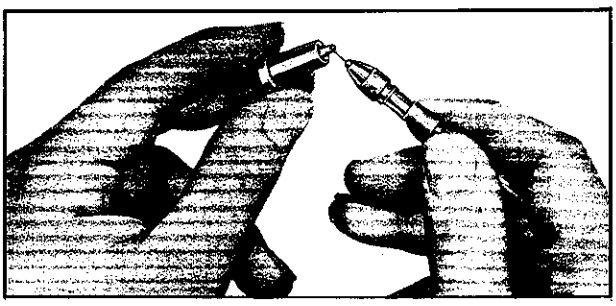


Fig. 12—Cleaning the Spray Tip Orifices with .006" Wire.

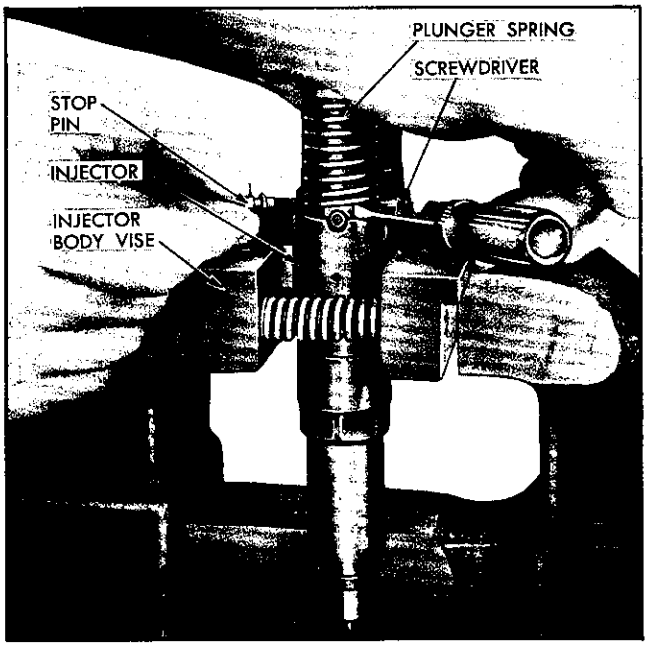


Fig. 13—Removing Stop Pin from Injector Follower

Injector Disassembly—Complete—The injector may be completely disassembled as follows:

1. Support the injector in the holding fixture, right side up, and loosen (not remove) the two filter caps with 9/16" deep socket and T-handle wrench.
2. Using a screw driver or similar tool, or if available Tool J-1290, as shown in Fig. 13, beneath follower spring, raise spring away from stop pin and withdraw the pin, while holding hand over follower to allow spring to assume free length position.
3. Remove the plunger, follower guide, follower, follower pin and spring from the injector body.
4. Remove the follower pin from the follower guide and separate the parts mentioned in Item 3.
5. Invert the injector in the holding fixture, unscrew the nut as shown in Fig. 9 and lift away from the injector body, being careful not to dislodge the spray tip and the other small parts resting on the end of the plunger bushing.

   If the injector has been in use for some time, the spray tip will possibly be removed with the nut.
6. Carefully lift the spray tip—if tip was not removed with nut—valve stop, valve spring, check valve, valve seat, spray tip valve, and spacer from the plunger bushing. (See Fig. 2 for identification of parts.)
7. If spray tip sticks in nut, remove by driving on outer end of tip with a hollow steel rod, or if available, use Tool J-1291-A. ***Do not drive on end of tip, as such treatment will damage the part.***
8. Jar the spill deflector from the nut.
9. Remove plunger bushing from body.
10. Jar the retainer and gear from the injector body.
11. Pull the rack from the injector body.
12. Remove the two fuel filter caps, filters and springs from injector body.

Inspect Injector Parts—Many of the close-fitting parts in the injector are carefully lapped; if, therefore, any of the internal working parts of the injector become scored or damaged, these parts are unfit for further use and should be replaced.

After the injector has been disassembled and all parts carefully cleaned in carbon tetrachloride or fuel oil, they should be protected from dirt by storing in fuel oil until replaced in the injector.

Examine the adjoining surfaces of the spacer and valve seat (pieces (15) and (16) in Fig. 2), and if necessary, lap surfaces as outlined under "Inspecting and Cleaning Injector Spray Tip," Page 6.

Clean the injector plunger bushing by immersing in a tank containing carbon tetrachloride or fuel oil and working a brush through the bushing. Blow out with compressed air and again wash in clean carbon tetrachloride or fuel oil. For final cleaning, wrap cleaning tissue around Tool J-1291-A, or some similar rod, and rotate in and out through bushing.

Injector Assembly—Before starting to assemble an injector, it is necessary to have an extremely clean workbench on which to work and store the parts. Care must be taken when assembling to place the various parts in their proper relative positions.

The various figures accompanying the build-up of the injector, therefore, should be thoroughly studied before attempting the assembly.

For purposes of simplicity, the injector assembly has been subdivided into four sub-assemblies and will be so treated in the injector assembly. These sub-assemblies are:

1. Filter assembly.
2. Rack and gear assembly.
3. Spray tip assembly.
4. Plunger and follower assembly.

1. **Filter Assembly**—When reassembling injector filters that have been used, even though they have been thoroughly cleaned in carbon tetrachloride or fuel oil and dried with compressed air, it is desirable to reassemble the filters in the respective openings from which they were removed; that is, the filter that was formerly used on the inlet side of the injector, and the one that

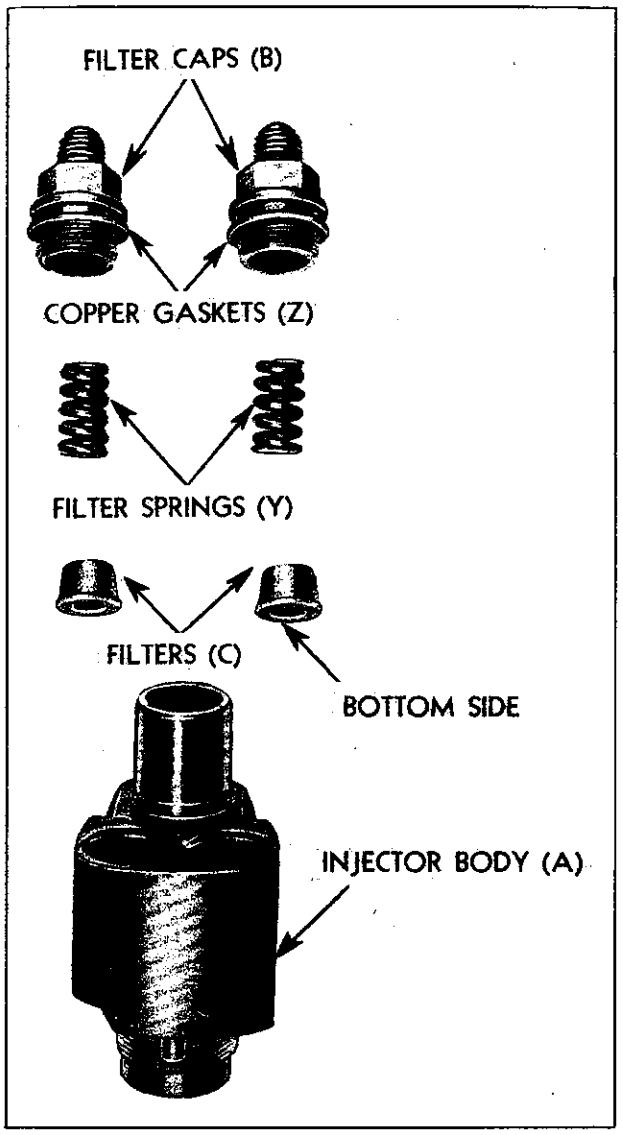


Fig. 14—Injector Filters, Springs, and Filter Caps.

was used on the outlet side, should be replaced in the same positions. This will guard against small particles that may have lodged on the inner surface of the outlet filter from being washed into the injector if used on the inlet side.

(a) Holding the injector body (A) right side up, place one of the filters (C) in each of the fuel cavities in the top of the injector body. (See Fig. 14.)

Note that the fuel filters are made of sintered bronze with a copper washer on the largest end. The fuel entering the injector body surrounds the filter element, passes through the element, and is discharged through the concave section in the lower part of the filter. When assembling the filters, always have the washer at the bottom as shown in Figs. 2 and 14.

(b) Place a spring (Y) above each filter, a copper gasket (Z) up against the shoulder of each filter cap (B), lubricate the threads and tighten the filter cap in place in the injector body.

2. **Rack and Gear Assembly**—Refer to Fig. 15 and note that two of the teeth of the injector rack (L) have a drill spot mark; also one tooth of the mating gear (K) is similarly marked. When the rack and gear are assembled, the marked tooth of the gear engages between the two marked teeth on the rack. This relation of rack and gear must be maintained for proper timing of the injectors.

(a) Hold the injector body, bottom end up, and slide the rack (L) through the ¼ inch (approximately) hole in the body so the two marked teeth can be observed when looking from the bottom into the bore for the gear.

(b) The injector rack can be placed in the injector body in only one position and have

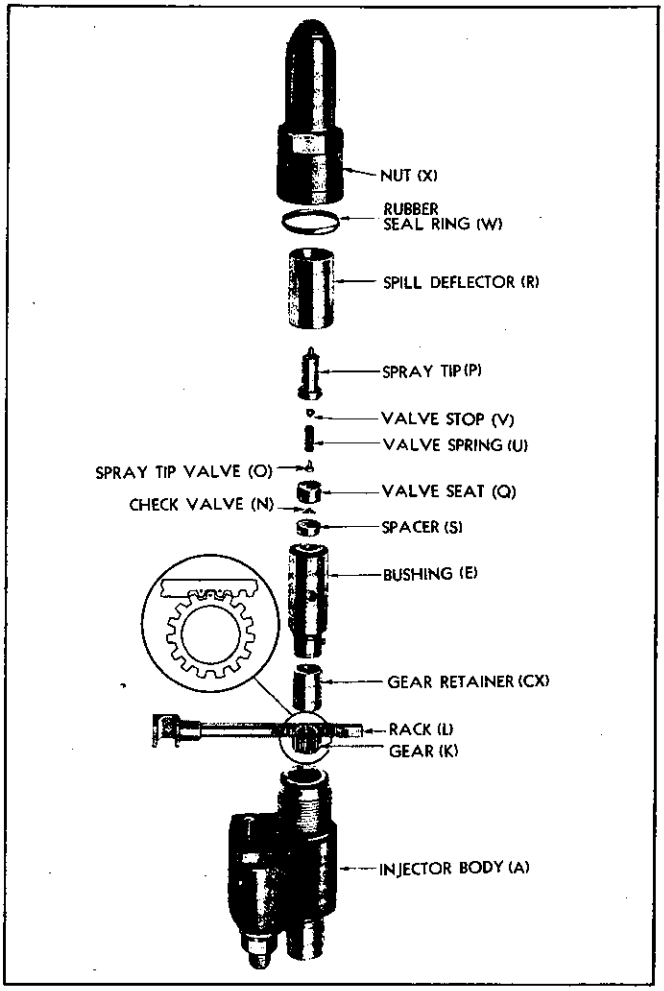


Fig. 15—Injector Rack, Gear, and Spray Tip Details.

the teeth marks show in the opening for the gear.

Whenever a filter cap is removed from the injector body, use a new copper gasket under each cap to insure a tight joint.

(c) Holding the rack in position so the teeth marks show, slide the gear (K) into proper engagement with the rack.

(d) Slide gear retainer (CX) down on top of gear and plunger bushing (E) down onto retainer with locating pin in bushing guided into slot of injector body.

(e) Slide the spill deflector (R) down into nut (X), and the rubber seal ring (W) on the injector body.

3. **Spray Tip Assembly**—Refer to Fig. 15 before assembling the following parts.

(a) Place spacer (S) flat down on a clean piece of paper. Place check valve (N) on spacer and spray tip valve seat (Q), recessed side down, over the check valve. Note that surface of valve seat opposite recessed side has either a small conical seat at center for spherical spray tip valve or a smooth, flat seat for flat spray tip valve.

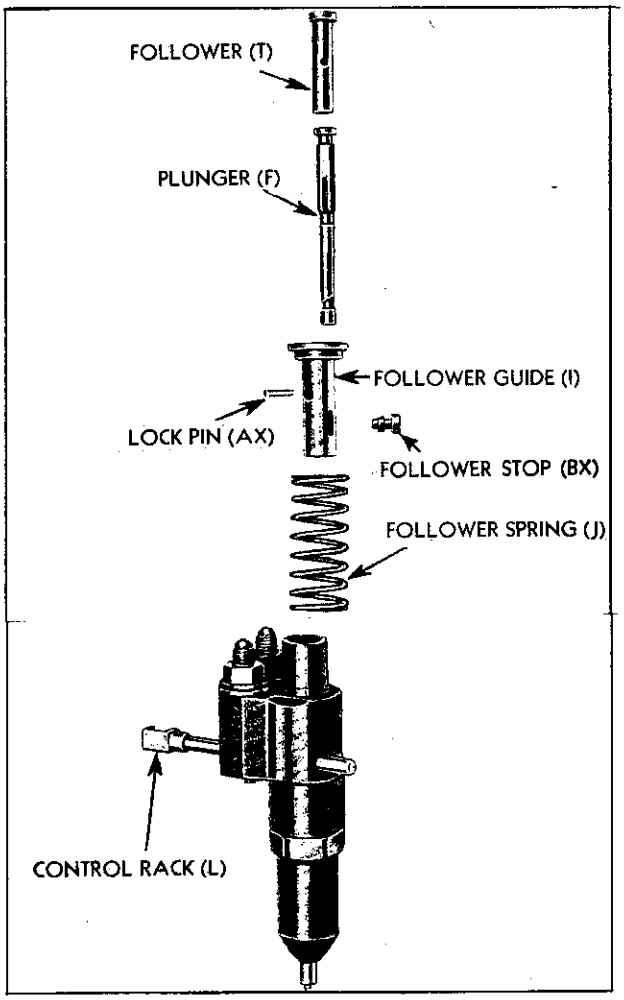


Fig. 16—Plunger and Follower Details.

(b) Position valve spring (U) over shank of valve stop (V), and place shank of spray tip valve (O) into the other end of the valve spring (U). While holding the spray tip (P) in a horizontal position, assemble valve stop, valve spring and valve into the tip, with the head of valve (O) toward the flanged end of spray tip.

(c) Hold injector body in the vise—bottom end up—then centrally place the check valve assembly, parts (S), (N), and (Q), on the end of the plunger bushing (E) and the tip assembly, parts (P), (V), (U), and (O) on the top of the valve assembly.

(d) Lubricate threads and carefully place the nut (X), containing the spill deflector (R), down over the top of the tip and check valve assemblies so the tip will slide through the small hole in small end of the nut.

(e) Screw the nut in place by hand (do not use wrench at this time), making sure that the check valve assembly, parts (N), (Q) and (S), has not shifted. If the check valve assembly is not centrally located on end of bushing, the valve seat (Q) and spacer (S) will not register into counterbore of the injector nut. This registration can be made by turning end of spray tip with the fingers while screwing the nut into place by hand.

4. **Plunger and Follower Assembly**—

(a) Refer to Fig. 16, and slide the plunger (F)—large end up—into the follower guide (I); place follower (T)—large end up—on plunger; slide follower pin (AX) through hole in follower guide and follower. Drop this assembly through plunger spring (J) for assembly to injector.

(b) Invert the position of the injector in the holding fixture—connector side up—push the rack (L) way IN, then assemble the plunger assembly parts (F), (I), (T), (AX), and (J) into top of injector body, as follows:

(c) Start stop pin (BX) into position in injector body so that bottom coil of follower spring (J) rests on the narrow flange on the stop pin. Then, with holes in the follower guide and the injector body in alignment for the stop pin, and flat side of plunger positioned to engage flattened side of gear, press down on top of follower and at the same time press

follower stop pin into position with the thumb. The stop pin will slip into position as soon as holes in follower guide and injector body come in alignment. When in place, the spring will hold the stop pin in position.

(d) Invert the injector assembly in the holding fixture, Tool No. J-1261, and by means of the special wrench, J-1238, shown in Fig. 9, screw nut (X) tight. Check for free movement of the injector control rack. Holding the injector in a horizontal position, the rack must fall by its own weight if plunger and bushing are properly assembled.

Testing Injector—After an injector has been repaired or overhauled, it should be tested before it is installed in an engine or put aside for future use. Also, when in doubt about an injector functioning properly, a test will usually indicate the difficulties quickly.

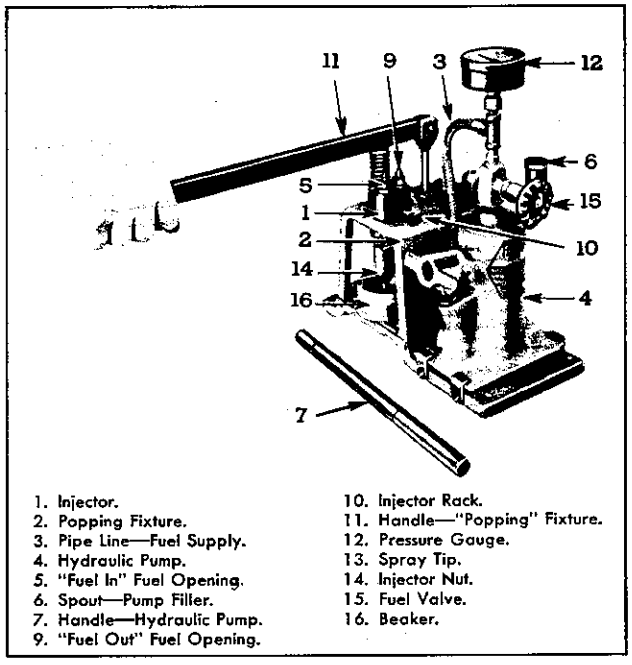
Two tests are recommended on the injector: (1) a "popping" test, (2) a pressure test.

A "popping" test is to operate the plunger, see that all parts are functioning properly and open the check valve suddenly, which will usually remove any small particles in the fuel or on adjacent parts that might prevent proper operation.

A pressure test is to determine if the check valve is seating properly and that there are no leaks at any of the gaskets.

Refer to Figs. 17 and 18 and test the injector as follows:

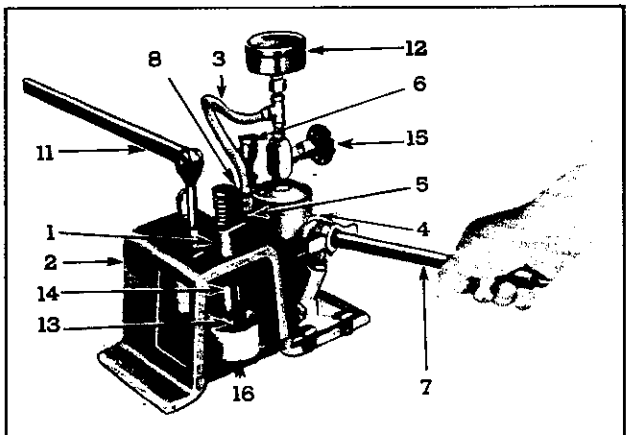
1. Place the injector (1) in the popping fixture (2) with dowel on underside of injector body located in hole of fixture.
2. Connect fuel supply pipe line (3) from hydraulic pump (4) to "fuel in" side of injector (5).
3. Fill the hydraulic pump through filler (6) then pump the hydraulic handle (7) and force all the air from the injector.
4. Screw cap (8) on "fuel out" side (9) of injector (1).
5. Work hydraulic handle (7) up and down a few times to check fuel supply line and "fuel out" cap (8) for leaks.
6. Push the injector rack (10) way IN to full fuel position and "pop" the injector sharply three or four times with popping handle (11) as shown in Fig. 17.
7. **Check "Popping" Pressure** by working the hydraulic pump handle (7) up and down with smooth, even strokes, at the same time watching the pressure gauge (12) and note at what pressure the injector sprays fuel. This pressure should be from 350 to 700 pounds per square inch on injectors with flat spray tip valves and at least 1000 lbs. on those with spherical valves.



1. Injector.
2. Popping Fixture.
3. Pipe Line—Fuel Supply.
4. Hydraulic Pump.
5. "Fuel In" Fuel Opening.
6. Spout—Pump Filler.
7. Handle—Hydraulic Pump.
9. "Fuel Out" Fuel Opening.
10. Injector Rack.
11. Handle—"Popping" Fixture.
12. Pressure Gauge.
13. Spray Tip.
14. Injector Nut.
15. Fuel Valve.
16. Beaker.

Fig. 17—"Popping" the Injector.

CAUTION: Always use beaker and keep hands away from spray tip when "popping" injectors; otherwise, THE FUEL FROM SPRAY TIP WILL PENETRATE THE SKIN AND MAY CAUSE IMMEDIATE BLOOD POISONING.



1. Injector.
2. Popping Fixture.
3. Pipe Line—Fuel Supply.
4. Hydraulic Pump.
5. Fuel Opening— "Fuel In".
6. Spout—Pump Filler.
7. Handle—Hydraulic Pump.
8. Cap.
11. Handle—"Popping" Fixture.
12. Pressure Gauge.
13. Spray Tip.
14. Injector Nut.
15. Fuel Valve.
16. Beaker.

Fig. 18—Pressure Checking Injector.

8. Work hydraulic pump handle again and note if all spray tip holes are open and spray pattern is even.
9. **Check for Leaks** around injector body seal ring, rack, spray tip and fuel connections (5) and (9) by working hydraulic pump handle (7) and bringing pressure up to *just below* the "popping" pressure. If a slight dribble is seen at the spray tip, "pop" the injector several times sharply with the "popping" handle (11), which will usually clear the injector of any small particles and allow the check valve to seat properly. If dribble cannot be stopped in this manner, remove nut (14) and clean spray tip as outlined under "Inspecting and Cleaning Spray Tips," Page 6.
10. **Check Pressure Drop** in the injector by pumping the hydraulic handle (7) and "popping" the injector sharply, then close valve (15) and note the pressure drop on the gauge.

    A drop not to exceed 200 pounds in 50 seconds on a new injector or the same drop in 35 seconds on a used injector is permissible.
11. Remove cap (8) from the "fuel out" side of the injector.
12. If the injector functions satisfactorily throughout the above tests, it may be used. If not, disassemble, inspect and reassemble as directed in this section.

NOTE: Never remove filters from injector unless unit is entirely disassembled because there is a possibility of dirt entering injector when filters are removed.

Install Injector—The injector is installed in the cylinder head by reversing the sequence of operations for removal. A dowel, provided on the injector body, registers with a hole in the cylinder head, so the injector can be located in only one position. After locating the injector, tighten in place with the hold-down clamp, spherical washer and nut, and attach fuel lines to injector and fuel connectors.

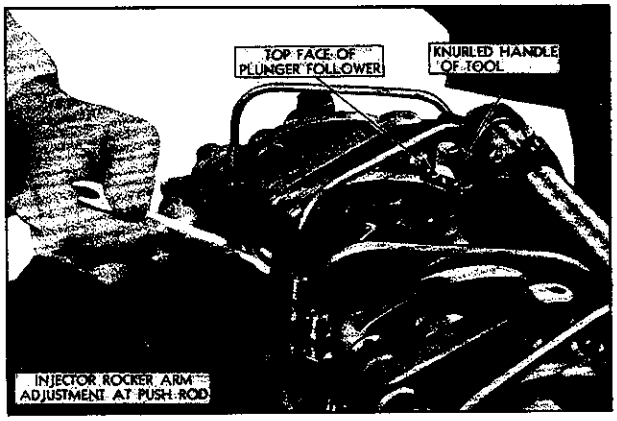


Fig. 19—Timing Fuel Injector with Timing Gauge.

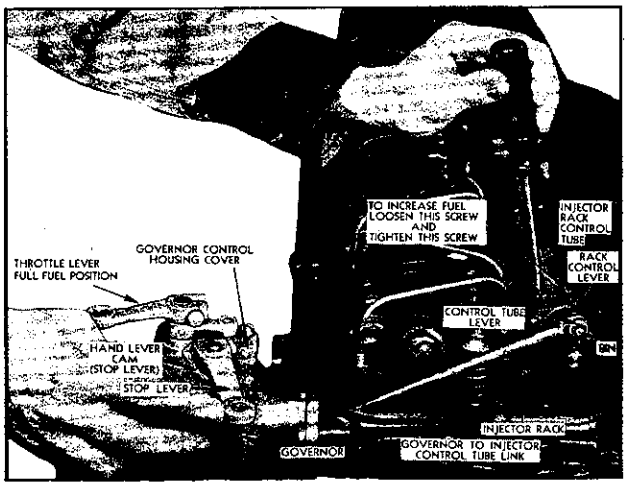


Fig. 20—Positioning Injector Control Racks.

Timing Fuel Injectors—After installation, injectors must always be checked and readjusted before the engine is run.

The ignition in each cylinder is governed by the proper injection of the fuel into the combustion chamber.

To insure the proper timing of the injection, the plunger follower of each injector has to be adjusted to a certain position in relation to the injector body.

If the injectors are not properly timed, the engine operation will be "ragged."

The injectors should be timed as follows:

1. Remove valve rocker cover.
2. Turn throttle control to "off" position.
3. Crank engine by turning flywheel by hand or by means of the starting motor, until the exhaust valves of the cylinder to be timed are fully open.
4. Place injector timing gauge in timing guage hole on the top of the injector body, as shown in Fig. 19.

NOTE: Timing gauge J-1564 or J-1242 with height dimension of 1.484"—the distance between lower surface of head and shoulder at lower end of stem—is used on models 71S and 71A. Gauge J-1853 with height dimension of 1.460" is used on models 71M and 71H.

5. Adjust the injector rocker arm, by means of the screw adjustment on the upper end of the push rod, until the lowest surface of the timing gauge head is just passing over the top surface of the plunger follower guide. Tighten lock nut on push rod. Recheck with timing gauge.
6. If the above timing operation was carried out on an injector just installed in the engine, do not run the engine until after the injector racks have been positioned as outlined below.

Position Injector Control Rack or Racks.

NOTE: On all engine models equipped with hydraulic governors, refer to Page 38, Sec. 16 on "Hydraulic Governors" for this operation.

Two different conditions will arise when it will be necessary to position the injector control racks:

1. When only one injector has been replaced and the other injectors or the governor adjustment has not been disturbed.
2. When more than one injector has been replaced.

In the first condition, the injector may be installed, valves lashed, injector timed, and its rack positioned to correspond with that of the other racks without repositioning the racks of the remaining injectors. In the second condition, valve lash should be checked, injectors timed, and racks positioned on all cylinders.

Procedure for both of these conditions is given below.

1. **To Position Injector Control Rack When Only One Injector Has Been Replaced,** and remaining injectors racks have not been disturbed:
   1. Back off several turns on both adjusting screws in rack control lever at the injector being adjusted. (See Fig. 20.)
   2. Hold the injector racks all the way IN (full-fuel position) by pushing the throttle lever to "full fuel" position as shown in Fig. 20. Adjust rack control lever to the full IN position by slowly turning down inner adjusting screw until injector rack can just be felt striking "bottom" and the other racks can be seen to just begin moving OUTWARD. Then tighten down outer adjusting screw and lock inner screw.
   3. After setting the rack, visual inspection should show that the shoulders on all injector racks extend approximately $^{27}/_{32}$" from the injector body, when the racks are held in the NO-FUEL position (throttle lever in "stop" position.)
   4. After positioning rack control lever, check, to see that the other racks have not moved out. This may be done by inserting a screwdriver under the control tube and pressing inward on the end of the rack of an adjacent injector as shown in Fig. 21. There should be no further inward travel of any of the remaining racks, with this injector rack in the full IN position. If the other levers can be moved in, the lever being positioned, of the injector just installed, has been moved in too far and should be readjusted by backing out on inner screw and tightening outer screw.

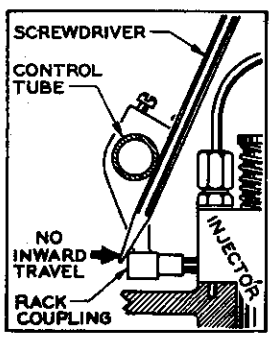


Fig. 21—Checking Injector Control Rack Position.

2. **Position Injector Control Racks When More Than One Injector Has Been Replaced In the Engine.**

When more than one injector has been replaced in the engine, the control racks must be correctly positioned so that all cylinders carry an equal share of the load, and so that the injector racks are in correct relationship with the governor. The amount of fuel injected into each cylinder is controlled by the position of the injector rack. The maximum amount of fuel is injected when the racks are all the way IN, and no fuel is injected when the racks are all the way OUT.

Helpful Hints When Positioning Injector Control Racks—If the injector control tube has been removed, care should be exercised when replacing the assembly to be sure that no bind exists between the tube levers and the injector racks to hamper free operation of the latter. The levers are free to move endwise on the tube a limited distance. When the adjusting screw and the levers are tightened, the levers should be so positioned on the tube that the operating lug at the lower end of the lever does not bind in the slot of the injector rack. Furthermore, the brackets holding the tube assembly to the cylinder head should be so positioned that the coil spring on the control tube will return the injector racks to the NO FUEL position freely.

If necessary, the control tube and bracket assembly may be shifted by loosening bracket-to-cylinder head bolts and tapping the brackets lightly to change their positions on the cylinder head, then retightening the hold-down bolts. Instances may arise when an injector rack does not move freely in the injector or the plunger in the bushing. This is particularly true if the injector has been used over a long period of time without cleaning. Knowing that no bind exists between the rack control tube and the injectors, and the tension spring on the control tube fails to return the racks freely to the NO FUEL position, when the control tube is disconnected from the governor fuel rod, a sticking injector rack may be identified by loosening the adjusting screws in five of the rack control levers so the levers are free to move on the tube. Then turn the engine crankshaft so that the exhaust valves are closed and the injector in the non-injection position (the three rocker arms in line) on the cylinder in which the adjusting screws were not loosened. Then press down with a screwdriver on the injector follower and at the same time move the injector rack of the cylinder being checked in and out by means of the control tube lever. After

checking, loosen adjusting screws. Follow this same procedure on each injector in turn until the faulty injector is located. Remove injector and refer to "Plunger and Follower Assembly" for correction of sticking rack.

Since the injectors are controlled by the governor, any major adjustment of either necessitates the resetting of the other. Therefore, before the injector racks are positioned on engines equipped with mechanical governors, the governor spring plunger gap must be established. Following this the injector racks are adjusted and then the engine idle speed is set. The above procedure involves four distinct operations which are set forth below.

A. **Initial Positioning of Injector Control Rack Before Starting Engine**—Immediately following the installation of injectors, they should be timed and the valves lashed. (See page 2, Sec. 11) Injector racks must then be approximately positioned to permit starting and stopping of engine. This is accomplished as follows:

1. Turn inner and outer adjusting screws on all injector rack control levers to equal depth. Tighten screws.
2. Hold governor control lever in the "stop" position (governor control link connected). Each injector rack must extend approximately $^{27}/_{32}$" from injector body. (See Fig. 22.) This measurement assures engine shut down.

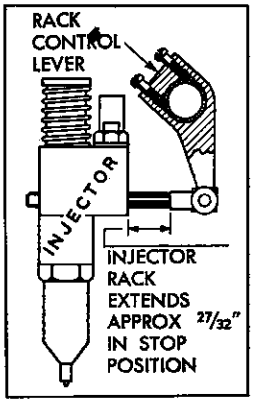
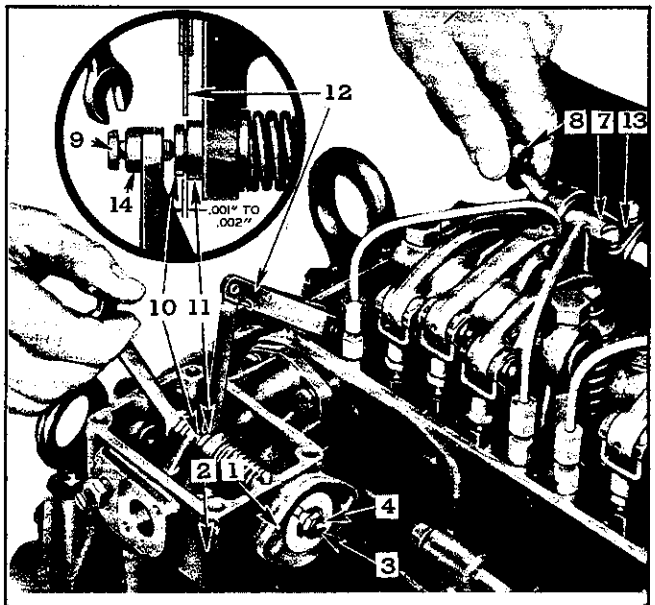


Fig. 22—Rack Stop Position.

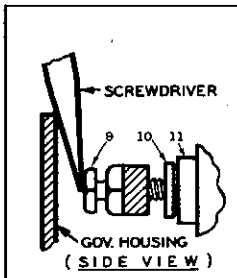
B. **Governor Spring Plunger Gap Setting**—

1. Refer to Figs. 23 and 25. Note name and position of numbered parts.
2. Remove the spring cover at the rear of the governor control housing and set the idle adjusting screw (3), Fig. 23, so that it projects $^1/_{16}$" from the locknut (4).
3. Remove the governor cover and the link between the governor and the injector control tube.
4. Start the engine with the aid of a helper and regulate the speed by hand operation of the injector control tube lever (8) as shown in Fig. 23. As the governor is now disconnected, care must be taken not to over-speed the engine.
5. Keep the engine running between 700 and 1000 R.P.M. and set the gap adjusting screw (9) so that the gap between the low speed spring cap (10) and the high speed spring plunger (11) is only .001 to .002". This may be measured with a .0015" or .002" feeler gauge (12) inserted between cap (10) and plunger (11). If no feeler gauge is available, this setting may be checked with a screw driver inserted between the governor housing and gap adjusting screw (9), and using it as a lever. (See Fig. 24.) When the gap is properly set, the movement between cap (10) and plunger (11) should be barely perceptible—about the width of a hair—when forced closed with the screw driver while engine is running between 700 and 1000 R.P.M. Tighten locknut (14) each time before checking above setting.



1. Boss for Cover.
2. Control Housing.
3. Idle Adjusting Screw.
4. Lock Nut.
7. Injector Control Tube.
8. Control Tube Lever
9. Gap Adjusting Screw.
10. Low Speed Spring Cap.
11. High Speed Spring Plunger.
12. Feeler Gauge.
13. Rack Control Levers.
14. Lock Nut.

Fig. 23—Governor Gap Setting—Mechanical Governor.



9. Gap Adjusting Screw.
10. Low Speed Spring Cap.
11. High Speed Spring Plunger.

Fig. 24—Setting Gap.

6. Stop the engine—replace the link and the governor cover.

7. The injector racks must be re-positioned by adjustment of the rack control levers after the gap setting has been made.

C. Injector Rack Control Lever Adjustment (Engine Not Running)

The position of the injector rack determines the amount of fuel injected into each cylinder.

Injector racks must be positioned so that they are in correct relationship with the governor, and so that all cylinders share the load equally at full load, with racks all the way in.

Before performing the following operations determine if resetting of injector racks is really necessary. While holding governor control lever (6) (See Fig. 25) securely in full fuel position, pull injector control tube lever (5) toward governor with thumb hooked over head of rocker arm bracket bolt as an aid to obtaining leverage. The maximum movement of the racks should not exceed 1/64".

Adjust No. 1 Injector Rack to Full Fuel Position—Purpose of this adjustment is to set No. 1 injector rack in proper relation to the governor in order to establish a guide for the setting of all injectors at full load.

1. Back out buffer screw (9) until it projects about 5/8" from the governor housing.

2. Back off several turns on both adjusting screws (1) and (2) of all rack control levers (3). Outer screw (2) on No. 1 lever should be backed off several additional turns. Be sure *all* levers are free to rotate on shaft.

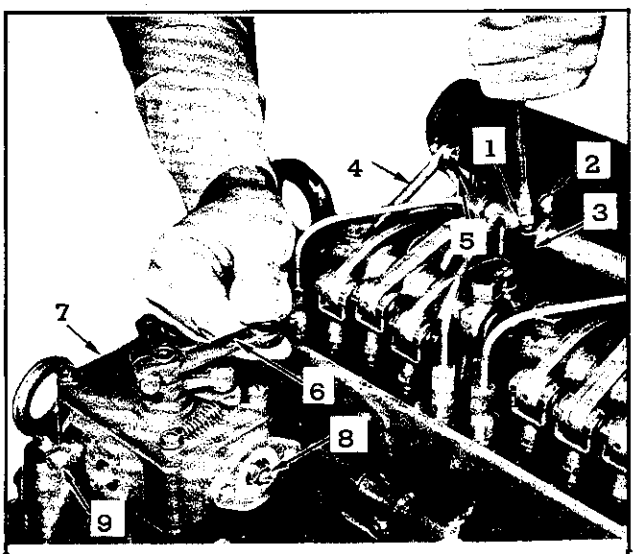
NOTE: Items 3, 4 and 5 vary slightly from previously established procedure to be found in manuals and charts.

3. Turn down inner adjusting screw (1) on the No. 1 injector rack control lever until screw "bottoms."

4. Move governor control lever (6) toward full open position. Do not force it past point at which resistance to movement suddenly increases, but hold it at this point, pressing lightly toward full, open position.

5. Back off inner screw (1) which will cause governor control lever (6) to move toward full open position. Continue until lever (6) just "bottoms" at end of governor cam.

6. Turn down outer adjustment screw (2) to lock rack control lever (3) in position. This should accomplish the desired full load setting of No. 1 injector.



1. Inner Adjusting Screw.
2. Outer Adjusting Screw
3. Rack Control Lever.
4. Link—Governor to Control Tube.
5. Control Tube Lever.
6. Governor Control Lever.
7. Governor Cover.
8. Idle Adjusting Screw.
9. Buffer Screw.

Fig. 25—Injector Rack Positioning.

7. To check the adjustment for presence of slight free play (maximum 1/64" at rack), pull injector control shaft lever (5) toward governor with thumb hooked over head of rocker arm bracket bolt, while holding governor control lever (6) securely in full fuel position.

8. If free play is in excess of 1/64", reduce to the smallest perceptible amount by loosening outer screw (2) and tightening inner screw (1).

Adjust Remaining Racks to Full Fuel Position

1. With governor control lever (6) in open position, note rotary movement of No. 1 injector rack coupling. Pressure of finger tip will produce a tendency to rotate, but coupling will not be loose. All injectors must now be adjusted to the same "feel" at coupling to insure full injection at full load, as follows:

2. Adjust No. 2 injector rack by turning down inner adjusting screw (1) while finger tip is touching No. 2 injector rack coupling. When coupling loses its free play, tighten outer screw (2).

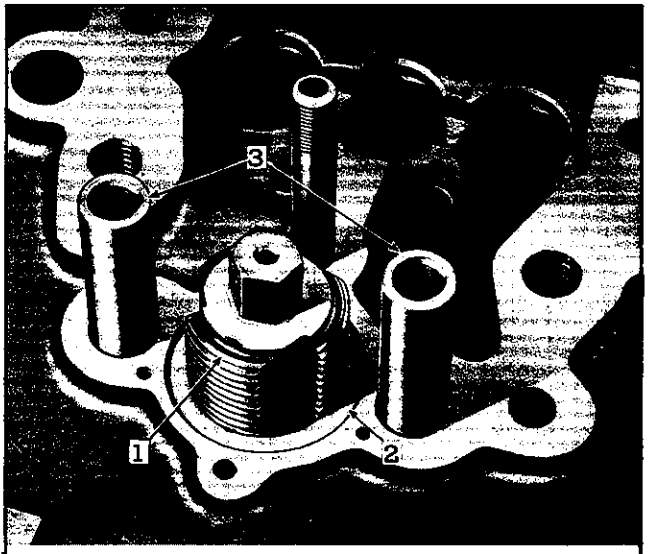
3. Check No. 2 and No. 1 rack couplings with finger tip for free play. If free play is excessive, or not present, correct by adjusting No. 2 injector rack.

4. When No. 2 rack coupling feels the same as No. 1, repeat this procedure (Operations 2, 3, 4, etc.) with No. 3, and all remaining injector racks. That is, compare No. 3 rack coupling with No. 1, etc.

5. **Check for Stop Position**—Hold the governor control lever (6) in the "stop position". The injector racks should not have more than 3/16" outward movement when the injector control tube lever (5) is moved with the hand.

6. **Set Idle Speed** as outlined in Sec. 16.

INJECTOR COPPER TUBE



1. Tool—Injector Hole Tube Removing—J-1891.
2. Copper Tube—Injector.
3. Valve Guide.

Fig. 26—Removing Injector Copper Tube from Cylinder Head with Tool J-1891 (Operation 1).

As will be seen by referring to Fig. 1, the bore in the cylinder head for the fuel injectors is directly through the water jacket of the head. To prevent cooling water from contacting the injector and still maintain maximum cooling of the injector, a copper tube is pressed into the injector bore. This tube is sealed at the top with a neoprene ring and spun into a flare on the lower side of the cylinder head to form water-tight joints at top and bottom.

Remove Injector Copper Tube from Cylinder Head—When removal of an injector copper tube becomes necessary, the operations may be carried out with the tools and in the manner given below:

1. Remove cylinder head. (See Page 2, Sec. 9.)

2. Remove rocker arm shafts and brackets and unscrew rocker arms from push rods as outlined in Sec. 11.

3. Remove exhaust valves from cylinder head. (See Page 3, Sec. 11.)

4. Remove injector or injectors from cylinders in question.

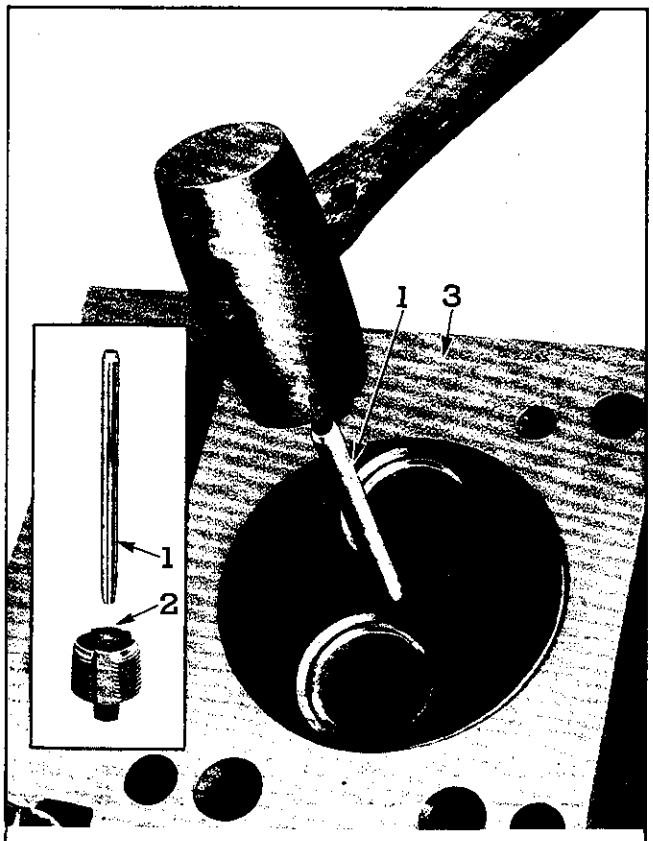
5. Suitably support the cylinder head, top side up, and screw threaded tool into upper end of copper tube as shown in Fig. 26.

6. Invert cylinder head and insert driving handle through spray tip opening of tube until it rests against threaded tool. Then drive copper tube out top of head as illustrated in Fig. 27.

Install Copper Tube in Cylinder Head:

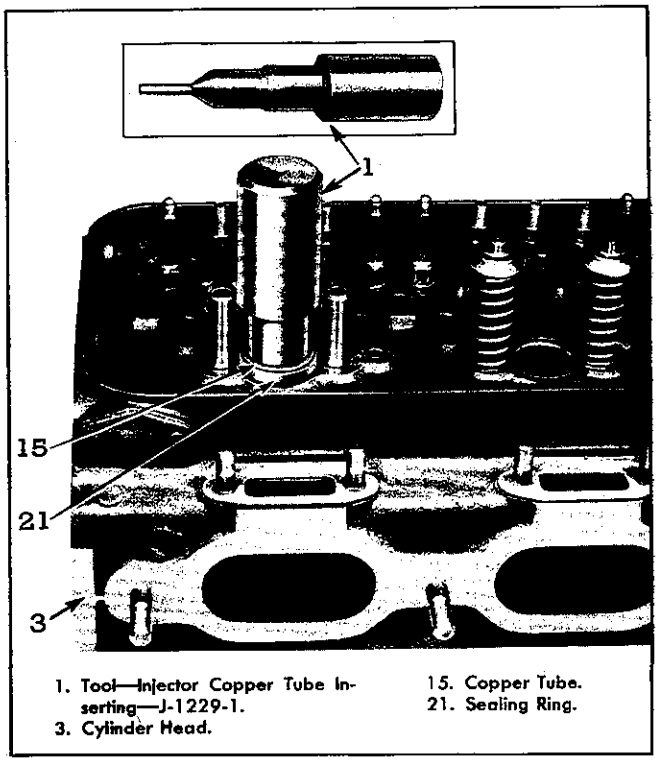
1. With cylinder head suitably supported in upright position, install seal ring in counterbore provided for same as shown in Fig. 1.

2. Crowd injector tube through seal ring and into bore of head. Insert driving tool in tube and drive tube into position as illustrated in Fig. 28. When tube is properly located the flange at upper end will seat on the seal ring and into counterbore of cylinder head.



1. Tool—Injector Tube Removing—No. J-1891—Rod.
2. Tool—Injector Tube Removing—No. J-1891—Tap.
3. Cylinder Head.

Fig. 27—Removing Injector Copper Tube from Cylinder Head with Tool J-1891 (Operation 2).



1. Tool—Injector Copper Tube Inserting—J-1229-1.
3. Cylinder Head.
15. Copper Tube.
21. Sealing Ring.

Fig. 28—Installing Injector Copper Tube in Cylinder Head with Tool J-1229-1 (Operation 1).

3. After driving tube in position, swage lower end at spray tip with Tools J-1229-2, J-1229-1 and J-1229-5, shown in Fig. 29, as follows:

NOTE: Swaging tool will work more satisfactorily if tapered end is ground down flat (90° to axis) to .470" O.D.

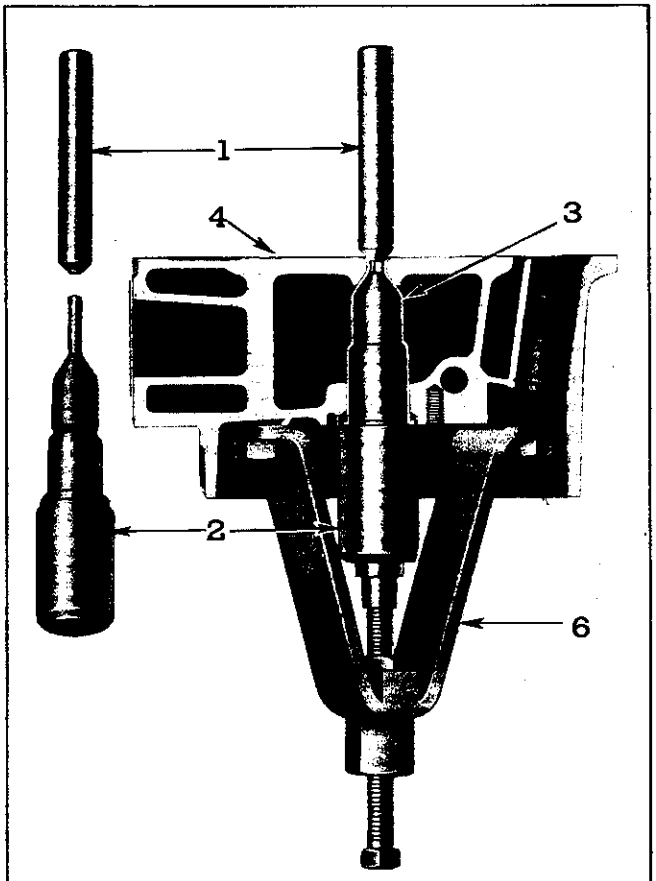
(a) Support edge of cylinder head on work bench and install tube driving Tool J-1229-1 inside of copper tube.

(b) Using the two hold-down bolts provided in feet of clamp fixture J-1229-5, attach clamp to top of cylinder head using two of the cylinder head-to-block stud holes, and with screw thread in clamp over top of driving tool.

(c) Loosen lock nuts on screw thread and turn screw down against top of driving tool so that copper tube is firmly seated in cylinder head and against sealing ring. Fix screw thread in position with lock nuts.

(d) Install flaring Tool J-1229-2 over lower end of driving tool and upset copper tube into counterbore at lower side of cylinder head.

Reaming Copper Tube in Cylinder Head for Injector Body Nut and Spray Tip—After copper tube has been installed in the cylinder head, it must be reamed: first, to receive the injector body nut and spray tip; and second, for good seating of the bevel on the lower end of the injector nut.



1. Tool—Injector Copper Tube Flaring—J-1229-2.
2. Tool—Injector Copper Tube Driving—J-1229-1.
3. Copper Tube.
4. Cylinder Head.
6. Tool—Clamping Fixture—J-1229-5.

Fig. 29—Installing Injector Copper Tube in Cylinder Head with Tools J-1229-1, J-1229-2 and J-1229-5 (Operation 2).

Reaming of upper end of tube to proper size for body nut and lower end for spray tip is accomplished by inserting and operating Tool J-1231-1 as illustrated in Fig. 30.

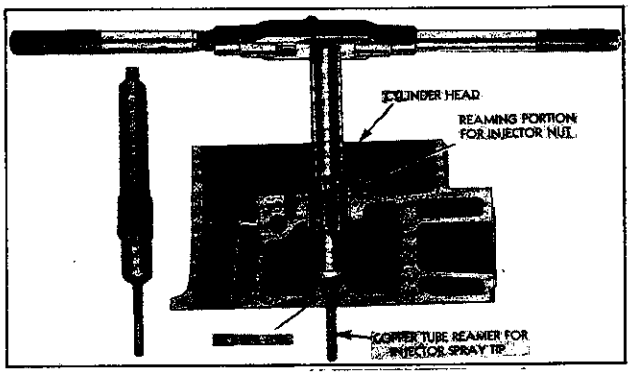
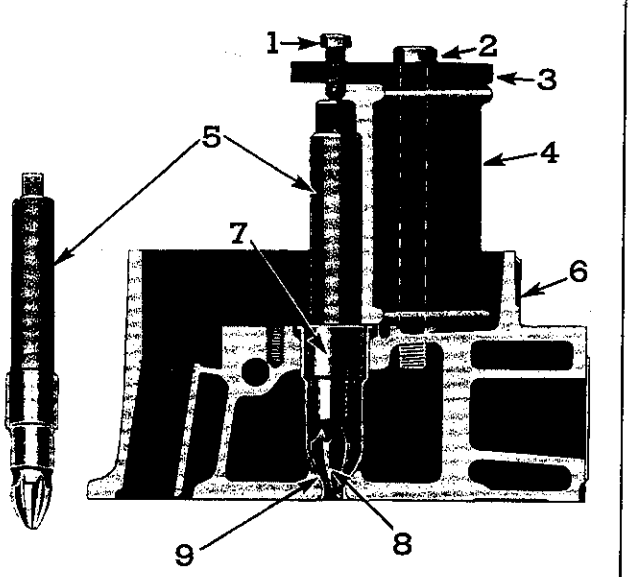
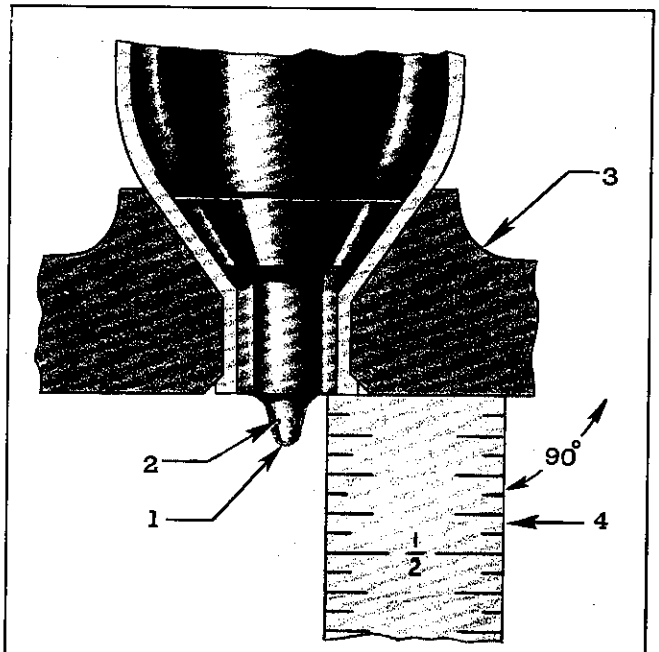


Fig. 30—Reaming Copper Tube in Cylinder Head for Injector Body Nut and Spray Tip with Tool J-1231-1.



1. Feed Screw (Cone Point).
2. Clamp Bolt.
3. Tool—Feed Plate (Steel)—No. J-1231-5.
4. Block—Wood or Iron.
5. Reaming Tool No. J-1231-2.
6. Cylinder Head.
7. Pilot Shoulder.
8. Cutting Flutes—Bevel Seat Reamer.
9. Copper Tube.

Fig. 31—Reaming Bevel Seat in Injector Copper Tube for Injector Nut with Tool J-1231-5.



1. Spray Tip.
2. Orifice—Injector Spray Tip.
3. Cylinder Head.
4. Straight Edge—Steel.

Fig. 32—Checking Location of Injector Spray Tip Relative to Lower Surface of Cylinder Head.

Reaming Bevel Seat in Injector Copper Tube for Injector Nut—This reaming operation is performed with Tool J-1231-5 as follows:

1. Insert reamer into tube and place feed clamp plate and block on cylinder head as illustrated in Fig. 31 with clamp bolt hole of plate and block over tapped hole for rocker arm shaft bracket bolt and with feed screw of tool directly over center of reamer.
2. Bolt plate and block securely to head and turn feed screw down *finger tight only.*
3. Using a cutting compound consisting of equal parts of cutting oil and kerosene, ream bevel seat for injector nut so that shoulder of spray tip will be just flush with under surface of cylinder head. (See Fig. 32.) One should check depth of cut during reaming operation by installing an injector in tube.

FUEL OIL PUMP

Description—The fuel oil pump shown in Fig. 33 is the positive displacement vane type having a capacity of approximately 35 gallons per hour at 1500 r.p.m. engine speed. The pump is bolted to the blower rear end plate cover and is driven from the lower blower rotor shaft through a U-shaped steel stamping which acts as a universal joint. An integral steel rotor and shaft, one end supported in the pump flange and other end in cover, revolves in the body, the bore of which is eccentric to the rotor.

Two spring-loaded vanes, carried in the rotor, revolve inside the eccentric body, thus displacing the liquid from the inlet to the outlet port. Two oil seals are used inside the flange at the drive end of the rotor shaft. One seal retains the fuel oil under pressure, the other prevents the lubricating oil in the blower timing gear compartment from creeping along the pump shaft.

The seals are located approximately 1/16" apart and the feather edge of the leather on the inner seal faces the blower and that on the outer seal faces the pump body. A drain hole located between the two seals vents to atmosphere or to an air box drain tank. (See Sec. 14.)

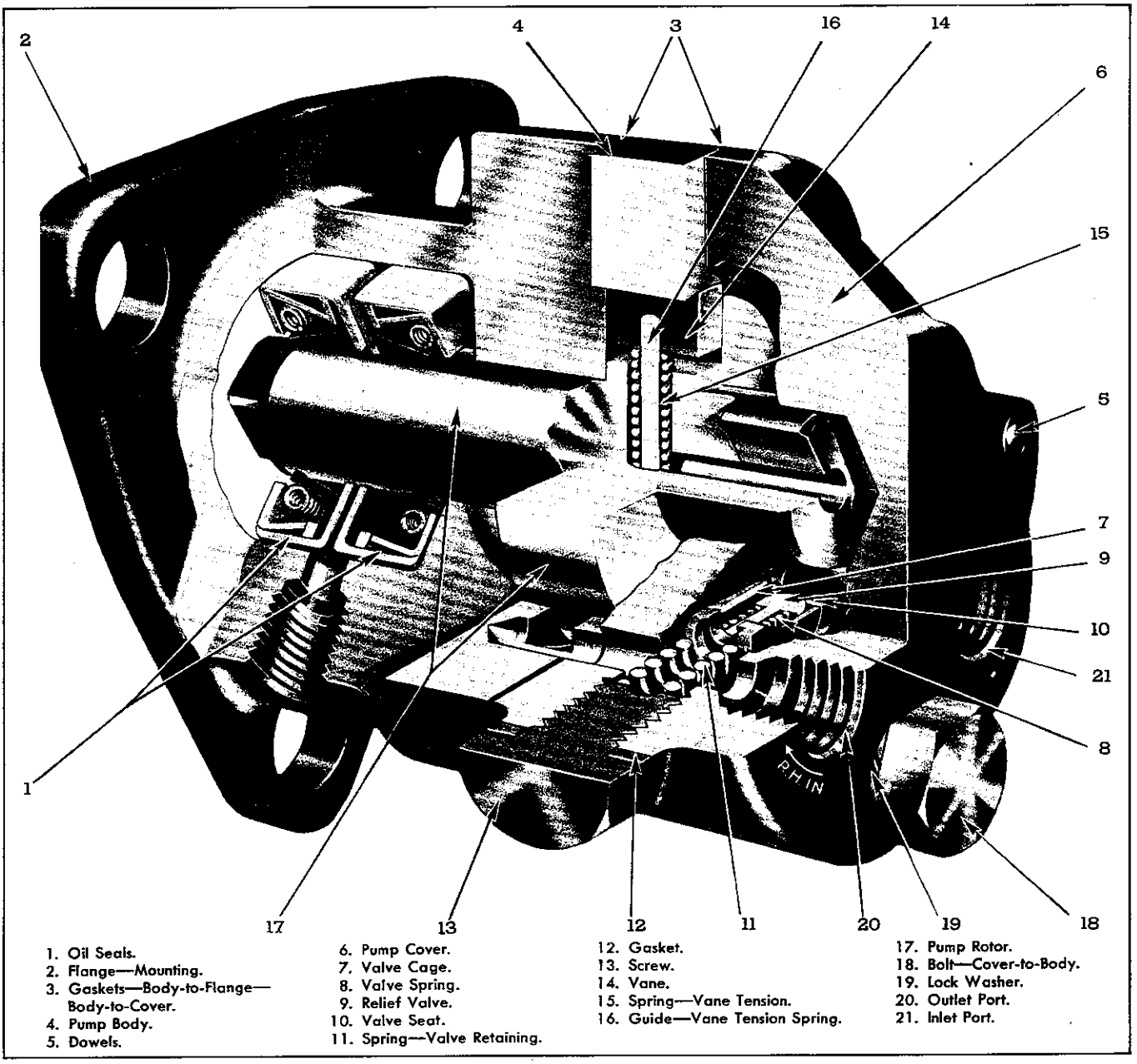


Fig. 33—Fuel Pump Assembly Showing Position of Rotor, Vanes, and Oil Seals in Pump. (Valve, Valve Seat and Cage Arrangement for RC, RD, LC and LD Engines Shown.)

A spring-loaded, horizontal relief valve is provided in the cover of the pump, connecting the inlet and outlet ports, and opens at a pressure of approximately 55 pounds per square inch. This valve normally does not open since its purpose is to relieve excessive pump pressure in case any of the fuel lines or filters become plugged and build up an extremely high pressure in the pump. When the valve opens, fuel passes from the discharge side (pressure side) to the suction side of the pump.

The pumps are the same for all engines except for the manner in which the relief valve, cage and seat are assembled. (See Fig. 34.) Pumps for the RA and LA engines are therefore identified by the marking "LH IN," while pumps for the RC and LC engines are identified by the marking "RH IN," signifying the rotation of the pump vanes. These markings appear at the inlet opening of the pump cover. When the pump is installed on the blower, the ***inlet opening must always be next to the cylinder block.***

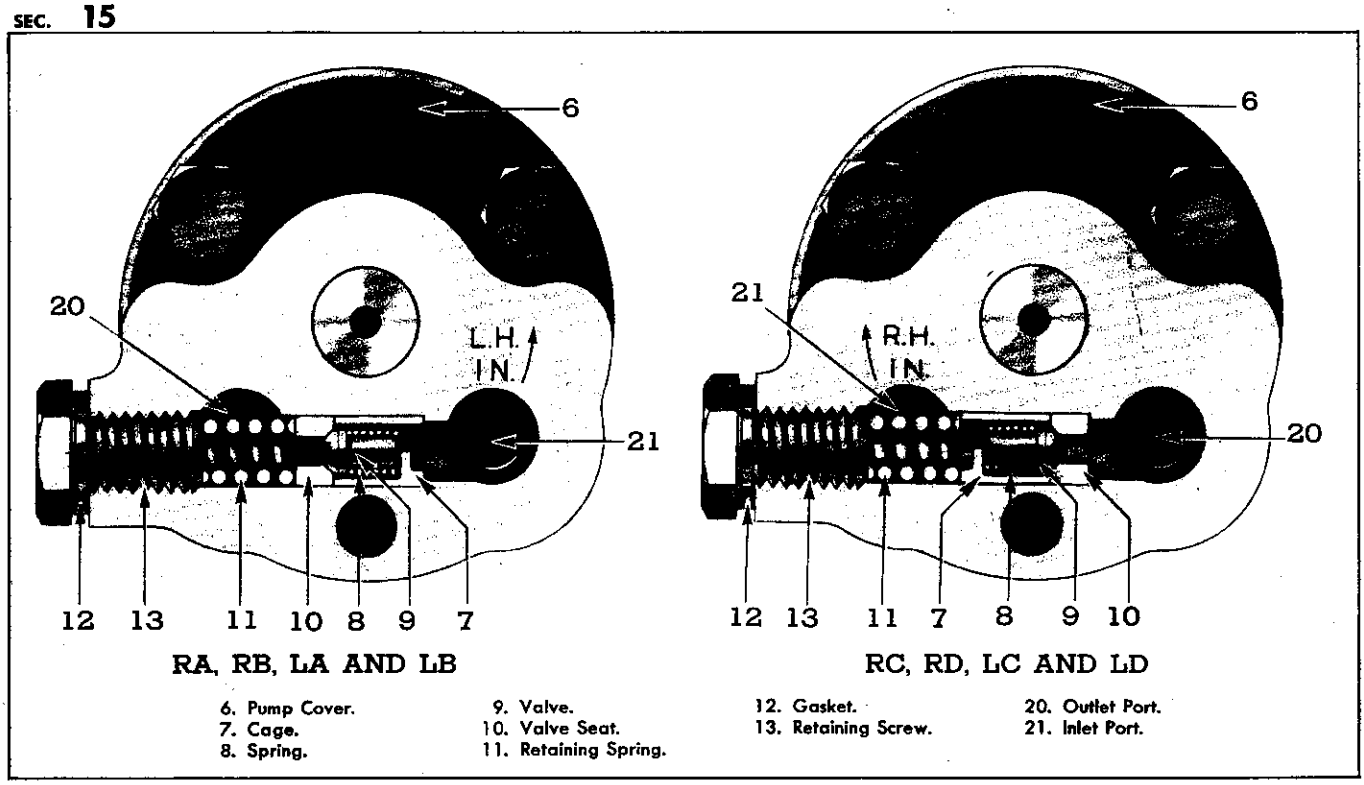


Fig. 34—Position of Relief Valve in Pump Cover for Engine Models Indicated.

Checking of Fuel Supply System—The fuel oil pump should maintain a minimum fuel pressure of approximately 10 lbs./sq. in. in the return manifold of the engine at a speed of 600-800 R. P. M.

Uneven running, excessive vibration, stalling when idling, and a loss of power, may be caused by an insufficient fuel supply to the injectors.

An insufficient supply of fuel at the injectors, providing supply tank is suitably filled, may be due to:

1. Air being drawn into fuel system.
2. Choked fuel filter elements.
3. Partially plugged fuel lines.
4. Faulty fuel oil pump. (See "Remove Fuel Oil Pump from Blower," below.)
5. Choked injector fuel filters.

These various conditions may be checked by conducting either a flow test of fuel being returned from the injector fuel return manifold, or checking the fuel pressure in the return manifold at the end opposite to the fuel line leading back to the fuel tank. A screw plug at that location may be removed for attaching a pressure gauge. If gauge shows a reading of 10 or more pounds at 600 to 800 engine R. P. M. flow tests outlined below need not be run, and difficulties should be looked for elsewhere.

1 and 2. **Check for Clogged Fuel Oil Filter Elements and Admission of Air,** as follows:

(a) After connecting one end of rubber hose or flexible tube to the fuel return manifold and immersing other end in a large container as illustrated in Fig. 35, start the engine and run at 1200 engine R.P.M. Measure the fuel being returned from manifold, which should be approximately one half gallon per minute; also, observe if air is being pumped through the fuel system as will be indicated by air bubbles appearing as foam on fuel in container.

If air is present, correct this condition by tightening all fuel connections on fuel lines on suction side of fuel oil pump; then, run engine to ascertain smooth operation and power before conducting further tests.

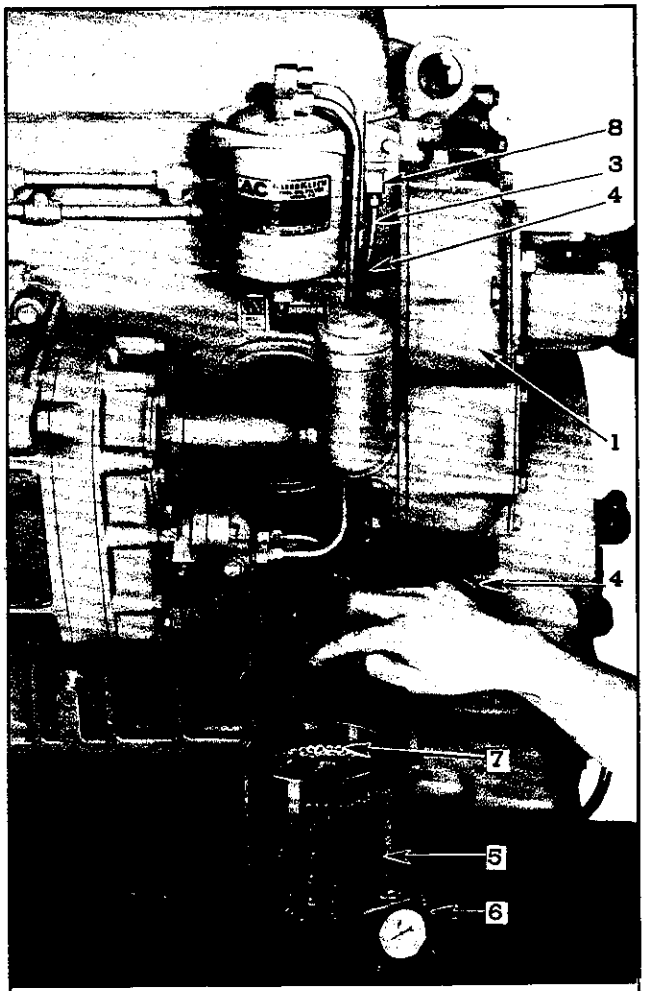
(b) Stop engine and remove element from the primary fuel oil filter and again run flow test as in (a). An increased flow of fuel with filter element removed indicates proportionate clogging of the element. In such case the element should be cleaned or replaced depending upon type of filter used. Refer to Page 25 for description and service of cleanable and replaceable element types of filters.

(c) If fuel flow is still insufficient, repeat operation (b) with secondary fuel filter. If check reveals a clogged filter, the element must be replaced as outlined on Page 27.

3. Check for dirt or chips in fuel line, by removing each line in turn and blowing out with dry compressed air.

4. If fuel flow is still insufficient after corrections as per items 1, 2 and 3 above, or if the chips have been drawn through the fuel oil pump, the relief valve in the pump should be removed, valve seat and valve parts thoroughly washed, then reassembled and flow test conducted.

   If clearing pump relief valve does not correct the pump condition, remove and overhaul pump, as directed below.



1. Engine.
3. Hose Fitting.
4. Rubber Hose or Flexible Tube.
5. Three or Four Gallon Container.
6. Watch with Second Hand.
7. Foam on Surface of Fuel in Container.
8. Fuel Return Manifold (Upper).

Fig. 35—Connections for Measuring Quantity of Fuel and Checking Air in Fuel System from Fuel Return Manifold.

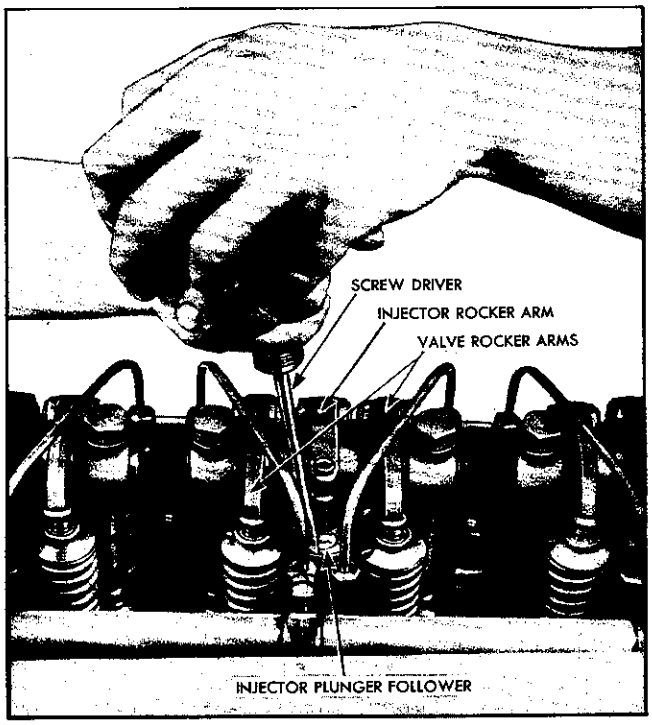


Fig. 36—Cutting Out an Injector While Engine is Running.

5. **Check for Choked Injector Filters**—If engine still runs "ragged" with suitable fuel return, one or more injector filters may be faulty, in which case:

   (a) Run engine at idling speed and cut out each injector in turn to determine faulty cylinder. Injector is cut out by holding follower down with screwdriver while engine is running as illustrated in Fig. 36.

   (b) Stop engine and remove fuel feed line from return manifold to injector.

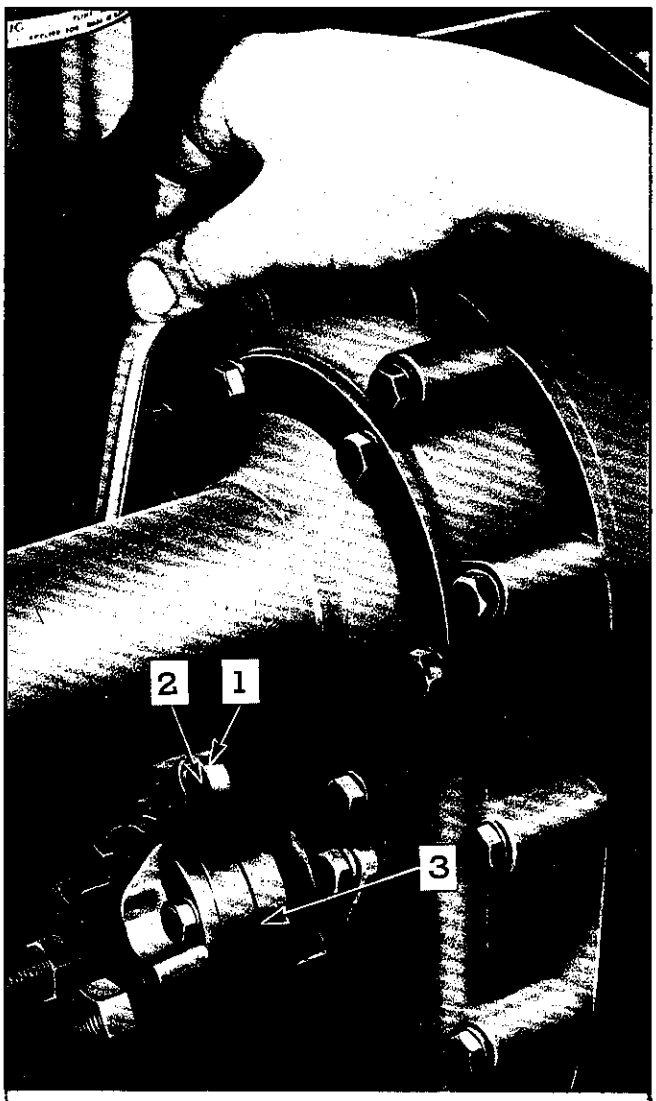
   (c) Hold finger over injector fuel outlet and crank engine with starter. Gush of fuel at injector while starter is turning engine indicates ample fuel supply.

Service—If the fuel oil pump is to be reconditioned the pump assembly must be removed from the blower, as directed below.

Remove Fuel Oil Pump from Blower—In case the pump fails to rotate when blower is running, the cause may be due to a broken drive fork on the end of the fuel pump shaft. This condition may be discovered by removing the pump from the blower as follows:

1. Disconnect both the intake and discharge fuel lines from the pump.

2. Remove the three pump flange-to-blower end cover capscrews. The capscrew next to the



1. Wrench—Tool KMO-326-A.
2. Capscrew—Fuel Pump-to-Cover.
3. Fuel Pump.

Fig. 37—Typical Fuel Pump Mounting and Removal of Capscrews with Tool KMO-326-A.

cylinder block can be removed readily with special wrench KMO-326-A, or, if not available, some similar tool as illustrated in Fig. 37. Withdraw pump straight out from rear blower end plate cover.

3. After the pump has been removed, rotate the shaft by hand to see if parts rotate freely. If the pump is binding or sticking, it should be replaced.

Disassemble Fuel Oil Pump (Pump Removed from Engine)—When disassembling the pump, the rotor shaft must not be pulled from the seals in the pump flange unless the special tool is available for guiding the rotor shaft back into the seals. If tool is not used to guide shaft through the seals, the end of the shaft will destroy the feather edges of the leathers in the seals and the pump will leak excessively. The relief valve assembly may be removed from the pump cover without disassembling the other parts of the pump by backing out the retaining screw and jarring the valve parts from the cover.

When removing this valve assembly, note the relative position of each part so the parts may be reassembled in their correct positions.

If relief valve only is to be inspected, no further disassembly is necessary. If entire pump is to be dismantled proceed as follows:

1. Remove three cover-to-body capscrews and install three bolts ¼—20 x 3″ long, so that heads of capscrews are about ¾″ from pump cover.
2. Holding the pump assembly in the hand, tap on the heads of the capscrews with a soft hammer, driving the flange off the dowels.
3. Withdraw the rotor assembly and separate the pump body from the cover.
4. Drive dowels from the pump cover, using a small punch and hammer, if necessary.
5. Using Tool J-1508-1, as shown in Fig. 38, screw threaded end of tool shaft into inner oil seal of pump flange (seal closest to bolting flange), and tap head on shaft with sliding weight and remove seal. Repeat this operation to remove the outer seal.

Inspection of Fuel Oil Pump Parts—All pump parts should be washed in fuel oil and carefully inspected before assembly. The oil seals, once pulled from the flange, should not be used again. If the

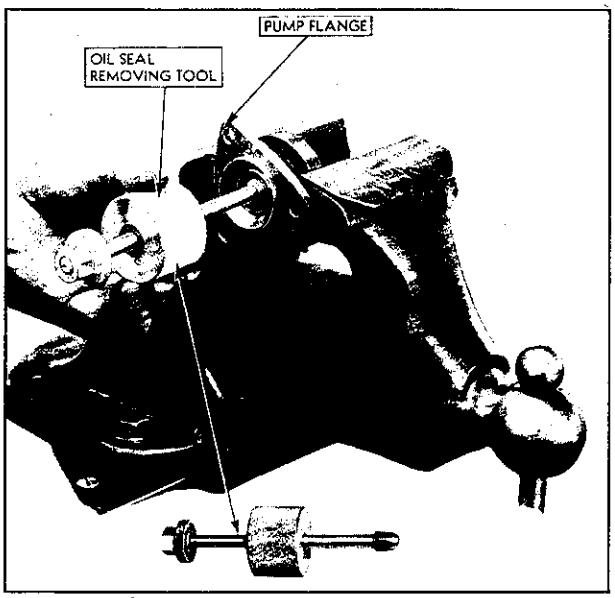


Fig. 38—Removing Oil Seals from Fuel Pump Flange.

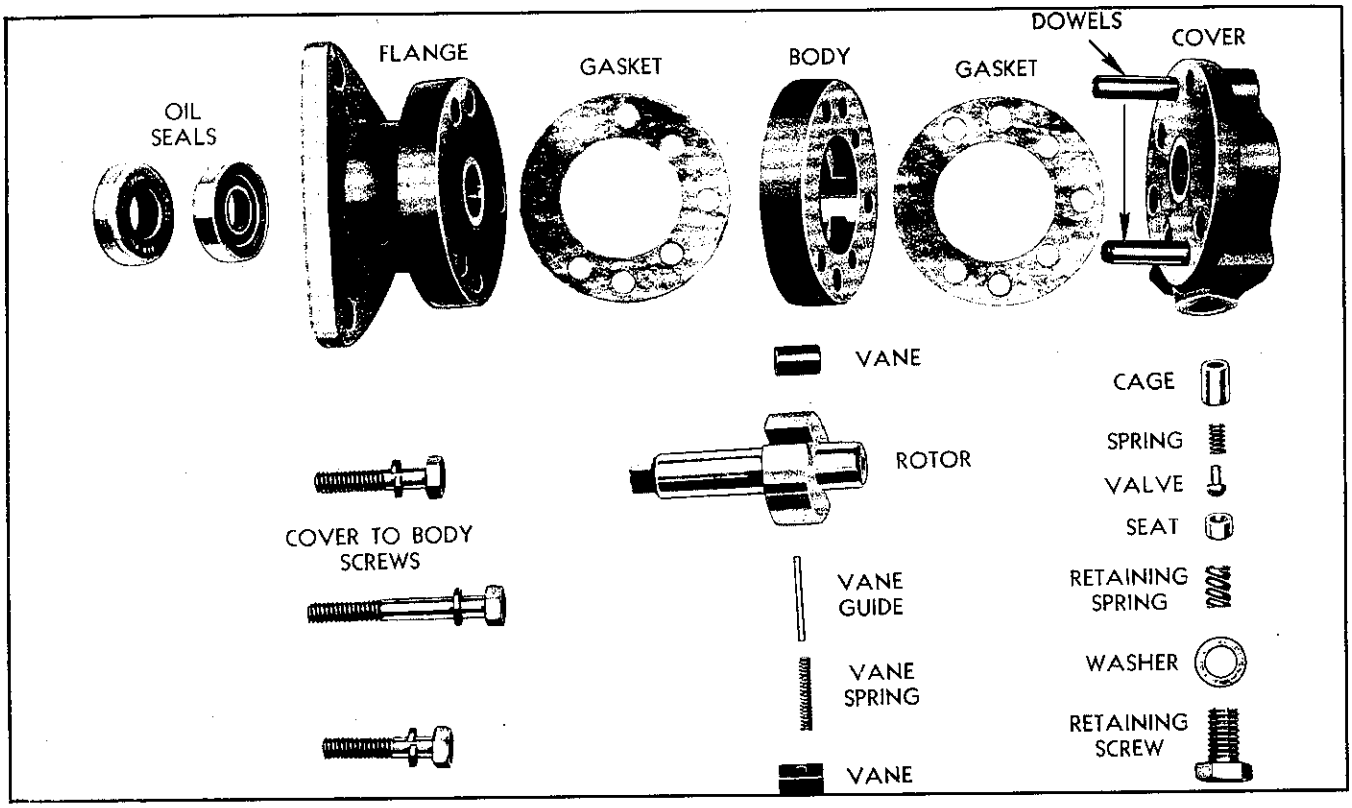


Fig. 39—Fuel Oil Pump Details and Relative Location of Parts.

feather edges of the leather seals are damaged in any way so they do not form a perfect seal around the shaft, either a fuel oil or lubricating oil leak will result. Use new seals if old ones are damaged.

The paper gaskets used on either side of the pump body are of the proper thickness to produce the correct clearance for the rotor and vanes between the pump cover and flange. If these gaskets are not usable, new gaskets of the same thickness must be used.

Although chances of rotor vanes becoming worn are very remote, their wiping surface as well as the inside surface of pump body should be inspected for scores, scratches, or burrs and parts replaced, if necessary, prior to assembly of pump. The clearance of rotor shaft in its bearings is .0015" and any increase by reaming or honing will result in pump not operating and thus complete replacement will be required.

Do not attempt to lap a relief valve or its seat if they fail to form a tight seal; rather, use new parts.

1. Using Tool J-1508-2, install outer oil seal into pump flange, as illustrated in Fig. 40, in the following manner:
   (a) With leather of seal pointing toward pump body, start seal into pump flange.

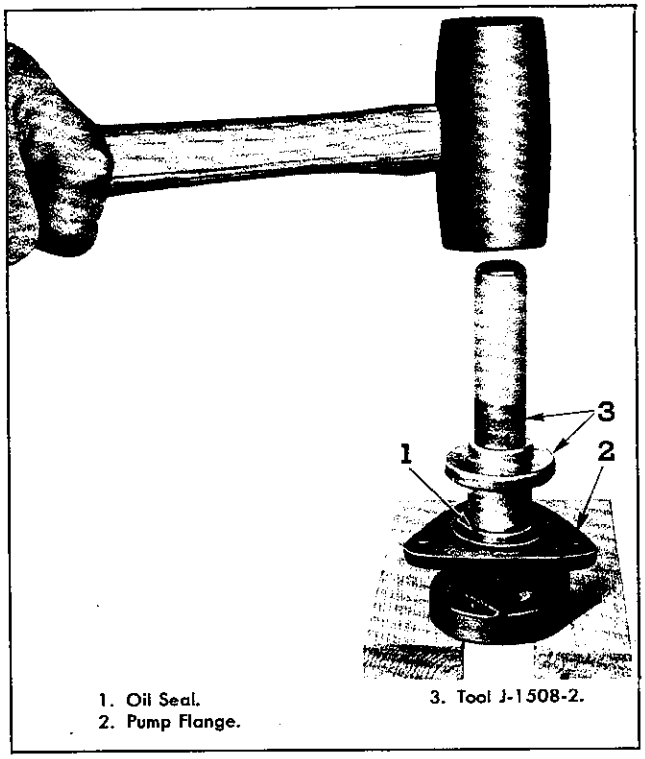


Fig. 40—Installing Outer Oil Seal in Fuel Pump Flange with Tool J-1508-2.

(b) Set driver head onto seal, with long portion of head toward seal; then slide handle through driver head and drive seal into place down tight into counterbore of flange.

(c) Position inner oil seal with leather pointed away from pump body; then reverse driver head on seal and drive seal into position, as shown in Fig. 41. The short end of the driver head will locate this seal the proper distance from the outer seal, which was first driven into the flange.

2. Support holding fixture, Tool J-1934, vertically in bench vise, set pump flange on three pins of fixture and place two guide pins, Tool J-1933, in the dowel pin holes as shown in Fig. 42.

3. Place a paper gasket in position on the face of the pump flange, then place the pump body in position over the guide pins.

4. Assemble the vane guide, vane spring, and vanes in rotor and hold them in place with the fingers.

5. Place oil seal pilot, Tool J-1508-3, over the square end of the pump rotor shaft. Lubricate pilot tool with clean engine oil and, while holding the pump vanes in position in rotor, insert rotor into place in the pump body.

6. Install a new paper gasket, then the pump cover, over the guide pins.

7. Replace the cover-to-body bolts and draw finger tight only. Remove the special guide pins and drive the two dowels, shown in Fig. 43, into place.

8. Tighten the cover-to-body bolts. Turn the pump shaft by hand and test for bind. The rotors should turn smoothly, with a slight drag, but should not bind or have tight spots.

9. Refer to Fig. 34 and replace the relief valve parts, including cage, spring, valve, seat, and retainer spring, being sure that the valve points toward the retainer screw on pumps for RA and LA engines and away from the retainer screw for RC and LC engines.

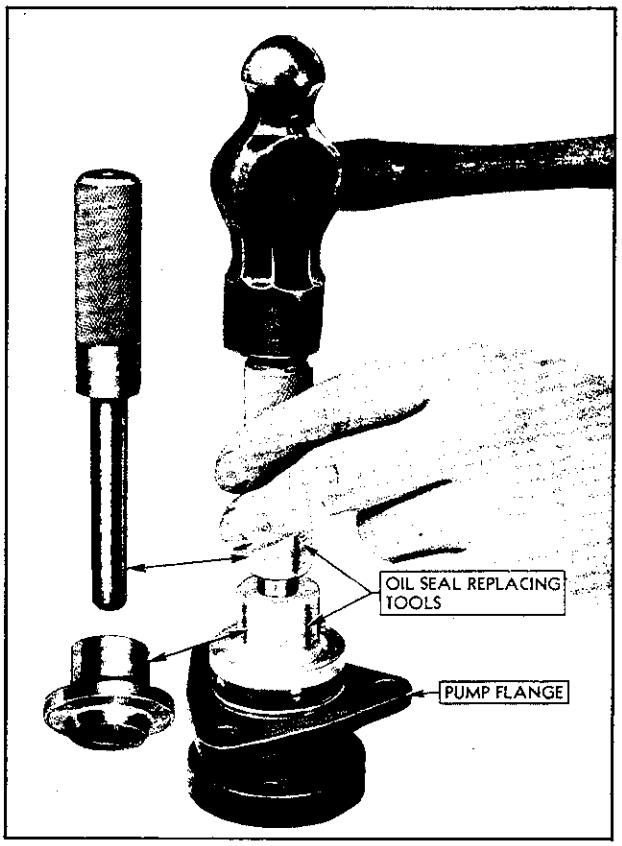
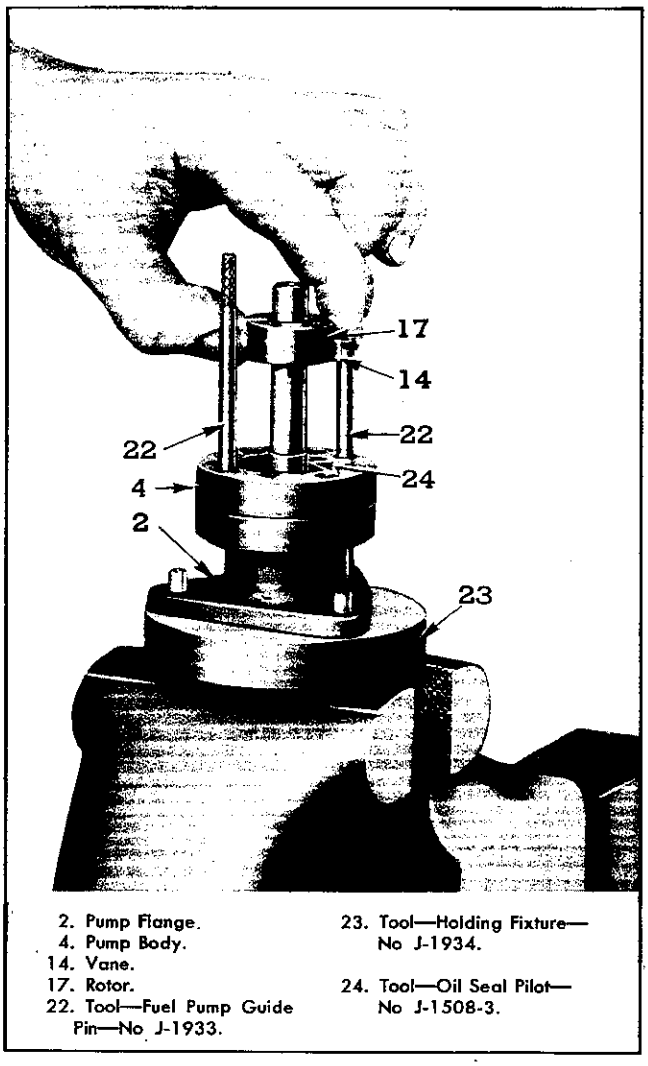


Fig. 41—Installing Inner Oil Seal in Fuel Pump Flange with Tool J-1508-2.



2. Pump Flange.
4. Pump Body.
14. Vane.
17. Rotor.
22. Tool—Fuel Pump Guide Pin—No. J-1933.
23. Tool—Holding Fixture—No. J-1934.
24. Tool—Oil Seal Pilot—No. J-1508-3.

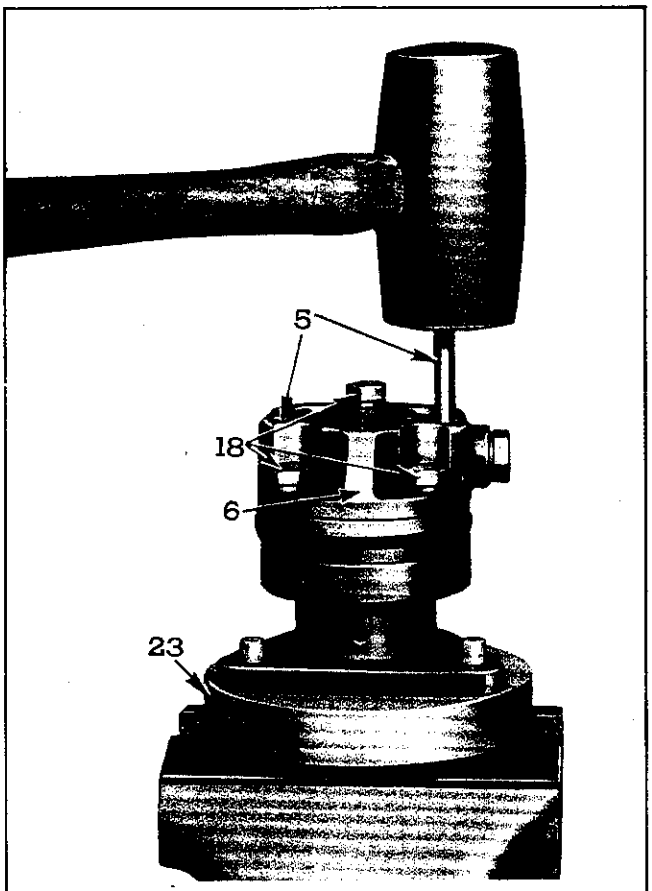
Fig. 42—Installing Rotor Shaft Through Oil Seal in Pump Flange with Tools J-1508-3, J-1933 and J-1934.

10. Place washer over retainer screw and screw into pump body so as to retain relief valve parts.

Attach Fuel Oil Pump to Blower—The fuel oil pump is attached to the engine at the rear of the blower as follows:

NOTE: The RH and LH pumps differ only in the manner of assembling the relief valve in the cover. To convert an LH pump to an RH pump, reverse the relief valve assembly. The fuel inlet and outlet will also be reversed. The opening marked "LH IN" will then be the outlet. In reversing an RH pump, the opening marked "RH IN" will be the outlet.

1. Select the correct pump for either the RA and LA or the RC and LC engines as illustrated in Fig. 34 and with the inlet marked—"LH IN" or "RH IN" on the pump cover—closest to the cylinder block, put the pump drive coupling fork (arms out) on the square outer end of the pump rotor shaft and a new paper gasket on the pump flange.
2. Set the pump assembly up against the blower end plate cover so that the lugs of the coupling fork register with the slots in the coupling disc which is attached to the end of the lower blower rotor shaft. When the lugs of fork are correctly engaged, the pump will slide readily into place tight against the end plate cover.
3. Recheck to ascertain markings on pump cover, as described above, are nearest the cylinder block; then attach pump securely to cover with capscrews.
4. Connect the fuel inlet and outlet lines to the pump.



5. Dowel Pin.
6. Cover—Fuel Pump.
18. Bolts.
23. Tool—Holding Fixture—No. J-1934.

Fig. 43—Replacing Pump Body and Cover in Fuel Pump While Holding Pump in Fixture—Tool J-1934.

FUEL OIL FILTERS

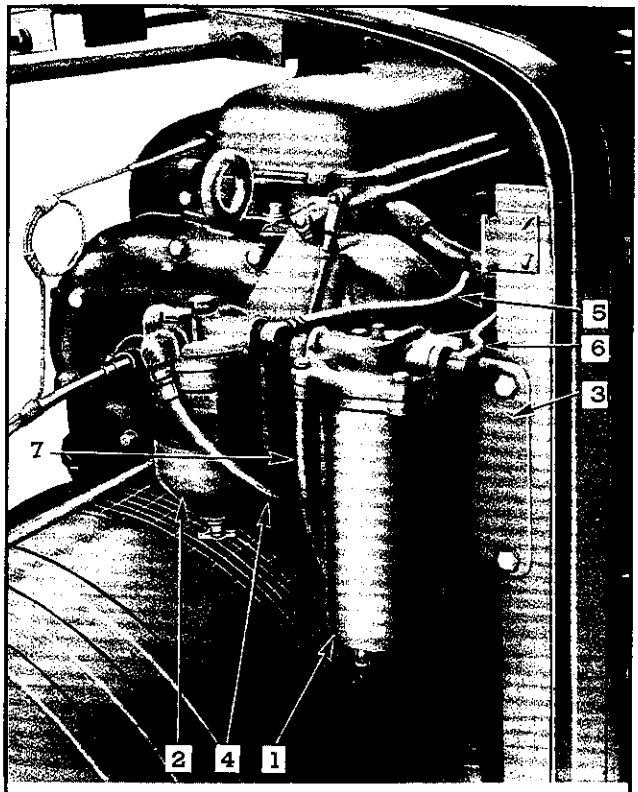
Description—Injector parts are protected against harmful solid material which may be in the fuel by two small filters within the injector body. These filters are not intended for separation of foreign matter from the engine fuel, but as an extra precaution against injury to injectors. It is therefore necessary to use additional filters in the fuel supply lines to the engine fuel inlet manifold.

To meet this condition, either a cleanable-element or a replaceable-element type primary filter is used between the supply tank and fuel pump while a secondary replaceable-element type filter is used between the fuel pump and engine inlet manifold as shown in typical installation, Fig. 44. Since the primary filter is between the tank and the pump, it is working under suction; whereas, the secondary filter, being placed between the pump and the fuel manifold, is under pressure.

PRIMARY FUEL OIL FILTER

NOTE: The primary filter described and illustrated herein is of the replaceable-element type; however, a cleanable-element type filter is used in some instances and serves the same function in the fuel system as the replaceable-element type.

Description—As seen in Fig. 45, the replaceable-element primary filter consists of a cast iron head (1) serving to direct the flow of fuel and support the entire assembly; a replaceable fabric element (4); a bowl (6), acting as a container for fuel and the element; and a seal (5) insuring a tight connection



1. Primary Filter.
2. Secondary Filter.
3. Mounting Bracket.
4. Fuel Line—Pump-to-Secondary Filter.
5. Fuel Line—Secondary Filter-to-Inlet Manifold.
6. Fuel Line—Supply Tank-to-Primary Filter.
7. Fuel Line—Primary Filter-to-Pump.

Fig. 44—Typical Mounting of Primary and Secondary Fuel Oil Filters.

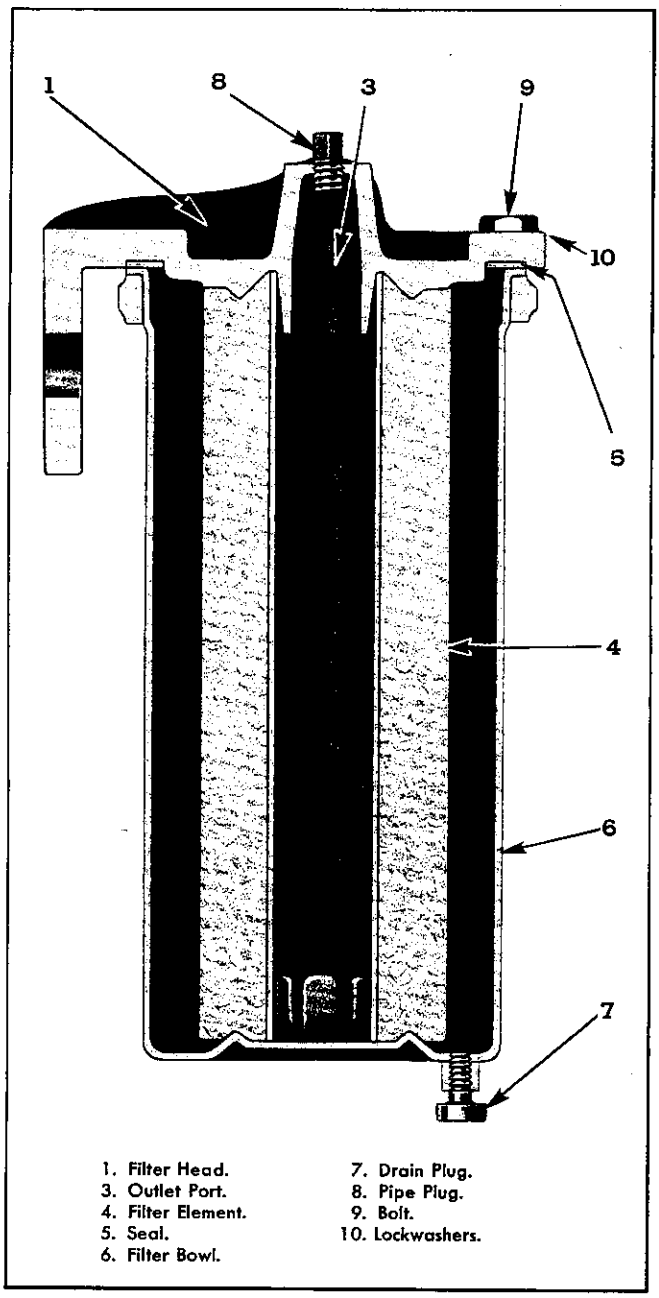
between bowl and head. These parts are held together by four bolts (9) which pass through the head and thread into the bowl. A drain plug (7) is provided at the bottom of the bowl for drawing off any moisture accumulations.

The replaceable-element consists of soft cotton string tightly wound on a wire mesh core. Once this element has become saturated with impurities, it cannot be cleaned, but must be replaced.

Operation—Primary Filter—Vacuum maintained in the filter by the fuel pump, draws fuel from the supply tank through the inlet port to that area of the bowl on the outside of the filter element. The fuel is then drawn, by the pump, through the filter element, where most impurities are removed, up the central passage of the element, through the filter outlet, and to the fuel pump.

Moisture which may have been mixed with the fuel will settle to the bottom of the filter bowl where it can be drawn off by loosening the drain plug.

Service—Primary Fuel Filter—The length of time



1. Filter Head.
3. Outlet Port.
4. Filter Element.
5. Seal.
6. Filter Bowl.
7. Drain Plug.
8. Pipe Plug.
9. Bolt.
10. Lockwashers.

Fig. 45—Primary Fuel Oil Filter Assembly.

that a replaceable-element may be used is governed largely by operating conditions and cleanliness of fuel. A safe rule to follow is to replace the element every 500 hours of engine operation.

Should the engine operation indicate shortage of fuel, which would be apparent by erratic firing or missing on the various cylinders, a fuel pressure check, described on Page 20, is a reliable indicator of fuel filter condition.

In addition to the element renewals mentioned above, about ¼ pint of fuel should be drained from each

filter bowl daily to remove dirt and water accumulations. A drain cock is provided in the bottom of the filter bowl for this purpose.

Replace Element—Primary Fuel Filter—When it becomes necessary to renew the element in the primary filter, the procedure should be as follows: (See Figs. 45 and 46.)

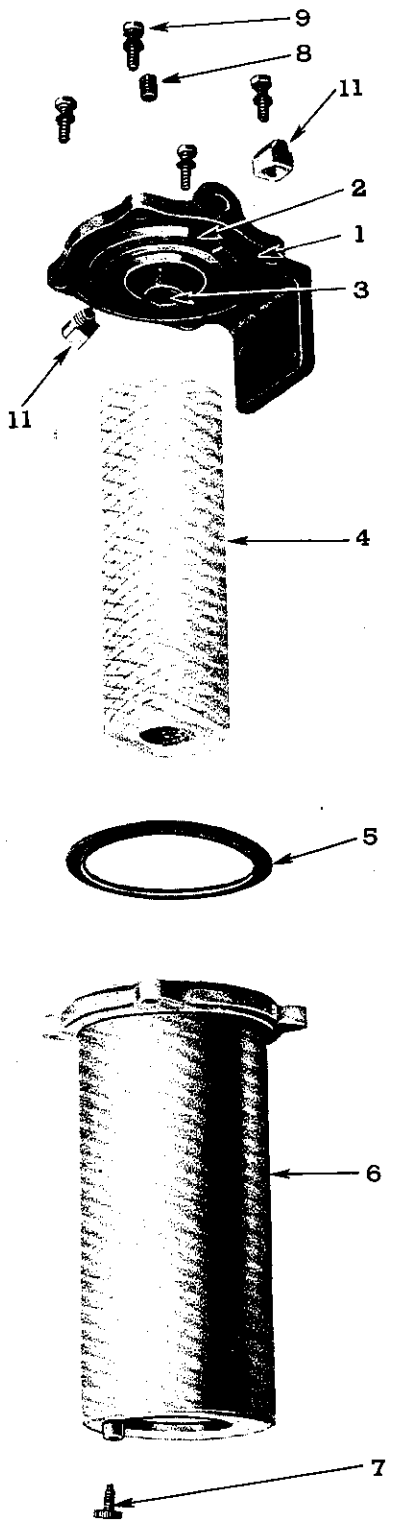
1. With engine stopped, open drain at bottom of filter bowl and with a suitable container catch drainings until tank is about half empty. Close drain.
2. Remove four bolts (9) holding bowl (6) to filter head (1). Lift bowl away from engine.
3. Remove old element (4) and wash bowl thoroughly in clean fuel oil. After setting new element into place, fill the area between element and bowl with clean fuel oil until bowl is about ⅔ full.
4. Using new seal (5), if necessary, set bowl into place under head and secure with the four bolts (9).
5. Remove small pipe plug (8) in top surface of filter head, and with a small funnel, fill remaining space in filter bowl with clean fuel oil. After running engine for a few minutes, inspect filter for leaks.

SECONDARY FUEL OIL FILTER

Description—The secondary filter assembly shown in Fig. 47 consists of a combination head and mounting bracket (1), a replaceable filter element (3), a steel bowl or element housing (2), a spring (5), and suitable seals, plugs, and connections.

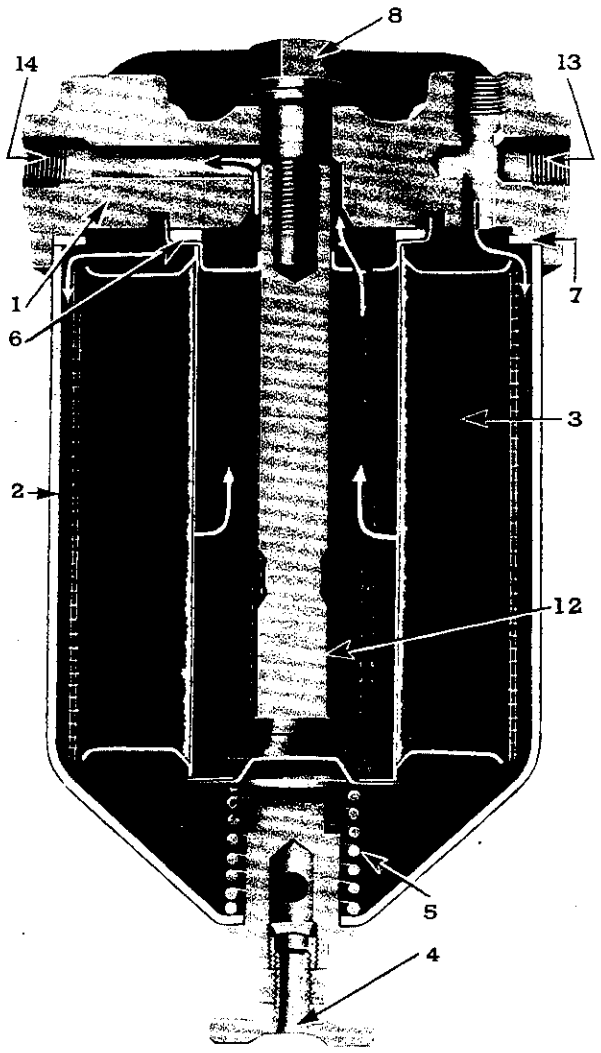
The filter element is placed inside the filter bowl over a steel center stud. A coil spring, placed over the center stud and between the bottom of the bowl and the element, holds the element securely in place against the head of the filter. A gasket built into the replaceable element on the bottom side seals the connection between element and center shaft, while another gasket, placed in a recess at the top of the element, seals the connection between the element and the filter head. The filter head contains passages for incoming and outgoing fuel, these passages being marked on the outside of the casting. The filter element is composed of a shell of filtering material mounted around a perforated metal cylinder. Suitable metal end retainers are attached to the cylinder to complete the replaceable element.

Operation—Unfiltered fuel enters through the inlet passage (13) in the head and flows into the filter bowl. Pressure created by the fuel pump forces fuel



1. Filter Head.
2. Inlet Port.
3. Outlet Port.
4. Filter Element.
5. Seal.
6. Filter Bowl.
7. Drain Plug.
8. Pipe Plug.
9. Bolts.
11. Connectors—Fuel Line.

Fig. 46—Primary Fuel Filter Details and Relative Location of Parts.



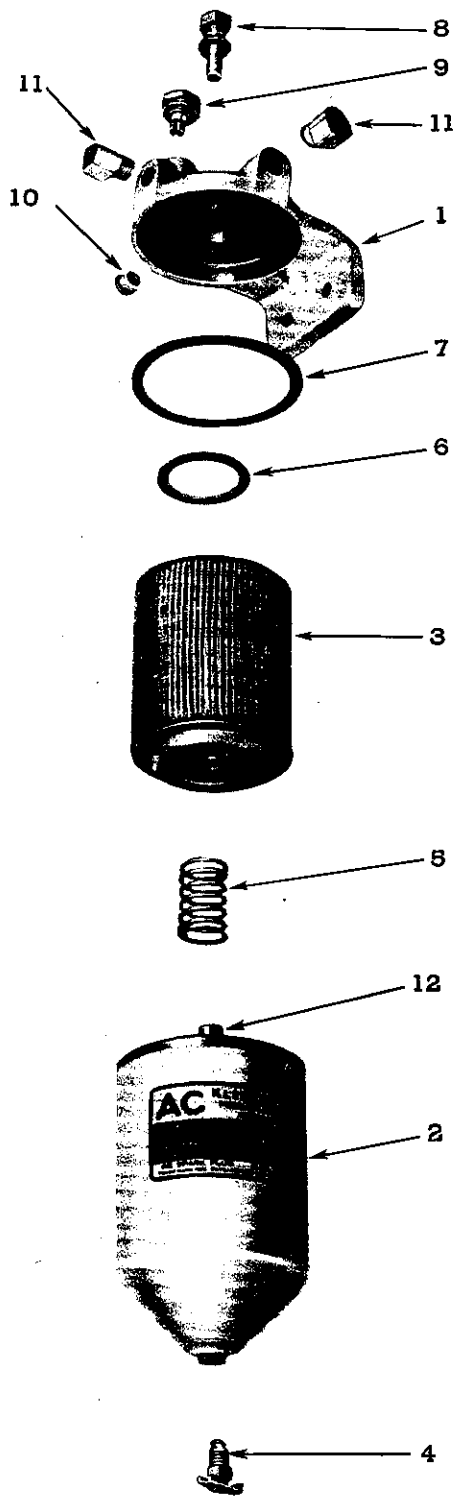
1. Filter Head.
2. Bowl Assembly.
3. Replaceable Element.
4. Drain Cock.
5. Spring.
6. Seal—Element-to-Head.
7. Seal—Bowl-to-Head.
8. Retaining Bolt.
12. Center Stud.
13. Inlet Passage.
14. Outlet Passage.

Fig. 47—Secondary Fuel Oil Filter Assembly.

through the filtering material where dirt particles are removed.

The clean fuel is then forced up through the central portion of the filtering element and into the outlet passage (14) of the filter head and then on to the inlet manifold of the engine.

Service—Secondary Fuel Filter—The length of time that this fuel oil filter may be used, before replacing the element, should be governed largely by operating conditions and cleanliness of fuel. A safe rule to follow is to replace the element every 500 hours of engine operation. Should the engine operation indicate shortage of fuel, which would be indicated by erratic firing or missing on the various cylinders, a fuel pressure check, described on Page



1. Filter Head.
2. Bowl Assembly.
3. Replaceable Element.
4. Drain Cock.
5. Spring.
6. Seal—Element-to-Head.
7. Seal—Bowl-to-Head.
8. Retaining Bolt.
9. Plug.
10. Plug.
11. Connections—Fuel Line.
12. Center Stud.

Fig. 48—Secondary Fuel Filter Details and Relative Location of Parts.

20, is a reliable indicator of fuel filter condition. In addition to the element renewals mentioned above, about ¼ pint of fuel should be drained from each filter bowl daily to remove dirt and water accumulations. A drain cock is provided at the bottom of the filter bowl for this purpose.

Replace Element—Secondary Fuel Filter—When it becomes necessary to renew the element in the secondary filter, refer to Fig. 47 showing relative location of filter parts and proceed as follows:

1. With engine stopped, open drain cock (4) at bottom of filter bowl and with a suitable container, catch drainings until tank is about ½ empty. Close the drain cock.
2. Remove the retaining bolt (8) holding bowl to filter head. Lift bowl (2) away from engine.
3. Remove and discard old element (3) and wash bowl thoroughly in clean fuel oil. After setting new element into place over the coil spring (5), fill the area between element and bowl with clean fuel oil until bowl is about two-thirds full.
4. Using new seals (6) and (7) between element and filter head and also between bowl and filter head respectively, set the bowl into place and draw up tight with the retaining bolt (8).
5. Remove the plug (9) on the top surface of the filter head, located just in front of the retaining bolt, and using a small funnel, fill the remaining space in filter bowl with clean fuel oil. After running engine for a few minutes, inspect the filter for leaks.

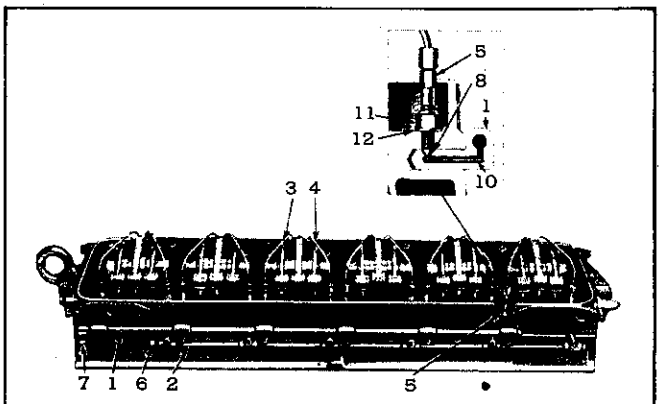
FUEL OIL MANIFOLDS

Description—Fuel injectors are supplied with fuel oil by the pump through the lower of two fuel manifolds located on the side of the cylinder head and connected to the injectors by short steel lines, as shown in Fig. 49. The upper manifold returns the excess fuel from the injectors through tubing to the fuel tank. Both manifolds are locked in position at the side of the cylinder head by fuel connectors which set into tapered seats in the manifold fittings.

Service—Since the manifolds are positioned and locked with the tapered-seat fuel connectors, care must be exercised when a connector is removed, to see that tapered seats are perfectly clean and properly positioned in the manifold fittings.

Remove Fuel Oil Manifold—When occasion requires, either fuel oil manifold may be removed. However, before removing, one should refer to Figs. 49 and 50 for assembly and relative location of parts; then proceed as follows:

1. Remove valve rocker cover.
2. Disconnect fuel oil pipes (3) and (4) from injectors to fuel connectors (5).
3. Disconnect fuel lines from manifolds at (6) and (7).
4. Unscrew lock nuts (11) on connectors, a few turns.
5. Remove connectors from head and discard copper washer (12).

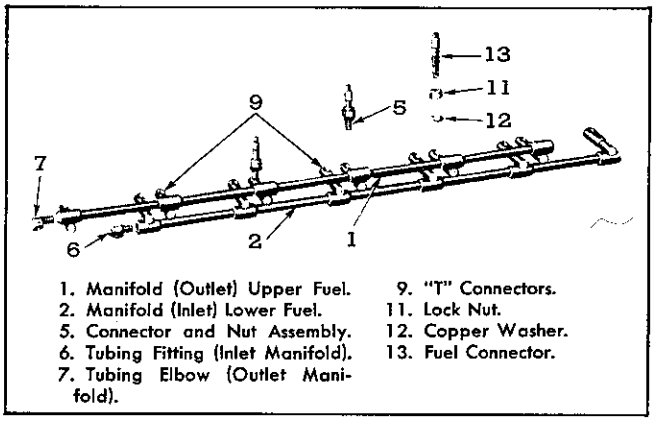


1. Manifold (Outlet) Upper Fuel.
2. Manifold (Inlet) Lower Fuel.
3. Fuel Pipe (Outlet from Injector).
4. Fuel Pipe (Inlet to Injector).
5. Fuel Connector.
6. Tubing Fitting (Inlet Manifold).
7. Tubing Elbow (Outlet Manifold).
8. Taper Seat.
10. Fuel Passage.
11. Lock Nut.
12. Copper Washer.

Fig. 49—Fuel Oil Manifold Assembly

6. Remove manifold, being careful not to bind tee connectors (9) in head.

Replace Fuel Oil Manifolds—The fuel oil manifolds are replaced by reversing the sequence of operations for removal. Refer to Fig. 50, and note that the "T" connectors (9) on the manifolds (1) and (2) leading into the cylinder head are on the top side of the lower (inlet) manifold (2) and on the bottom side of the upper (return) manifold (1). These



1. Manifold (Outlet) Upper Fuel.
2. Manifold (Inlet) Lower Fuel.
5. Connector and Nut Assembly.
6. Tubing Fitting (Inlet Manifold).
7. Tubing Elbow (Outlet Manifold).
9. "T" Connectors.
11. Lock Nut.
12. Copper Washer.
13. Fuel Connector.

Fig. 50—Fuel Oil Manifold and Connected Part Details and Relative Location of the Various Parts.

manifolds are not interchangeable, due to location of tapered hole. To install:

1. Clean holes in cylinder head for fuel connectors and manifold fittings.
2. Guide manifold "T" connectors (9) attached to fuel manifold (1), into openings at side of cylinder head so that tapered seat is in approximate alignment with the hole in the top of the head for the fuel connector (13).
3. Centralize "T" connectors (9) with fuel connectors (13) by alternately turning connectors and moving manifold. ***This is an important operation and is necessary to insure leak-proof joints.***
4. Tighten fuel connectors equally and secure lock nuts (11) against new copper washer (12). Special lock nuts contain a fibre insert which seals the threads against leakage.
5. Attach fuel oil lines (3) and (4) at fuel connectors (13) and injectors.
6. Connect fuel lines to manifolds at (6) and (7).
7. BEFORE REPLACING VALVE COVER, RUN ENGINE AND SEE THAT ALL FUEL LINE CONNECTIONS ARE TIGHT, SO THAT NO FUEL OIL LEAKS INTO CYLINDER HEAD TO DILUTE THE LUBRICATING OIL. IF LUBRICATING OIL IS DILUTED WITH FUEL OIL, ENGINE BEARINGS WILL BE SERIOUSLY DAMAGED.
8. Replace valve rocker cover.

NOTE: Any leakage between fuel connectors and tapered seats of manifold would be observed at holes on outside of cylinder head.

FUEL OIL REQUIREMENTS FOR GENERAL MOTORS SERIES 71 TWO-CYCLE DIESEL ENGINES

General Requirements—High-speed Diesel engine fuels should be procured from a reliable source. Quality and suitability of the fuel are responsibilities of the supplier, who should first be consulted if fuel difficulties are experienced.

For satisfactory operation of high-speed Diesel engines over long periods of time, clean, completely distilled petroleum fuel oils must be used.

Specifications—As a guide for the purchase of suitable fuels, the following specification data are recommended:

	Summer	Winter	ASTM Test Method Number
Flash Point	See Note 1		D-93
Initial Boiling Point, min.	325°F		D-158
90% Boiling Point, max.	625°F	550°F	D-158
Final Boiling Point, max.	675°F	590°F	D-158
Distillation Recovery, min.	97%		D-158
Carbon Residue, max.	0.15% (Note 2)		D-189
Ash, max.	0.01%		D-482
Viscosity at 100°F, Centistokes	1.5— 4.5	1.5— 3.0	D-445
Saybolt Seconds	31.0—40.7	31.0—36.0	D-446
Cloud Point	See Note 3		D-97
Total Sulfur Content, max.	0.50%	0.25%	D-129
Corrosive Sulfur Content	See Note 4		D-130
Water and Sediment, max.	0.05%		D-96
Cetane No., min.	See Page 31		D-613

NOTES:

1. The Flash Point of a fuel oil has no influence on its performance in an engine but may have to be specified by the purchaser for storage or legal reasons.

2. Carbon Residue to be determined on final 10% distillation residuum.

3. The fluidity of a fuel oil at low temperatures is indicated by its "Cloud Point." To insure adequate fuel flow in cold weather, the "Cloud Point" must be specified below the lowest expected fuel temperature. If the "Pour Point" is used, it must be specified from 10°F to 15°F below the lowest expected fuel temperature.

4. Test to be conducted for three hours at 212°F. No more than a slight discoloration of the copper strip is permissible.

Fuel Selection—Efficient combustion in high-speed Diesel engines depends primarily upon two fuel properties: **Volatility** and **Ignition Quality.**

The large number of distilled fuel oils available in the range of the above specifications makes it necessary to consider these two properties together.

Volatility—The volatility of fuel oils is numerically represented by their boiling temperature range. Low boiling fuels vaporize in the engine more readily and burn more completely than fuels with a higher boiling range.

Automotive engines operating over a wide range of speeds with frequent load changes are more critical in their fuel volatility requirements than stationary engines running at constant speed and load. Consequently, suitability of a Diesel fuel depends to a large extent on the type of service for which the engine is being used.

The lighter fuels specified above for Winter operation may, therefore, be used to advantage all year around on vehicle engines.

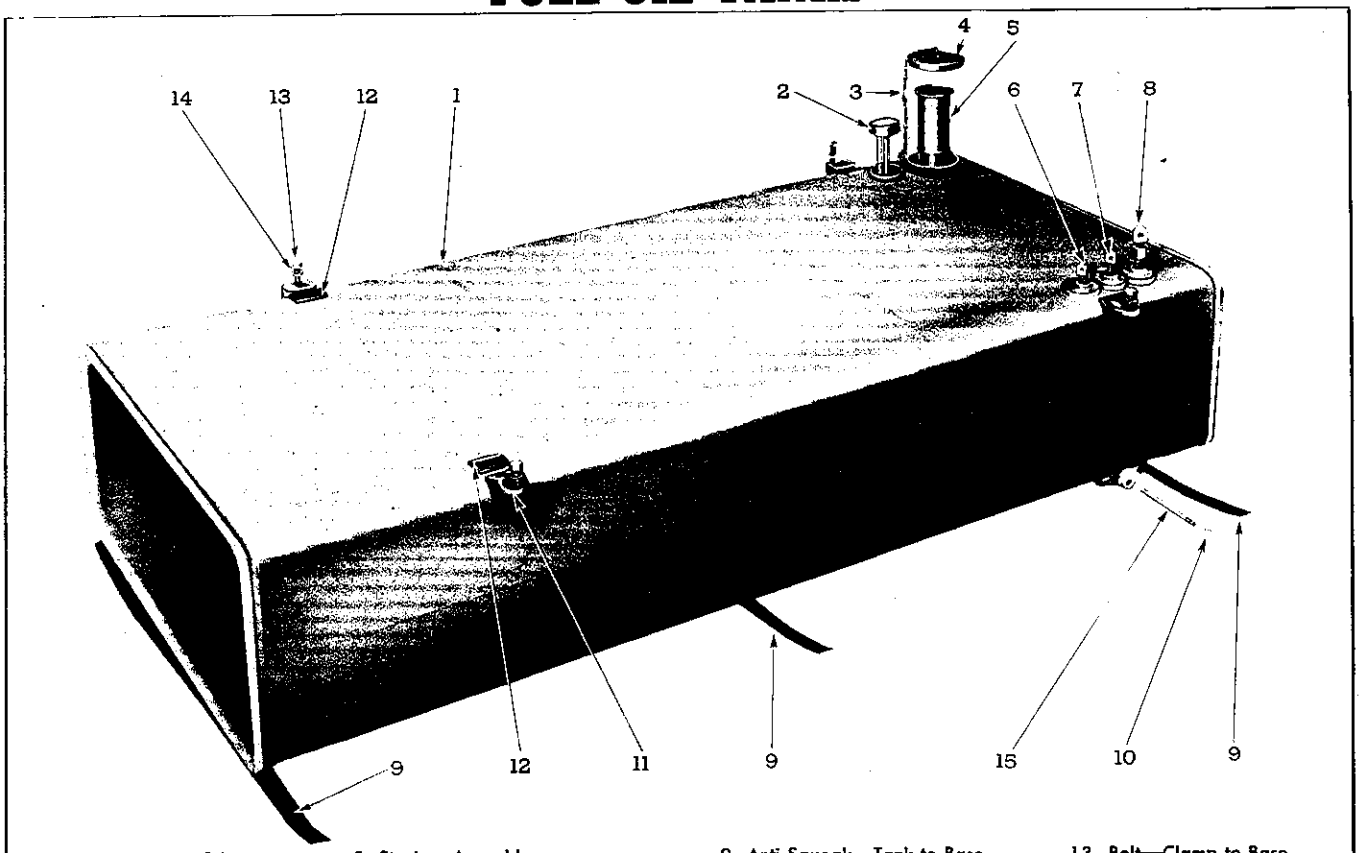
Ignition Quality—The ignitibility of Diesel fuels is expressed in terms of "Cetane Number," high numbers indicating easy starting, short ignition delay, and smooth combustion.

As the cetane number decreases or the final boiling point goes higher, the combustion cleanliness is adversely affected. Exhaust smoke, rapid blackening of the lubricating oil, short oil filter life, and formation of carbon deposits on pistons and piston rings accompany this condition.

The minimum acceptable Cetane number depends, upon the fuel volatility.

Operation in below freezing weather requires Cetane ratings above 50, particularly if no auxiliary starting equipment is being used.

FUEL OIL TANKS



1. Tank—Fuel Oil.
2. Gauge—Fuel Oil.
3. Chain.
4. Cap—Fuel Oil Tank.
5. Strainer Assembly.
6. Fitting—Fuel Return.
7. Fitting—Fuel Supply.
8. Fittings—Air Heater Supply and Drain from Drain Tank.
9. Anti-Squeak—Tank-to-Base.
10. Pipe Cap.
11. Clamp.
12. Anti-Squeak—Clamp-to-Tank.
13. Bolt—Clamp-to-Base.
14. Lock Washer.
15. Pipe Nipple.

Fig. 51—Fuel Oil Tank Details and Relative Location of Parts.

Description—Some portable power sets are equipped with a fuel oil tank mounted in the base with clamps and anti-squeak material.

A filler pipe containing a finely meshed wire screen for straining the fuel oil is located on the top of tank together with a float type gauge and openings for line connections to the engine.

Service—The tanks are pressure tested at the factory before installation and service will not be required unless one is accidentally punctured. In such a case, the tank may be replaced.

The sediment which collects in the bottom of the tank can be eliminated by occasionally opening the drain.