

MAINTENANCE MANUAL



IN-LINE DIESEL ENGINE SERIES 71

**GMC TRUCK & COACH DIVISION
GENERAL MOTORS CORPORATION
PONTIAC, MICHIGAN**

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Introduction

This maintenance manual includes complete maintenance and repair information on the basic current GM Diesel engines used in GM coaches and GMC Trucks.

Information on accessories allied with the diesel engine such as starters, generators, air cleaners, etc., are covered in applicable truck or coach Maintenance Manuals. Operation information from the standpoint of the driver will be found in applicable Truck or Coach Operating Manuals.

The manual is divided into ten general sections as shown on opposite page. The page numbers in the book are consecutive; *however, the illustration numbers are consecutive within each section.*

The index on opposite page shows page numbers of each major item in each general section. The alphabetical index at end of book lists important subjects together with page numbers.

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Replacement Engines

The models 4-71 and 6-71 Diesel engines are supplied as complete automotive replacement units for trucks. Available in four and six cylinder models, with a wide power range to choose from, these engines provide operators and the truck replacement field in general with a complete automotive power plant.

Everyday GMC engineered Diesel replacement power units are making new records of savings in fuel and maintenance costs in many different makes of trucks and tractors.

The GMC Diesel reputation for performance and "up to the minute" improvements is upheld by the experience of our Transportation Engineers who have been modernizing commercial equipment with the GMC Diesel power unit for many years.

When replacing present equipment with GMC Diesel power, you may be sure of these four points:

1. Correct Application for your requirements.
2. Engineered installation.
3. Nation-wide parts and service.
4. Latest Diesel design and engineering.

See your GMC dealer for information on the availability of GM Diesel engines for installation in practically any make of truck.

General Information

THE GM 2-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 compressed, then 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.

THE GM 2-CYCLE 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, on the side of the engine, forces cleaned air into the cylinders to expel the exhaust gases and fill the cylinders with fresh air for combustion, as shown in figure 1.

A series of ports cuts into the circumference of the cylinder wall (liner), above the piston, in its lowest position, admits air from the blower into the cylinder when top face of piston uncovers the ports, as shown in figure 1. The swirling flow of air toward the exhaust valve produces a scavenging effect, leaving the cylinders full of clean air when the piston rises and covers the inlet ports.

As piston continues on upward stroke, exhaust valves close and the charge of fresh air is subjected to the final compression, as shown in figure 1. Air in cylinder is heated to approximately 1000°F. while being compressed.

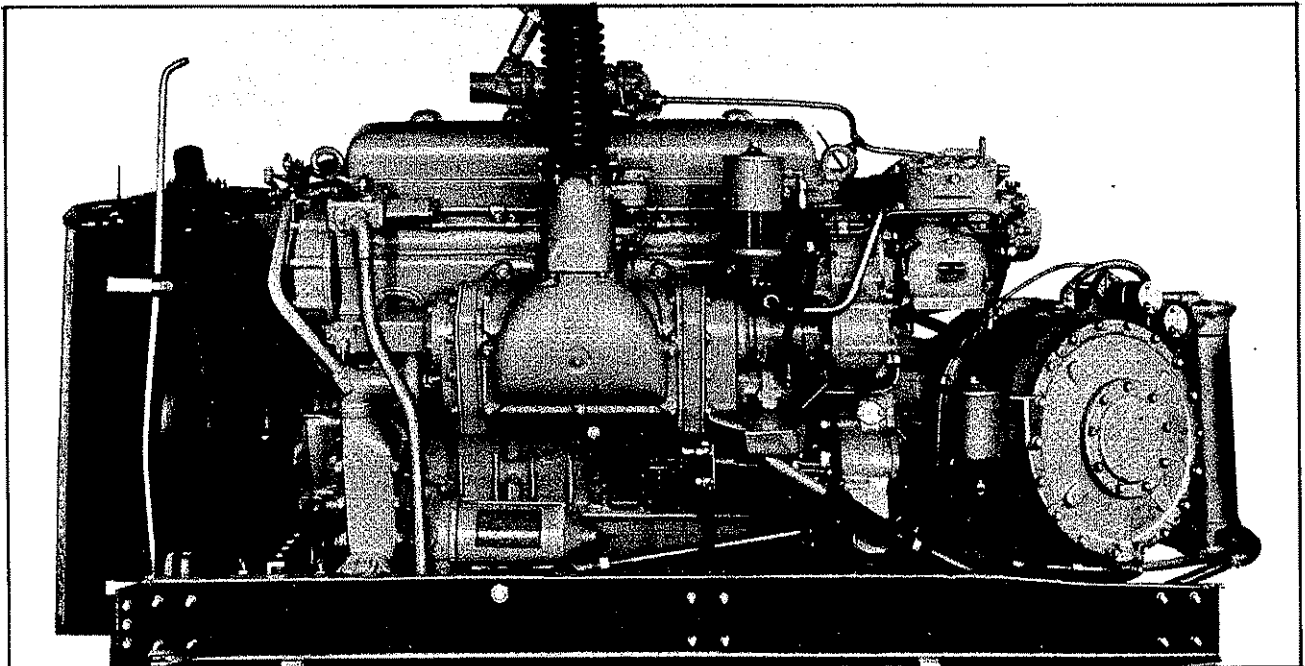


Figure 1—Transit Coach Power Plant

GENERAL INFORMATION

Shortly before the piston reaches its highest position, the required amount of fuel is sprayed into the combustion space by the unit fuel injector. 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 to provide a power stroke. Figure 3 illustrates fuel injection and beginning of power stroke.

As piston nears the bottom of the downward stroke exhaust valves are opened (fig. 1) and spent gases are released. Still further downward movements of piston uncovers liner ports and cycle is repeated.

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."

GM DIESEL ENGINE DATA**GENERAL**

An engine model and serial number are stamped on the blower side of the cylinder block at the upper right hand corner. Refer to figure 4.

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

The two-cycle Diesel engines discussed in this text include the 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,

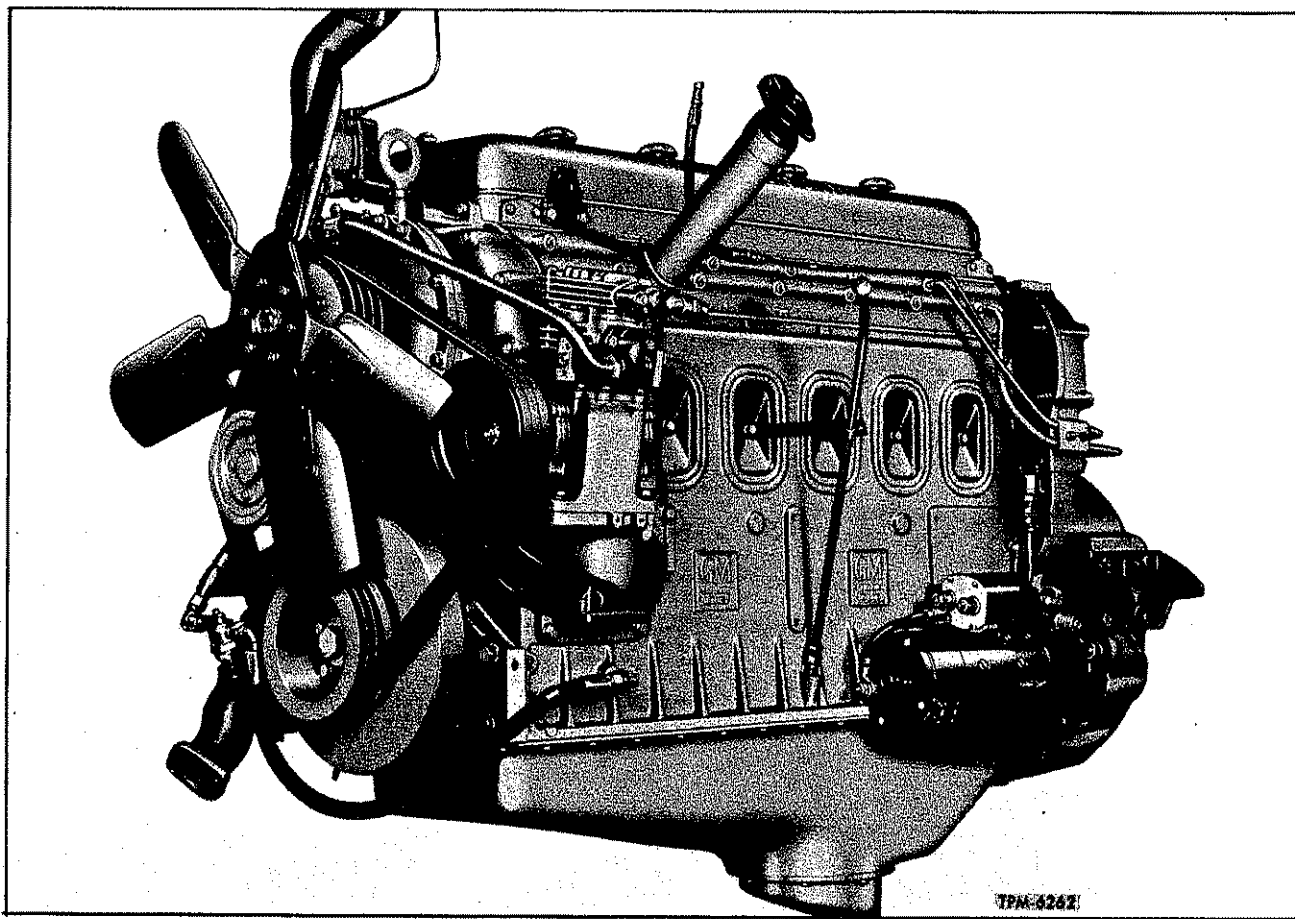


Figure 2—Truck Diesel Engine—4 Cyl. Shown

GENERAL INFORMATION

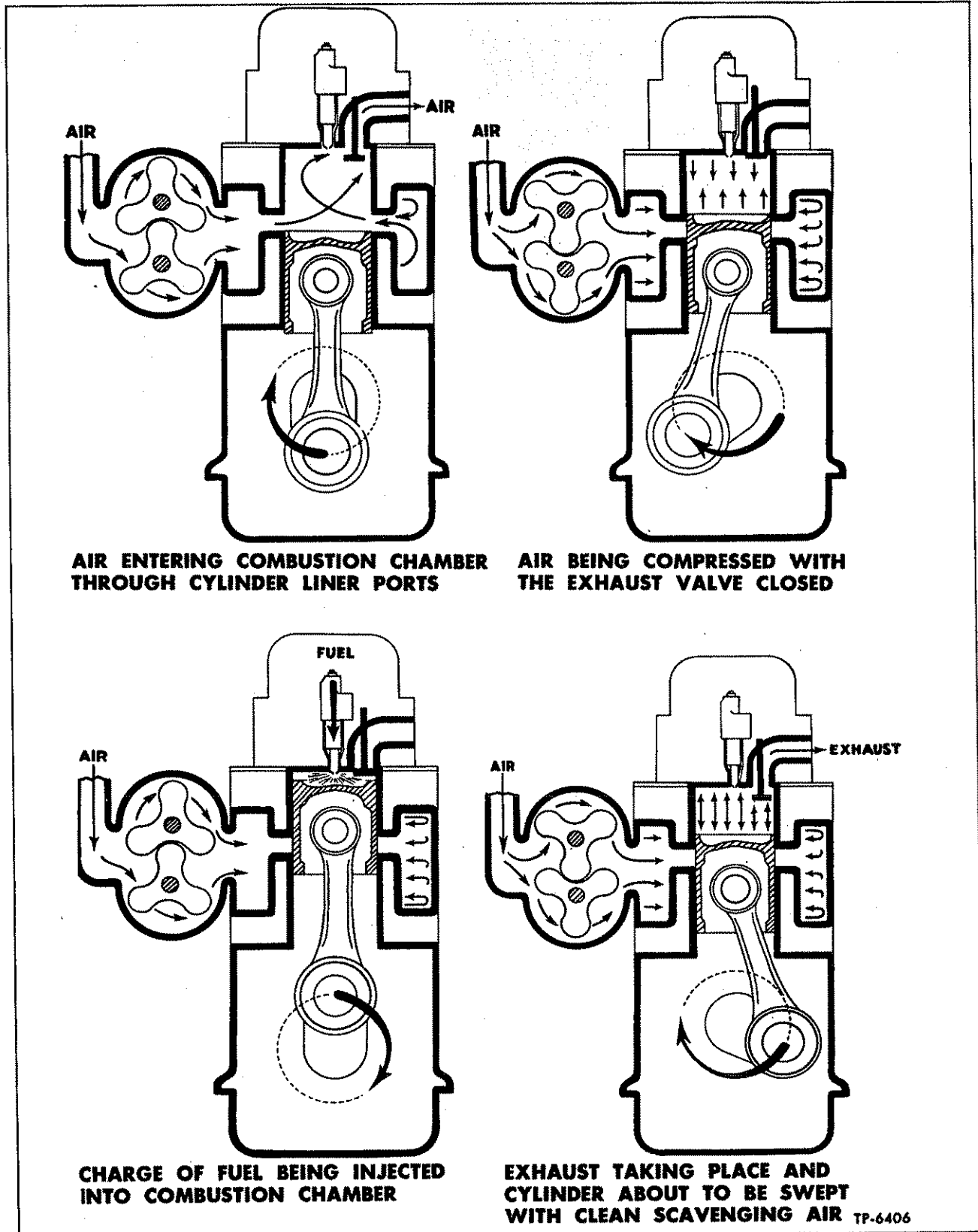
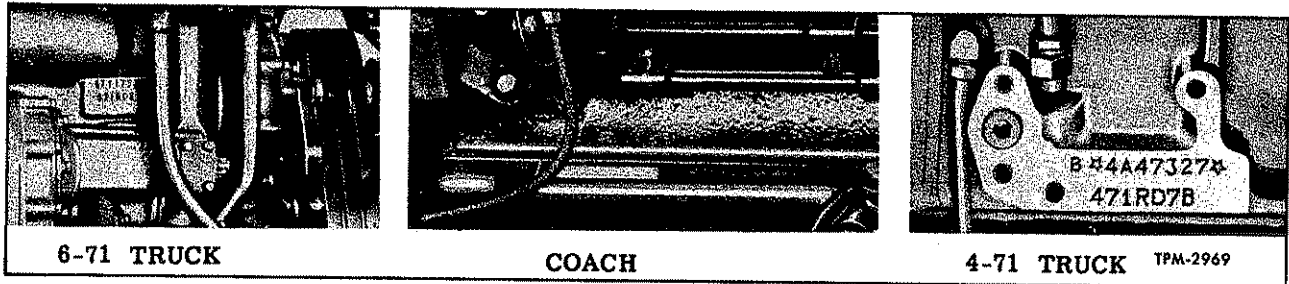


Figure 3—GM Diesel Engine 2-Cycle Operation

GENERAL INFORMATION**Figure 4—Engine Model and Serial Number Locations**

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 direction of rotation. Further flexibility in meeting installation requirements can be had by placing the exhaust manifold and 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.

Figure 4 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 in figure 5 shows the particular arrangement of standard accessories and exhaust and water outlet manifolds designated by letter A, B, C, or D, used as part of the model number.

Right and left side of engine is determined by standing at rear (transmission end) and looking toward front. Transmission end of engine is referred to in manual as rear end, while opposite end is front.

Rotation is determined by standing at front and

CAMSHAFT (THRUST—REAR) WATER EXHAUST BLOWER FLYWHEEL RA MODELS	CAMSHAFT (THRUST—FRONT) WATER EXHAUST BLOWER FLYWHEEL RB MODELS	CAMSHAFT (THRUST—FRONT) WATER EXHAUST BLOWER FLYWHEEL RC MODELS	CAMSHAFT (THRUST—REAR) WATER EXHAUST BLOWER FLYWHEEL RD MODELS															
CAMSHAFT (THRUST—REAR) WATER EXHAUST BLOWER FLYWHEEL LA MODELS	<table><tr><th>ENGINE TYPE</th><th>ON LEFT SIDE</th><th>ON RIGHT SIDE</th></tr><tr><td>A</td><td>All standard accessories</td><td>Exhaust outlet. Water outlet</td></tr><tr><td>B</td><td>All standard accessories Exhaust outlet Water outlet</td><td></td></tr><tr><td>C</td><td>Exhaust outlet Water outlet</td><td>All standard accessories</td></tr><tr><td>D</td><td></td><td>All standard accessories Exhaust outlet Water outlet</td></tr></table>			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
ENGINE TYPE	ON LEFT SIDE	ON RIGHT SIDE																
A	All standard accessories	Exhaust outlet. Water outlet																
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C	Exhaust outlet Water outlet	All standard accessories																
D		All standard accessories Exhaust outlet Water outlet																

TPM-2672

TPM-2672

Figure 5—Rotation and Accessory Arrangement

GENERAL INFORMATION

looking toward rear (transmission end). If crankshaft rotates clockwise engine is right-hand or "R" model, or if rotation is anti-clockwise engine is left-hand or "L" model.

Selection of the proper flywheel housing permits placing the starting motor on either the right or left side of the engine. Other accessories may be driven from either the camshaft or balancer shaft timing gear at the rear end of the engine or from the front end of the crankshaft.

GENERAL SPECIFICATIONS

Engine Model	4-71	6-71
Number of Cylinders	4	6
Bore	4- $\frac{1}{4}$ "	4- $\frac{1}{4}$ "
Stroke	5"	5"
Total Displacement—Cu. In.	283.7	425.6
Taxable H.P. (S.A.E.-A.M.A.)	28.9	43.35
Firing Order		
R.H. Rotation	1-3-4-2	1-5-3-6-2-4
L.H. Rotation	1-2-4-3	1-4-2-6-3-5

MAXIMUM ENGINE RPM

The following information is the approved maximum no-load setting of governor for current engines used in various truck and coach models. Do not permit engine operation with governor settings higher than indicated.

<i>Model</i>	<i>No-Load RPM Gov. Setting</i>
4-71—Truck	2450 + 0 — 25
6-71—Truck	2450 + 0 — 25
6-71—("E" or "SE" Series) Truck	2150 + 0 — 25
Transit Coach (4-71)	2100 + 0 — 25
Transit Coach (6-71)	2100 + 0 — 25
Parlor Coach (PD-4104)	2150 + 0 — 25

USE OF ORIGINAL PARTS

At the present time several types and capacities of units, such as: injectors, pistons, cylinder liners, and blowers are being used. In no instance should operators install any parts other than those originally used in the engine, unless permission is obtained from an authorized source. The use of such parts may result in premature failure of engine parts, and will be considered sufficient cause to void the warranty.

GENERAL INFORMATION

SERVICE BULLETINS

Service Bulletins are issued, whenever required, supplementing information in this Manual. The information contained in these bulletins should be noted in the text and bulletin filed for future reference.

Basic Engine Overhaul

CONTENTS OF THIS SECTION

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This section includes maintenance and repair information on the components and subassemblies of the basic engine assembly under major sub-titles. Reference is made to other sections for information on related units. It is recommended that the informa-

tion in special tools and equipment also specifications sections be studied before using this section, particularly bolt sizes, torque specifications, and fits and tolerances.

CYLINDER BLOCK

Cylinder block and crankcase (fig. 1) which is main structural part of the engine, is a box-like, one-piece casting made of alloy cast iron. The blocks for the four- and six-cylinder engines are identical in design and dimensions, except the necessary length for the additional bores and the correspondingly larger blower mounting flanges. The two ends of block are similar, so that same flywheel housing and gear train can be installed on either end of any one of the models.

Rugged transverse members, cast integral, provide rigidity and strength, and assure perfect alignment of bores and bearings under all loads. Cylinder bores are counterbored and fitted with an insert to support cylinder liners, into which a number of air inlet ports are drilled. Water jackets extend full length of bores and are divided into upper and lower sections, which are connected by hollow struts. Cooling water enters at bottom of water jacket from the water pump and leaves jacket at top through holes which register with corresponding openings in cylinder head. Surrounding the water space is an air chamber which conducts air from blower to all of the inlet ports in cylinder liners (fig. 2).

The upper halves of main bearing seats are cast integral with block. Drilled passages in block carry lubricating oil to all moving parts thereby eliminating tubing.

Hand-hole plates (fig. 3) on the side opposite to

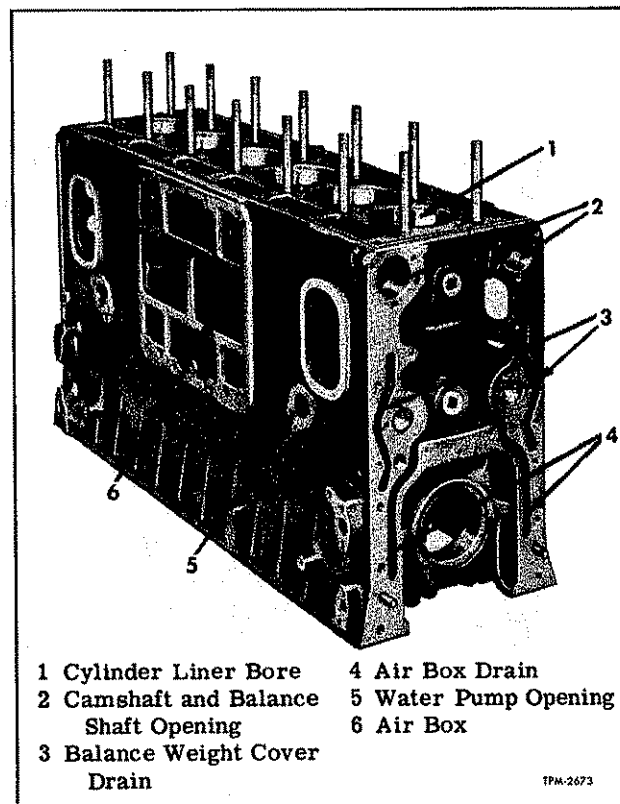


Figure 1—Typical Cylinder Block and Crankcase

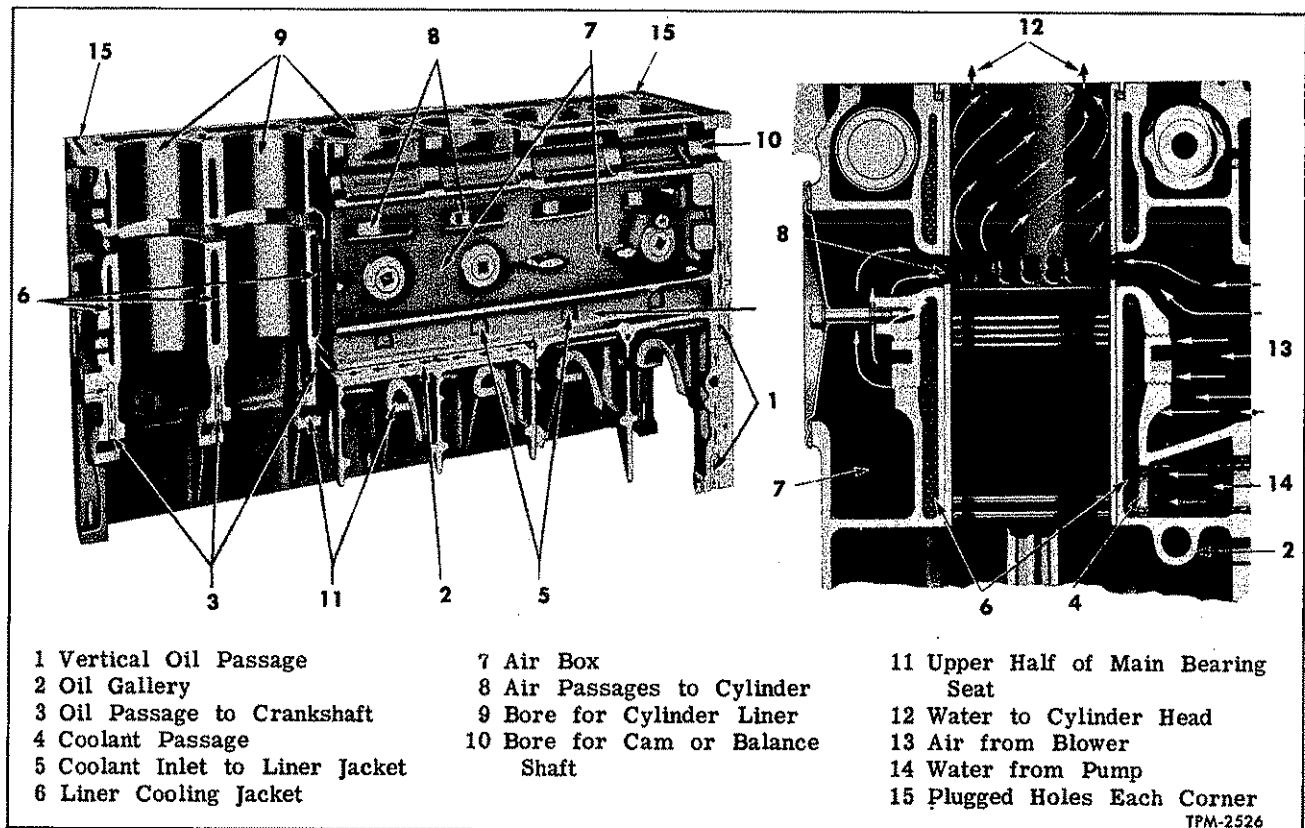
CYLINDER BLOCK


Figure 2—Cylinder Block and Crankcase Sections

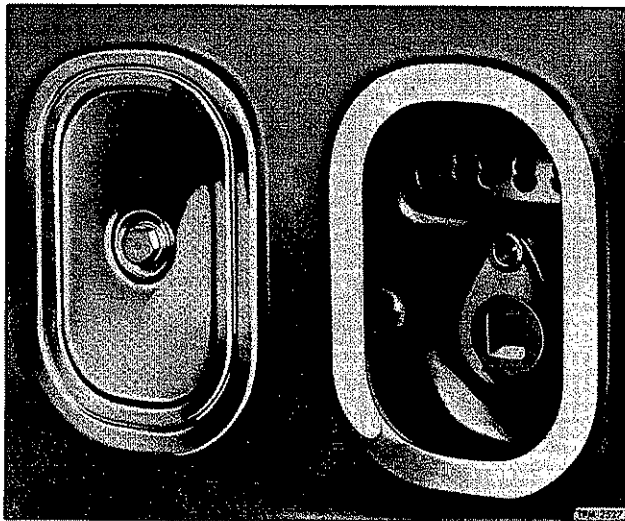


Figure 3—Hand-hole Plates and Air Intake Ports

blower permit access to air chamber, and inspection of liner wall, pistons, and rings through the air intake ports in cylinder walls. The six-cylinder engine also has two hand-hole plates on the blower side.

Camshaft and balancer shafts, located on opposite

sides near the top of the block, are supported by bearings located in machined supports near top of block.

DISASSEMBLY

Procedure for removing each assembly and sub-assembly from the cylinder block together with disassembly, inspection, repair, and reassembly of each, will be found in the various sections of this manual. Reference to the subject and alphabetical indexes will show the location of any desired information on particular accessories or engine parts.

After stripping and before any parts are reassembled to the cylinder block, the block should be cleaned and thoroughly inspected for any conditions that would render the part unfit for further use.

CLEANING

Since the cylinder block is main structural part of engine, whenever engine is being overhauled, block should be thoroughly cleaned and inspected for any conditions that would render the block unfit for further use. Such inspections should take place after

CYLINDER BLOCK

block has been thoroughly cleaned in either live steam or suitable solvent and blown dry with compressed air.

If shop facilities are available, it is recommended that block be completely disassembled; then cleaned of grease and scale in the following manner:

1. Remove grease by agitating the block in a commercial heavy duty alkaline bath as sold by trade chemical suppliers.

2. Wash in hot water or steam clean to remove alkaline.

3. Remove scale by agitating the block in a bath of inhibited commercial pickling acid, as sold by trade chemical suppliers. A 50-50 solution of Oakite 32 and water has been found satisfactory. After block is cleaned of grease and scale it must be rinsed and the cleaner acid neutralized. Carefully follow directions of chemical manufacturer as to cleaning, rinsing, and neutralizing.

4. Wash block in a bath of clean water or steam clean.

5. Make certain that all oil galleries, water passages, and air box drain holes are thoroughly cleaned.

6. After block is inspected, dip in rust preventive, such as Rust Ban No. 392 or equivalent as castings free of grease and oil will rust immediately when exposed to atmosphere.

NOTE: Completely clean all traces of rust preventive from block before reassembling.

INSPECTION

Air box drains should be opened and blown out with dry compressed air after air box has been cleaned. NOTE: When servicing air box drains on an assembled engine, remove or at least loosen an air box hand hole cover, or blower or end plate gaskets may be damaged by excessive air pressure. Refer to "Air Box Drains" in AIR INTAKE SYSTEM section of this manual.

After cleaning inspect all surfaces to be sure that all traces of gaskets and sealing compound are removed.

PRESSURE TEST

1. Block off water inlets and outlets so that they are air tight (fig. 4).

2. Immerse cylinder block for twenty minutes in water heated to 180° to 200°F.

3. Using a suitable fitting at one of the water inlets or outlets, apply 80 to 100 lbs. per sq. inch of air pressure and observe water in tank for air bubbles. Presence of air bubbles in water indicates cracks or leaks in block.

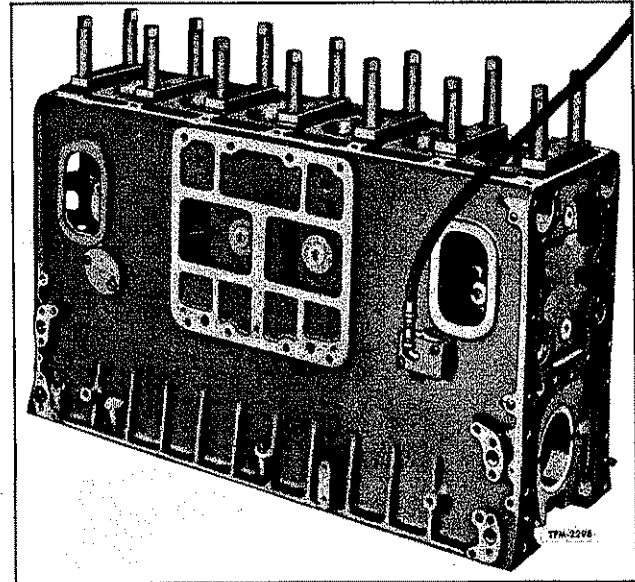


Figure 4—Checking Cylinder Block for Cracks and Leaks

FLATNESS

1. Remove cylinder head studs from cylinder block and smooth down any nicks or raised areas around studs.

2. Check flatness of block using straight edge and feeler in manner illustrated in figure 5. Top of block should not vary more than .003" transversely or longitudinally more than .007" for the 4-71 and .009" for the 6-71 engines.

3. Whenever necessary to machine top of cylinder block do not remove more than .008". The amount removed should be stamped on the face of the block. Counterbores for oil and water seal rings must be

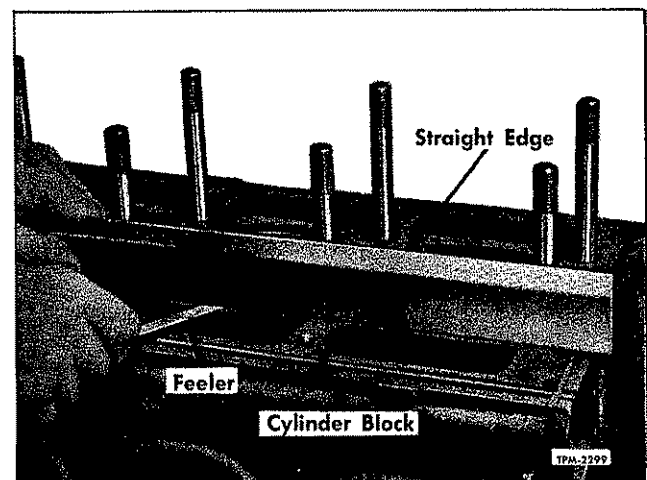


Figure 5—Checking Top of Cylinder Block

CYLINDER BLOCK

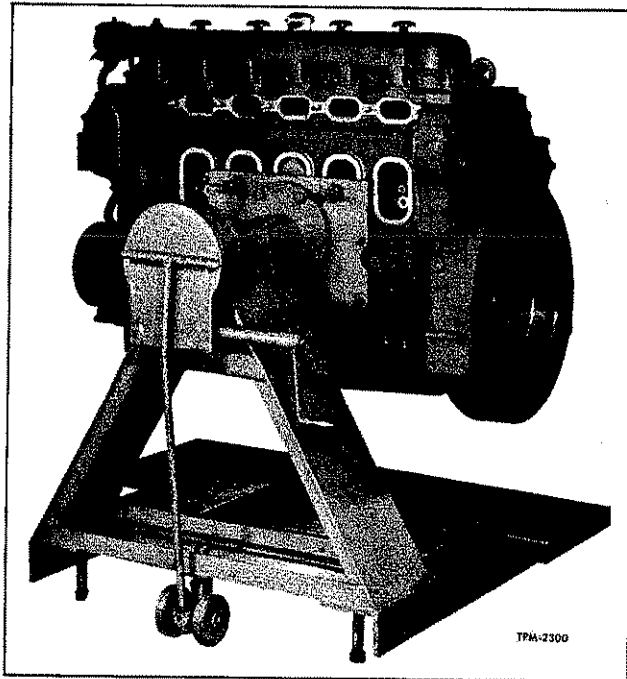


Figure 6—Engine Mounted in Overhaul Stand

machined deeper by the same amount as was removed from top of block. Counterbores for cylinder liners should not be deepened, since .004" and .008" undersize inserts are available.

STUDS

Cylinder block studs should be inspected for damaged or stretched threads, also for straightness and tightness. Studs should extend $4\frac{7}{16}" \pm \frac{3}{32}"$ above the block. Studs should be tightened to 50 ft. lbs. when being installed.

MAIN BEARING BORE ALIGNMENT

1. Install main bearing caps and tighten cap bolts to recommended torque.
2. Check for longitudinal alignment using an aligning bar which has a diameter of .00075" less than bearing bore. Aligning bar must extend through all the bores.
3. If bores are in proper alignment the alignment bar can be turned with a 15" wrench.
4. Main bearing bores that are out of alignment can be line bored. However, not more than 0.001" of stock should be removed from any bore.

COUNTERBORES

Check cylinder liner counterbores for squareness, depth and diameter. Refer to **SPECIFICATIONS** section of this manual for dimension and limits.

Whenever top of cylinder block has been machined, it is not necessary to deepen the liner counterbore as undersize inserts are available.

Check oil and water seal ring counterbores for depth and diameter. Counterbores for oil and water seals must be deepened whenever top of cylinder block is machined to provide flatness within limits.

CYLINDER BLOCK LINER BORE

Refer to **CYLINDER LINERS** section later in this manual for information on inspection, boring, and fitting of cylinder liner in cylinder block.

MOUNT ENGINE ON OVERHAUL STAND

1. Locate center lug of overhaul stand support-plate in proper air-box opening on exhaust manifold side of block. The center lug is located in the number two air-box opening on four cylinder engines, and in the number four air-box opening of six cylinder engines (see fig. 6).

2. Loosen lock nuts on the two holding lugs of overhaul stand and lower engine while entering these lugs into air-box openings opposite adjacent cylinders.

3. Turn holding lugs crossways of air-box openings. Tighten lock nuts, drawing engine tight against overhaul stand support-plate.

4. To insure engine does not shift on or break away from the overhaul stand support-plate, insert a $\frac{7}{16}"$ -14 x 2" bolt through hole in overhaul stand support-plate and into pad on cylinder block, using a plain washer under head of bolt.

CAUTION: Be absolutely positive that engine is securely mounted to stand before releasing lifting sling. Severe injury to personnel and destruction of engine parts will result if engine breaks away from overhaul stand. Check fastenings carefully.

SERVICE CYLINDER BLOCK

NOTE: Cylinder block must have an opening at port area that will fully expose liner ports. Whenever new block is being installed inspect carefully to be sure that all liner ports are fully exposed.

Service cylinder blocks are furnished with cylinder head studs, also main bearing caps, studs and nuts. Included with each service block is a bag containing miscellaneous plugs, studs, dowel pins, and other small parts. Whenever a service block is being built-

CYLINDER BLOCK END PLATES

up, extreme caution should be exercised to be sure that the new block is fitted the same as the old block. In some instances, it may be necessary to remove some of the plugs already installed in block in order that new

block will be the same as old block. Bag attached to block, contains an assortment of parts that would be necessary to build any type of block, therefore all of these parts are not always necessary.

CYLINDER BLOCK END PLATES

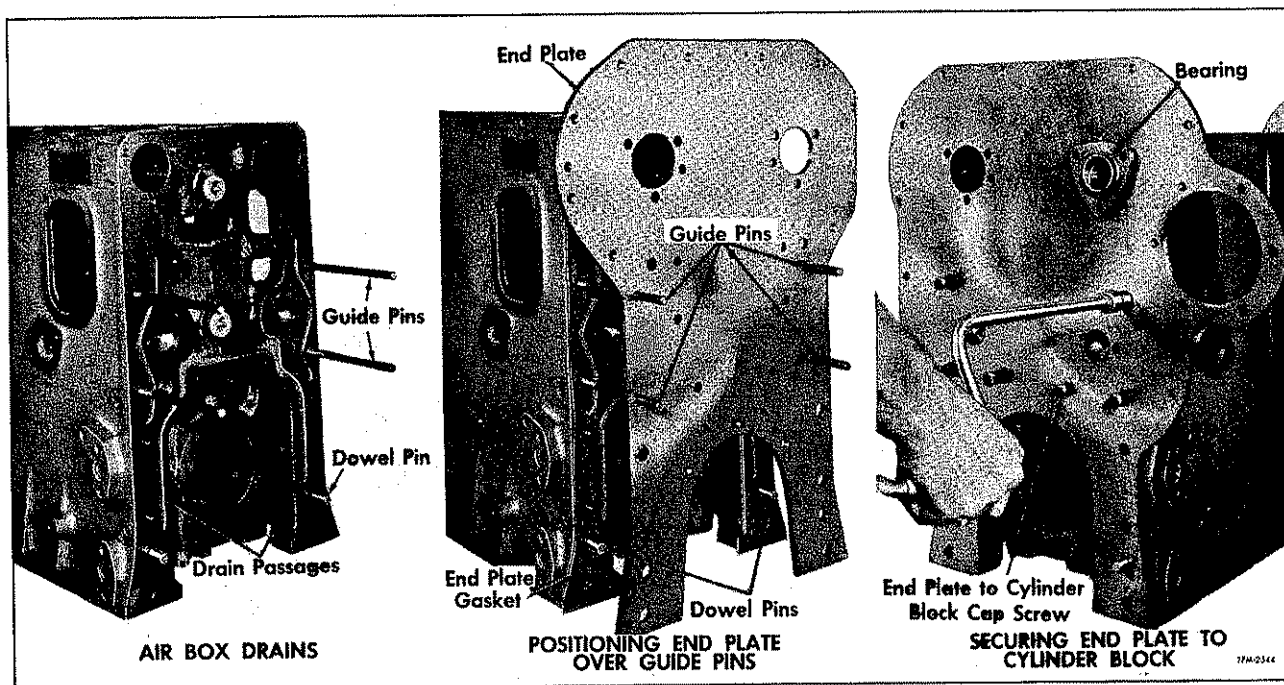


Figure 7—Cylinder Block End Plate Installation

GENERAL

A flat steel end plate, bolted to each end of cylinder block, affords a rigid construction and a means of attaching 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 one used at front. As both ends of cylinder block are alike, the same gasket is used between block and each end plate.

INSPECTION

Cylinder block end plates should require very little service under ordinary conditions. At the time of complete engine overhaul or of cylinder block change, end plates will be removed and reinstalled. When such replacement is necessary, inspect as follows:

1. Remove all of the old gaskets from inner and outer plate surfaces. Clean both surfaces of plates to

remove all dirt, grease or other foreign matter.

2. Plates must be flat and smooth.

3. Remove nicks or damaging marks which would prevent a tight seal between the surfaces of block and plates, also flywheel housing, and plate.

INSTALLATION

The holes in the end plates for cam and balancer shaft bearing cages are not the same size. The smaller hole is accurately machined to 2.1885" diameter while larger hole measures 2 1/4" diameter. When installing end plates, the smaller hole must be accurately aligned with the bearing bore in cylinder block before end plate attaching bolts are tightened. The smaller hole in front end plate should be on same side of cylinder block as the smaller hole in the rear end plate. Installation may be properly accomplished by referring to figure 7 and proceeding as follows:

1. Inspect to be sure that all necessary plugs are properly installed in block and end plate to cylinder

CYLINDER LINERS

block dowels are in place (fig. 7). Four guide studs made locally ($\frac{1}{2}$ "-13 x 6") with screwdriver slot in end, such as shown in figure 7 will be found essential when locating the plates on the cylinder block.

2. Apply a light even coating of non-hardening cement to each side of gasket. Position new gasket at end of cylinder block, being careful that gasket is aligned with mating holes.

3. Carefully position end plate over temporary guide studs and with blower drive gear opening in rear plate on blower side of the block.

4. Temporarily install bearing (fig. 7) through the smaller of the two cam and balancer shaft holes in end plate to align plate with block. Start six attaching bolts into place and draw up only finger tight. **BE SURE REAR PLATE** is installed with blower drive support bore on blower side of block, also that **SMALL CAM OR BALANCE BEARING HOLE** in front and rear plates are both on same side.

5. The six cap screws may now be tightened and bearing removed. Temporary guide studs can be left in place until flywheel housing has been installed.

CYLINDER LINERS

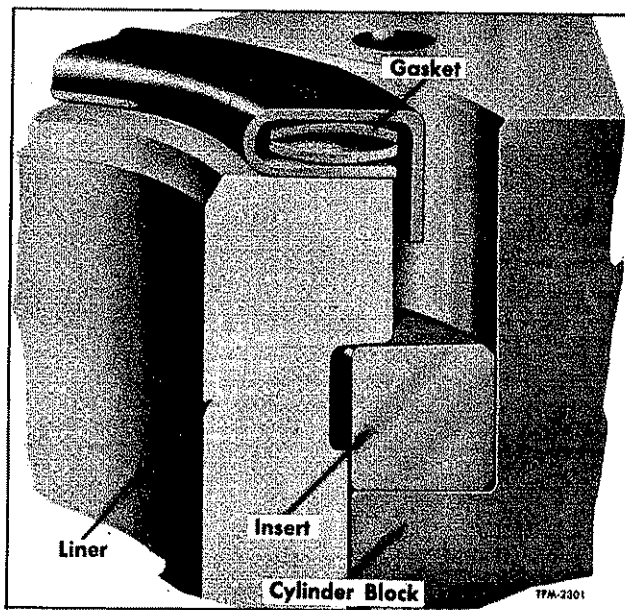


Figure 8—Cylinder Liner, Insert, and Gasket Mounting in Block

GENERAL

Construction of cylinder block, cylinder head, and liner provides that top of cylinder liner flange be below the top of cylinder block and compression seal is accomplished by use of individual gaskets at each cylinder (fig. 8), thus cylinder head rests directly on cylinder block and is called metal-to-metal contact. Water and oil passages between cylinder block and cylinder head are individually sealed with special grommet type rubber gaskets which are installed in cylinder block counterbores.

The replaceable liner, made of hardened alloy cast iron, in each cylinder is accurately honed to a very smooth finish. Even temperature and minimum

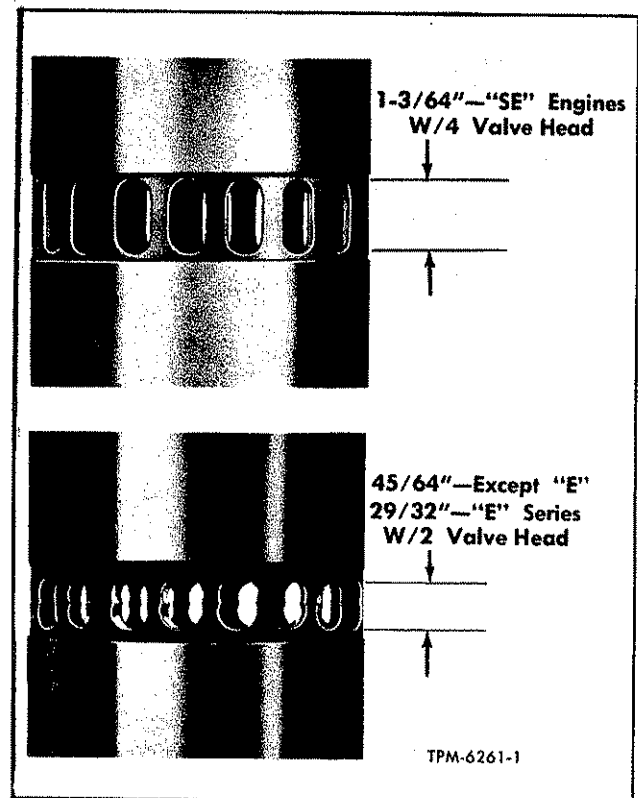


Figure 9—Cylinder Liner

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, twenty ports, with a figure 8 appearance, are drilled into the circumference of each cylinder liner. Refer to figure 9.

NOTE: Cylinder liners with three sizes of ports are used. Liner used in “E” series engines with two valve heads measure .900” (approx. $2\frac{9}{32}$ ”) high, or

CYLINDER LINERS

1 $\frac{3}{64}$ " with four-valve heads, others measure .703" (approx. $\frac{1}{16}$ "). Refer to figure 9.

LINER MAINTENANCE

Cylinder liners will render satisfactory service for extended periods if the engine has proper care. Wear on a cylinder liner and piston is directly related to the amount of abrasive dust and dirt 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 vehicle air cleaners should be serviced regularly as instructed in the maintenance manual covering the specific vehicle.

When the clearance between the piston and cylinder liner becomes excessive the performance of the engine will be unsatisfactory. Replacement or reconditioning of liners and associated parts will be necessary.

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 available only in the standard size inside diameter; however, .005", .010", .020", and .030" oversize outside diameter liners are available for use in cylinder block bores which have been oversized to correct distortion or out-of-roundness.

CLEANING LINER PORTS

Whenever 1000 hour inspection indicates that air ports in liners require cleaning, the operation can be performed as follows:

1. Remove hand hole covers at side of cylinder block, also remove blower assembly.
2. Use suitable tool to remove deposits from liner ports, being careful that liner is not damaged.
3. Use vacuum to lift all carbon deposits from air box, then use compressed air to remove all remaining particles.
4. Inspect air box drains to be sure they are clean.
5. Install blower assembly and hand hole covers as directed in respective sections of this manual.
6. Whenever cylinder liners have been removed, the air ports can be cleaned by soaking in a hot caustic soda or lye solution to loosen carbon deposits. Final cleaning can then be accomplished by brushing loose deposits.

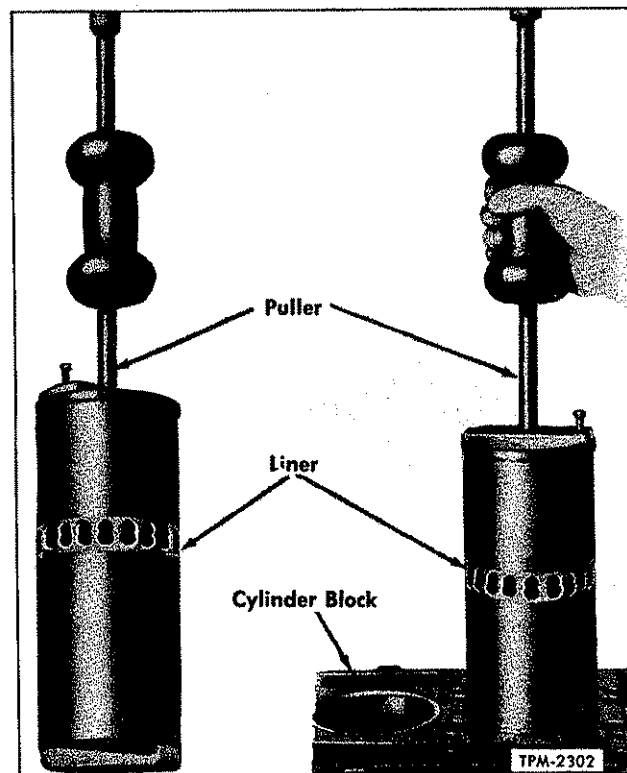


Figure 10—Removing Cylinder Liner

LINER REMOVAL

To remove a cylinder liner, the following preliminary operations will be necessary.

1. Remove the cylinder head assembly as instructed in CYLINDER HEAD section of this manual.
2. Remove the oil pan.
3. If necessary, remove the lubricating oil pump and discharge line assembly together with the pump drive shaft. Refer to LUBRICATING OIL PUMP in LUBRICATION section of this manual.
4. Remove cylinder liner compression gasket from each liner.
5. Scrape carbon from the upper inner surface of cylinder liner, before attempting to remove piston assembly.
6. Remove piston and connecting rod assembly. Refer to PISTON AND CONNECTING ROD section later in this manual.
7. 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 illustrated in figure 10. Use tool in following manner:

- (a) Slip lower puller clamp upward on puller rod and off tapered cone. Cock lower clamp on

CYLINDER LINERS

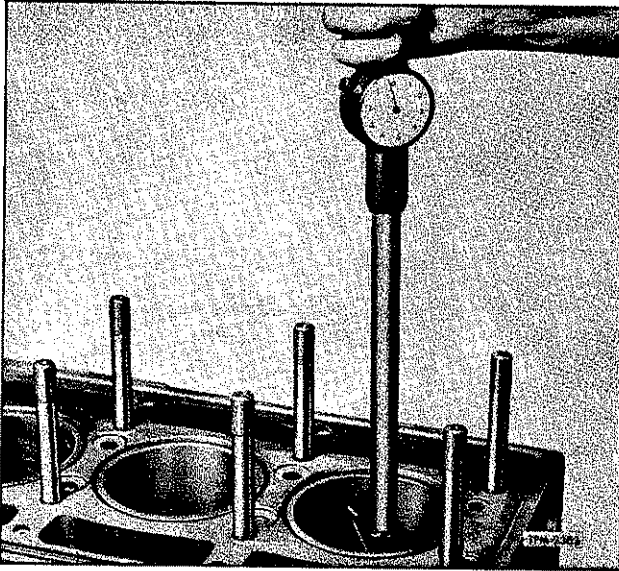


Figure 11—Checking Bore of Cylinder Liner

rod so it will slide down through liner. When rod is lowered down through liner, clamp will drop back onto the tapered cone in a horizontal position.

(b) Slide upper clamp down against top edges of 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 liner from cylinder block.

CLEANING AND INSPECTION

CLEANING

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

1. Use a brass rod or sharpen a stick of 1" square x 12" long 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.
2. After cleaning ports, examine the inside of the liner around the port area for burrs. If burrs are found, remove with 250 grit emery paper. Burrs must be removed by hand whether liner is to be honed or not. Failure to remove these burrs may result in premature failure of piston and rings.
3. 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 be accomplished with a bristle brush.

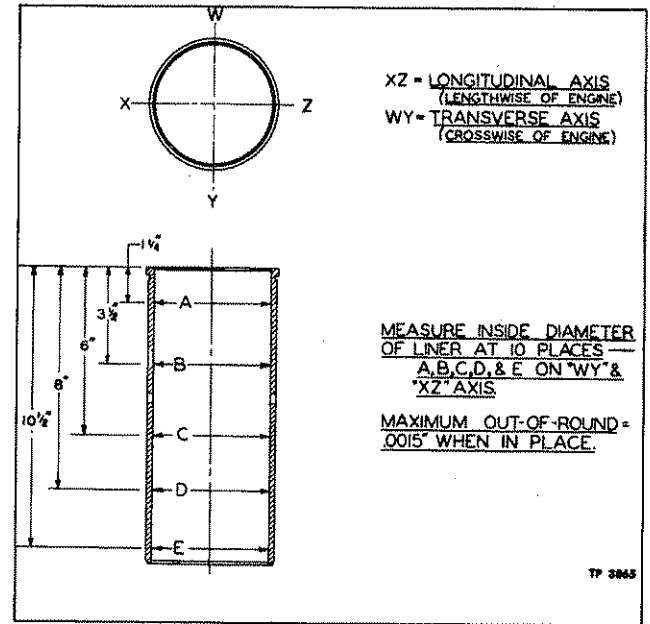


Figure 12—Cylinder Liner Measurements

INSPECTION

The liners must not taper more than 0.001" in full length or be out-of-round more than 0.002". When measuring cylinder liner with dial indicator as shown in figure 11, measurements must be taken on inside diameter of liner at ten places. Refer to figure 12 for diagram of cylinder liner measurement.

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 glaze must be removed by working the hone up and down lightly once or twice.

HONING LINER

Cylinder liners are furnished in standard size inside diameter only, therefore installation of oversize pistons becomes necessary when liners are honed oversize. Also, liners are furnished in oversize outside dimensions which must be used whenever cylinder block bores are honed.

A cylinder liner may be honed on inside diameter and used again, if honing operation is carried out in proper manner. To be sure that none of the abrasive gets into the air box or ports, it will be necessary to remove liners from cylinder block, place in a honing fixture (a scrapped cylinder block will make an

CYLINDER LINERS

excellent honing fixture), and then hone to proper size. After honing, the liners may then be replaced in the cylinder block.

Whenever liners must be honed to cylinder block, completely dismantle engine, and then after honing, wash block in a solution of hot caustic soda, to be sure that all abrasive is removed from openings in block and liners.

The ordinary honing stones used on cylinder blocks are rather ineffective on hard cylinder liners. For rough honing, use a No. 80 grit and for smooth mirror finish required for inside of liners use No. 120 grit.

Necessary steps for honing liners are as follows:

1. Remove liner from cylinder block as previously described under "Liner Removal" in this section.
2. Place liner into liner honing fixture.
3. Hone liner in fixture with honing stones described above.
4. After cylinder liner has been honed and removed from honing fixture, it must be thoroughly washed and blown off with air before installation into cylinder block. If this precaution is not taken some of the honing abrasive might be drawn into engine and cause serious damage.
5. Remove liner from fixture and install in cylinder block in manner described under "Liner Installation" in this section.

HONING CYLINDER BLOCK

The fit of a liner depends to a great extent 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 $1\frac{1}{4}$ " or 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 No. 80 grit stone may be used for roughing, and a No. 120 grit stone is satisfactory for finishing.

The following inspection should be made before honing cylinder block:

1. Remove oil, dirt, and grease from the bore and inlet port opening.
2. Measure the bore for high spots and the most narrow section.
3. Liners are fitted from .0005" to .0025" loose. A clearance of .0005" produces a slip fit and .0025" clearance allows the liner to slide freely into place. Refer to chart for standard and oversize cylinder liner bore in cylinder block.

CYLINDER LINER AND CYLINDER BORE DIMENSION CHART

Size	Liner Diameter	Block Diameter	Use Next Oversize Liner when Bore Measures
Std.	4.6250"	4.6265"	4.6280"
	4.6260"	4.6275"	
0.005"	4.6300"	4.6315"	4.633"
	4.6310"	4.6325"	
0.010"	4.6350"	4.6365"	4.638"
	4.6360"	4.6375"	
0.020"	4.6450"	4.6465"	4.648"
	4.6460"	4.6475"	
0.030"	4.6550"	4.6565"	4.658"
	4.6560"	4.6575"	

Rough Honing

Insert hone in bore and adjust stones snugly to the most narrow section. When correctly adjusted, hone will not shake in bore, but will still drag freely up and down the bore while the hone is stopped.

Start hone and "feel out" bore for high spots. These will cause an increased drag on the stone. Move hone up and down 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 drag of hone becomes light and smooth, increase the feed on the stones. Feed lightly to avoid excessive oversize of bore; roughing stones cut rapidly even under low tension.

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

CYLINDER LINERS

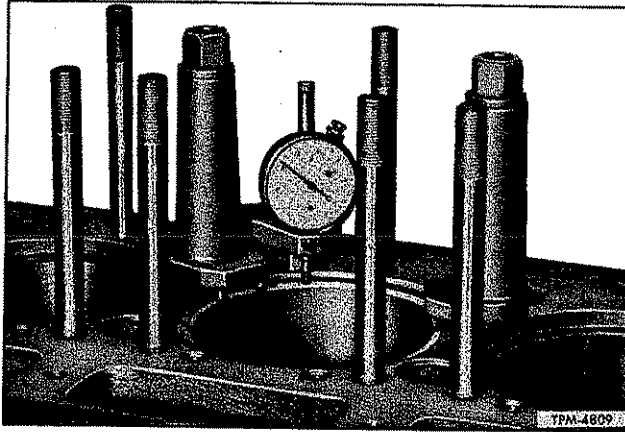


Figure 13—Checking Depth of Liner Below Top of Block

FINISH HONING AND FITTING LINER

Rough hone cylinder bore until the liner can be pushed from 3" to 4" into the bore, or until bore is within approximately .0005" of the 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.

If new liners are to be used after honing the block, follow instructions for replacing loose liners. If old liners requiring re honing on the inside diameter are to be used, follow instructions under "Honing Liner" previously in this section.

LINER INSTALLATION

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 "Honing Cylinder Block" previously

in this section to remove roughness or distortion.

Before installing the liner or insert in cylinder block wipe the liner, insert and block counterbore until absolutely clean. Use a fine flat honing stone to remove any burrs that may be present on the liner or insert or in cylinder block counterbore. Liner must be installed dry—do not use oil.

Since cylinder head and cylinder block are metal-to-metal contact, each cylinder liner is sealed individually by compression seals. This construction requires that top of liner flange be .0465" to .050" below top of cylinder block.

When insert and cylinder liner are installed, height of liner must be checked to determine that liner is proper distance below top of cylinder block. Install hold-down tool over top of liner to hold liner tightly in place, while measuring liner depth below top of block (fig. 13). Use a dial indicator and a surface plate on a flat surface gauge to measure depth of cylinder liner below top of cylinder block.

LINER HEIGHT

When cylinder liner and insert are installed and liner depth is checked in manner previously outlined the depth should be .0465" to .050" as indicated. If liner depth is not within these limits, and inspection indicates they are properly installed, the insert or liners or both should be removed for careful inspection of mounting surfaces and condition of cylinder block counterbore. Undersize cylinder liner inserts are available for use when top of cylinder block has been "trued up" by removing a small amount of stock. **DO NOT USE SHIMS TO OBTAIN CORRECT LINER HEIGHT.**

Having replaced the cylinder liners, the pistons may be fitted and the engine rebuilt. In this process, see "Fitting Pistons," in PISTON AND CONNECTING ROD section later in this manual, also refer to the various other sections of this text for detailed instructions relative to correct location of parts, bearing clearances, etc.

Operate engine as instructed in ENGINE RUN-IN PROCEDURE section later in this manual.

CRANKSHAFT AND MAIN BEARINGS

CRANKSHAFT AND MAIN BEARINGS

CRANKSHAFT

Crankshaft is high-carbon steel drop forging, heat-treated to insure strength and durability. All main and connecting rod bearing journal surfaces are hardened by the Tocco process.

Complete static and dynamic balance of the rotating parts has been achieved by counterweights incorporated with the crankshaft.

Crankshaft thrust is taken through two-piece washers (fig. 14) on each side of the rear main bearing. Crankshaft is drilled for full pressure lubrication to the main and connecting rod bearings.

The 4-71 has 5, and 6-71 engine has 7 main bearings, each $3\frac{1}{2}$ " in diameter and $1\frac{1}{2}$ " long. The crankshaft pins are $2\frac{1}{4}$ " in diameter and $2\frac{1}{2}$ " long on all Series 71 engines.

MAIN BEARINGS

Main bearing shells are the precision type and are replaceable without machining. 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 must always be replaced in its respective position. Bearing cap "5" on 4-71 or "7" on 6-71 must always be at flywheel end.

Upper halves of main bearing shells are seated in the crankcase; lower halves are held in place by the main bearing caps, each of which is held to the crankcase by two special bolts and lock washers. 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 crankcase.

All upper halves of the main bearing shells carry a circular groove midway between the bearing edges which runs from 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 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.

All the main bearing load of these engines is car-

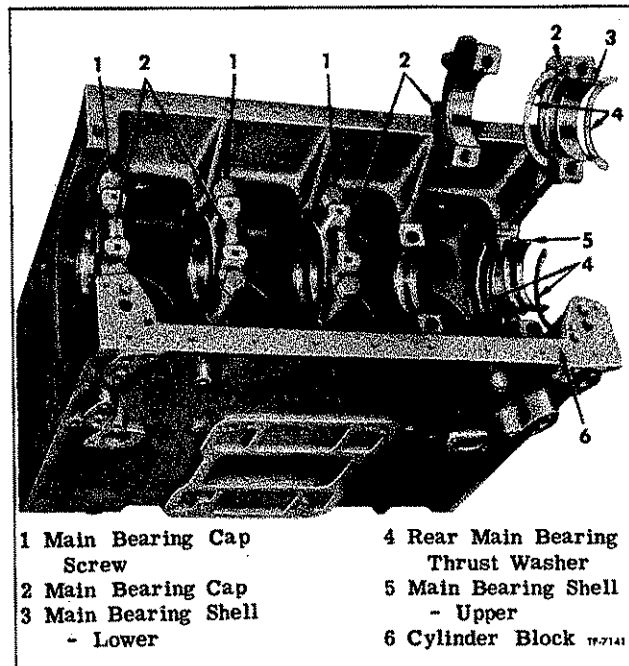


Figure 14—Upper and Lower Main Bearing Shells, Bearing Caps, and Rear Main Bearing Thrust Washers

ried on the lower half of the bearings only. The main 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. Bright spots on backs of the shells will indicate that shells have been shifting in their supports, and must be carefully inspected before being reinstalled. If crankshaft has been overheated, examine the journals for cracks. If the crankshaft journals show signs of overheating or are badly scored; then the crankshaft must be removed from the engine, and either replaced or reconditioned.

Low oil pressure may be an indication of worn main bearings, as evidenced by slow response of oil pressure gauge when starting and insufficient pressures at running speeds.

CRANKSHAFT OIL SEALS

Effective oil seals have been incorporated in flywheel housing cover at rear, also in cover at front of crankshaft. Seals consists of a special treated lip type seal assembly set into front and rear covers.

CRANKSHAFT AND MAIN BEARINGS

The rolled-over inner diameter of the seal is held by a coil spring, to prevent oil leakage. The crankshaft timing gear at rear 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. An oil slinger at front also assists in preventing excessive oil reaching seal.

An effective oil seal is also used at front end of crankshaft and is installed in front cover. Refer to **CRANKSHAFT FRONT COVER** and **OIL SEAL** section later in this manual.

CRANKSHAFT REMOVAL

When necessary to remove crankshaft the operation may be performed as follows:

1. Drain oil from the oil pan, then remove the oil pan.
2. Remove the lubricating oil pump assembly as instructed under **LUBRICATING OIL PUMP** in **LUBRICATION SYSTEM** section of this manual.
3. Remove the vibration damper assembly, if used, as instructed in **VIBRATION DAMPER** section later in this manual.
4. Remove flywheel and flywheel housing as instructed in their respective sections in this manual.
5. Remove crankshaft front cover as instructed in **CRANKSHAFT FRONT COVER AND OIL SEAL** later in this manual.
6. Remove connecting rod bearing caps. Note that

each cap and rod is stamped with a number corresponding with the cylinder number.

7. Remove main bearing caps. Note that each cap is stamped with a number which corresponds with number stamped on cylinder block.

8. Lift crankshaft, timing gear, oil pump drive gear and slinger as an assembly from crankcase.

9. Remove main bearing inserts from crankcase and bearing caps, also thrust washers at rear main bearing. Carefully identify each bearing so that it can be replaced in its original location, providing inspection indicates that it is within permissible tolerances and is satisfactory for continued use.

CRANKSHAFT INSPECTION**CLEANING**

Entire crankshaft must be thoroughly cleaned with steam or other suitable cleaning solvent. Remove all pipe plugs. Particular attention should be given oil passages to be sure all oil deposits or other foreign material is removed. Dry with compressed air and coat with oil to prevent rusting.

ALIGNMENT

Position crankshaft on V-blocks or in lathe and check alignment at two intermediate journals, using dial indicator. If run-out limit is greater than given in **SPECIFICATIONS** section of this manual, crankshaft must be replaced.

JOURNALS

Journals which do not meet inspection requirements as to diameter, taper or out-of-round should be reground; also, all journals must be reground if one or more do not pass this inspection.

The journals may be reground undersize, and undersize main bearing shells (.010"; .020"; .030") used. If the crankshaft journals have been overheated, the heat-treating will be destroyed; then a new crankshaft should be used.

Carefully check each bearing journal for evidence of a raised ridge around circumference of journal in line with the oil hole (fig. 15). This ridge must be removed before new bearings are installed, if ridge is .0002" or more in height. A good method of removing ridge not in excess of .0002" is to wrap crocus cloth, wetted in fuel oil or kerosene, around bearing journal. Then using a belt or strip of cloth around crocus cloth, work the belt or cloth back and forth as a bowstring. Rotate crankshaft at frequent intervals to maintain concentricity of journal.

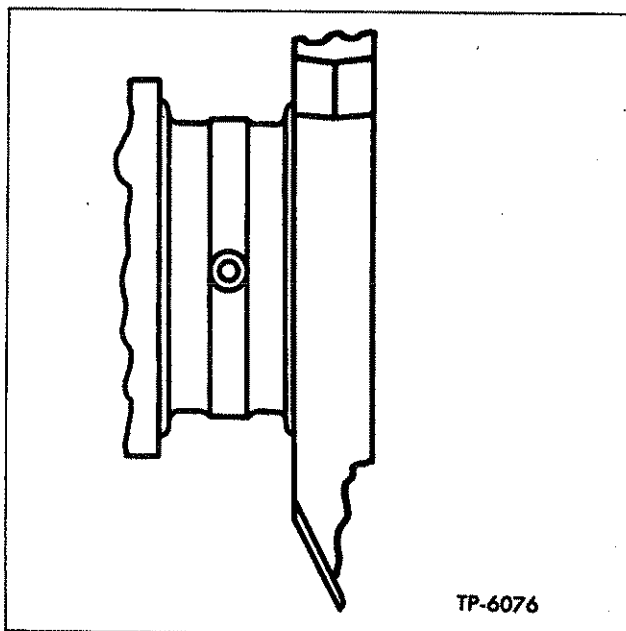


Figure 15—Crankshaft Journal Ridge—Typical

CRANKSHAFT AND MAIN BEARINGS

For ridges in excess of .0002" first use 120 grit emery cloth to clean up ridge, followed by 240 grit emery cloth to finish it off; then wet crocus cloth should be used for the polishing operation, in manner described above. Whenever ridge is .001" or greater crankshaft should be reground.

Measure each bearing journal to determine if regrounding is necessary, also measure thrust surfaces, (fig. 16). These measurements must be taken with extreme care and should be accurate to .0002". Check each journal for taper and out-of-round condition. Taper must not exceed .0005" and out-of-round must be within .00025".

CRACKS

Carefully check all surfaces of crankshaft for evidence of cracks. Note particularly for cracks which start at an oil hole and follow the journal surface at an angle of 45° to axis. Any crankshaft with a crack at an oil hole must be replaced as these cracks indicate torsional fatigue. It is advisable, if at all possible, to magnaflux the crankshaft to determine the presence of minute cracks not visible to the eye. Very careful attention should be given the area in the vicinity of journal fillets as circumference cracks at this point usually indicate early failure.

THRUST SURFACES

Carefully check thrust surfaces for evidence of excessive wear or roughness. In many instances only slight grinding or "dressing up" of the thrust surfaces is necessary. In such cases, use of new standard thrust washers will probably hold the thrust clearances within the dimensions given in SPECIFICATIONS, otherwise it may be necessary to use .005" oversize rear thrust washer or regrind thrust surfaces to maintain end thrust with oversize thrust washers.

KEYWAY

Inspect keyways for evidence of cracks or worn condition, and replace shaft if necessary.

OIL SEAL CONTACT

Carefully inspect crankshaft in area of rear oil seal contact for evidence of rough or grooved condition. Any imperfections of oil seal contact surface will result in oil leakage at this point. Refer to FLYWHEEL HOUSING AND GEAR TRAIN COVER section later in this manual for methods of relocating oil seal.

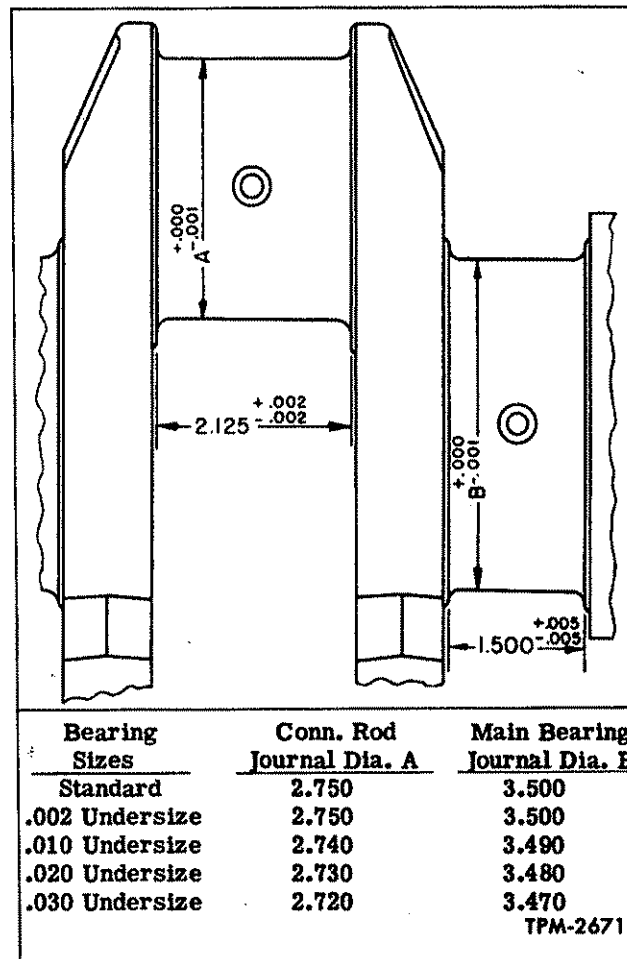


Figure 16—Crankshaft Journals and Thrust Surfaces—Standard Dimensions

CRANKSHAFT GRINDING

Grinding operations should be performed carefully in accordance with grinding equipment manufacturer's recommendations and good shop practices. Care must be taken to avoid localized heating which often produces grinding cracks. The crankshaft should be cooled while grinding, using coolant generously. The grinding wheel must not be crowded into the work.

JOURNALS

Measurement of the crankshaft journals and comparison of these measurements to the diameters required for various undersize bearings shown in figure 16 will determine the size to which crankshaft journals must be reground. The .002" undersize bearings are for use with a standard crankshaft only to maintain minimum allowable bearing clearances.

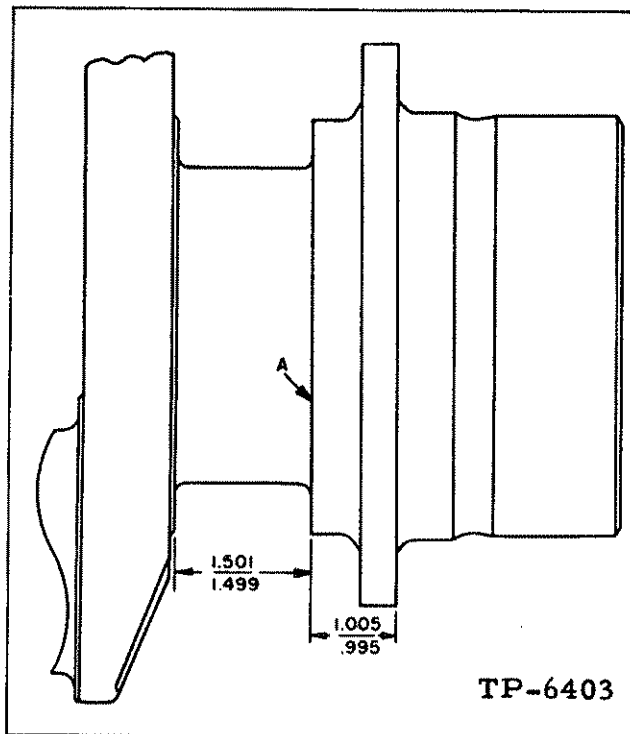
CRANKSHAFT AND MAIN BEARINGS

Figure 17—Crankshaft Rear Main Bearing Thrust Surfaces

Crankshaft main and connecting rod bearings are available in standard, .002", .010", .020", and .030" undersizes.

Reground crankshaft journals will be subject to excessive wear unless the ground surfaces are polished absolutely smooth. A simple test to determine if surfaces are smooth enough is to rub the edge of a penny over the surface. If a copper colored mark is left, the surface is too rough and needs further polishing. Surfaces must be clean and dry when this test is made.

THRUST SURFACES

The amount of grinding necessary on the crankshaft thrust surfaces depends upon how badly the

surface is scored or worn. This in turn determines the particular thrust washers, standard or oversize, which must be used after grinding. In many cases only slight grinding or "dressing-up" of the thrust surfaces is necessary. In such cases, use of new standard thrust washers will probably hold the thrust clearances within the specified .004 to .011 of an inch. However, if thrust clearance exceeds .018 of an inch when crankshaft thrust is checked, after slight grinding of the crankshaft and with new standard thrust washers, then .005 of an inch oversize thrust washer should be installed in place of the standard washer on the crankshaft rear thrust surface face (against thrust surface "A," figure 17). Standard dimensions which indicate that standard thrust washers should be used are illustrated in figure 17. Comparison of these dimensions with corresponding dimensions on crankshafts with reground thrust surfaces will indicate size of thrust washer required to provide correct clearance.

The information given for grinding journals also applies to the grinding operations for thrust surfaces. Likewise, the fillets where journal joins the thrust surfaces must be properly ground, as described below.

After grinding thrust surfaces of crankshaft they, like the journals, will wear excessively if not polished absolutely smooth. The penny test can be applied to the thrust surfaces in the same way as for checking finish of journals.

FILLETS

Grinding the fillets at the end of crankshaft journals requires careful dressing of the grinding wheel, as the fillets must have a smooth radius, free from scratches. The radius must be not less than $\frac{1}{8}$ of an inch, and preferably $\frac{5}{32}$ of an inch, when measured with a fillet radius gauge. A correctly ground fillet is shown in figure 18 together with incorrect fillets.

OPERATIONS AFTER GRINDING

The edges of all oil holes in the journal surfaces should be stoned smooth to provide a radius of approximately $\frac{3}{32}$ of an inch at the edge of the hole. Plugs at the ends of the oil holes should be removed and a stiff wire brush run through the oil holes after which plugs should again be installed.

After all regrounding operations have been completed, the crankshaft should be magnafluxed again to determine whether grinding cracks have originated due either to insufficient cooling or crowding

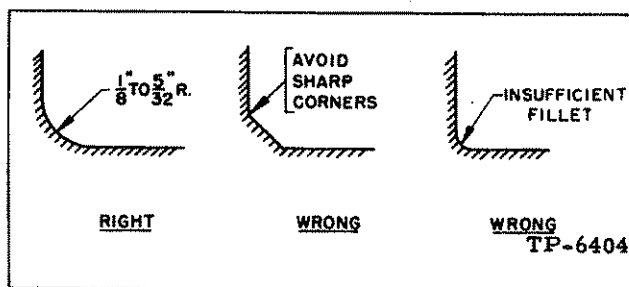


Figure 18—Crankshaft Journal Fillet

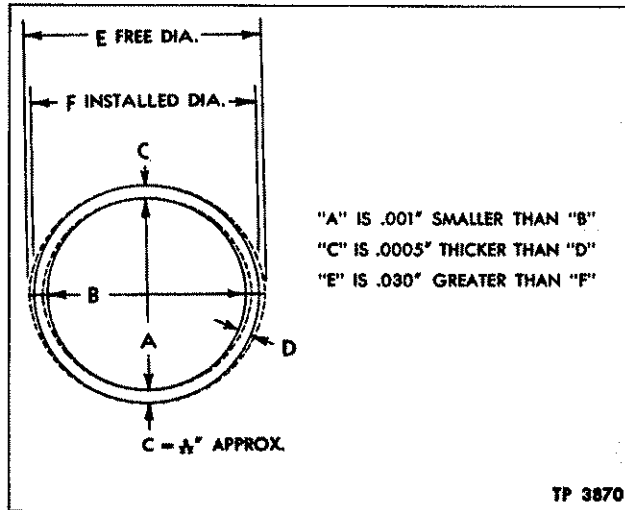
CRANKSHAFT AND MAIN BEARINGS

Figure 19—Inside Diameter of Bearing Shell at Parting Line and 90° to Parting Line

of grinding wheel during grinding operations. Finally, crankshaft must be demagnetized.

MAIN BEARING INSPECTION

Main bearing shells are of the precision type and replaceable without machining. The clearance between the main bearing shells and the crankshaft journals is from .0014\" to .0044\". Main bearing shells are furnished in standard, and undersizes.

As will be seen in figure 19, bearing shells when in place have .001\" larger diameter at parting line than 90 deg. from parting line. Also, thickness of bearing shells 90 deg. from parting line is .1548\"-.1553\". The two shells do not form a true circle when not installed, and when measured for inside diameter must be installed in the caps and block, with caps bolted in place.

The two halves of the shells have a squeeze fit in case and cap, and must be tight when cap is drawn down. Shells may be measured with micrometers at points marked \"C,\" as shown in figure 20.

A recommended method of determining running clearance is to insert a soft lead or plastic wire across center of each lower bearing shell by removing and replacing one bearing cap at a time. When all insertions have been made, tighten bearing cap screws, thus \"squeezing\" wire or plastic to shim thickness between shells and crank journals. Remove the lead shims and measure for thickness. Clearance between shells and journals should be as specified in **SPECIFICATIONS** section.

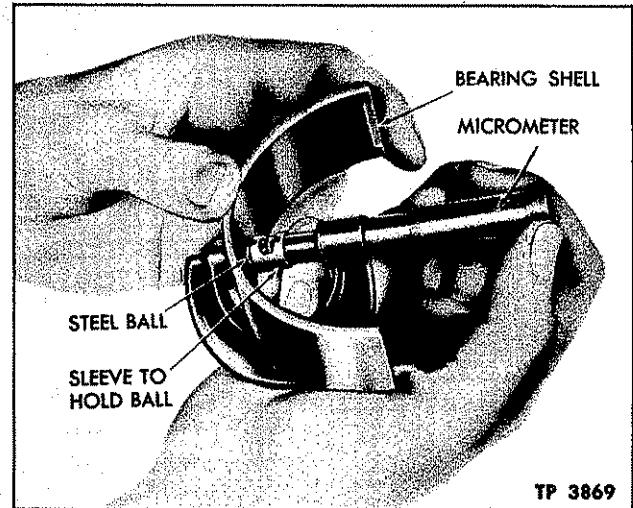


Figure 20—Measuring Thickness of Bearing Shell

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 limits, 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.

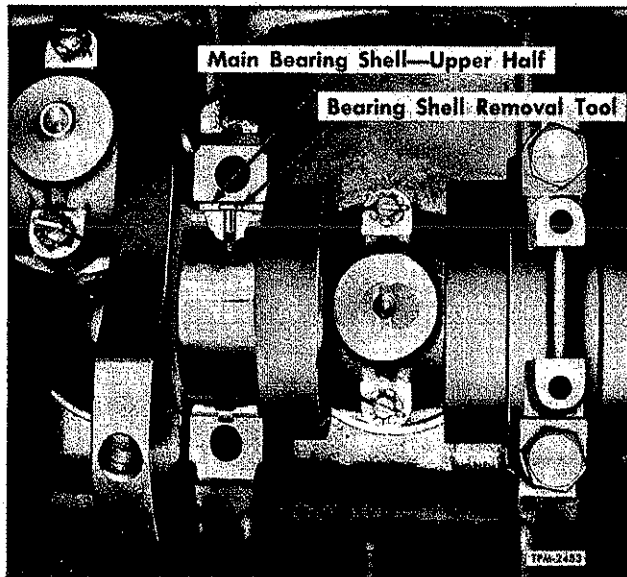
CRANKSHAFT AND MAIN BEARING INSTALLATION

The crankshaft main bearing upper shells are grooved for lubrication; the lower shells are not grooved. When replacing the bearing shells, prior to setting the crankshaft in place, see that the grooved shells are placed in crankcase as shown in figure 14.

1. After the bearing upper shells have been placed in the crankcase, apply light film of 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 are in alignment. Refer to **GEAR TRAIN** section later in this manual.

2. Install the two-pieced thrust washers on each side of the rear main bearing.

NOTE: IF ONE CRANKSHAFT THRUST SURFACE HAS BEEN REGROUND, IT IS SOMETIMES NECESSARY TO INSTALL THRUST

CRANKSHAFT AND MAIN BEARINGS

**Figure 21—Removing Main Bearing Upper Shell
(Except Rear Main) As Shown**

WASHERS OF DIFFERENT THICKNESSES IN ORDER TO PROPERLY CENTER CRANKSHAFT AT MAIN BEARING JOURNAL. IF THRUST SURFACES WERE NOT WORN ENOUGH TO REQUIRE REGRINDING, OR IF WORN AND GROUND OFF EQUALLY, THEN THRUST WASHERS OF THE SAME THICKNESS SHOULD BE INSTALLED ON BOTH SIDES OF THE SAME BEARING.

3. Main bearing caps are numbered "1," "2," "3," etc., indicating their respective positions. The marked side is always toward blower side of cylinder block. Noting the marks, place bearing lower shells in bearing caps, and install caps, locking in place with bolts and washers. Tighten to torque recommended in **SPECIFICATIONS** at end of this manual. When tightening bearing cap bolts, rap caps several sharp blows with a plastic hammer to assist in positioning shells.

NOTE: IF BEARING HAS BEEN PROPERLY INSTALLED, THE CRANKSHAFT WILL TURN FREELY WHEN ALL MAIN BEARING CAPS ARE BOLTED TIGHT.

4. In the event oil pump drive gear has been removed from crankshaft, install as directed under **LUBRICATING OIL PUMP** in **LUBRICATION SYSTEM** section of this manual.

5. Position new gasket to bolting flange of crankshaft front cover, and attach to cylinder block with lock washers and cap screws finger-tight only. Do

not tighten cap screws until after front spacer is put in position, as described in next item.

6. Replace the spacer or vibration damper inner (rear) cone (or spacer) on front end of crankshaft next to the oil slinger. Refer to **VIBRATION DAMPER** section of this manual.

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.

7. Tighten cover cap screws as directed in **CRANKSHAFT FRONT COVER AND OIL SEAL** section later in this manual.

8. Install flywheel housing and flywheel as directed in respective sections of this manual.

9. Install connecting rods as directed in **PISTON AND CONNECTING ROD SECTION LATER** in this manual.

10. Refer to **LUBRICATING OIL PUMP** in **LUBRICATION SYSTEM** section for oil pump installation instructions.

MAIN BEARING REPLACEMENT**REMOVAL**

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 and by referring to figure 21. 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 rear that is not drilled.

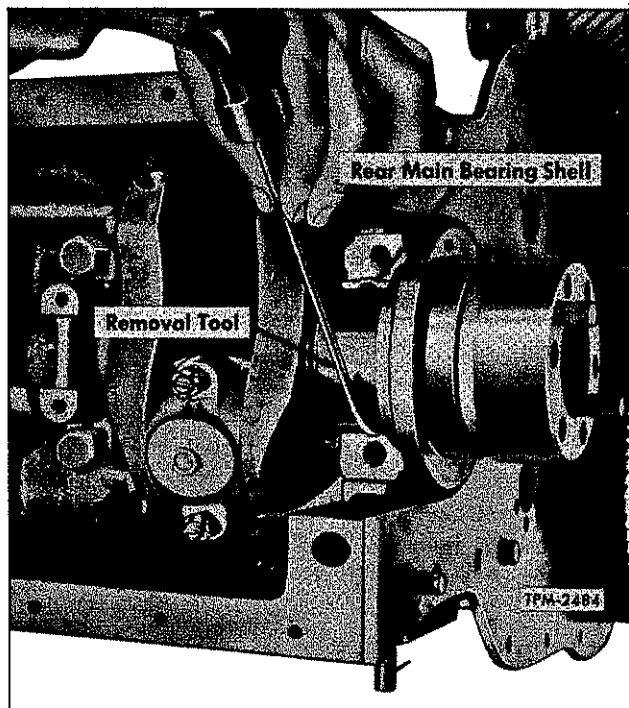
1. Remove the oil pan to expose the main bearing caps.

2. Remove oil pump as directed under **Lubricating Oil Pump** in **LUBRICATION SYSTEM** section of this manual.

NOTE: If shims are used between the oil pump mounting brackets and bearing caps, special care must be taken of them so that they may be reinstalled in exactly the same location when reinstalling the oil pump.

3. Remove one main bearing cap at a time and complete replacement of shell and reinstallation of cap before another cap is removed.

4. Two-piece thrust washers are used each side of the rear main bearing. The lower half of these washers will be removed when removing the rear main bearing cap; upper half can be removed by

CRANKSHAFT AND MAIN BEARINGS**Figure 22—Removing Rear Main Bearing Upper Shell**

pushing one end of washer with a suitable instrument, thus forcing washer around and out on opposite side of bearing.

5. The bearing cap having been removed, insert a $\frac{3}{8}$ " 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 shaft in direction necessary to move notch lock from its recess and roll the bearing shell out of position, as shown in figure 21. The head of the bolt should not extend beyond the outside diameter of the shell.

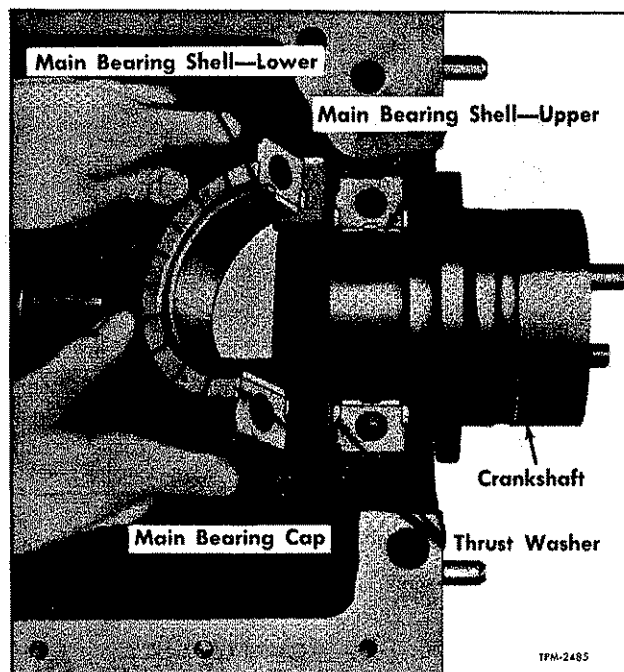
6. Upper half of all main bearing shells may be removed in the above manner except the rear main. On this bearing, the upper shell must be removed by tapping on the edge of the bearing shell with a small curved rod, at the same time revolving the crankshaft, thus rolling the shell from position, as shown in figure 22.

INSTALLATION

Clean bearing shells, caps, crankshaft, and crankcase thoroughly then apply lubricating oil to journals and shells.

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.

CAUTION: Be sure to install the grooved shell in

**Figure 23—Rear Main Bearing Lower Shell, Cap, and Thrust Washer**

crankcase and non-grooved shell in bearing cap, otherwise oil supply to bearing will be cut off.

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

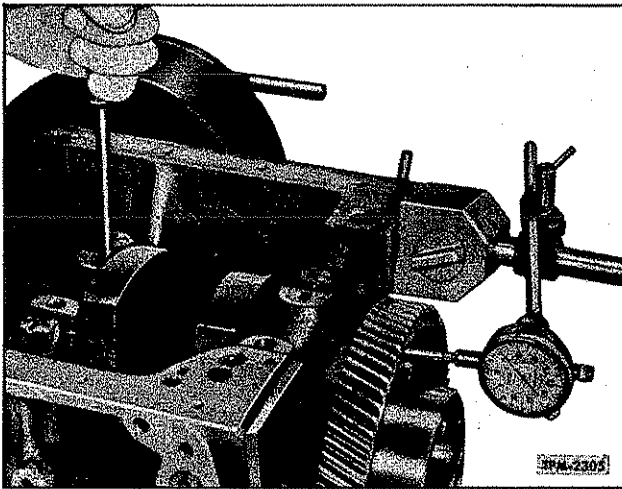
NOTE: Main bearing caps are bored in position and marked "1," "2," "3," etc. Whenever bearing caps are removed, they must be replaced in their original positions with marked side of caps toward blower side of cylinder block.

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 with a plastic hammer to align bearing shell. The cap screws may be tightened to recommended torque then locked.

NOTE: Since the bearing shells have a squeeze fit in the cap and block, bearing nuts should be drawn tight so shells will not shift.

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

4. Install lubricating oil pump, drive and discharge pipe assembly. Refer to LUBRICATING OIL PUMP in LUBRICATION SYSTEM section.

FLYWHEEL AND CLUTCH PILOT**Figure 24—Checking Crankshaft End Play**

5. Install oil pan with new gasket.

6. After installing new bearing shells, the engine should be operated on a run-in schedule as instructed in **ENGINE RUN-IN PROCEDURE** section later in this manual.

REAR MAIN BEARING THRUST WASHERS

As shown in figure 23, crankshaft thrust washers located at rear main bearing consist of two pieces on each side of bearings. The lower portion is doweled to bearing cap in two places at each side of cap. If washers have become scored, or otherwise damaged, they must be replaced. End thrust as measured between crankshaft flange and thrust washer should be .004" to .011" and should not exceed .018". End thrust is checked with dial indicator in manner illustrated in figure 24. Washers for replacement are available in standard .005" and .010" oversize.

FLYWHEEL AND CLUTCH PILOT**FLYWHEEL**

Flywheel is made of alloy cast iron or steel forging and is attached securely to crankshaft flange with cap screws and straight dowels.

A starter ring gear made from heat-treated steel is shrunk onto the rim of flywheel. The ends of the ring gear teeth are chamfered to permit a smooth,

silent, and positive engagement of starter gear when engine is being started.

MAINTENANCE

The construction of the flywheel makes the necessity for service on this part remote. Service operations, such as replacing clutch pilot bearing and starter ring gear, require removal of the flywheel.

REMOVAL

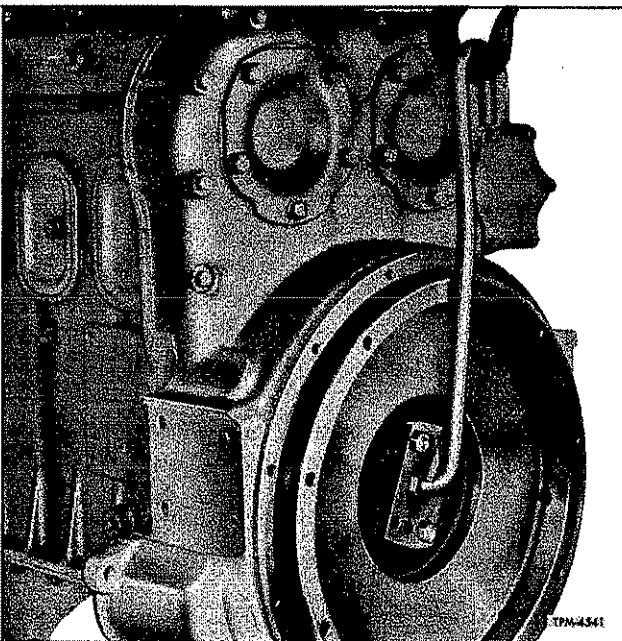
The power transmitting unit and clutch, having been removed from the flywheel housing and flywheel respectively, the flywheel may be removed from crankshaft flange, using puller screws and lifting hook (fig. 25).

1. Withdraw the lockwire (if used) from the six cap screw heads then remove cap screws and pilot bearing retainer (when used).

2. Screw the two puller screws into tapped holes provided at flywheel bolting flange until inner ends of tool press against crankshaft flange. Continue to turn puller screws until flywheel is removed from dowels.

INSTALLATION

Install two pilot studs in crankshaft flange (fig. 25) to support flywheel when it is being located on dowels. Due to one offset hole in the crankshaft holding flange, flywheel can be located in only one position. Install pilot bearing, retainer and retaining

**Figure 25—Flywheel Lifting Hook**

FLYWHEEL AND CLUTCH PILOT

cap screws. Install and tighten six cap screws alternately and evenly to torque listed in SPECIFICATIONS section of this manual. Run wire through the heads of each two screws and twist together to prevent screws loosening.

Mount dial indicator on clutch housing and check run-out of flywheel at clutch facing contact. Runout should not exceed .005" total dial indicator reading.

RING GEAR REPLACEMENT**REMOVAL**

With flywheel removed from crankshaft, the old ring gear may be removed from the flywheel by grinding a notch through the ring at the root of one tooth, then expanding ring and driving from position. Unless ring gear is already broken at the root of a tooth, no attempt should be made to drive it from position without first splitting gear as instructed.

INSTALLATION

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.

After heating, start ring gear onto flywheel with chamfered ends of the teeth on the ring gear towards the cylinder block when flywheel is installed. These edges of the teeth engage the pinion on the starting motor. Drive gear down tight against shoulder on flywheel. Ring gear should be air-cooled before using.

Ring gear should not be heated excessively as the original heat treatment will be destroyed. However, it must be heated sufficiently to expand the ring and make a tight fit on flywheel when cooled.

CLUTCH PILOT BEARING**REMOVAL**

On some engines it is first necessary to remove pilot bearing retainer before bearing may be removed from flywheel. Remove bearing with recommended removal tool as follows:

1. Adjust puller with thumb until fingers on puller are closed.
2. Insert puller through base of bearing as far as it will go, then tighten thumb screw to spread puller fingers behind bearing.
3. Slide weight sharply against stop nut on puller shaft to remove the bearing.

INSPECTION

After removal and before installing, 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 to prevent turning; then 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 must be replaced.

INSTALLATION

1. Fill cavity in crankshaft and lubricate bearing with high melting point grease.
2. Start bearing into bore of flywheel by hand; then, using a suitable driver, drive bearing flush with outer face of flywheel.

CAUTION: Do not drive bearing on inner race. Be sure bearing is not cocked in flywheel, and that it rotates freely after installation.

3. Install pilot bearing retainer.

CLUTCH PILOT BUSHING

Vehicles using automatic transmissions use a bronze bushing, instead of the conventional pilot bearing, in the flywheel. Also, trucks equipped with Hydra-Matic use a steel sleeve at flywheel hub.

When inspection indicates that bronze bushing or steel sleeve are worn, replacement is necessary.

REMOVAL

1. Remove flywheel assembly as directed under heading "Flywheel Removal" in this section.
2. Use suitable removing tool or arbor press to remove bushing. Bushing should be pressed or driven from engine side of flywheel.

INSTALLATION (Coach V-Trans.)

1. Locate bushing over hole in flywheel on coupling side (opposite engine side) then install round pilot in bushing. Pilot is part of special tool listed in SPECIAL TOOLS section of this manual. Pilot will hold inside diameter of bushing to its correct size and therefore provides proper bushing clearance.
2. Position legs of anvil against opposite (engine) side of flywheel. Insert special bolt through anvil, flywheel, bushing and pilot, then install bearing and nut on bolt.
3. Thread nut on bolt until finger tight then locate bushing and tool, so that bushing will be

FLYWHEEL HOUSING AND GEAR TRAIN COVER

drawn straight into flywheel.

4. Tighten nut with wrench while bolt is being held with another wrench. Continue tightening nut until bushing is drawn flush with flywheel and pilot collar prevents further entry.

INSTALLATION (Truck Hydra-Matic)

1. Position bushing over replacer tool then drive bushing into flywheel hub until it is $\frac{1}{16}$ " below edge of hub.

2. When bushing is positioned, it should be bored or honed to dimension given in **SPECIFICATIONS** section of this manual.

3. Position steel sleeve over flywheel hub, then using hardwood block, drive sleeve onto hub, until it is $\frac{1}{64}$ " below end of hub.

4. Grind outer diameter of steel sleeve to dimension given in **SPECIFICATIONS** section of this manual.

Combination flywheel housing and gear train cover is attached to cylinder block end plate, idler hub, and spacer hub at rear of engine.

The engine is usually supported by stabilizing cushions, used between flywheel housing and engine supports. These stabilizers absorb torsional vibration and produce a smooth operating power plant.

FLYWHEEL HOUSING AND GEAR TRAIN COVER**MAINTENANCE**

At periodic intervals, flywheel housing and gear train cover must be checked for looseness of bolts, oil leaks, and deterioration of stabilizing cushions or other evidence of failure.

REMOVAL

With engine in overhaul stand or out of vehicle the combination housing is removed in following manner:

1. If cylinder head has not been removed, it will be necessary to remove the two bolts holding engine lifting bracket to cylinder head, leaving the lifter bracket attached to flywheel housing for convenience in handling.

2. Remove accessories such as air compressor, generator, starter, etc. mounted to gear train cover or flywheel housing.

3. Remove flywheel as directed in respective section of this manual.

4. If oil pan is not already removed remove plug to drain pan, then remove bolts attaching pan to flywheel housing, cylinder block, and crankshaft front cover. Remove pan.

5. Remove twelve bolts from inside and twelve from outside of housing, also two from front side of end plate.

6. With flywheel housing supported by chain fall at the lifter bracket, strike housing on alternate sides with plastic hammer until loosened from locating dowels.

INSPECTION

1. Inspect all bolt holes.

2. Crankshaft rear oil seal should be replaced.

3. Remove all traces of old gasket and gasket cement. Check gasket flange for nicks or other imperfections, clean with stone if necessary.

4. Examine engine mountings. If deteriorated, replace.

5. Using straight edge or surface plate. Check flywheel housing for warp. Replace if damaged.

OIL PAN

While flywheel housing is removed, this is an excellent opportunity to clean and inspect oil pan and oil pump inlet screen. Inspect as follows:

1. Examine pan carefully inside and out for evidence of corrosion. If apparent, replace with new part. Check for bent or damaged condition, also for loose baffle plates (if used). Special attention must be given to bolting flange to be sure it is straight in order to form a tight seal at crankcase, crankshaft front cover, and flywheel housing.

2. Examine threads in oil pan, and in oil pan drain hole and drain plug. Replace plug gasket if necessary.

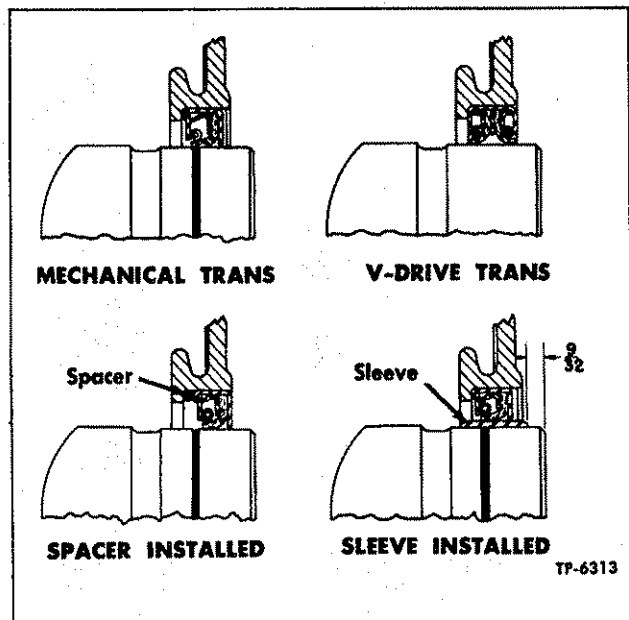
3. Replace gaskets, even though they appear to be in good condition.

OIL SEAL REPLACEMENT

Whenever inspection of oil seal reveals that seal is cut, worn or otherwise damaged it must be replaced to prevent loss of engine oil.

REMOVAL

Defective oil seal can be driven from flywheel housing, using a blunt drift and hammer. During removal

FLYWHEEL HOUSING AND GEAR TRAIN COVER**Figure 26—Crankshaft Rear Oil Seal Modifications**

tap seal alternately around edges so as not to damage the seating surface in flywheel housing. Thoroughly clean seal seating surface of any sealing compound or other foreign matter.

INSTALLATION

Apply a light coating of sealing compound around circumference of seal to prevent oil leaks between seal and flywheel housing. Position seal on flywheel housing with lip of seal toward inside (engine side). Use suitable replacing tool to drive seal tightly into place.

SEAL MODIFICATIONS

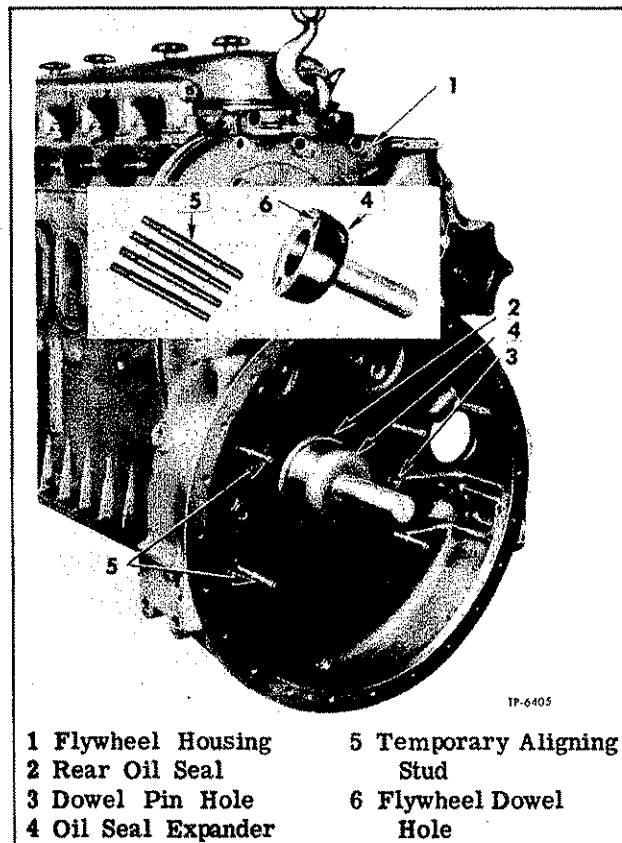
When sealing surface at crankshaft becomes grooved or worn as illustrated in figure 26. In order that crankshaft may continue to be used the following modifications may be applied.

Spacer Installation

As illustrated in figure 26 a spacer may be installed before seal is installed which re-positions seal in flywheel housing and therefore permits lip of seal to contact crankshaft at a new location.

Sleeve Installation

As illustrated in figure 26 a sleeve may be installed on crankshaft to provide a new seal surface. Position sleeve to crankshaft and drive into place with oil seal sleeve installing tool. Refer to **SPECIAL**

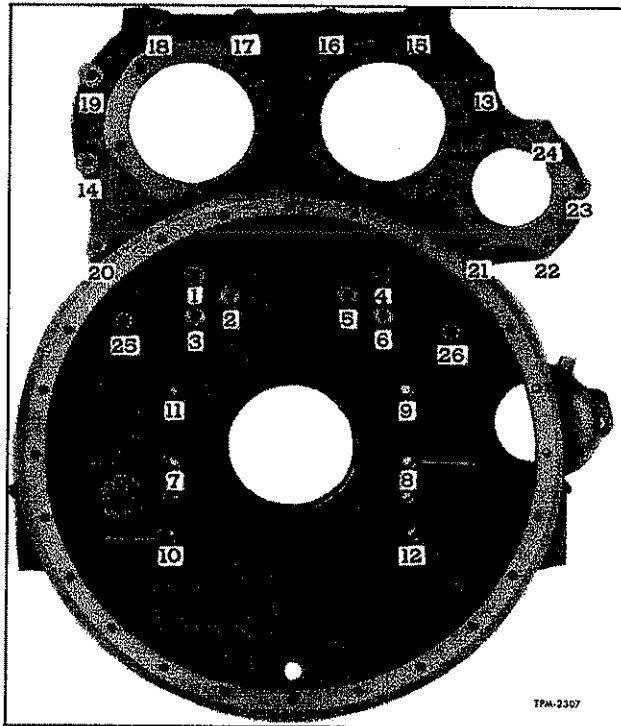
**Figure 27—Installing Flywheel Housing**

TOOLS AND EQUIPMENT at end of this section. Be sure sleeve in held to $\frac{3}{32}$ " dimension as indicated in figure 26.

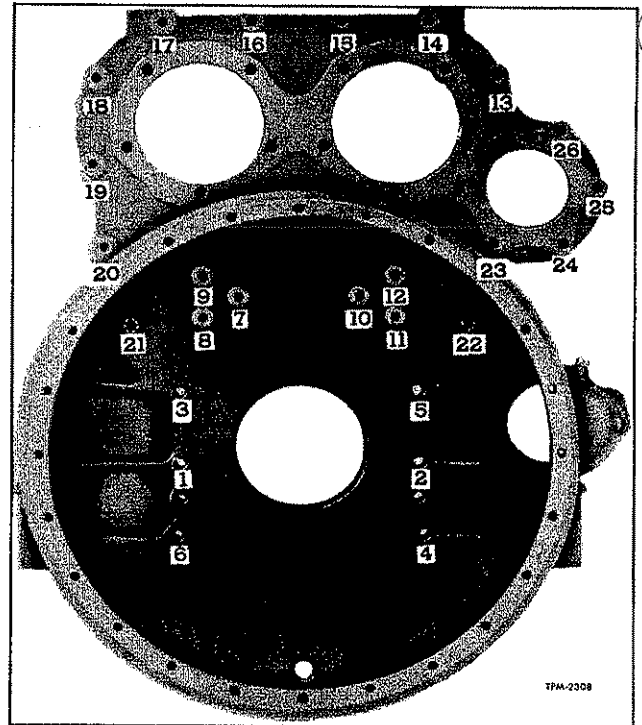
INSTALLATION

Refer to figure 27 for use of guide tools. Install flywheel housing as follows:

1. Position new gasket to bolting flanges of flywheel housing.
2. To prevent oil seal damage, be sure to install rear oil seal guide tool on the two dowels at rear end of crankshaft. Locate housing in place over dowel pins being sure that housing is fully seated, then install cap screws, bolts and washers.
3. The cap screws and bolts should first be tightened finger tight, then drawn down in the order shown in figure 28 until they are snug, finally tighten to recommended torque in sequence illustrated in figure 29. Be especially careful that cap screws numbered 1 through 6 (fig. 29) are tight since an oil leak at this point would necessitate complete disassembly to correct.
4. Use dial indicator mounted on crankshaft and

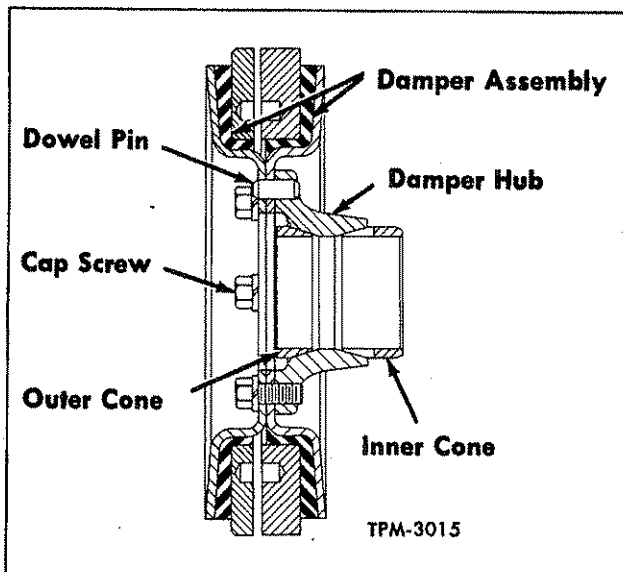
VIBRATION DAMPER**Figure 28—Flywheel Housing Initial Tightening**

check concentricity of housing pilot diameter, also mounting flange. The permissible concentricity between these surfaces and crankshaft axis is .0065"

**Figure 29—Flywheel Housing Final Tightening**

(.013" total indicator reading).

5. Reinstall flywheel as directed in FLYWHEEL AND CLUTCH PILOT section previously.

VIBRATION DAMPER**Figure 30—Sectional View of Rubber Vibration Damper**

Engines which operate in the higher speed ranges or under unusual conditions are equipped with a vibration damper 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.

Two types of damper assemblies are used, one of which is an elastic type and the other a fluid or viscous type. The elastic type consists of a rubber ring bonded to a heavy metal ring on one side and a stamped metal disc on the opposite side (fig. 30). The fluid type consists of a heavy metal disc suspended in fluid inside a sealed metal drum (fig. 31).

Each damper assembly is securely bolted and doweled to a hub. Hub assembly is accurately located on crankshaft by two tapered cones which support the hub. When fan hub or pulley is drawn up tight against outer cone by the bolt in end of crankshaft the cones, damper hub and pulley or fan hub are held rigidly in their correct location.

VIBRATION DAMPER

MAINTENANCE

The elastic type damper should be kept as clean and free of fuel and lubricating oils as possible as they are destructive to rubber.

Inspect hub to damper bolts at regular intervals to be sure they are tight.

At regular intervals inspect fan hub or pulley bolt in end of crankshaft to be sure it is tight. Any looseness of this bolt will allow cones to become loose and thus minimize effectiveness of vibration damper.

The fluid type damper is sealed; therefore, no servicing is required other than keeping the mounting bolts tight.

REMOVAL

The following procedures apply when engine is out of vehicle or with engine in vehicle and radiator assembly removed. Since several installation arrangements are used it is important that relative location and manner of installation be noted at time of removal so that reassembly can be correctly accomplished.

1. On coaches remove snap ring inside fan hub, then remove bolt, retainer and spacer. Remove fan hub using special puller.

2. On trucks, remove pulley retaining bolt and washer. Remove fan belt pulley using suitable puller.

CAUTION: Do not strike viscous type dampers with hammer, as damper will be useless and require replacement if it should be bent. Also damper is not repairable.

3. Remove cap screws and lock washers attaching damper assembly to hub, then remove damper from hub.

4. Strike the front face of the damper hub, near the outside diameter, a sharp blow with a heavy rubber hammer, to loosen outer cone wedged between the crankshaft and damper hub. After loosening in this manner, the cone may be removed from beneath damper hub with two screwdrivers at opposite sides of cone.

5. Pry against damper hub, using a bar between damper hub and crankshaft front cover. At the same time, strike opposite outer face with rubber hammer. Pull hub away from shaft.

6. Remove inner cone by inserting a small bolt or rod in the two puller holes provided in the cone.

INSPECTION

After removal and before damper is assembled to

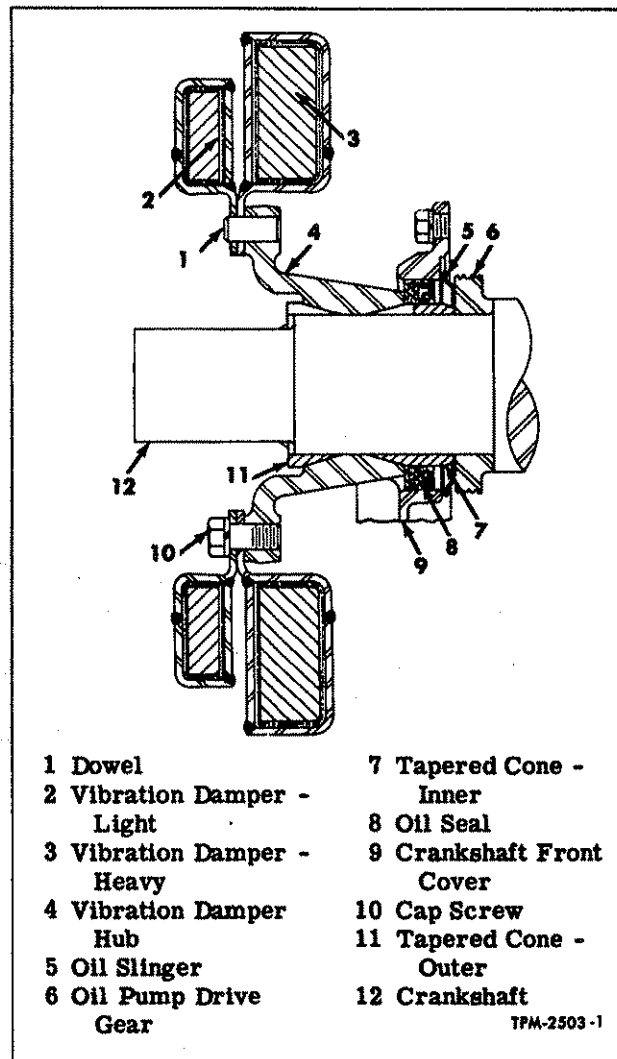


Figure 31—Sectional View of Fluid Vibration Damper

crankshaft, inspect to see that rubber is firmly bonded to the metal parts at each side, and that flanges are not bent. If rubber 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 with a new unit.

Viscous type dampers should be carefully inspected for any dents or nicks in outer surface damper. Should damper become bent it is not repairable and must be replaced.

Inspect both retaining cones (inside and outside diameters), damper hub, and crankshaft front end for "gall" marks or burrs. Remove slight scratches or burrs with emery cloth. If seriously damaged, the

CRANKSHAFT FRONT COVER

damper parts should be replaced and the crankshaft remachined.

INSTALLATION

1. Having carefully inspected each part, slide inner cone on crankshaft next to oil slinger, with tapered end of cone pointing toward front end of crankshaft.

2. Install damper hub with long end of hub toward crankcase.

3. Install outer cone over shaft and into hub of damper.

4. Place fan hub, or pulley, as case may be against outer cone and insert bolt into end of crankshaft.

5. Draw bolt up to correct torque then strike end of bolt with hammer and retorque.

6. Install damper assembly to damper hub, using cap screws and lock washers, also dowel pin.

CAUTION: Be sure that damper assembly is attached to hub in same manner as when disassembled, also that all bolts are tight.

CRANKSHAFT FRONT COVER AND OIL SEAL

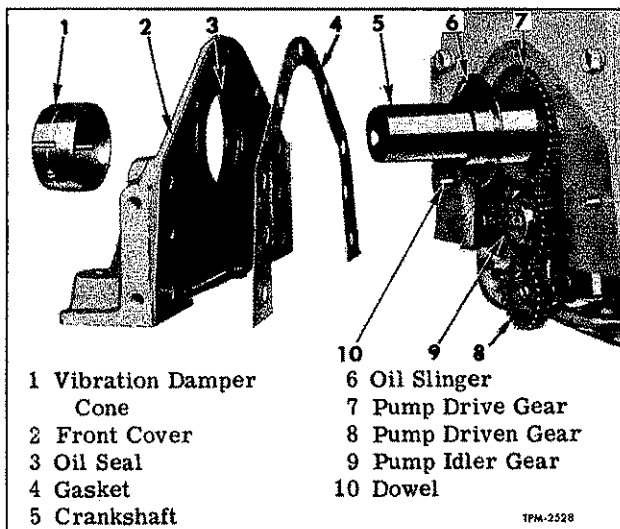


Figure 32—Crankshaft Front Cover Mounting

Crankshaft front cover, containing a spring loaded lip type oil seal, is attached to cylinder block front end plate with cap screws and locating dowels.

Oil seal in front cover bears against inner cone of vibration damper assembly. Front flange of oil pan is retained to crankshaft front cover flange with cap screws. Refer to figure 32 for cover and mounting details.

MAINTENANCE

Front cover and oil seal assembly must be visually checked periodically for evidence of oil leaks that may occur at oil seal, oil pan front flange gasket, or between cover and front end plate, also between plate and crankcase.

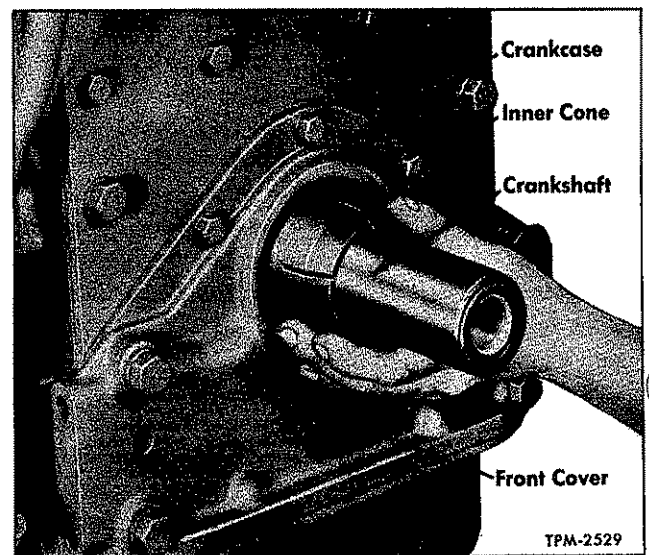


Figure 33—Installing Oil Seal Spacer (Inner Cone)

REMOVAL

Crankcase front cover may be removed from cylinder block front end plate in the following manner:

After oil pan, fan hub, pulley, or pulley and vibration damper, have been removed as instructed in respective sections of this manual, the cover may be removed by removing capscrews attaching cover to front end plate. Do not damage oil seal when removing cover from crankshaft.

INSPECTION

1. Remove all traces of old gasket from cover and oil pan bolting flange.
2. Inspect cover for cracks and warpage. Replace

CRANKSHAFT FRONT COVER

if necessary.

3. If oil seal is damaged, replace.
4. Inspect oil pan bolting flange. Flange must be flat and cap screw holes clean.

INSTALLATION

1. Position new gasket to bolting flange of crankshaft front cover, and attach to front plate with lock washer and cap screws finger tight only. Do not tighten cap screws until after front spacer or vibration damper inner cone is installed.

2. Replace the spacer or vibration damper inner (rear) cone, on front end of crankshaft next to oil slinger (fig. 33).

NOTE: THIS SPACER OR CONE MUST NOT BE PUT IN PLACE UNTIL AFTER FRONT COVER IS IN PLACE, OTHERWISE THE OIL SEAL IN THE COVER MAY BE DESTROYED.

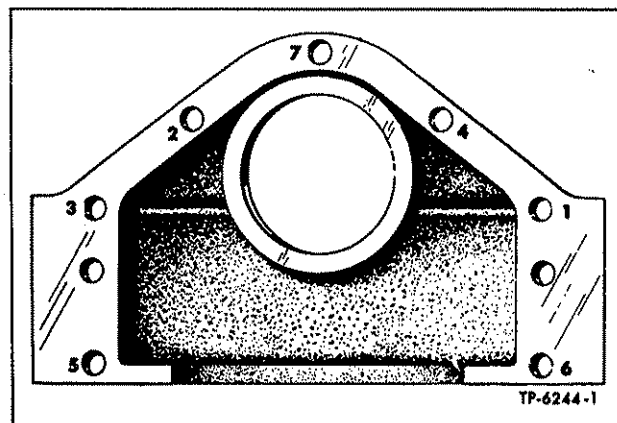


Figure 34—Crankshaft Front Cover Tightening Sequence

3. Tighten cover cap screws to proper torque using tightening sequence illustrated in figure 34.

PISTONS AND CONNECTING RODS

PISTONS, PINS AND RINGS

Malleable iron pistons (fig. 35) with extra long skirts, accurately ground the full length, are plated below compression ring grooves with a coating of tin, which permits a closer fit in cylinder, eliminating scoring and prolonging life of piston.

NOTE: Two types of piston and piston ring arrangements are being used, as illustrated in figure 36. Standard type piston incorporates a conventional arrangement of four compression rings above piston pin. Piston and ring arrangement, used on "E" series engines, consists of three conventional compression rings above piston pin and a "Fire Ring" near top of piston. Oil control ring arrangement near bottom of piston skirt is same for both type pistons.

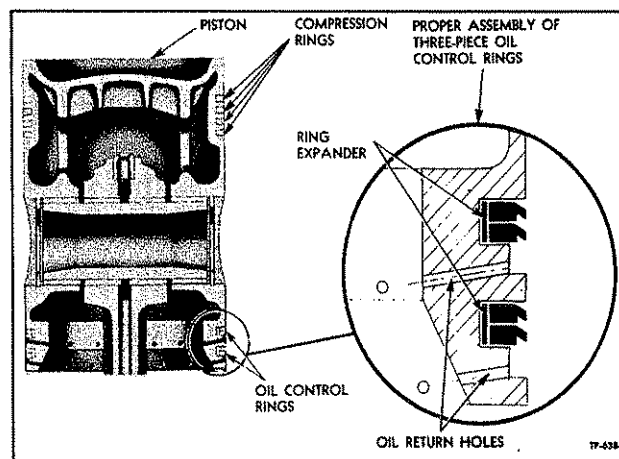


Figure 35—Piston and Piston Ring Assembly

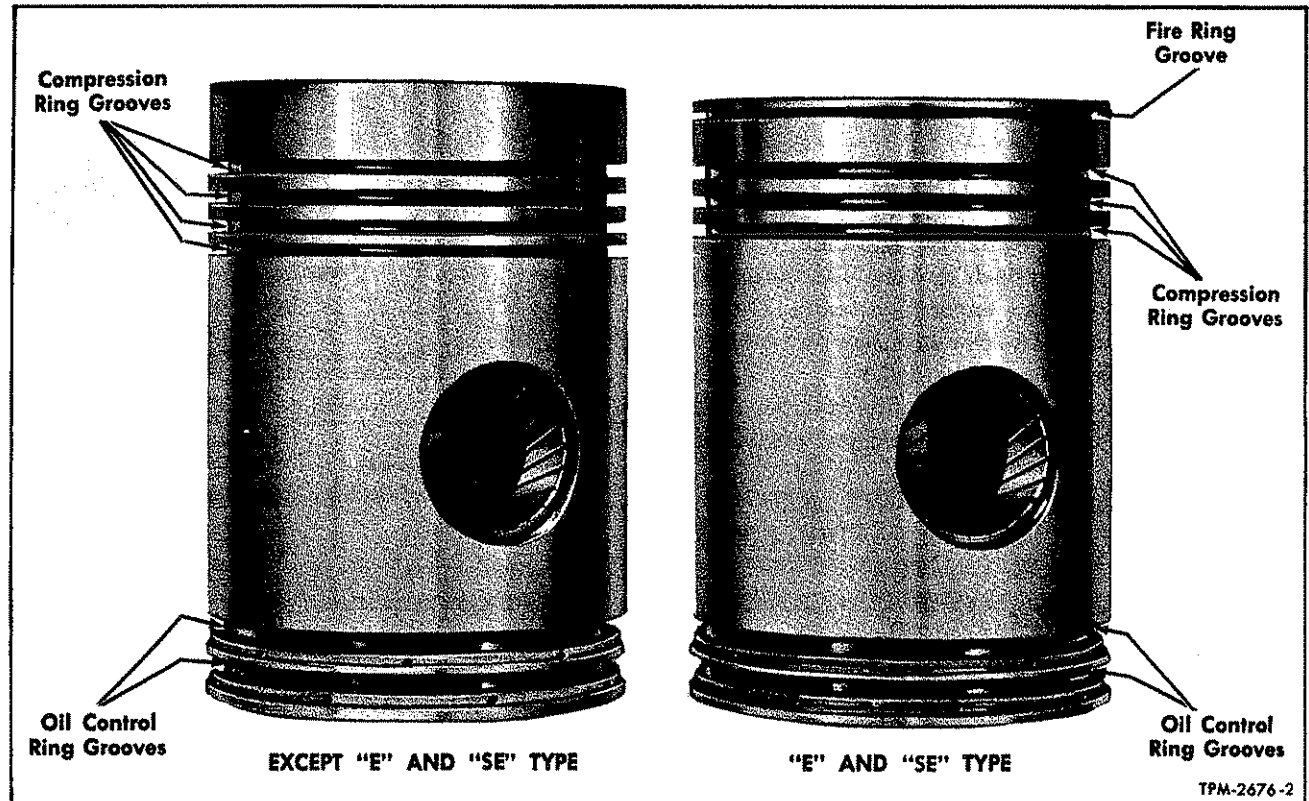
The top of the piston forms the combustion chamber, and is designed to displace the air into close proximity to the fuel spray. The under side of the piston head is strongly reinforced with circular ribs, to provide maximum strength. The ribs are also connected to piston pin bosses for better stress distribution. The ribbed head is cooled by lubricating oil forced from spray jet on top of connecting rod.

Each piston boss is lined with a bronze bushing which serves as a bearing for piston pin which floats in piston and connecting rod. Bushing has helical oil grooves for passage of oil from connecting rod

bushing. Piston pin is held in piston with a retainer at each side of piston. Retainer prevents lubricating oil, which returns from the sprayed piston head and the grooves in piston bushings from reaching cylinder walls.

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

Each piston is fitted with six rings of the butt joint

PISTONS AND CONNECTING RODS**Figure 36—Piston Assemblies**

type. Four $\frac{1}{8}$ " wide compression rings with chrome plated face, are placed above the pin, and two $\frac{3}{32}$ " wide special oil control rings and expanders are used in each of the two grooves below the piston pin.

CONNECTING RODS AND BEARINGS

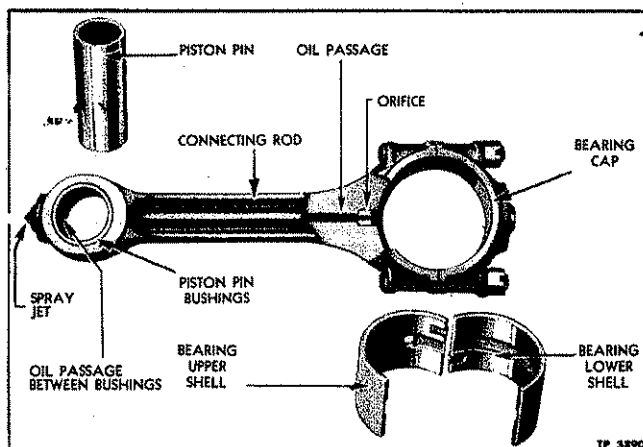
Each connecting rod (fig. 37) is made of drop-

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 a plug which meters oil through the rifle-drilled connecting rod. Connecting rod bearing shells are of the precision type, without shim adjustment.

The upper and lower halves of the connecting rod bearing shells are not interchangeable. The bearings however are replaceable without machining.

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 oil holes in crankpins, thereby providing a constant supply of lubricating oil through the hollow connecting rod to the piston pin bearings and spray jet.

**Figure 37—Connecting Rod, Piston Pin, and Bearing Assembly**

PISTONS AND CONNECTING RODS

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 $\frac{3}{16}$ " between the inner ends of bushings which register 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 piston pin floats in the connecting rod bushings and piston bushings.

The connecting rod assembly as serviced includes the lower bearing cap and retainers (less bearing shells), the rifle drilled hole plug, spray jet, and the upper piston pin bearings pressed in place and bored to size. The spray jet and rifle drilled hole plug are not removable.

The bearing shells (upper and lower) are replaceable without machining, and the upper piston pin bushings are also replaceable. Bearing shells are available in .002", .010", .020" and .030" undersizes.

PISTON AND CONNECTING ROD REMOVAL.

The piston and connecting rod may be removed as outlined below. These procedures apply when engine is in overhaul stand or with engine in vehicle, with cylinder head, oil pan, and oil pump removed as directed in respective sections of this manual.

INSPECTION BEFORE REMOVAL

Before removing the piston and connecting rod assemblies, check for any excessive looseness of the piston in cylinder liner. Check for excessive end play of connecting rods on crankpins. End play is minimum .006", maximum .012". Results of inspection should be noted for use when assembling or repairing connecting rods.

IDENTIFICATION

The piston and connecting rod are so closely related from a service standpoint that one cannot be entirely separated from the other.

Connecting rods and caps are stamped with cylinder number in which they are installed.

NOTE: This number is stamped on the blower side. If number is not visible use a numbering stamp to identify rod. Do not file or cut marks on rod.

REMOVAL

1. Remove carbon from the upper inside diameter of the cylinder liners.

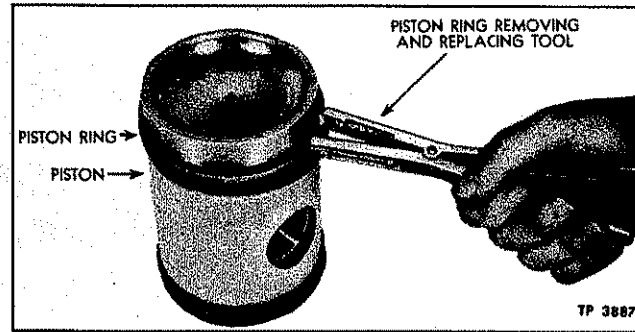


Figure 38—Removing and Installing Piston Ring with Tool

2. Remove 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 cylinder block. Piston cannot be removed from bottom of cylinder block.

DISASSEMBLING PISTONS

1. Secure connecting rod in a vise equipped with soft jaws. Remove piston rings from pistons using remover and replacer tool in manner illustrated in figure 38.

2. Remove piston pin retainer. It will be necessary to pierce retainer with chisel. Remove piston pin from connecting rod and piston. Place piston pin inside of piston from which it was removed.

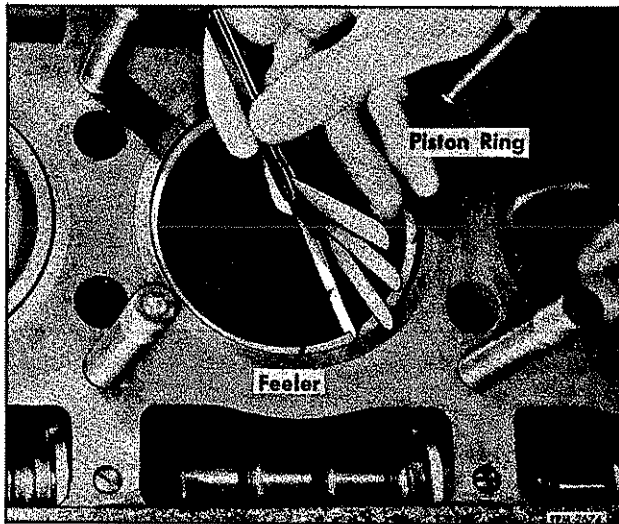
CLEANING AND INSPECTION

PISTON

Remove gummy deposits from piston walls and ring grooves with fuel oil or gasoline.

NOTE: If fuel oil or gasoline will not remove deposits, parts may be cleaned by using a chrome cleaner or its equivalent, and then blown off with dry compressed air. After cleaning the piston skirt, the piston rings and ring grooves should be thoroughly inspected. The tin coating extends from bottom of lower compression ring groove to bottom of piston and presence of this coating of soft metal, will therefore indicate the 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. Observe piston for evidence of excessive heat and scoring. Discard piston if such

PISTONS AND CONNECTING RODS**Figure 39—Measuring Piston Ring Gap**

conditions are evident.

Carefully measure piston out-of-round, taper, and width of ring grooves. Refer to **SPECIFICATIONS** section of this manual for dimensions.

The standard clearance between cylinder liner and piston skirt is given in **SPECIFICATIONS** section of this manual. The upper part of the piston (above the lower compression ring) is not tin-plated and does not touch the cylinder wall. If this part of piston shows any coating of hard carbon, rings must be removed and piston surface, as well as ring grooves, thoroughly cleaned using a ring groove cleaning tool or section of discarded piston ring, ground for this purpose. Open oil return holes in lower grooves of piston skirt, using a $\frac{3}{32}$ " drill in a hand bit. 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.

PISTON PIN BUSHING

Inspect and measure the inside diameter of the piston pin bores or bushings. If bushing is worn excessively, install new bushing. If bushing bore in piston is damaged, install new piston.

PISTON RINGS

The presence of the original tool marks on the piston ring surfaces indicates the general absence of wear. Rings should be inspected for free fit in the grooves, side clearance, and wear.

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.

CONNECTING ROD

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 for further use. Refer to **SPECIFICATIONS** section of this manual for fits and tolerances. Such an inspection would include the following:

1. Measure the outside diameter of piston pin to determine amount of wear.
2. Measure inside diameter of the bushing in the connecting rod to determine amount of wear. If bushings show excessive wear, they may be replaced, and reamed to size as outlined below. Worn clearances up to .010" are permissible.
3. Inspect restriction plug hole at lower end, and the spray jet at upper end of connecting rod, and blow dry compressed air through rifle drilling in rod. Be sure all oil passages are clean and free of obstructions.
4. The connecting rod bearing load is on upper half of shell only. Any wear, therefore, will show only on upper half of shell. If connecting rod bearing trouble is suspected, upper halves of 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 backs of shells will indicate that shells have been moving in their supports, and are unfit for further use. If any of above conditions exist, the shells must be replaced.

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 figure 39. 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 also oil ring gap is given in **SPECIFICATIONS** section of this manual. The gap may be changed by using a thin, flat, fine mill file, however chrome plated compression rings must not be filed.

PISTONS AND CONNECTING RODS

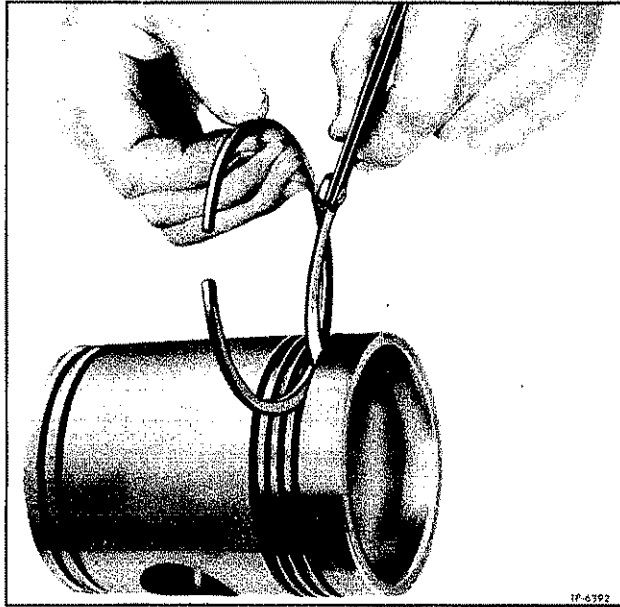


Figure 40—Measuring Piston Ring Clearance in Piston Groove

Position each ring in its respective groove (fig. 40) and check ring to groove clearance with feeler gauge. Proper clearance is given in **SPECIFICATIONS** section of this manual. Replace piston when maximum dimensions are exceeded.

After the proper gap has been fixed, the rings may be installed on the piston with tools as shown in figure 38.

NOTE: The oil rings are the three-piece type and should be placed in the grooves as instructed in replacement kit and illustrated in figure 35. 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 engine oil to the piston wall, rings, and lower connecting rod bearings before replacing in cylinder block. See **CYLINDER LINER** section previously in this manual for removing glaze from liner when installing new piston rings.

PISTON PIN BUSHING REPLACEMENT (At Connecting Rod)

REMOVAL

Piston pin bushings may be removed from the connecting rod with remover and replacer tools shown in figure 41 in the following manner:

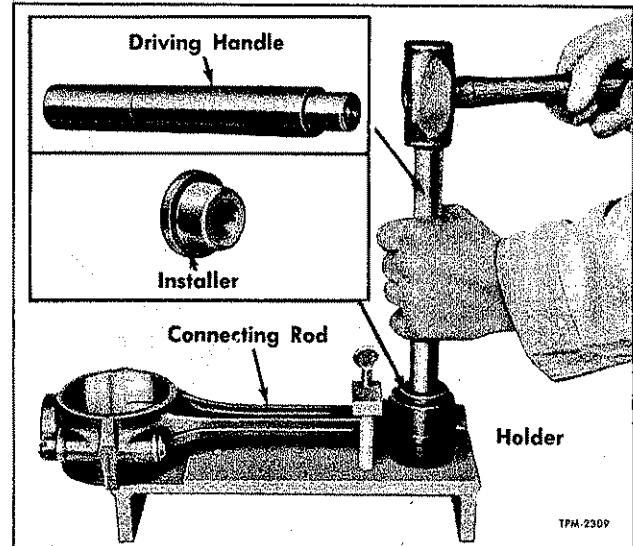


Figure 41—Removing or Installing Piston Pin Bushings in Connecting Rod

1. Rest connecting rod on block, and hold in place with thumb screws.
2. Drive bushings from rod, using driving handle in manner illustrated in figure 41.

INSTALLATION

Piston pin bushings are replaced in the connecting rod with the same tool used for their removal (fig. 41).

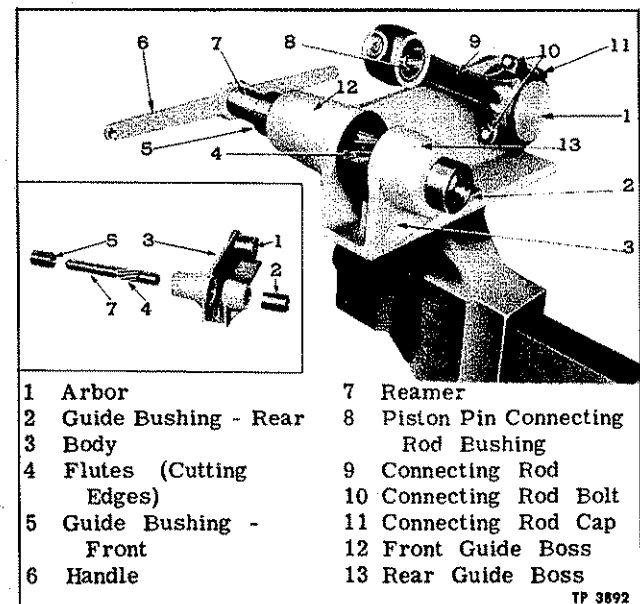


Figure 42—Preparation for Reaming Pin Bushings in Connecting Rod

PISTONS AND CONNECTING RODS

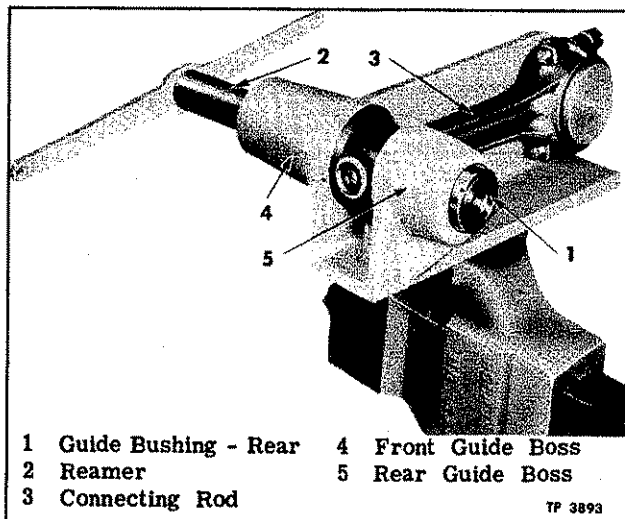


Figure 43—Reaming Piston Pin Bushings in Connecting Rod

NOTE: Split in bushing must be toward top or upper end of connecting rod.

Each bushing is pressed into the rod until outer end of bushing is flush with outer edge of rod, leaving an oil space of approximately $\frac{3}{16}$ " between the bushings.

REAMING

Since inside diameter of replacement bushing is smaller than final finished diameter, bushing must be reamed after pressing into place. This operation is accomplished with tool as illustrated in figures 42 and 43, respectively. Figure 42 illustrates how connecting rod is placed on fixture preparatory to ream-

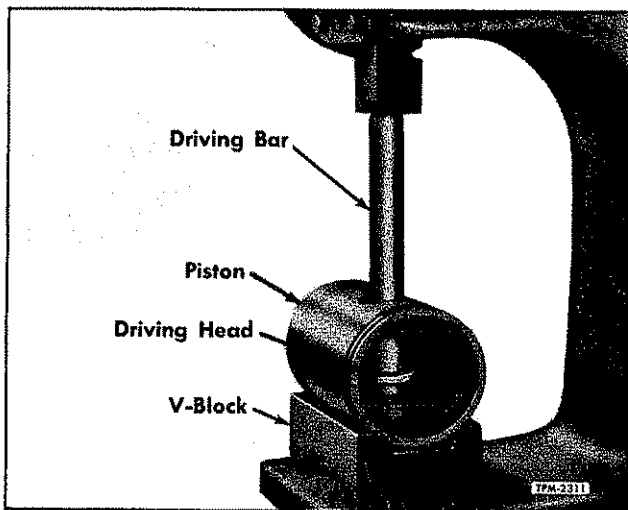


Figure 44—Installing Pin Bushings in Piston

ing. Figure 43 shows actual reaming operation.

1. Place connecting rod over arbor (1) on fixture body (3), and draw bearing cap up tight.

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

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

4. 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.

5. After reaming, inspect for good bearing in bushings, with a very light coating of prussian blue, and slide a standard piston pin through the bushings to check for clearance. If bushings have been properly reamed, the clearance will be as indicated in SPECIFICATIONS section of this manual.

PISTON PIN BUSHING REPLACEMENT (At Piston)

REMOVAL

Piston pin bushings may be removed from the piston with remover and replacer tools, as illustrated in figure 44, and in the following manner.

1. Place piston on holder, so that bushings align with hole. Install remover into bushing at inside of piston, then install handle through opposite bushing and into remover. Refer to figure 44.

2. Press bushing from piston, then repeat above operation at opposite piston bushing.

INSTALLATION

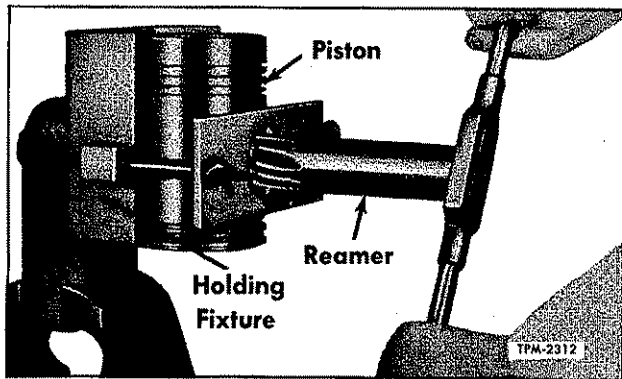
1. Install spacer in hole in piston holder, then position piston in holder with spacer protruding into bushing hole.

2. Install bushing on installer, then slide inside piston and over hole.

3. Insert handle through upper bushing bore and into installer. **NOTE:** Split in bushing must be toward bottom, or away from piston head. Press bushing until it bottoms on spacer, which should properly position bushing.

4. Repeat above operations at opposite bushing.

5. Inspect bosses inside piston and remove any metal chips. Inner edge of bushing must be flush with piston boss.

PISTONS AND CONNECTING RODS**Figure 45—Reaming Piston Pin Bushings in Piston****REAMING**

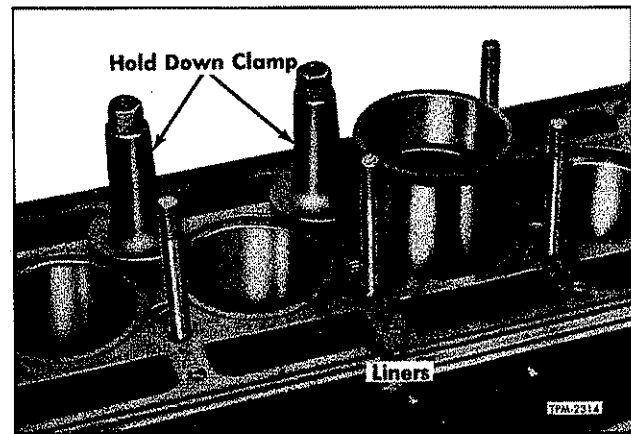
Since the inside diameter of replacement bushings is smaller than the final finished diameter, the bushings must be line reamed after being pressed into place. Suitable fixture is available for this operation as shown in figure 45.

1. Place holding fixture in vise (fig. 45).
2. Place piston in fixture with piston bushing and hole in fixture in alignment. Place clamping bar over piston and install wing nuts.
3. Slide reamer through piston bushing until reamer pilot engages hole in fixture. Tighten wing nuts until clamping bar holds reamer and fixture in alignment.
4. Turn reamer clockwise with a smooth uniform motion. **DO NOT** force reamer too hard as better results will be obtained when moderate pressure is used. Continue turning until reamer bottoms.

FITTING PISTON

Measurements and fitting of piston to cylinder liner should be accomplished while liner is installed in cylinder block. Never check piston-to-liner clearance on the bench, since the reading is false. Fitting should always be performed with parts and room at a temperature of 70°F. Install cylinder liner hold-down clamp in manner illustrated in figure 46.

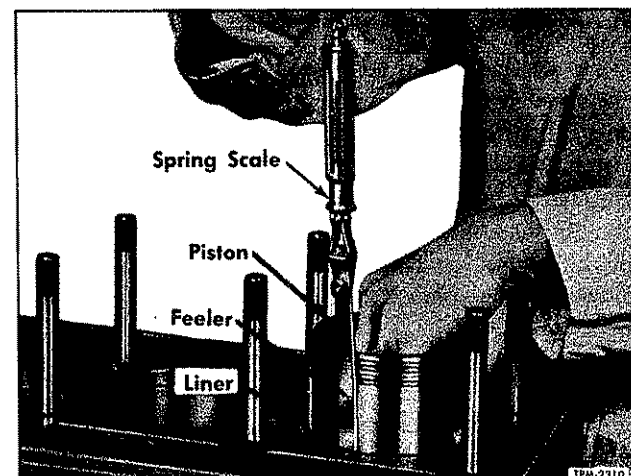
Pistons are furnished in standard and oversizes. Liners are furnished with standard inside diameter only, however they are available with oversize outside diameter. Oversize pistons are available in .010", .020", and .030"; also cylinder liner oversizes are .005", .010", .020", and .030". Refer to CYLINDER LINER section previously in this manual for liner installation fitting instructions, also to SPECIFICATIONS section for piston and liner fits and tolerances.

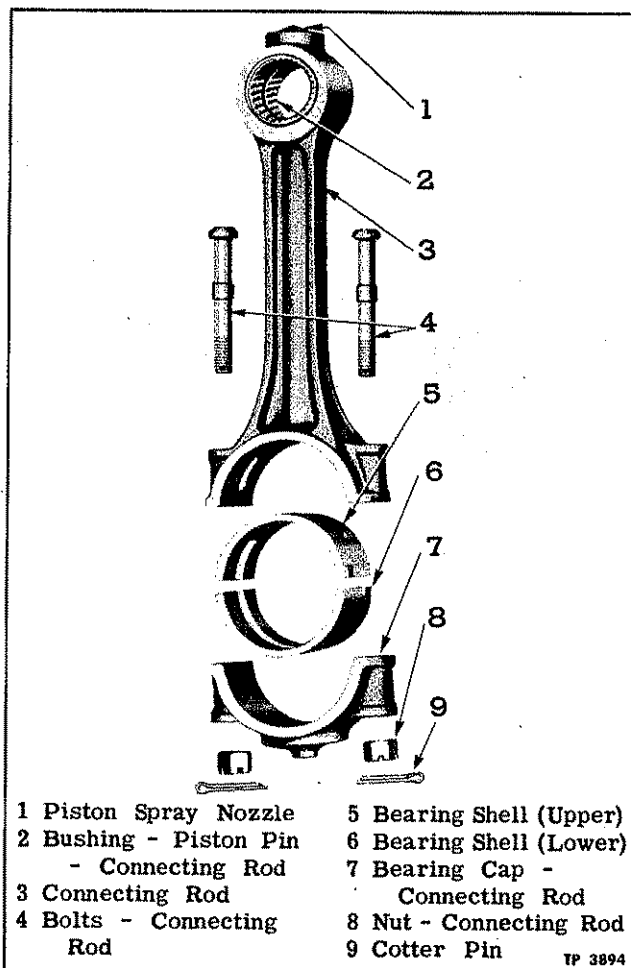
**Figure 46—Using Cylinder Liner Hold-Down Clamp****FITTING STANDARD PARTS**

Whenever new pistons are being installed in new liners it is important that they be fitted, since other factors not readily apparent may affect the fit of these parts. Even though standard pistons and liners are being installed it is also necessary to fit the liner to cylinder block bore in manner described in CYLINDER LINER section previously in this manual.

FITTING OVERSIZE PARTS

The piston must be fitted in cylinder liner with piston upside down (fig. 47). Select a ribbon feeler ½" wide and 15" long, attached to a spring scale. Insert feeler in cylinder sleeve at side, 90° opposite to piston pin axis. Insert piston into liner until oil ring grooves are above liner. Pull spring scale and

**Figure 47—Measuring Piston to Cylinder Liner Clearance**

PISTONS AND CONNECTING RODS**Figure 48—Connecting Rod Assembly Details**

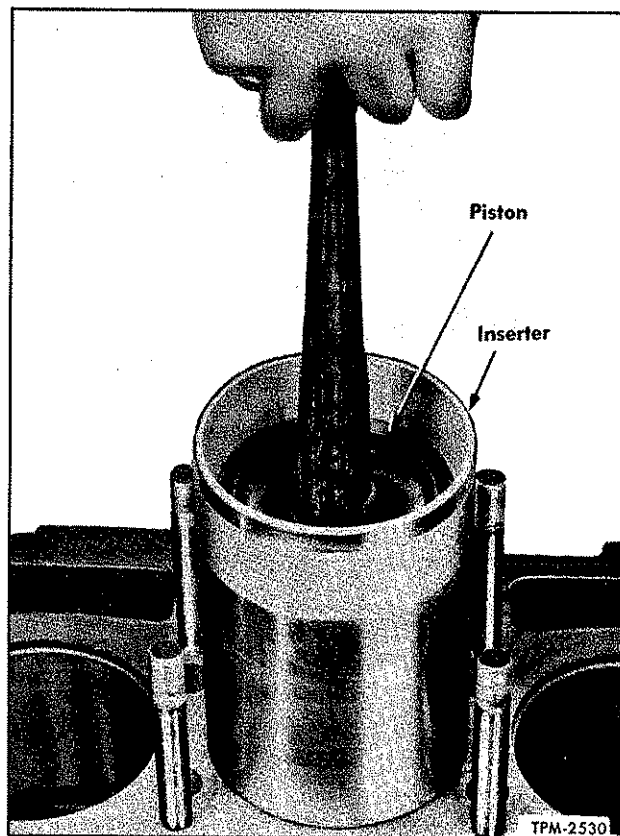
note tension necessary to withdraw ribbon feeler. Tension of 6 lbs. on a feeler indicates that piston to liner clearance is .001" greater than feeler being used.

An alternate method of checking piston to liner clearance is to place a $\frac{1}{8}$ " wide feeler ribbon in the liner, then insert a piston in the liner. When the piston will slide slowly to the bottom of the liner, the clearance between liner and piston will be .001" greater than the thickness of the feeler being used. If the piston or feeler binds, examine feeler and piston for smoothness and freedom from burrs.

ASSEMBLING ROD TO PISTON

1. Install one piston pin retainer, using recommended tool to seat retainer in place.

2. Locate connecting rod in place in piston in line with pin bushings. Lubricate pin with clean engine oil, then slide pin into position. Pin should

**Figure 49—Installing Piston and Rod in Liner Installed in Block**

slip readily into place without forcing, if fitted correctly.

3. Install opposite retainer in same manner as previously described above.

CAUTION: Do not drive too hard on retainer as piston pin bushing may be driven inward so as to interfere with connecting rod or retainer may interfere with pin.

PISTON AND CONNECTING ROD INSTALLATION

The lower end of each connecting rod, as well as the caps, are stamped on one side—"1," "2," "3," etc. These numbers identify caps with rods, and show the particular cylinder in which each rod is used. These locations should always be maintained when rebuilding an engine. The marked side of rod must always be on blower side of cylinder block (fig. 48).

1. Stagger piston ring gaps around piston, apply clean engine oil to piston and rings. Position piston inserter over cylinder liner with large end of taper

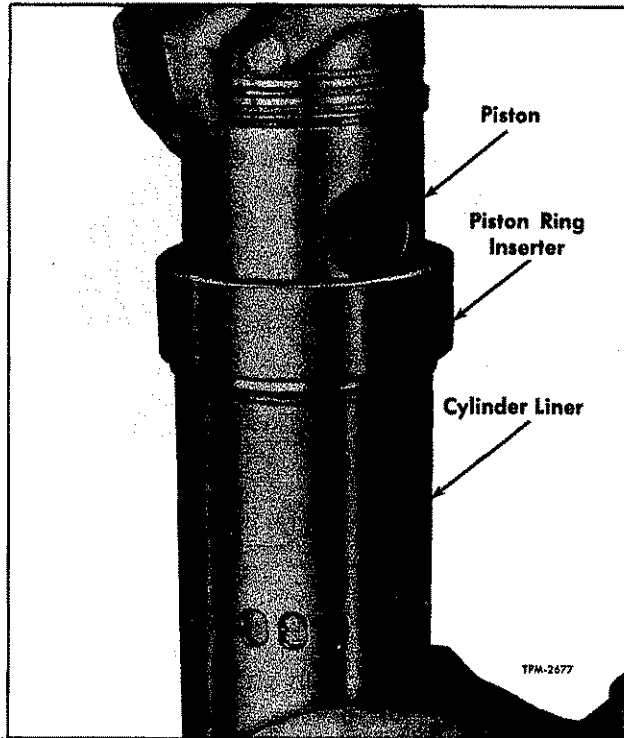
PISTONS AND CONNECTING RODS

Figure 50—Installing Piston in Cylinder Liner

up. Turn piston and rod assembly so that identification mark on lower end of connecting rod is toward blower side of cylinder block.

2. Align lower end of rod with crankshaft before pushing piston in cylinder. Push piston in the cylinder bore by tapping on upper end of piston with a wood block (fig. 49). Hold compressor tool down tight on top of liner so rings cannot snap out before entering liner bore.

3. Piston and connecting rod assembly can also be installed in liner as a bench operation (fig. 50) with wood, heavy cardboard, or cloth protecting liner. Insert piston into the large end of piston inserter. Align piston and inserter with top of liner and press the piston into liner with a steady push until piston and rings are completely within the liner.

4. Turn assembly so that identification marks on

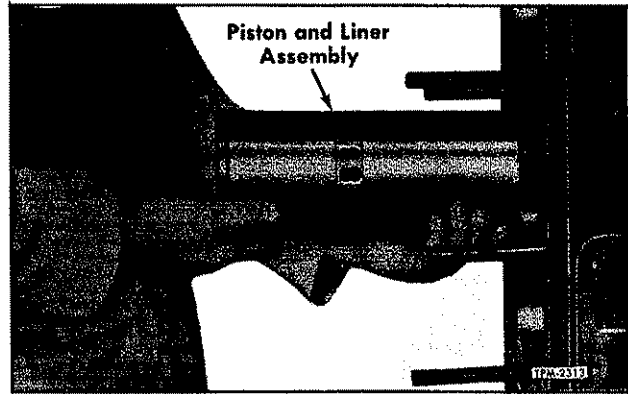


Figure 51—Installing Piston, Rod, and Liner Assembly in Cylinder Block

connecting rod are on blower side of blocks, then push (fig. 51) entire assembly into cylinder bore.

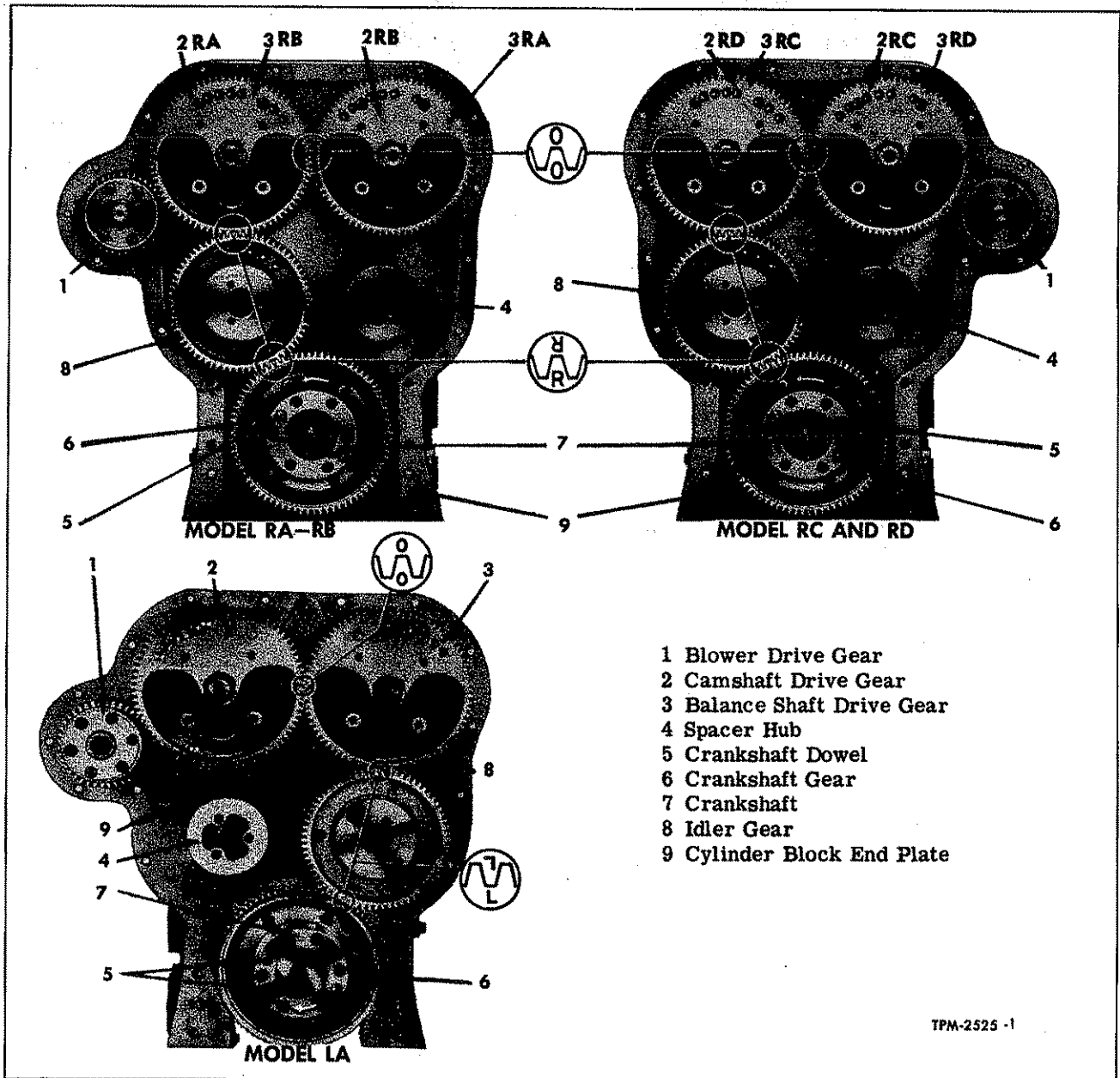
5. Clean and lubricate each connecting rod crankshaft journal. Install upper bearing shell with the one short groove at each parting-line in the connecting rod (fig. 48) then position rod onto crankshaft journal.

6. 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; then position cap and shell in place.

7. Lock cap securely in place with bearing cap bolts and nuts, tighten to recommended torque then install cotter pins.

8. Install lubricating oil pump assembly, oil pan, and cylinder head as directed in respective sections of this manual.

9. After installing new pistons, rings, main bearings, or connecting rod bearings, the engine should be operated on a run-in schedule, as instructed in **ENGINE RUN-IN PROCEDURE** section later in this manual.

GEAR TRAIN**GEAR TRAIN****Figure 52—Gear Train and Timing Marks**

A train of five helical gears, illustrated in figure 52, is located at rear of engine, and is completely enclosed between cylinder block end plate and flywheel housing or gear train cover.

A gear bolted to crankshaft flange drives camshaft and balancer shaft gears, as well as the blower and accessory drive gear, through an idler gear mounted between the crankshaft and either the camshaft or

balancer shaft gear.

Camshaft gear and balancer shaft gear mesh with each other and run at same speed as the crankshaft. Either one of these gears may be driven from crankshaft through the idler gear. Such drive arrangement depends upon crankshaft rotation. Camshaft and balancer shaft gears are keyed to their respective shafts, and held securely against a

GEAR TRAIN

shoulder on shaft by a nut and retainer. While camshaft and balancer shaft may be placed on either side of cylinder block the right-hand gear (L.H. Helix) always remains on the right side, and the left-hand gear (R.H. Helix) is always installed on the left side.

The idler is mounted between the crankshaft gear and camshaft or balance shaft gear depending upon whether the engine is an "L" (counterclockwise) or an "R" (clockwise) crankshaft rotation. Idler gear is mounted on opposed roller bearings and stationary hub attached to cylinder end plate and crankcase.

Blower drive gear is driven by the camshaft or balancer shaft gear depending upon which side of the engine the blower is mounted. Gear is supported by a hub which is assembled into a housing and attached to front side of cylinder block end plate. Arrangement of blower drive gear is shown in figure 53 and details in figure 54.

INSPECTION

Whenever accessible, or at regular major inspection intervals as established by the operator, careful inspection should be made of the following items in the gear train.

1. Visually inspect all gears to be sure that teeth are not chipped, burred or rough.
2. Check backlash between each mating gear. Gears that are worn .005" more than new limit maximum should be replaced. Refer to SPECIFICATIONS for new limits.
3. Check tightness of bolts attaching gear to crankshaft, also those attaching blower flexible drive coupling and gear to drive hub.
4. Check tightness of nuts attaching cam and balance gears to their respective shafts. This is especially important since these gears are also used to drive accessory units such as air compressor, generator, etc. Gear nut retainers should also be secure.
5. Idler gear should be removed, disassembled, and inspected as directed under "Idler Gear Assembly" later in this section.

CRANKSHAFT GEAR

Crankshaft gear, mounted against flange at rear of crankshaft, is slip fit and is held securely in place by six cap screws and lock washers.

REMOVAL

1. Remove flywheel housing and gear train cover

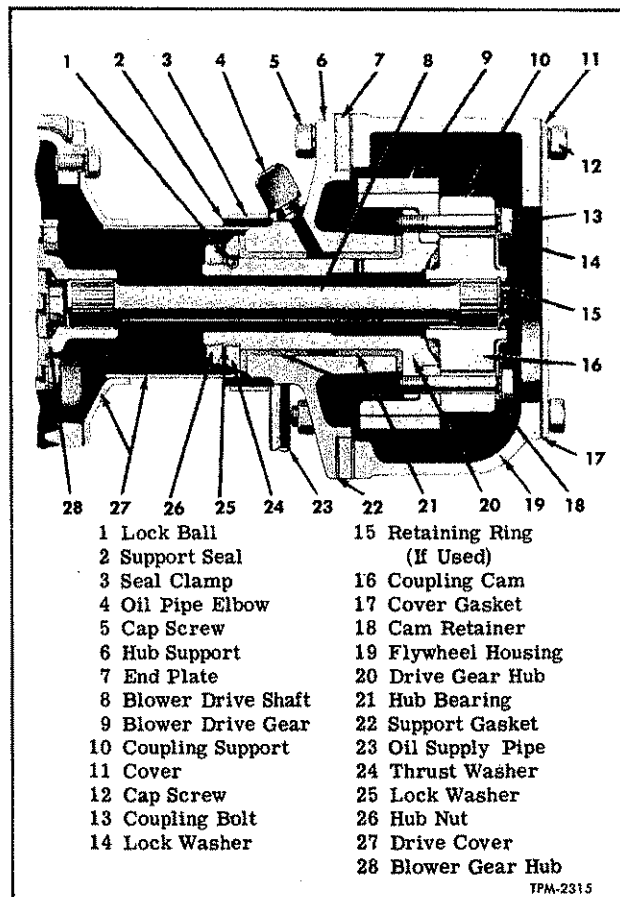


Figure 53—Typical Blower Drive Assembly

as directed in FLYWHEEL HOUSING AND GEAR TRAIN COVER section previously in this manual.

2. Remove six cap screws and lock washers attaching gear to crankshaft.

3. Gear will ordinarily slide off, however suitable puller should be used whenever necessary.

INSTALLATION

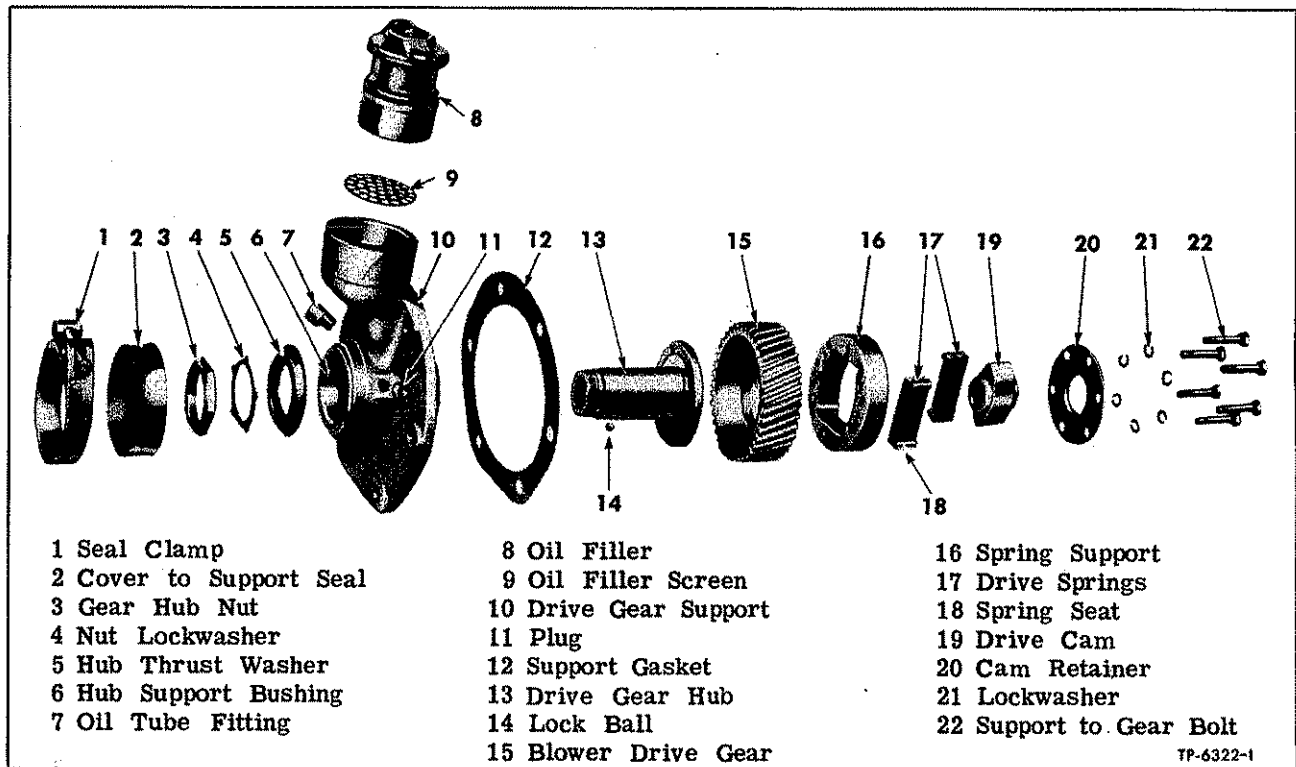
1. Note that one bolt hole is slightly offset and correctly locates gear to crankshaft.

2. Position gear onto crankshaft with flat finished face of gear toward cylinder block. Rotate crankshaft and gear until timing mark "R" or "L" matches corresponding mark on idler gear (fig. 52).

3. Slide gear against crankshaft flange noting that offset holes in crankshaft flange and gear are in alignment and that timing marks match.

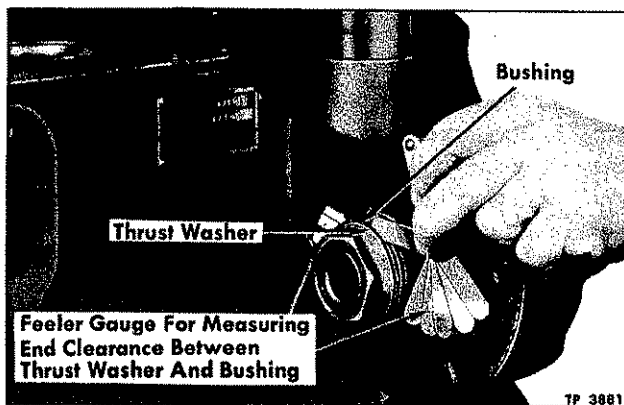
4. Install cap screws and new lock washers, then tighten to specified torque.

5. Install flywheel housing and gear train cover as directed in FLYWHEEL HOUSING AND GEAR TRAIN COVER section previously in this manual.

GEAR TRAIN**Figure 54—Details of Blower Drive Assembly****BLOWER DRIVE GEAR ASSEMBLY**

Following text covers only the blower drive gear, coupling, hub and housing assembly, as illustrated in figures 53 and 54. Blower rotor drive gears are illustrated and described under **BLOWER in AIR INTAKE SYSTEM** section of this manual.

Coupling assembly consists of support, 42 springs, four seats and cam (fig. 54)

**Figure 55—Checking End Clearance of Blower Drive Gear****REMOVAL**

Following procedures apply when removing blower drive gear assembly. Flywheel housing and gear train cover may be removed, if desired, as described under **FLYWHEEL HOUSING AND GEAR TRAIN COVER** section previously in this manual.

1. Remove cap screws and nuts from through bolts, then remove cover and gasket at flywheel housing.

2. Use a pair of sharp nose pliers and compress snap ring retaining drive shaft in flexible coupling.

3. Pull drive shaft out of flexible coupling assembly.

4. Remove six cap screws and lock washers securing flexible coupling assembly to blower drive gear. Remove retainer and coupling assembly through opening in flywheel housing.

5. Loosen blower from cylinder block and also from the various other attaching points, as described in Blower section of this manual; then move blower assembly forward sufficiently to permit removal of blower drive gear assembly.

6. Before loosening lock nut on gear hub, check end clearance between gear hub bushing and thrust washer (fig. 55). If end clearance is excessive, this

GEAR TRAIN

condition alone is sufficient reason for renewing the inner bearing assembly. Specified end clearance between gear hub and thrust shoulder of hub bushing is given in **SPECIFICATIONS** section of this manual.

7. If gear has not been removed from hub and still engages either camshaft or balance shaft gear, the ears on lock washer may be straightened and lock nut loosened before support is completely loosened from cylinder block end plate. If gear was previously removed, loosening of lock nut may follow removal by holding assembly in vise.

8. Loosen nuts at each end of oil line leading from cylinder block to blower drive gear housing, then remove oil line.

9. Remove cap screws holding housing to cylinder block end plate, then tap the assembly forward from end plate to complete removal.

DISASSEMBLY

If blower drive gear assembly is to be disassembled for inspection or to change any parts, the following procedures apply:

1. Remove the previously loosened lock nut, lock washer, lock ball, and thrust washer from end of gear hub; then withdraw hub from hub support.
2. If bearing support is to be changed, remove oil line connection.
3. Press drive gear from gear hub.
4. If inspection indicates, necessity remove bushings from drive gear support.
5. Disassemble flexible coupling assembly by removing cam, springs, and spring seats from coupling.

INSPECTION

1. Inspect inside diameter and thrust faces of bushings in blower drive gear hub bearing support. Inspect outside diameter of drive gear hub at bearing surfaces (journals) for wear. The proper clearance between bushings and hub journal is listed in **SPECIFICATIONS** section of this manual and must not exceed maximum by more than .0025".
2. Bearing support bushings are diamond-bored in place; therefore, in case of bushing failure or if inspection shows bushings or journals worn in excess of .005", a new support and bushing assembly must be installed.
3. Inspect serrations on blower drive shaft and if worn so that appreciable backlash is felt when shaft is inserted into flexible coupling cam or blower timing gear drive flange, a new shaft must be used.
4. Inspect driving springs and cams of flexible

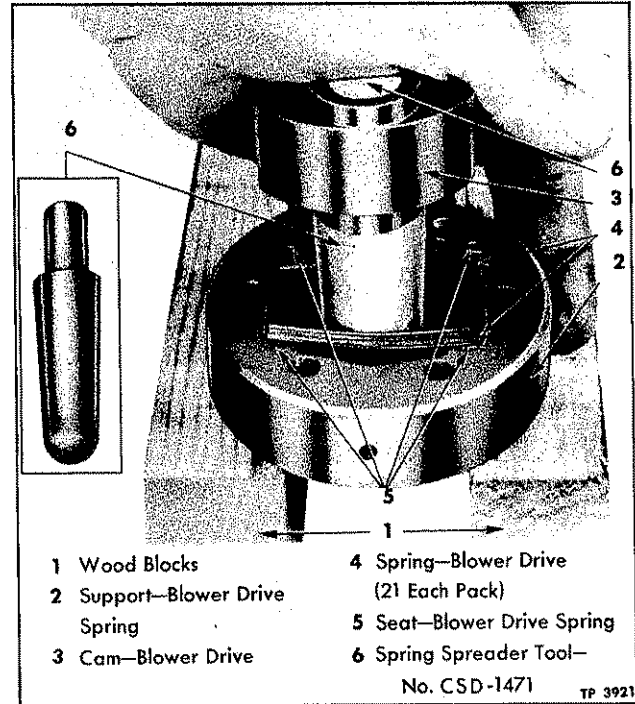


Figure 56—Inserting Blower Drive Cam in Shim Pack with Spreader Tool

couplings. Springs must be intact and cams not worn.

5. Oil holes must be open and cavities free from dirt.

REASSEMBLY

The relative positions of all parts constituting the blower drive gear assembly are shown in figure 53. All parts having been cleaned and inspected, they may be assembled as follows: Reference numbers following refer to figure 54.

1. Coat outside diameter of drive gear hub (13) with engine oil, then slide hub into support (10) from rear.
2. Install locking ball (14) into gear hub then install thrust washer (5) in place over ball, with large diameter flat face of washer next to thrust face of bushing.
3. Prevent hub turning by inserting bolts into two holes in hub; then holding with a bar. Install a new lock washer (4) next to thrust washer, and tighten lock nut until clearance (fig. 55) between thrust washer and bearing flange is as given in **SPECIFICATIONS** section of this manual. Bend the ears of lock washer against flats on nut to prevent nut loosening.
4. Tap blower drive gear (15) onto hub. Flat finished face of gear must be away from bearing

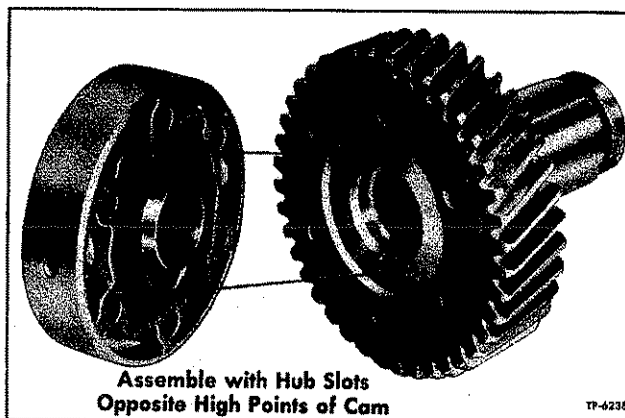
GEAR TRAIN

Figure 57—Reassemble Flexible Coupling Gear and Hub as Shown

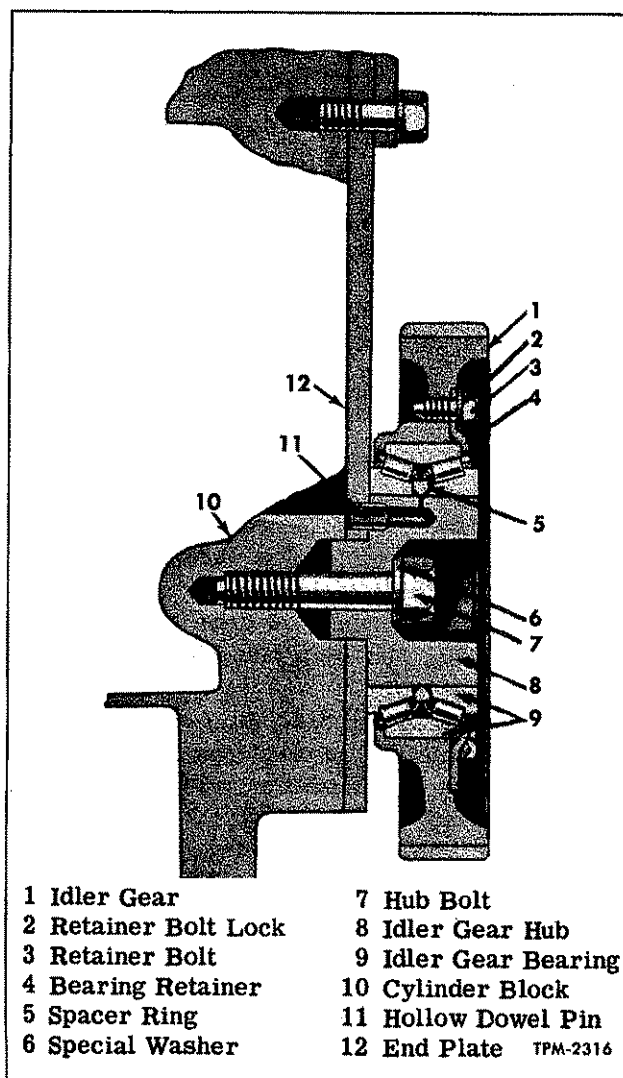


Figure 58—Idler Gear Assembly

support.

5. Place drive spring support (16) on two blocks of wood, as shown in figure 56.

6. Grease springs (17) to hold the leaves together. Slide two spring packs consisting of 21 springs each into spring support together with a drive spring seat (18) at both ends of each spring pack. Locate spring seats (18) so rounded surface of seats will set in corresponding curve in spring support.

7. Install blower drive cam (17) over end of spreader tool; then insert tool between spring packs until lower edge of cam rests on blocks beneath spring support.

8. The outer end of flexible drive coupling cam is counterbored for about $\frac{1}{4}$ " on the inside diameter. Counterbore must be away from face of gear. Also slots in hub must be opposite high points of cam (fig. 57) to provide proper lubrication at cam.

9. Place retainer (20) against outer face of coupling, with flange at center of shield pointing away from coupling. Lock in place with lock washers and cap screws.

10. Install a new seal around drive gear hub support.

INSTALLATION

The blower drive gear assembly is attached to front face of cylinder block rear end plate (fig. 53).

1. Finished face of support should be up against end plate, and a new gasket placed between end plate and support.

2. Replace the cap screws and through-bolts when flywheel housing is installed. If cap screws are too long and project inside gear housing they may interfere with the gears.

3. Install oil line from blower drive gear housing to cylinder block into its two connections.

4. Install shaft into serrations of drive coupling cam, then secure with snap ring located either on shaft or inside coupling cam.

5. Apply engine oil at each thrust shoulder of bushing, and again check end clearance between bushing and thrust washer (fig. 55).

6. Blower may be installed at this time without interfering with any other work to be performed on the gear train. Refer to "Blower Installation" in AIR INTAKE SYSTEM section of this manual.

IDLER GEAR ASSEMBLY

Idler gear assembly and mounting is illustrated

GEAR TRAIN

in figure 58. Gear and opposed tapered roller bearings are supported by a hub held securely between cylinder block end plate and flywheel housing. Gear thrust, is absorbed by opposed tapered roller bearing. Lubrication to gear bearings is supplied under pressure through a hollow dowel pin leading from cylinder block oil passage to drilled passage in support hub.

REMOVAL

1. Remove flywheel housing and gear train cover as directed in that section of this manual.
2. Remove cap screw and lock washer from center of idler gear hub and withdraw hub, gear and bearing as a complete assembly.
3. Before disassembling further, check for bearing pre-load as instructed in paragraph following.
4. If further disassembly is necessary, remove six cap screws, three lock plates, and retainer, then press hub from bearing and bearing from gear.

INSPECTION

Before the idler gear assembly is reassembled, each part should be washed in clean kerosene, inspected for wear, and worn parts replaced. The force required to rotate the idler gear on its bearings should be measured to determine if assembly is satisfactory for further use.

1. Mount assembly in a vise, using soft jaw plates, so that inner races are pinched tightly against spacer between races.
2. Tie small piece of soft metal or wood to end of $\frac{1}{8}$ " cord, then lay metal or wood piece between gear teeth and wrap cord around circumference of gear. Attach a set of pull scales to end of cord.
3. Maintain a straight pull on scales and note pull on scales at time gear starts to rotate on its bearings. Make several checks to be sure that correct scale reading is obtained.
4. Normal scale reading should be between 2 to 25 inch lbs. If indicated scale reading cannot be obtained change spacer several times and recheck

after each change.

5. If reading is below specified torque it indicates that bearing is worn or inner races are not tightly pressed against spacer. If the reading is above the specified torque or if the bearing is rough it should be carefully inspected before being installed and replaced if necessary.

INSTALLATION

1. Press bearing outer race into idler gear until race seats against flanged lip of gear.
2. Press hub into bearing inner race until race and hub are flush with each other.
3. Position hub and inner bearing race into idler gear outer race, then install spacer over hub.

IMPORTANT: SPLIT IN SPACER MUST BE 180° (DIRECTLY OPPOSITE) FROM HOLLOW DOWEL PIN IN HUB.

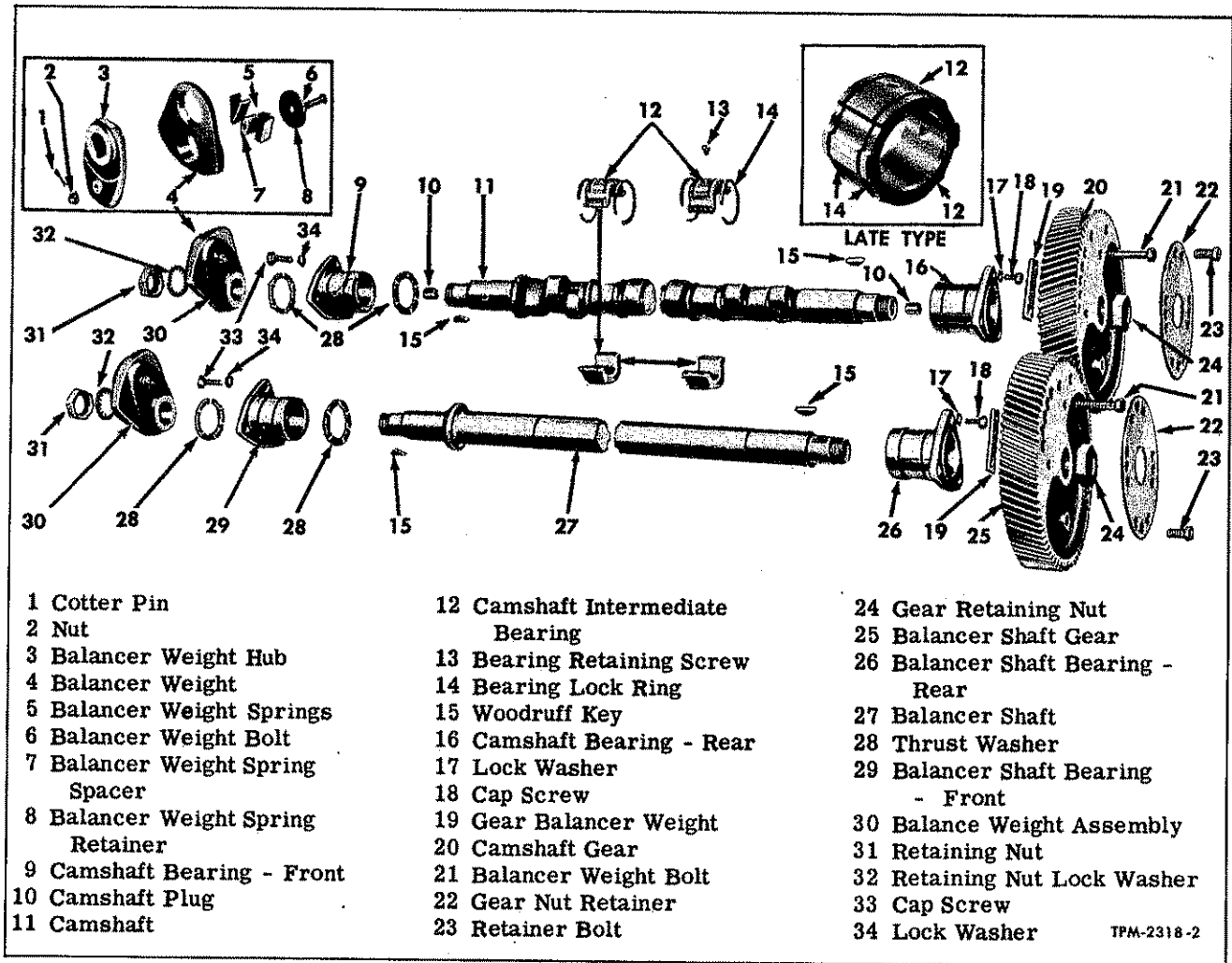
4. Press outer bearing race onto hub and tighten against spacer. Be sure split in spacer is still opposite to dowel pin.
5. Install bearing retainer to idler gear using six bolts and three bolt lock plates. Tighten bolts to recommended torque, then bend lock plate ears against flat of each bolt head.
6. Check for proper bearing preload and correct if necessary as described in "Inspection" paragraph previously.
7. Position crankshaft gear and either balancer shaft gear or camshaft gear so marks (fig. 52) align with those on idler gear; then roll idler gear into position. Rotate gear hub so that hollow dowel pin registers with oil hole in the end plate.
8. Tap hub gently until hub seats against end plate. Secure hub in place with cap screw and lock washer at center of hub. Tighten cap screw to recommended torque.
9. Check backlash between various mating gears in gear train, which should be from .002" to .004" between each set of gears.
10. Attach dummy hub (spacer) on side opposite to idler gear.

CAMSHAFT AND BALANCE SHAFT**CAMSHAFT**

Camshaft is a one-piece drop-forging, case hardened at cams and journals, and is located near top of 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. Loose steel-backed bronze thrust washers, are used at the thrust end of the shafts. Details of camshaft and balance shaft are shown in figure 59.

The intermediate bearings are two-piece, and held together by lock rings. Each bearing assembly

CAMSHAFT AND BALANCE SHAFT**Figure 59—Cam and Balancer Shaft Details**

is located and locked in the cylinder block by a fillister-head screw, sunk into a counterbore at the top of the block.

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

BALANCER SHAFT

Balancer shaft, running parallel to camshaft and at same distance from crankshaft, is located on opposite side of cylinder block. Balancer shaft is supported in same manner as camshaft, except no intermediate bearings are used. End bearings, together with loose thrust washers at the thrust end, are identical with those used on camshaft. Details of camshaft and balancer shaft are shown in figure 59.

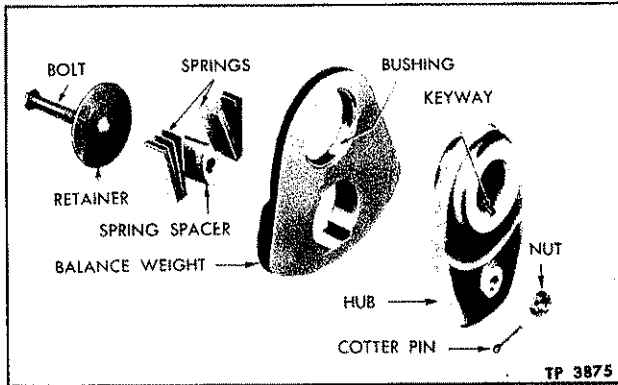
The function of balancer shaft, as its name implies,

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 front ends of both shafts, are so designed as to dampen out these forces.

BALANCE WEIGHTS

In addition to counterweighted gears at rear end, balance weights are used at front end of both camshaft and balancer shaft, as shown in figure 59. Front end balance weights are different for the four and six cylinder engines in that the weights are heavier for the four cylinder than for the six cylinder.

The balancing members used on early six cylinder engines (fig. 60) are known as balance-weights and hub assemblies. The hub of each assembly is securely fastened to the front ends of both camshaft

CAMSHAFT AND BALANCE SHAFT

**Figure 60—Cam and Balancer Shaft Details
(6-cyl.—Early Type)**

and balancer shaft by means of a Woodruff key and nut. Weights incorporate a bushing, which bears on the hardened surface of the hub, permitting the weight to oscillate (rock) on the hub. Torque variations, developed in shafts during speed or load changes, are transmitted from hubs to weights through the spacers and spring leaves. The bolt, retainer, and nut maintain the correct relation between the weights and hubs.

All four cylinder and latest 6-cyl. engines are equipped with one-piece non-adjustable balance weights. Weights are attached to cam and balance shafts by means of Woodruff key and nut.

REMOVAL

1. Remove cylinder head as directed in CYLINDER HEAD section later in this manual.

2. Remove flywheel housing as directed in FLYWHEEL HOUSING and GEAR TRAIN COVER section previously in this manual.

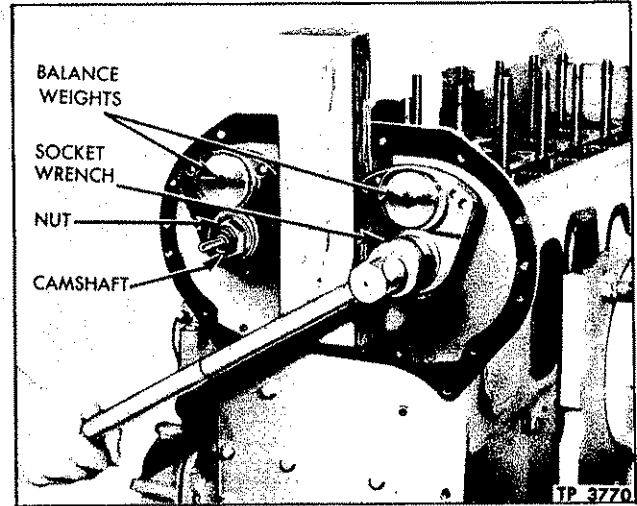
3. Remove cap screws holding balance weight cover to cylinder block and front end plate. Loosen cover from gasket surface and remove.

4. Wedge a block of wood between balance weights to prevent rotation; then loosen nuts at both ends of shafts with socket wrench, as shown in figure 61.

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 figure 62. Remove Woodruff keys.

6. Remove the special fillister-head screws from top of cylinder block at each camshaft intermediate bearing.

7. Remove three cap screws from rear end of both camshaft and balancer shaft bearing cages by means

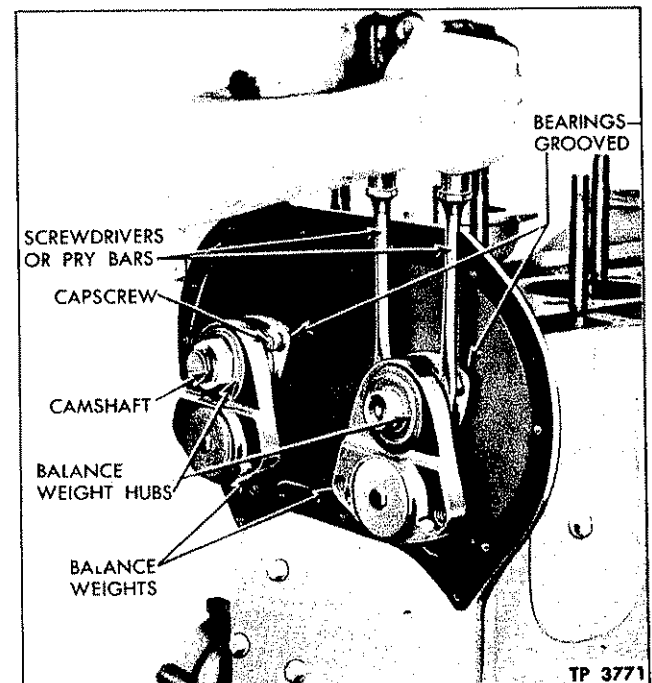


**Figure 61—Loosening Cam and Balancer Shaft
Weight Retaining Nut (Early 6-cyl. Shown)**

of a socket wrench inserted through hole in the web of timing gears (fig. 63).

8. Remove loose washers, located between bearing and balance weight hubs; then withdraw balancer shaft and camshaft (with 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



**Figure 62—Removing Balancer Weight Assemblies
(Early 6-cyl. Shown)**

CAMSHAFT AND BALANCE SHAFT

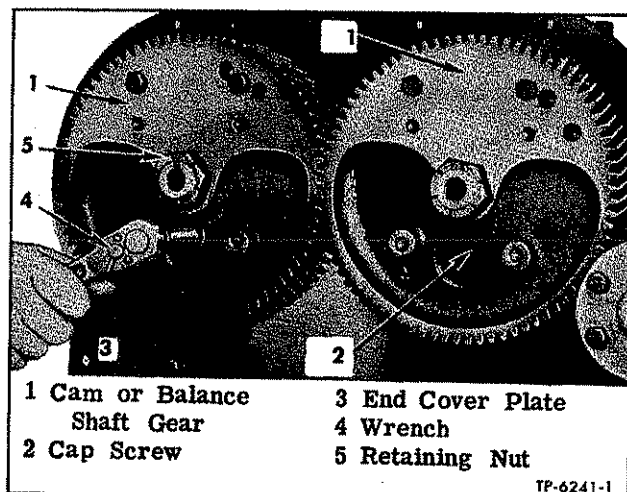


Figure 63—Cam and Balance Shaft Bearing Retaining Screw

not removed together with the shafts, they should be removed when removing the bearings as outlined in item 9 below.

9. Remove the three cap screws at front end of engine holding each balancer shaft and camshaft bearing to end plate, then remove bearings and loose washers from cylinder block. See note in item 8 above relative to removal of loose thrust washers with bearings.

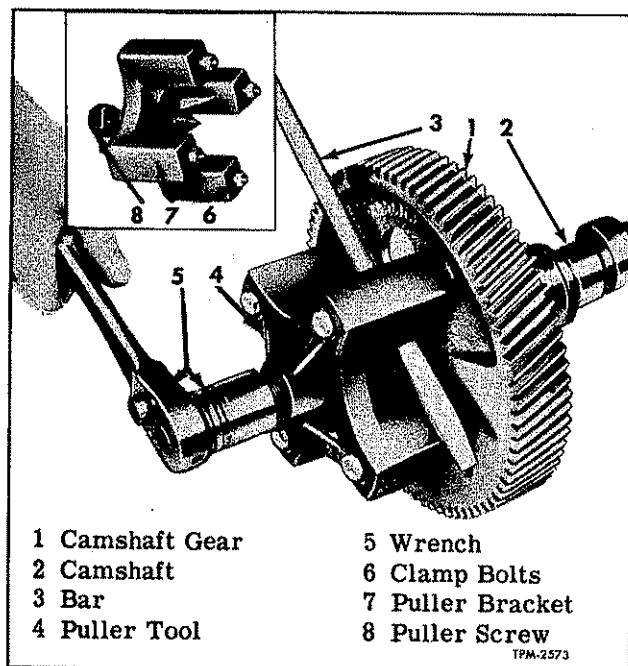


Figure 64—Removing Cam and Balancer Gears with Gear Puller

DISASSEMBLY

CAMSHAFT AND BALANCER SHAFT

1. Support camshaft in soft jaws of bench vise, being careful not to damage cams, then pull gear from shaft, using puller tool as shown in figure 64.

2. Back out puller screw in fixture and attach puller to outer face of gear with the four bolts provided.

3. Turn puller screw down against end of shaft. Hold puller with bar in manner illustrated as puller screw is turned to remove gear.

4. After gears are removed, bearings may be withdrawn from shafts.

5. Remove lock rings from camshaft intermediate bearings, also, remove the two halves of each bearing. Tachometer drive (if used) may be removed with special tool.

BALANCE WEIGHT—Early 6-Cyl. (Fig. 60)

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

INSPECTION

After parts have been cleaned with fuel oil and dried by air, inspect all bearings and journals for good bearing surfaces and wear before replacing. Refer to **SPECIFICATIONS** section of this manual.

Examine both faces of 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, if score marks are too deep to be removed, or parts badly worn, use new parts.

Should thrust surface (side facing loose thrust washer) of 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 matched parts, measured and machined as an assembled unit.

Radial clearance on camshaft and balance shaft bearings is given in **SPECIFICATIONS** section of this manual and should not exceed the maximum by

CAMSHAFT AND BALANCE SHAFT

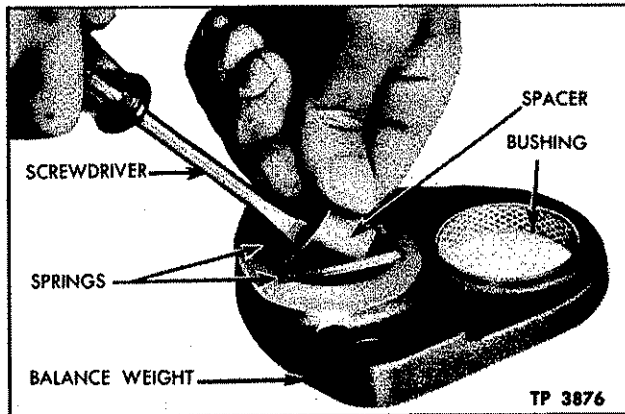


Figure 65—Installing Spring Spacer Between Spring Pack (Early 6-cyl.)

more than 0.006".

Radial clearance between balance weight bushing and balance weight hub is given in **SPECIFICATIONS** section of this manual and should not exceed maximum by more than 0.006". End clearance between weight and hub should be as indicated in **SPECIFICATIONS** section of this manual.

If bearings are scored or worn so clearances exceed limits, 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, must be removed.

ASSEMBLY

BALANCE WEIGHT AND HUB—Early 6-Cyl.

1. If old bushing was removed from balance weight, press new split bushing into place. Edge of bushing should be flush with shoulder opposite flat machined side of weight. Burnish bushing to dimension given in **SPECIFICATIONS** section of this manual.

2. Select 17 springs to make up spring packs. Pack thickness to be determined while springs are tightly cramped together in vise or arbor press and must be within limits given in **SPECIFICATIONS** section of this manual.

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

3. Place weight, machined face down, flat on clean work bench.

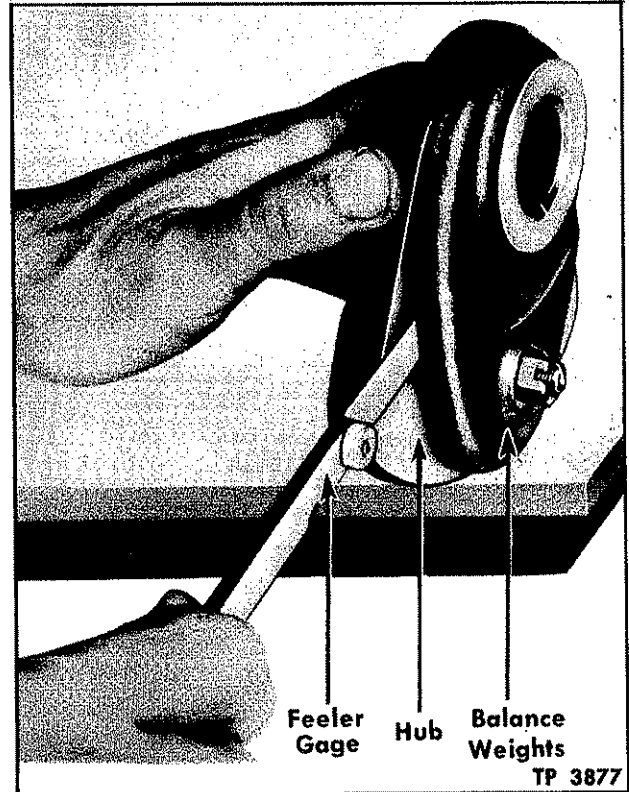


Figure 66—Measuring Balance Weight to Hub Clearance (Early 6-cyl.)

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 in balance weight (fig. 65).

7. Place journal of hub into bushing of balance weight. Weight should swing freely on hub. Burnish bushing if specified clearance 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 figure 66. Refer to **SPECIFICATIONS** section for clearance. Adjust clearance by tightening or loosening castellated nut. Lock nut in position with cotter pin when proper clearance is obtained.

CAM AND BALANCE SHAFT

Camshaft gears and balance shaft gears are the same for all engines; however balance weights are

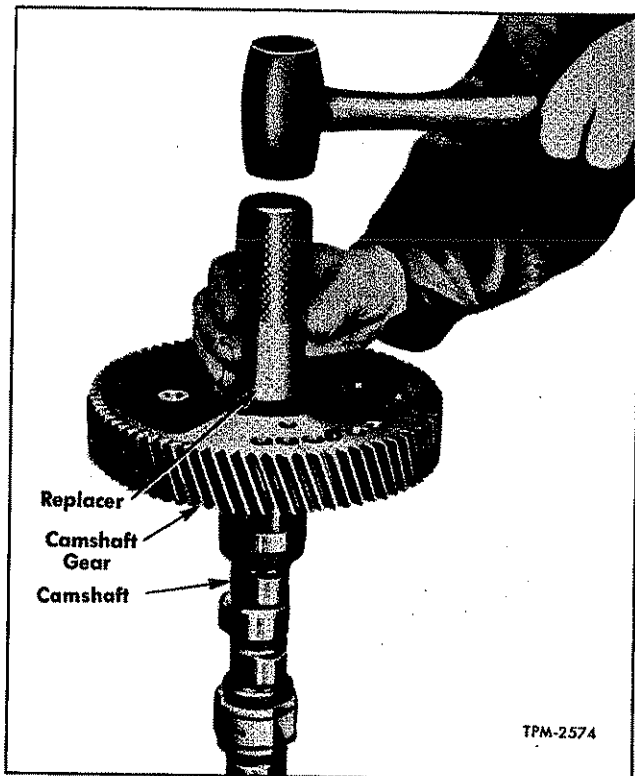
CAMSHAFT AND BALANCE SHAFT

Figure 67—Use of Cam and Balance Shaft Gear Replacing Tool

attached to these gears on the four and six-cylinder engines for balancing purposes. Camshaft and balance shaft gears from a four cylinder engine may be used on the six cylinder engine if the necessary specified weights are attached to the gears. Refer to "Balance Weight" previously in this section for description of cam and balancer shaft weights.

When viewing engine from flywheel end 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. These marks are in addition to the "O" which is used to time camshaft and balancer shaft gears.

On engine models RA, RD, and LA the camshaft and balance shaft thrust is taken by loose thrust washers installed at rear of engine. On models RB and RC the thrust is taken in the same manner except that the loose thrust washers are installed at front of engine.

1. Determine if thrust washers are to be used on gear end or opposite end of shafts. Install thrust washers with steel side of washer facing bearing. Use cup grease to hold washer in place during as-

sembly. Lubricate the journals, and place support bearings on shaft journals, with bolting flange of bearing towards outer ends of shafts.

2. Install Woodruff keys in both shafts.

3. Rest 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.

4. Using replacer in manner illustrated in figure 67, drive gear onto shaft, tightly against shoulder. Drive gear on balancer shaft in same manner.

5. Start nuts on shaft by hand, and tighten after shafts are installed.

6. Install intermediate bearings on camshaft, and lock the two halves together with two lock rings on each bearing (fig. 59).

INSTALLATION**GENERAL**

The timing marks "O" on camshaft and balancer shaft gears must match. Refer to figure 52 for gear markings. Looking at engine from flywheel end, 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 marking "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 (RA, RC, RD, RB), the idler gear is located on the left side of cylinder block, and the marking "R" which appears on crankshaft gear must match one of the "R" marks on the idler gear. The other "R" mark on idler gear must match the "R" mark on either the camshaft gear or balancer shaft gear, whichever one of these two gears meshes with the idler gear (fig. 52).

If engine is left-hand rotation, (LA) 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 match each other (fig. 52).

BALANCE SHAFT

1. Coat steel side of thrust washer (when washer is used at front) then install washer over bearing with steel side toward bearing support. Install support bearings for front end of camshaft and balance shaft in cylinder block front end plate. Secure in

CAMSHAFT AND BALANCE SHAFT

place with lock washers and cap screws. Be careful not to dislodge loose washers on ends of bearings.

2. Start balancer shaft, including rear bearing and gear assembly, into position at rear end of block. On models having thrust bearing at front, use care that thrust washer on inner end of front bearing is in position. Continue to push shaft into position to the point where gear teeth are about to engage.

3. Correctly position crankshaft, idler, and balancer gears so the timing marks ("R" or "L") match as shown in figure 52, then slide balancer shaft gear into mesh.

4. Secure balancer shaft rear bearing to engine block end plate with three lock washers and cap screws. Cap screws are accessible through the web of gear, (fig. 63).

CAMSHAFT

After the balancer shaft is installed in the cylinder block, the camshaft may be installed, as follows:

1. Start camshaft and gear assembly into camshaft bore in cylinder block, use extreme care 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 camshaft and balancer shafts gears match; also rotate idler gear until timing mark ("R" or "L") on idler gear and camshaft match. Refer to figure 52 for timing gear marks. Slide gears into mesh. Be careful not to dislodge loose thrust washers at the thrust absorbing bearing.

2. Secure camshaft rear bearing to engine block end plate with three lock washers and cap screws. Cap screws are accessible through web of gear (fig. 63).

3. Revolve camshaft intermediate bearing assembly so locking holes in bearings align with holes in top of cylinder block; then secure lock screws in place.

BALANCE WEIGHTS

1. When loose thrust washers are used at front of engine, coat steel side with grease then install washer over bearing with steel side toward bearing support.

2. Install Woodruff keys in keyways at front of camshaft and balancer shaft.

3. Align keyway in balance weight hub with key in shaft; then place balance weight-and-hub assembly on camshaft, with weight and spring retainer facing away from engine block. On the four-cylinder engines, balance weight is placed on end of shaft,

with overhanging section of weight facing away from engine block.

4. Place balance weight-and-hub assembly on balancer shaft. Install lock washers and plain nuts on both shafts.

5. Wedge a block of wood between balance weights, as shown in figure 61 and tighten the lock nuts, using a 1½" socket wrench.

CAUTION: When tightening retaining nuts for balance weights and gears, double check and make sure the loose thrust washers are in their proper position over the extended bronze bushings.

6. Wedge a clean cloth between the gears, at the rear of the engine, and tighten the lock nuts with the same wrench used above.

7. Position gear nut retainer over both gears and secure with cap screws. Refer to figure 59.

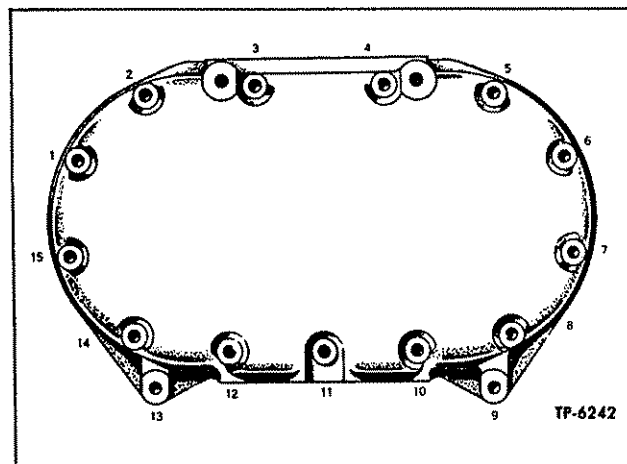
FLYWHEEL HOUSING

Refer to FLYWHEEL HOUSING AND GEAR TRAIN COVER section previously in this manual and install cover as instructed. Proper tightening sequence of attaching bolts is extremely important and should be carefully followed.

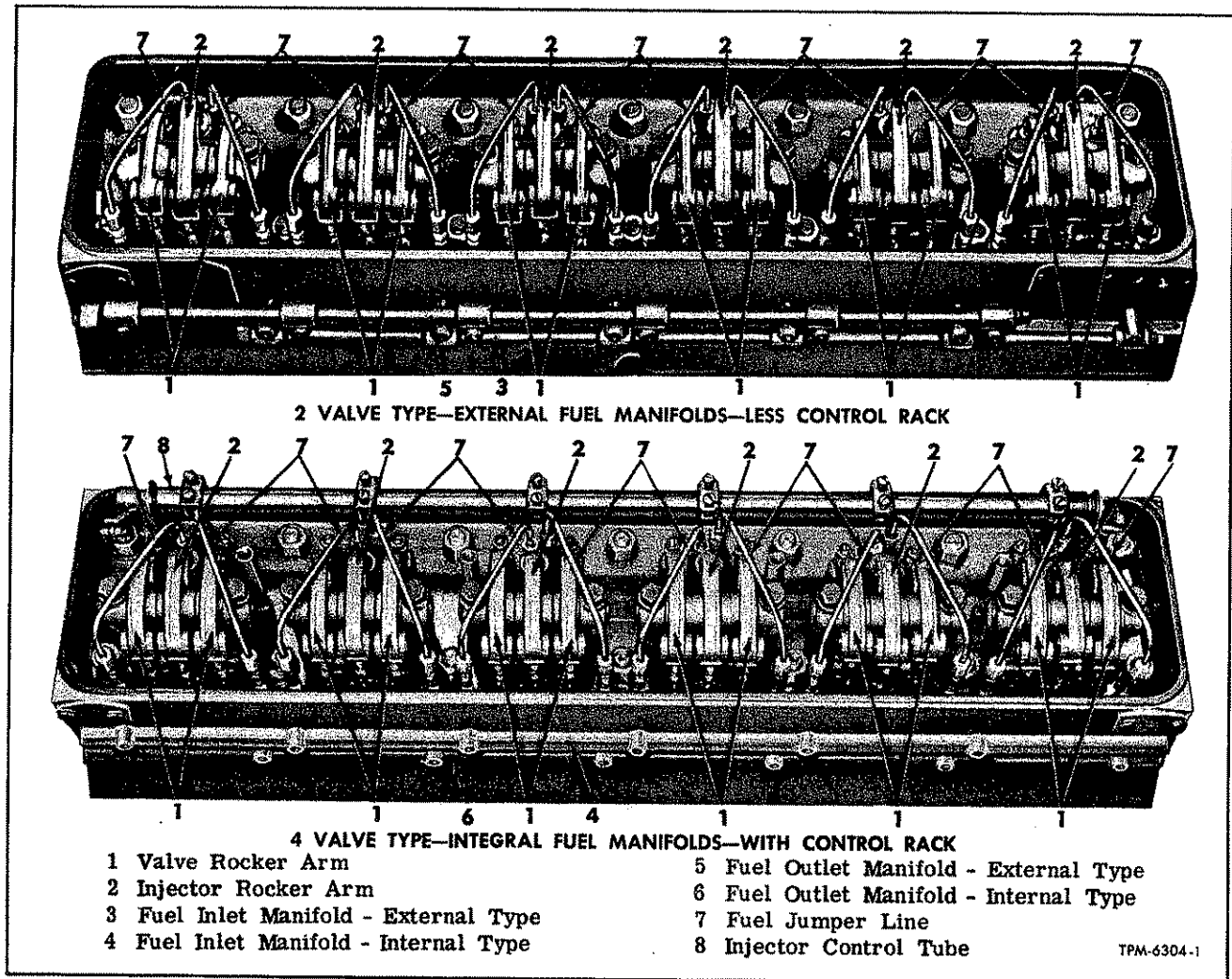
BALANCE WEIGHT COVER

1. Remove traces of previously used gasket and check bolting flange of cover for any imperfections that could cause oil leaks.

2. Position new gasket to front end plate. Install cover and secure with bolts and lockwashers. Refer to figure 68 and tighten bolts in sequence indicated. If cylinder head is removed, leave top bolts loose to prevent interference when installing head.



**Figure 68—Balance Weight Cover
Tightening Sequence**

CYLINDER HEAD**CYLINDER HEAD****Figure 69—Cylinder Head Assembly****DESCRIPTION**

Cylinder head (fig. 69) is a one-piece alloy iron casting which may be removed from the engine as a complete assembly with valve mechanism, injectors, and fuel lines. The head is securely held to top of cylinder block by heat-treated alloy steel studs and nuts.

Cylinder block mating surfaces are milled flat, thus permitting metal-to-metal contact and elimination of conventional cylinder head gasket.

Located in the head are two or four exhaust valves, (fig. 69), a fuel injector, and three drop-forged rocker arms, also valve and injector operating mechanisms for each cylinder. The two outer arms operate the

exhaust valves, and the center arm operates the fuel injector as shown in figure 88.

VALVE SEATS

Exhaust valve seats (fig. 70) are shrunk into the cylinder head, thus accurate seating of the valves under varying temperature conditions and prolonged life of cylinder head is attained. Seats are ground to very accurate limits to prevent loss of compression, freedom from warpage, and maximum valve life.

VALVE GUIDES

Exhaust valve guides are pressed into cylinder head and are pre-finished type which do not require reaming.

CYLINDER HEAD

INJECTOR TUBES

To insure efficient cooling, each fuel injector is seated in a thin walled copper tube which extends through the water space in cylinder head as shown in figure 71. 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, prevents water leaks around the copper tube.

WATER NOZZLES

In addition to being surrounded by cooling liquid, cooling of injector tubes, valve seats, and valve guides is further assured by the use of water nozzles in cylinder head (fig. 71). Nozzles are positioned in such a manner that cool water entering the cylinder head is directed against these sections which are subject to greatest heat.

CYLINDER HEAD GASKETS

Combustion in each cylinder is individually sealed by Belleville cupped type ring seals, which are installed on top of cylinder liner and seals compres-

sion. Synthetic rubber rings and seals are installed in counterbores in cylinder block and effectively seal oil and water passages between cylinder block and cylinder head. An additional gasket around outer edge of head seals against leakage of oil (fig. 72).

The top of each cylinder head is completely enclosed by a removable pressed steel valve rocker cover. Cover is held in place by screws fitted with hand knobs, and is sealed against leakage by a gasket, held in place by a retainer and flanged edge of the cover.

REMOVAL

Equipment and accessories on the engine varies with individual installations to such an extent that no attempt is made to specifically list the steps necessary to remove the head. However, the following general procedures may be used.

1. Remove governor control housing assembly as directed under "Removal" in respective governor sections in **FUEL SYSTEM** section of this manual.
2. Remove cap screws attaching cylinder head lifting brackets to flywheel and balance weight covers.

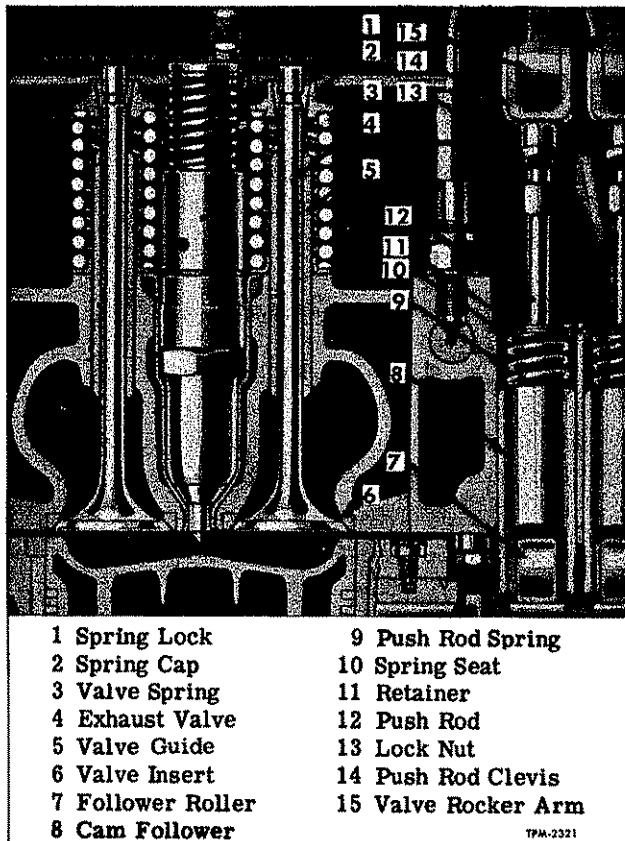


Figure 70—Exhaust Valves, Guides and Inserts in Cylinder Head

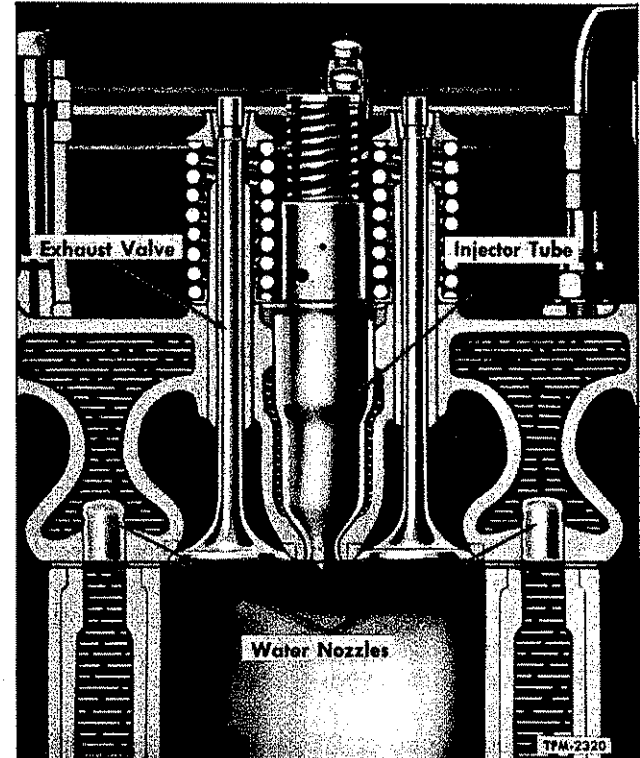
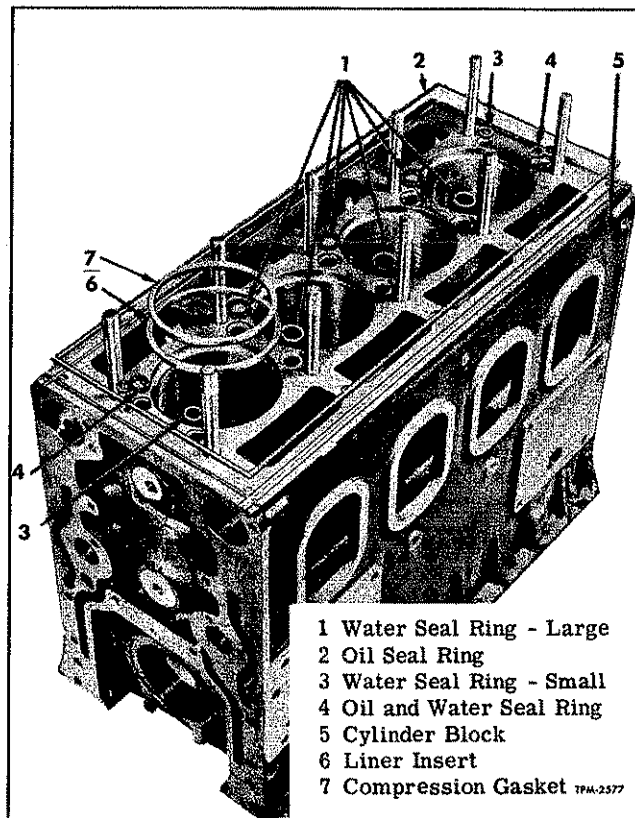


Figure 71—Water Cooling at Valves and Injector in Cylinder Head

CYLINDER HEAD



**Figure 72—Cylinder Compression Gaskets,
Oil and Water Seals**

3. Loosen jumper line nut at injector, then remove line at connectors and swing line aside so that cylinder head stud nuts can be reached.

4. Remove cylinder head hold-down stud nuts using special wrench to reach nuts under injector control tube. If wrench is not available remove control tube and brackets.

CAUTION: When removing cylinder head with injectors in place, care must be taken to avoid damaging injector tips and cam followers at the instant head clears the cylinder head studs. Raise cylinder head clear of studs. **DO NOT ALLOW CYLINDER HEAD TO BIND ON STUDS.**

5. When resting cylinder head assembly on work bench, protect injector tips, also cam followers and rollers by resting the valve side of head on wooden blocks at least 2" thick.

6. Remove cylinder head compression and oil seal gaskets.

7. If engine is removed from vehicle for a major overhaul, and is positioned in engine overhaul stand, cylinder liner clamps should be installed between each two cylinders to prevent possibility of liners

falling from block while engine is turned to various positions in overhaul stand. Install liner clamps over cylinder block studs and secure with cylinder head hold down stud nuts.

DISASSEMBLY

Conditions will arise when a complete cylinder head overhaul becomes necessary. For such conditions the removal of all working parts attached to cylinder head is necessary. **NOTE:** New cylinder heads are furnished with valve guides, studs, injector copper tubes and plugs. If a new cylinder head is to be installed, 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 following procedure applies when a cylinder head is to be completely overhauled:

1. Remove rocker arms and shafts as instructed under "Rocker Arm, Shaft and Bracket Replacement" in **VALVES AND INJECTOR OPERATING MECHANISM** section later in this manual.

2. Remove valve springs as instructed under "Valve Spring Replacement" in **VALVES AND INJECTOR OPERATING MECHANISM** section later in this manual. After valve springs and locks are removed valves may be removed from lower side of cylinder head.

3. Remove injectors as instructed under **FUEL INJECTORS** in **FUEL SYSTEM** section of this manual.

4. Remove fuel oil connectors and manifolds as instructed under "Fuel Manifolds" in **FUEL SYSTEM** section of this manual.

5. Remove cam follower and guide as instructed under "Push Rod, Cam Follower, and Spring Replacement" in **VALVES AND INJECTOR OPERATING MECHANISM** section later in this manual.

CLEANING

Whenever engine is overhauled, the cylinder head should be thoroughly inspected for any condition that would render it unfit for further service. Such inspection will take place after the head has been removed from the block, completely disassembled, and thoroughly cleaned in either live steam or a suitable solvent; then cleaned with dry compressed air.

If shop facilities permit, grease and scale should be removed from disassembled head in following manner:

1. Remove grease by agitating the head in a bath of commercial heavy duty alkaline, as sold by trade chemical suppliers.

2. Wash in hot water or steam clean to remove alkaline.

3. Remove scale by agitating the head in a bath of inhibited commercial pickling acid as sold by trade chemical suppliers. A 50-50 solution of Oakite 32 and water has been found satisfactory. After head is cleaned of grease and scale, it must be rinsed and the cleaner acid neutralized. Carefully follow directions of chemical manufacturer on cleaning, rinsing, and neutralizing.

4. Wash head in a bath of clean water or steam clean.

5. After head is inspected for cracks, dip in rust preventive to prevent rusting. Castings free of grease and oil will rust immediately when exposed to atmosphere.

INSPECTION

The information described under the following headings pertain to the cylinder head after it has been removed from the engine, disassembled and thoroughly cleaned.

WARPAGE (FLATNESS)

The cylinder head must be flat within certain tolerances longitudinally and transversely in order to ensure proper contact with the cylinder head gaskets and cylinder block to obtain the desired sealing effect. In continued service, cylinder heads may assume a contour to match that of the cylinder block and gaskets over a prolonged period of operation. This is a normal reaction. However, if the cylinder heads are allowed to become overheated because of coolant loss, high temperature causes stresses to occur in the castings which affects the flatness of the cylinder head. The maximum allowable variation in cylinder head flatness is shown in the following table:

Engine	Longitudinal	Transverse
4-71	.008"	.004"
6-71	.010"	.004"

When determining or measuring the flatness of the cylinder head fire deck, the use of a heavy, accurate straight edge and accurate feeler gauges should be employed. Measurements should be taken longitudinally at each bridge between cylinders and on

CYLINDER HEAD

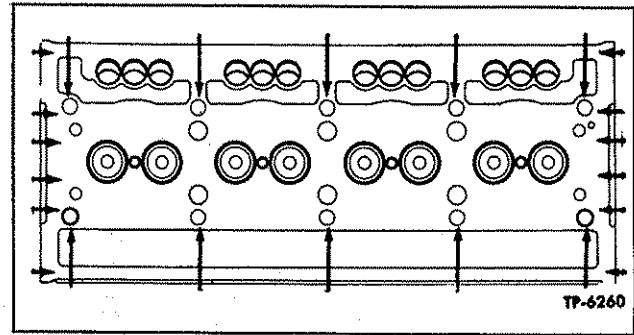


Figure 73—Check Cylinder Head Flatness at Points Indicated

both right and left sides of the cylinder head (fig. 73).

If the flatness is not within the dimensions given in the table, then the fire deck of the cylinder head should be refaced. A limit of .015" to .020" is the maximum amount of stock that should be removed. Critical dimensions such as protrusion of valve seats, valves, injector hole tubes, and injector spray tips should be observed. In the event a cylinder head is not flat within its re-use limits then head should be replaced.

LEAKS

Following the inspection of the cylinder head for flatness as described above, the next step that should be performed is checking the cylinder head for leaks. Install dummy injectors, tap lightly, and hold in place with injector crab and nut tightened to recommended torque. Dummy injectors may be made up with old injector nuts and bodies—the injector spray tip is not necessary. Remove pipe plugs at both ends of the cylinder head oil gallery.

Seal all water openings in the cylinder head with suitable gasket material and clamping fixture equipment; however, provision should be made to introduce air into the water passageway cavities of the cylinder head as it is being tested.

The cylinder head assembly should then be submerged into water heated to a temperature of 180° to 200° for about fifteen to twenty minutes to thoroughly heat the cylinder head. Any leaks in the cylinder head assembly will be detected by allowing air to enter the cylinder head water passageways until a pressure of 80-100 lbs. (maximum) has been attained and noting any air bubbles in the water. Some of the places to inspect for leaks are as follows: Bottom and top of the injector tubes; oil gallery; cylinder head stud holes; exhaust ports; top, bottom, and sides of cylinder head proper.

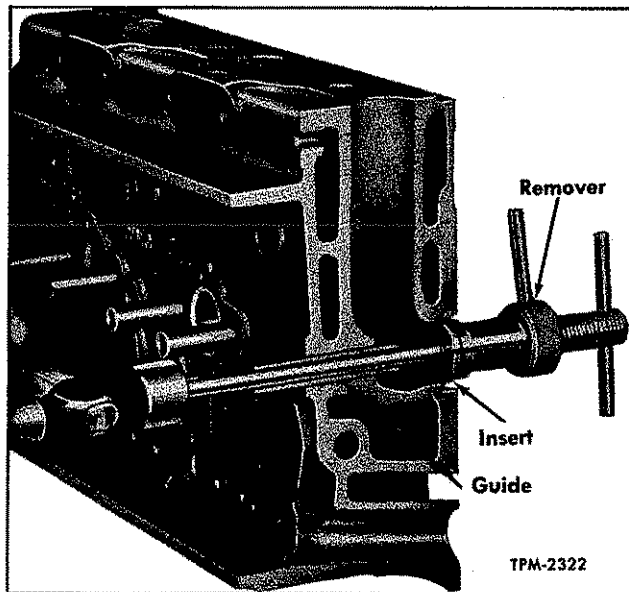
CYLINDER HEAD

Figure 74—Removing Valve Seat Insert from Cylinder Head

Relieve air pressure, remove cylinder head from water, remove gaskets and clamps, and allow cylinder head to dry. Replace any leaking injector tubes. If leaks are apparent in the cylinder head, it should be replaced.

INJECTOR COPPER TUBES

If pressure test for leaks, previously performed, indicates that a leak exists at the bottom of the tube, compression will leak into cooling system causing loss of coolant. A leak at top of tube will permit water to leak into lubricating oil.

Whenever either of these conditions exist the tube must be replaced as directed under "Injector Copper Tube Replacement" later in this section.

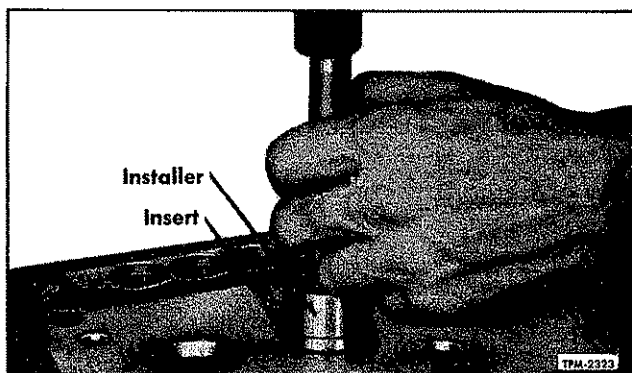


Figure 75—Installing Valve Seat Insert in Cylinder Head

WATER DEFLECTOR NOZZLES

Water nozzles must be in good condition (not corroded or distorted) and flush with the bottom of cylinder head. Nozzles are press fit in cylinder head and can be replaced as instructed under "Water Nozzle Replacement" later in this section.

VALVE GUIDE

Carefully inspect each valve guide for fractured, chipped, scored or excessively worn condition. If inspection indicates replacement is necessary, refer to "Valve Guide Replacement" later in this section.

VALVE SEAT INSERT

Inspect valve seat to determine if they are fit for further use. Inspection should include cleanliness, concentricity, flatness, and presence of cracks. Sun-burst pattern of cracks in the cylinder head around valve insert indicates head has been overheated, also cracks between the valve insert and injector tube may be the result of overstressed injector crabs as well as overheating.

Before installing a new or used valve, the valve seat in the cylinder head must be reconditioned as described later in this section. If exhaust valve seat inserts are loose in cylinder head, or if for any reason due to wear pitting, etc., replacement of valve seat is necessary, oversize (.010") exhaust valve seat inserts are available.

Check for concentricity of seat as directed under "Valve Seat Insert Replacement" later in this section.

CAM FOLLOWER HOLES

Inspect cam follower holes in head to be sure they are clean and smooth so as to permit proper operation of cam follower. Any existing score marks should be removed.

VALVE SEAT INSERT REPLACEMENT**REMOVAL**

Valve seat insert is shrunk into cylinder head and must be removed with special tool to avoid damage to head.

1. Place 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 screw handle. Be sure that flange of collet firmly engages bottom of valve insert. Refer to figure 74.

2. Insert driver bar through valve guide and against collet. Tap driver with hammer to move

CYLINDER HEAD

seat from head. Readjust collet, if necessary so that collet flange is below seat.

INSTALLATION

Particular care must be used when replacing valve seat inserts. The inserts are installed into cylinder head with a .0005" to .0025" press fit, and must be started true with counterbore in head.

1. If oversize inserts are to be installed, counterbore exhaust valve port to oversize dimensions as listed in **SPECIFICATIONS** section of this manual. It is extremely important that head be counterbored within these limits, and that bore is concentric with hole in valve stem guide within .003" total indicator reading.

2. Cylinder head must be clean, particularly the counterbore for inserts.

3. Immerse cylinder head for 30 minutes in water at temperature of 180° to 200°F.

4. Place new inserts in dry ice for a minimum of 15 minutes before installing.

5. Place cylinder head bottom-side-up on bench; blow out insert counterbores with air; and place an insert in counterbore valve side up.

6. Using replacer tool in manner shown in figure 75 insert pilot end of tool into valve guide, and drive insert down tightly into counterbore. This operation must be done quickly, while the valve seat insert is cold.

7. Grind valve seat insert, check concentricity with valve guide, and depth of seat in manner described under "Reconditioning Valves and Valve Seats" in **VALVES AND INJECTOR OPERATING MECHANISM** section of this manual.

INJECTOR TUBE REPLACEMENT

Whenever inspection indicates that injector copper tube in cylinder head requires replacement, the operation must be performed with the greatest of care and with special tools in the manner following.

REMOVAL

1. Cylinder head must be completely disassembled and should be installed in cylinder head holding plates for ease of handling.

2. Apply a small amount of light engine oil to inside of copper tube, then thread tap into copper tube until approximately $\frac{3}{4}$ " of threads are obtained. Refer to figure 76.

NOTE: If the tube begins to rotate while threading tap into tube, drive tube holder into tip end and use wrench at tube holder to prevent tube turning.

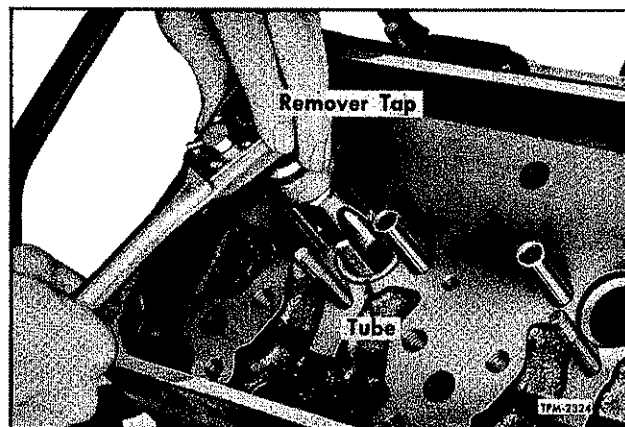


Figure 76—Removing Injector Copper Tube from Cylinder Head (Operation No. 1)

3. Remove tube holder, if used. Insert driving rod through injector tip hole until it is against center of tap. Use hammer and drive against end of rod, thus forcing threaded tap and copper tube from cylinder head. Refer to figure 77.

INSPECTION

Installation of the injector tube requires careful preparation and inspection to make sure that the area of the cylinder head is clean so that when tube contacts the cast iron cylinder head, foreign material will not prevent tube seating at bottom or sealing at top. Refer to figure 78, and check at points indicated by arrows.

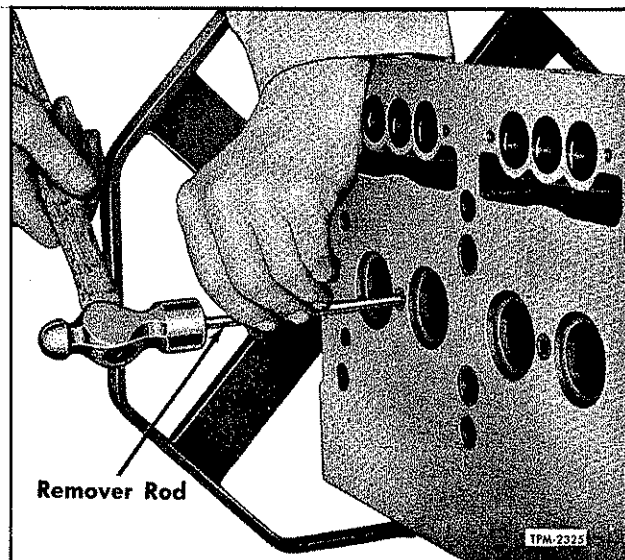


Figure 77—Removing Injector Copper Tube from Cylinder Head (Operation No. 2)

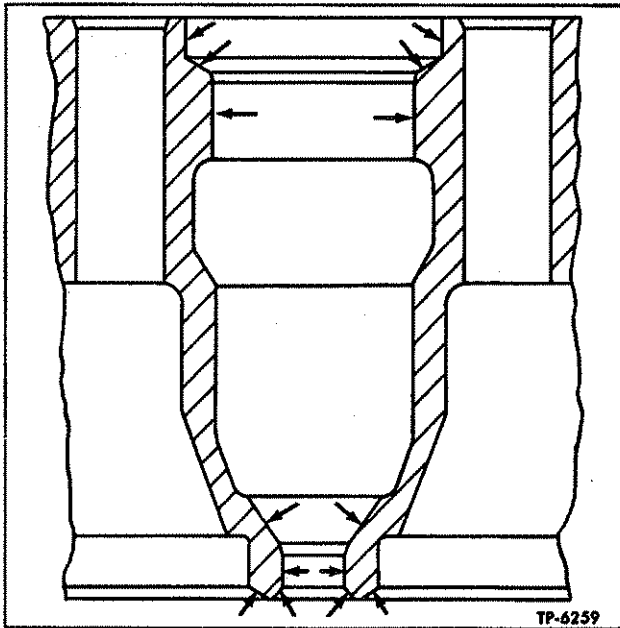
CYLINDER HEAD

Figure 78—When Replacing Injector Copper Tube, Check for Absolute Cleanliness at Points Indicated by Arrows

INSTALLATION

1. Install seal ring into cylinder head injector tube counterbore.
2. Position driver through injector tube, then insert pilot into small opening of injector tube, and thread pilot into driver (fig. 79).
3. Insert injector tube, with tools attached, into bore in cylinder head. Drive tube down until flange

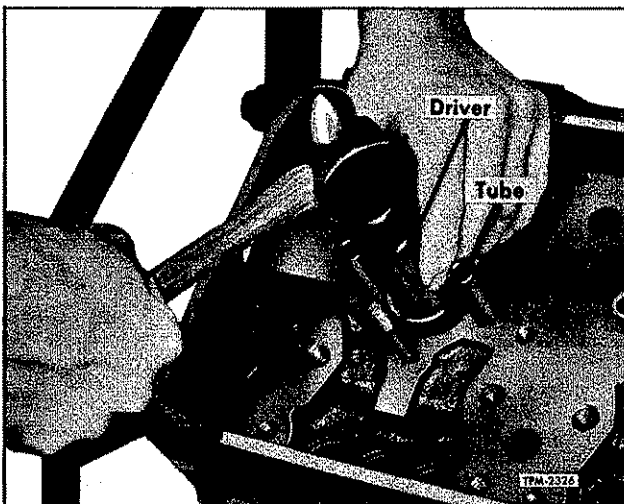


Figure 79—Installing Injector Copper Tube in Cylinder Head (Operation No. 1)

at upper end of tube is against the seal ring, and lower portion of tube is against bevel seat in the bottom of cylinder head tube bore (fig. 79).

4. Remove pilot from injector tube and driver. Install flaring die through injector tube tip and thread into driver. Tighten flaring die, using torque wrench (fig. 80), until a torque reading of 30 ft. lbs. is obtained. Remove flaring die and driver from injector tube. Follow reaming instructions as described in following paragraphs.

REAMING

Reamers used in the following operation are hand type and must not be used with a fixture, clamp, or drill press. Reaming must be accomplished carefully and slowly so as to provide a smooth surface. Use a light cutting oil on reamer flutes and do not turn reamer in opposite direction as this will dull the cutting edges. Reaming operations are divided into two operations—Reaming Body Nut and Spray Tip, and Reaming Bevel Seat.

Reaming Body Nut and Spray Tip

1. Apply a few drops of light cutting oil on reamer flutes, then position reamer in tube. Turn reamer clockwise at all times until shoulder of reamer contacts injector tube (fig. 81).

NOTE: Withdraw reamer frequently and clean chips from tube and reamer flutes. During installation and removal of reamer always turn in a clockwise direction.

2. Insert injector tube tip refinisher into injector tip hole, then using a socket and speed handle to

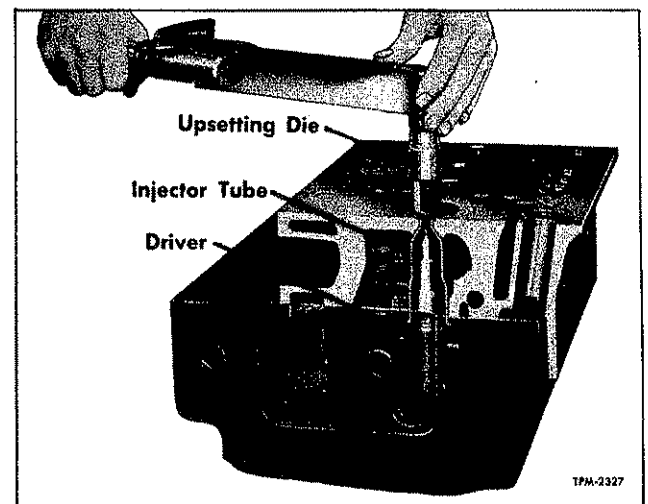


Figure 80—Installing Injector Copper Tube in Cylinder Head (Operation No. 2)

CYLINDER HEAD

remove excess from tube tip. When refinisher contacts cylinder head the operation is complete and tube tip will be flush to .010" below surface of head.

Reaming Bevel Seat

1. Clean interior of injector tube with clean fuel oil to remove all metal particles, then dry with compressed air.
2. Apply a few drops of light cutting oil on reamer flutes, then carefully insert reamer into injector tube until the reamer contacts the bevel seat (fig. 82).
3. Make one or two turns of the reamer, using a very light pressure, then remove reamer and clean inside of injector tube.
4. Use injector as a gauge, and continue reaming and checking with injector until the shoulder of the spray tip is flush to .015" below the surface of the cylinder head. Refer to figure 83.

VALVE GUIDE REPLACEMENT

Whenever inspection indicates valve guides should be replaced this should be done before valve inserts and valves are reconditioned.

REMOVAL

Support the cylinder head so that guide can be removed from head. Use valve guide remover and drive guide downward and from the head.

INSTALLATION

1. Insert countersunk end of valve guide into installer tool.

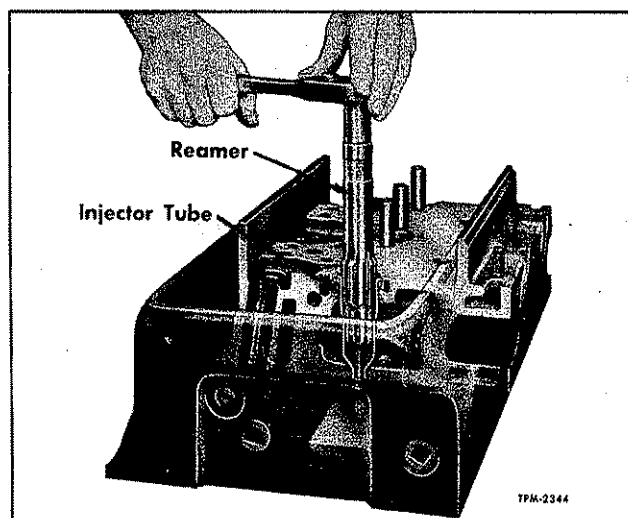


Figure 81—Reaming Injector Copper Tube in Cylinder Head for Injector Body Nut and Spray Tip

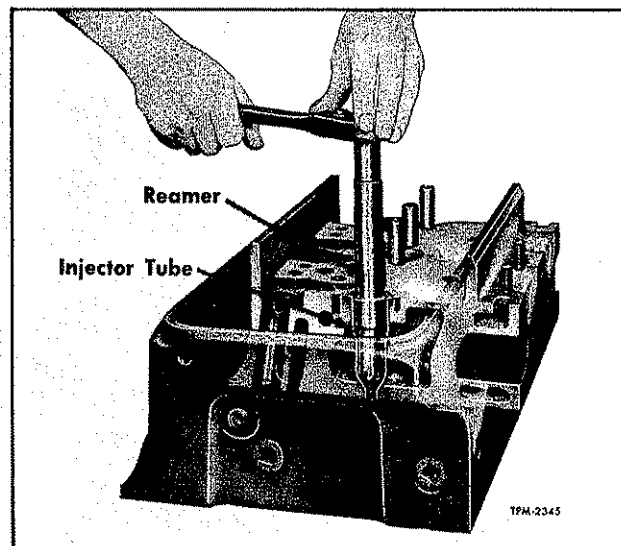


Figure 82—Reaming Injector Copper Tube Bevel Seat for Injector Body Nut

NOTE: Valve guides must be installed with countersunk end up to provide lubrication to valve stems.

2. Position valve guide squarely into head, then drive or press into place (fig. 84).
3. When the guide is properly installed, it will project above the cylinder head. Refer to "Specifications" for dimension. When installer is used, this dimension is automatically provided.

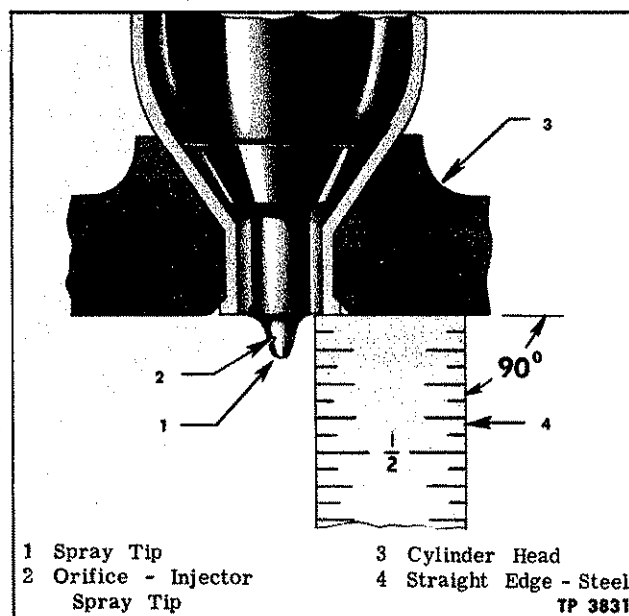
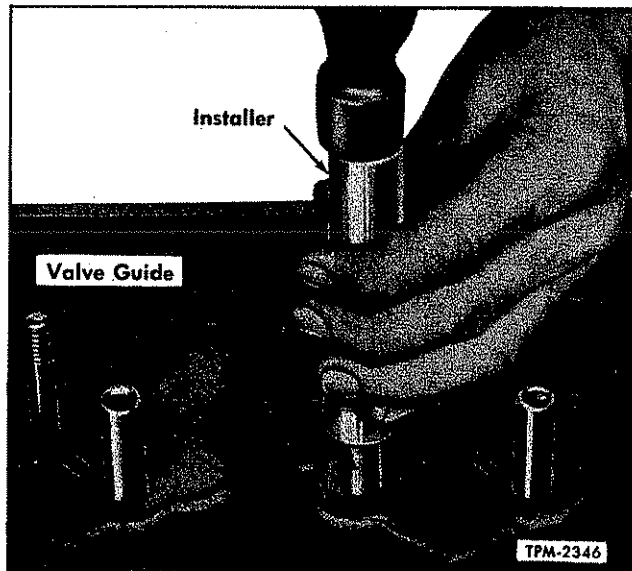
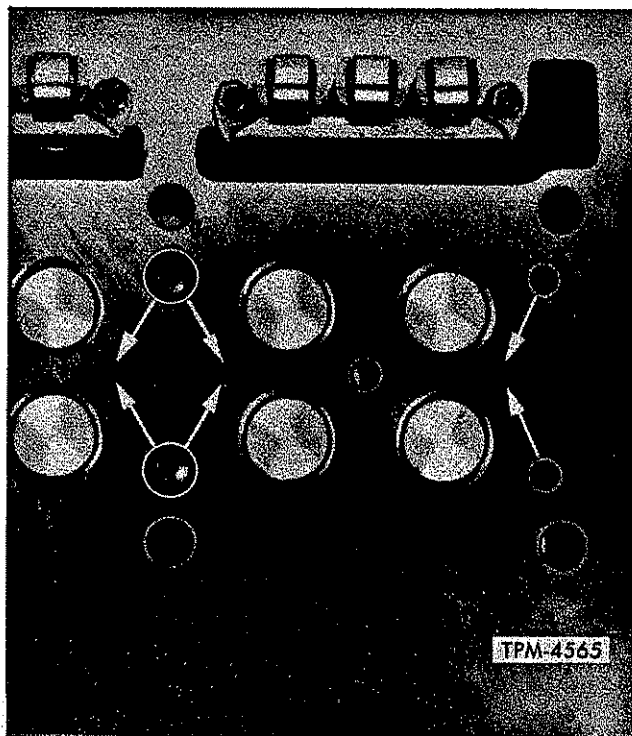


Figure 83—Checking Location of Injector Spray Tip in Relation to Surface of Cylinder Head

CYLINDER HEAD**Figure 84—Valve Guide Installer****REAMING**

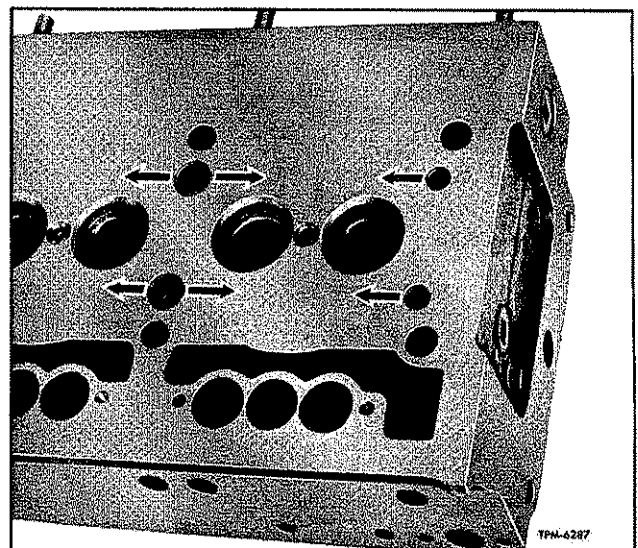
GUIDE IS MANUFACTURED TO SIZE AND DOES NOT REQUIRE REAMING AFTER INSTALLATION.

**Figure 85—Cylinder Head Water Nozzle Installation (4-Valve Head)****WATER NOZZLE REPLACEMENT****REMOVAL**

If it should become necessary to install new water nozzles, removal of old parts can be easily accomplished with cape chisel or other suitable tool. Use caution during removal so that no burrs are raised.

INSTALLATION

1. Clean the two water holes at each end with $\frac{1}{8}$ " diameter drill. Break edges of holes slightly.
2. Clean all other water holes with $\frac{13}{16}$ " diameter drill. Break edges of holes slightly.
3. Check fit of nozzles in their respective holes. Nozzles must be a press fit so that the nozzle opening maintains proper directional flow of cooling water. If the water holes in the cylinder head have corroded so that when cleaned they are larger than the nozzle, the nozzles must be tinned with solder on the outside diameter so they will remain tight after installation.
4. On two valve heads, press nozzles into place with their openings parallel with the center line of engine (fig. 86). On four-valve heads, press the nozzles into heads so that openings are directed diagonally across the head. Refer to figure 85.
5. Nozzle should be flush to $\frac{1}{32}$ " below the seating surface of the cylinder head. The nozzles must not interfere with proper seating of the cylinder head, when installed.

**Figure 86—Cylinder Head Water Nozzle Installation (2-Valve Head)**

CYLINDER HEAD

HEAD GASKET INSTALLATION

Sealing cylinder combustion is by use of individual ring seals at each cylinder (figs. 8 and 72). Oil and water passages between cylinder block and head are sealed by synthetic rubber seals installed in counterbores at top of cylinder block. Installation of these seals requires careful placement of each part.

1. Clean top of cylinder block, area around cylinder liners, also oil and water passage counterbores so to remove all traces of dirt, carbon or other foreign material that may effect good seal between cylinder block and head.

2. Install large synthetic rubber oil seal in milled slot on four sides near edge of cylinder block. Be sure gasket is evenly distributed and is not drawn thin on one side of block.

3. Two seals are figure eight shaped and should be installed in counterbores at each end of block.

4. Install two small seals ($\frac{3}{8}$ " dia.) and large ($1\frac{1}{16}$ " dia.) seals in counterbores in cylinder block. Six cylinder engines require ten and four cylinder requires six of the large seals.

5. Position one compression seal ring carefully over each cylinder liner, being especially cautious that ring rests evenly on top of liner flange.

CYLINDER HEAD INSTALLATION

Before installing cylinder head (fig. 69), be sure seals (fig. 72) are properly installed and that all parts are dirt free. The necessary steps for replacing head are outlined below:

1. Wipe under side of cylinder head clean, and by means of the lifting brackets, set cylinder head in place on block.

2. Loosen cap screws that attach lifting brackets to cylinder head so bracket is loose. Coat cylinder head studs with Hypoid lubricant, then install and tighten cylinder head stud nut to recommended torque, in the sequence shown in figure 87. Tightening of stud nuts will be simplified by the use of special wrench in conjunction with torque wrench.

3. Tighten cap screws at each end of cylinder head that attach lifting brackets to flywheel housing and balance weight cover in sequence illustrated in figure 88.

4. Install valve and injector operating mechanism as directed under respective headings in VALVES AND INJECTOR OPERATING MECHANISM section of this manual.

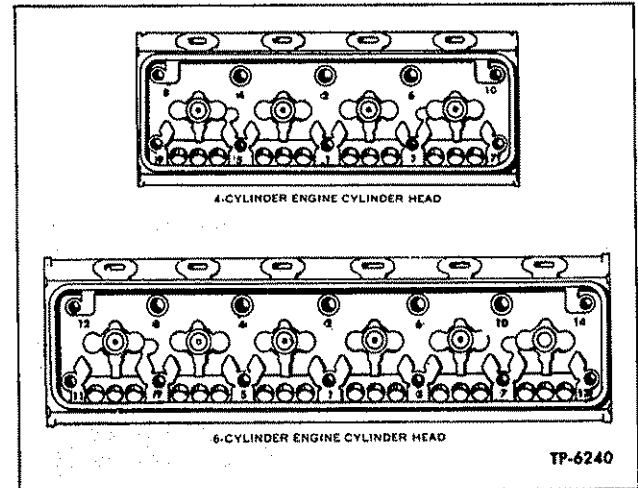


Figure 87—Head Stud Nut Tightening Sequence

5. Install injectors as instructed under "Injector Installation" in FUEL INJECTOR section of this manual.

6. Install and position injector control rack as instructed under "Control Rack Positioning" in FUEL INJECTOR section of this manual.

7. Time injectors as instructed under "Timing Injectors" in ENGINE TUNE-UP section of this manual.

8. Lash exhaust valves as instructed under "Valve Lash" in VALVES AND INJECTOR OPERATING MECHANISM section of this manual.

9. Install fuel jumper lines between injectors and fuel manifold connectors. Be sure connections are tight and leak proof.

10. Install governor control housing as directed in respective governor section of this manual.

11. During engine run-in check for fuel and water leaks. Recheck and tighten cylinder head stud nuts to recommended torque.

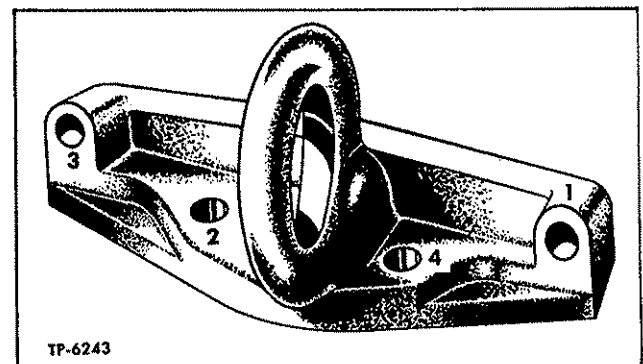
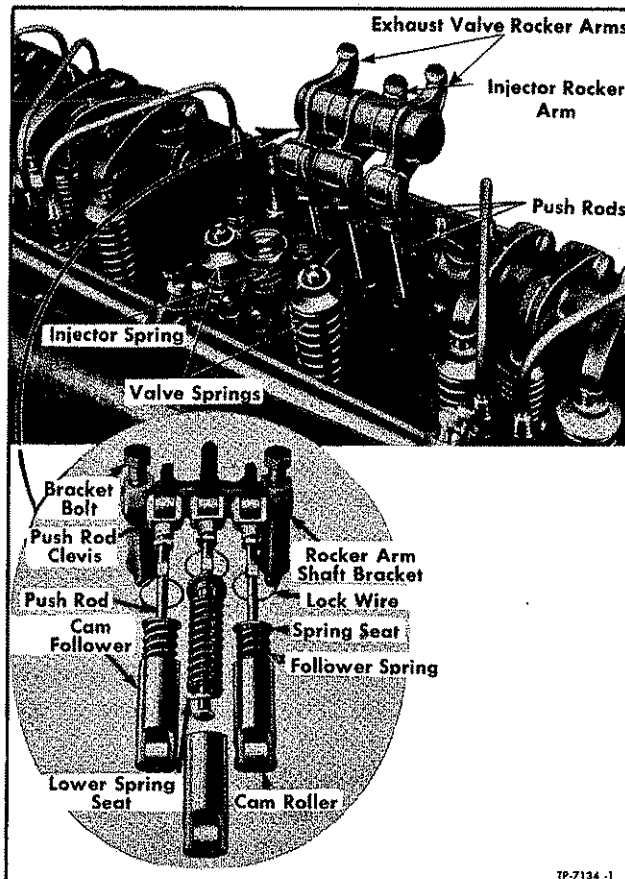


Figure 88—Head Lifting Bracket Tightening Sequence

VALVE AND INJECTOR MECHANISM**VALVES AND INJECTOR OPERATING MECHANISM**

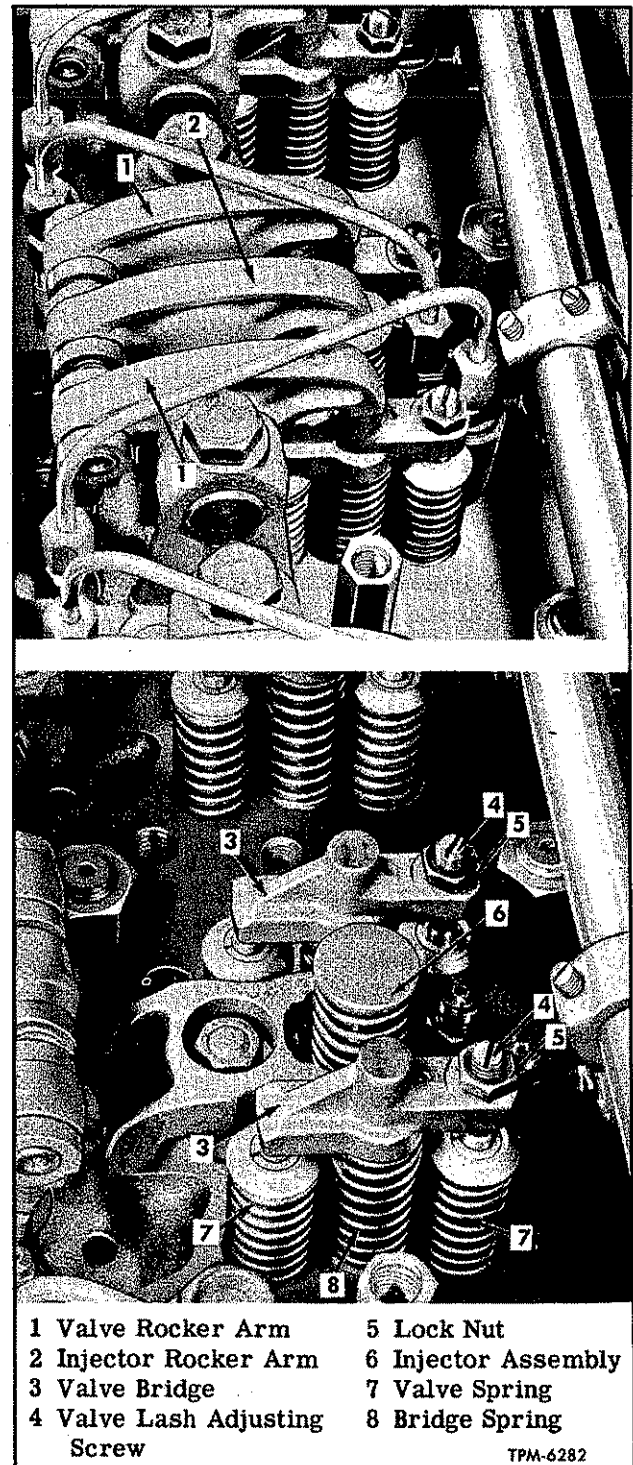
**Figure 89—Valve and Injector Operating Mechanism
—2-Valve**

Two types of valve operating mechanism are described in text following; (1) 2-valve type illustrated in figures 89 and 91, (2) bridge type used on four-valve heads, illustrated in figures 90 and 92.

DESCRIPTION**ROCKER ARMS**

Valve and injector rocker arms for each cylinder operates on a separate shaft supported by two cast iron brackets. A single bolt fastens each bracket securely to top of cylinder head.

The valve and injector ends of rocker arms are hardened and ground to a cylindrical surface, which bears directly on the end of the valve stem or injector follower. Rocker arms are operated from cam-shaft through short push rods.



**Figure 90—Valve and Injector Operating Mechanism
—4-Valve Type with Bridge**

Two or four exhaust valves are provided for each cylinder. Valves are heat treated and ground to the proper stem diameter and seat angle.

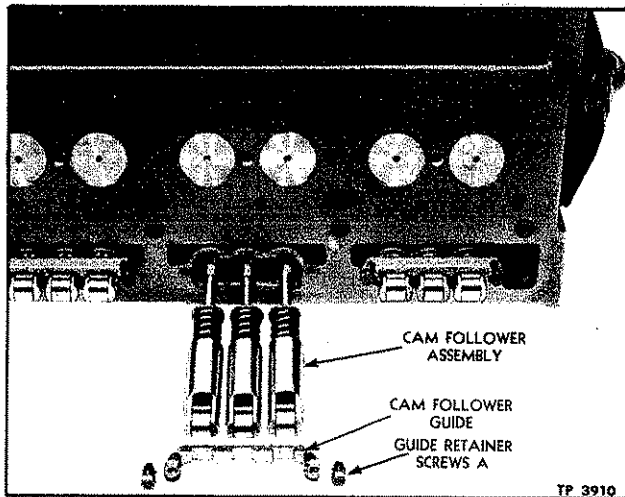
VALVE AND INJECTOR MECHANISM

Figure 93—Cam Follower and Guide Assembly

MAINTENANCE (On Vehicle)

Several service operations which may be accomplished on cylinder head, valves, and injectors assembly without necessity of removing the cylinder head assembly from the block. These operations are:

1. Valve Lash.
2. Valve Spring Replacement.
3. Valve Bridge Adjustment (Bridge Type).

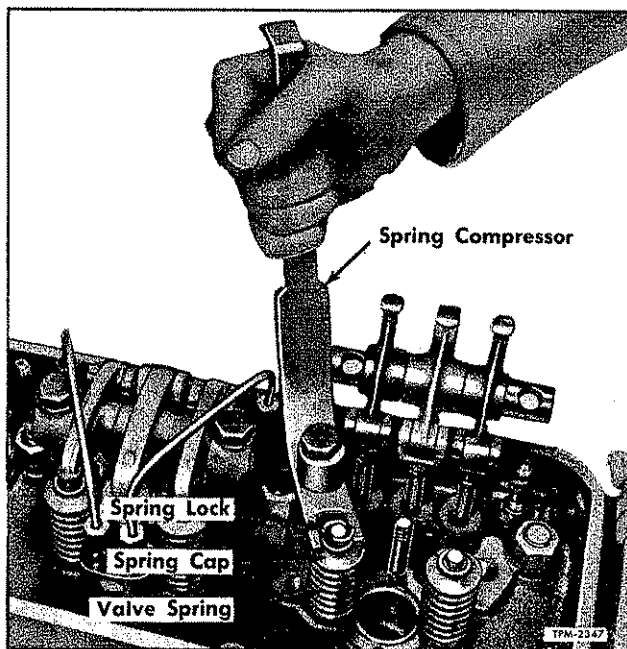


Figure 94—Compressing Valve Spring with Tool to Remove Valve Lock (2 Valve Head)

4. Rocker Arm, Shaft, or Shaft Bracket Replacement.
5. Injector Replacement.
6. Cam Follower Retainer Spring Replacement.
7. Cam Follower Replacement.
8. Push Rod Replacement.

VALVE LASH AND BRIDGE ADJUSTMENT

Refer to ENGINE TUNE-UP section of this manual for valve lash and bridge adjustment procedure.

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 valve lash is checked. **IF THIS IS NOT DONE, BEFORE ENGINE IS TURNED, THE PISTON MAY HIT HEAD OF VALVE DUE TO THE SMALL CLEARANCE BETWEEN VALVES AND PISTON HEAD AT THE PISTON UPPER POSITION.**

Correct valve lash is important due to high compression pressures. Too little clearance causes a loss of compression, missing cylinder, and eventual burning of valves and valve seats. Too much clearance between valve stem and valve rocker arm results in noisy operation of engine, especially in idling range.

NOTE: It is recommended when lashing valves to set them first cold; then start engine and warm up to normal operating temperature. Reset valve lash after engine has warmed up to operating temperature. Refer to "Specifications" for dimension.

VALVE SPRING REPLACEMENT

REMOVAL

1. Crank engine until piston is at top of stroke, which is indicated when the injector plunger has traveled approximately $\frac{3}{16}$ " on the downward stroke.
2. Disconnect and remove fuel feed lines from injector to fuel oil connectors. After removing fuel lines, temporarily install injector shipping caps to prevent dirt entering injectors.

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

Two-Valve Head

1. Install a cap screw through valve lifter tool bushing and valve lifter tool (fig. 94). Thread this cap screw into tapped hole of cylinder head adjacent to the valve spring to be removed.

2. With slight pressure on end of the tool, the valve spring retainer can now be depressed, the locks, retainer, and spring removed.

Four-Valve Head

1. Remove exhaust valve bridges and springs (when used).

2. Thread adapter end of compressor tool (J-7455) into rocker shaft bolt hole in cylinder head (fig. 95).

3. Place compressor foot on top of the valve spring cap (fig. 95).

4. Press down on compressor handle to compress valve spring, then remove two spring locks.

INSTALLATION

1. The valve spring may be installed by reversing the sequence of operation for removal.

2. After replacing the valve spring, adjust the valves, also bridge on 4-valve heads and retune injector as instructed under respective headings in ENGINE TUNE-UP section of this manual.

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

INSPECTION

Examine valve and bridge springs for pitted or fractured coils. Test valve springs for pounds pressure at height and length given in SPECIFICATIONS section of this manual.

ROCKER ARM, SHAFT, AND BRACKET REPLACEMENT**REMOVAL**

1. Disconnect and remove fuel feed lines from injector to fuel oil connectors. After removing fuel lines, temporarily install injector shipping caps to prevent dirt entering injectors.

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

3. Loosen lock nut at upper end of push rod, then unscrew push rod clevis from push rod.

VALVE AND INJECTOR MECHANISM**INSPECTION**

Before installing rocker arms or parts, check the bushings inside the rocker arms for excessive wear. Clean out oil holes in rocker arms, hollow bracket bolt, and rocker shafts with fuel oil, small wire, and dry compressed air.

INSTALLATION

1. 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.

2. 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 installed and valves are lashed.

3. Slide rocker arm shaft through rocker arms and then place one of the end brackets over each end of shaft, with finished face of the bracket boss next to rocker arm. Position rocker arm bracket bolts in place through brackets and shaft; then tighten bolts.

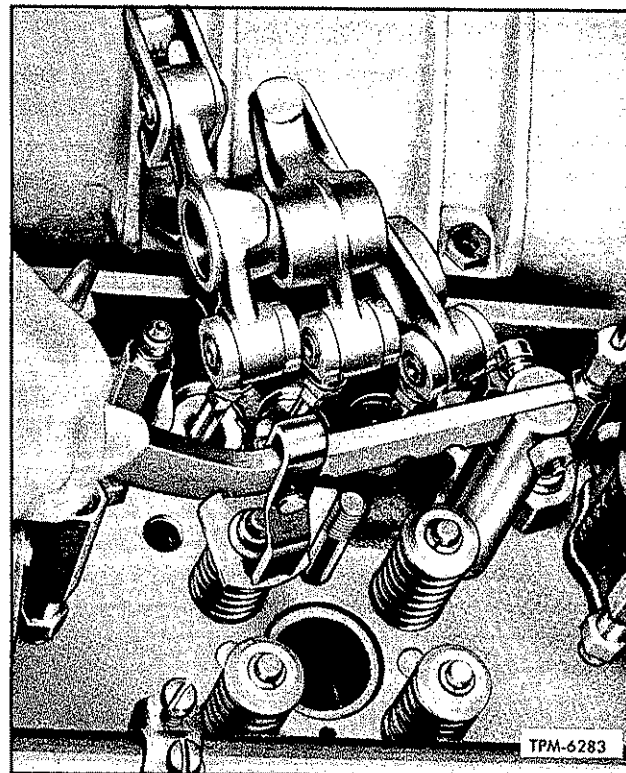


Figure 95—Compressing Valve Spring with Tool to Remove Valve Lock (4 Valve Head)

VALVE AND INJECTOR MECHANISM

4. After replacing rocker arms, valve lash and bridge must be adjusted and injector retimed as instructed under respective headings in ENGINE TUNE-UP section of this manual before engine is started.

NOTE: Connect the fuel feed lines to the injector and the fuel oil connectors. After engine has been started and before valve cover is installed, inspect all fuel oil connections for leaks. If fuel oil leaks into cylinder head and dilutes lubricating oil, engine bearings may be seriously damaged.

PUSH ROD, CAM FOLLOWER, AND SPRING REPLACEMENT

REMOVAL (Head Installed)

1. Remove valve rocker arm cover.
2. Crank engine until piston is at or near top of stroke, which relieves follower spring to minimum tension.
3. Disconnect and remove fuel feed lines from injector to fuel oil connectors. After removing fuel lines, temporarily install injector shipping caps to prevent dirt entering injectors.
4. Remove two cap screws holding rocker arm shaft brackets to cylinder head; then remove brackets and shaft.
5. Loosen lock nut at upper end of push rod, then unscrew push rod clevis from push rod.
6. Use a screwdriver to press follower spring upper seat down to relieve spring tension on retainer or lock wire. Use another screwdriver to dislodge retainer from groove in cylinder head.
7. Lift push rod, spring and retainers from cam follower. Lift cam follower and roller assembly from cylinder head.

REMOVAL (Head Removed)

Cam followers can be removed from either top or bottom of cylinder head, however they can best be removed from the bottom when the head is removed, as follows:

1. Place cylinder head on its side on bench as illustrated in figure 93. Remove two cap screws that secure cam follower guide to head, then remove guide.
2. Pull cam follower and roller assembly from

bottom of cylinder head.

3. Loosen lock nut, then unscrew push rod from push rod clevis.

4. Pull push rod, spring, and spring seats from bottom of cylinder head.

5. Push rod spring seat retainer (lock wire) remains in the cylinder head and may be left there unless cylinder head is to be changed.

INSPECTION

1. Clean and inspect cam follower for wear or damage. Check follower to cylinder head clearance.
2. Check roller for wear, also for scuffed and flat spots. Replace if necessary.
3. Should follower roller inspection reveal that roller is scuffed, inspect camshaft lobes.
4. Inspect push rod clevis to rocker arm for evidence of excessive wear at bushings and pin. Repair or replace as necessary.

INSTALLATION (Head Installed)

1. Install cam follower and roller assembly in opening in cylinder head. Assemble follower spring lower seat, spring, upper seat and retainer (lock wire) to push rod, then install assembly in follower.
2. Compress follower spring with screwdriver, then install retainer lock wire in groove in cylinder head.
3. Reinstall rocker arm clevis to push rod and install shaft, brackets, and bolts as instructed under "Rocker Arm, Shaft, and Bracket Replacement" previously in this section.
4. Adjust valve lash as instructed under "Valve Lash"; also adjust bridge as instructed under "Bridge Balancing Adjustment" in ENGINE TUNE-UP section of this manual. Retime injector as instructed under "Timing Injector" in ENGINE TUNE-UP section of this manual.

NOTE: Connect the fuel feed lines to the injector and the fuel oil connectors. When engine has been started, and before valve cover is installed, inspect all fuel oil connections for leaks. If fuel oil leaks into cylinder head and dilutes oil, engine bearings may be seriously damaged.

INSTALLATION (Head Removed)

1. If removed, install push rod spring seat retainer (lock wire) in place in cylinder head.

VALVE AND INJECTOR MECHANISM

2. Assemble to push rod the lower spring seat, push rod spring, upper spring seat and lock nut. Insert the assembly into cylinder head from the bottom.

3. Thread push rod into rocker arm clevis as far as possible or until rod contacts rocker arm.

4. Observe oil hole in the cam follower, then install follower assembly into head with oil hole pointing away from valves so that the hole is not covered by the follower guide.

5. Secure follower assembly to cylinder head using follower guide, two cap screws, and lock washers.

RECONDITIONING 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 face reground to proper angle. The valve guide should be thoroughly cleaned with valve guide cleaner in manner illustrated in figure 96. If bore in valve guide is worn oblong, or if valve heads are warped relative to the stem, the parts should be replaced.

REFER TO CYLINDER HEAD SECTION OF THIS MANUAL FOR VALVE SEAT, AND VALVE GUIDE REPLACEMENT INSTRUCTIONS.

Exhaust valves which are to be reused may be refaced. The edge of the valve at the valve head should not be less than .020" in thickness after refacing. Before installing either a new or used valve, examine the valve insert in the cylinder head for proper valve seating. The proper angle for the seating face of both the valve and valve seat insert is 30°.

The angle of the valve seat insert must be exactly the same as the angle of the valve face so as to provide proper seating of the valve.

When new valve seat inserts are installed or old inserts are reconditioned, the work must be done with a grinding tool (Fig. 97). The eccentric valve seat grinder set, used to recondition or grind valve seat inserts consists of: Grinder, Dial gauge, Pilot, and 15°, 30°, 60° Grinding wheels.

Grind the valve seat in the following manner:

1. Use 30° grinding wheel on valve seats.

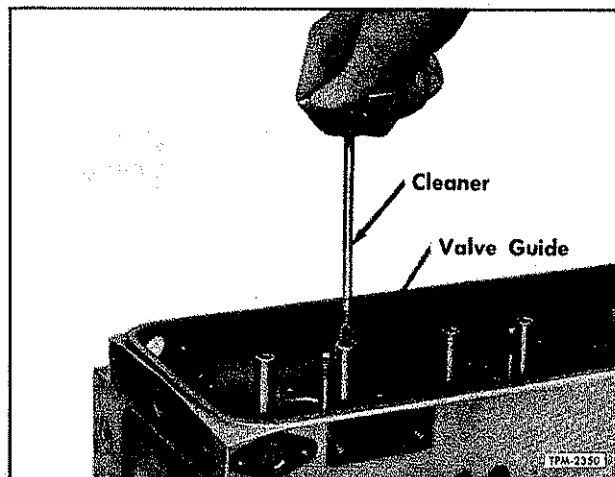


Figure 96—Cleaning Valve Guides

2. Use 60° grinding wheel to open the throat of the insert.

3. Grind top surface with 15° wheel to narrow width of seat to $\frac{1}{16}$ " to $\frac{3}{32}$ ", see figures 98 and 99. The 30° face of the insert may be adjusted relative to the center of valve face with the 15° and 60° grinding wheels.

CAUTION: For best results, do not permit grinding wheel to contact the cylinder head when grinding the inserts.

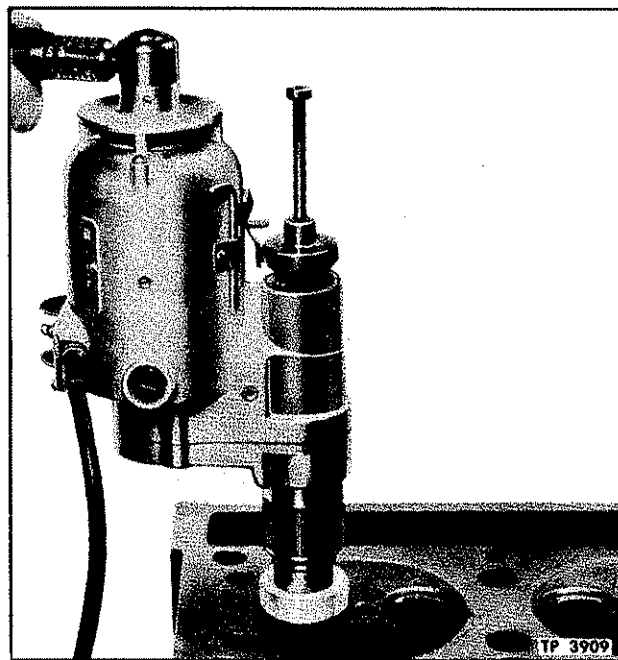


Figure 97—Reconditioning Valve Seat Insert

VALVE INJECTOR MECHANISM

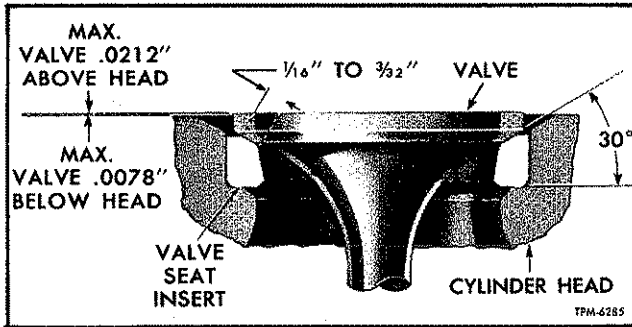


Figure 98—Installation of Valve and Valve Seat Insert—(Two Valve Head)

As shown in figures 98 and 99, a new valve must not protrude more than .0212" beyond the surface of the two-valve cylinder head or .006" beyond the surface of the four-valve head. After several re-conditions, the valve seat insert diameter will be increased so that the valve will recede into the head.

After the grinding has been completed, clean the valve inserts thoroughly with fuel oil and blow dry with air. Set the dial indicator, in position as shown in figure 100 and rotate to determine the concentricity of each valve seat insert relative to its valve guide. Total runout for a good insert should not exceed .002". If a runout of more than .002" is indicated, check for bent valve guide before regrinding insert.

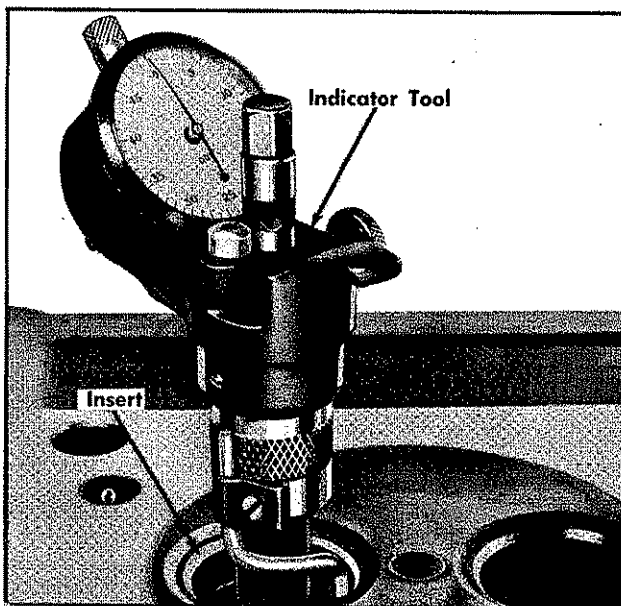


Figure 100—Checking Concentricity of Valve Seat with Valve Guide

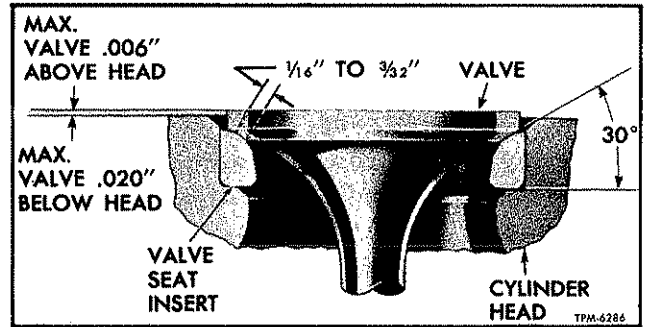


Figure 99—Installation of Valve and Valve Seat Insert—(Four Valve Head)

When a valve insert runout within the desired limits is obtained, the position of the contact area between valve and valve insert may be determined in the following manner:

1. Apply a very light coat of Prussian blue or similar paste to the valve seat insert.
2. Lower stem of valve in the valve guide and "bounce" valve on the insert, but do not rotate valve. This procedure will show (on the valve face) the area of contact. The most desirable area of contact is at the center of the valve face.

After valve inserts have been ground, the cylinder head should be thoroughly cleaned before installing the valves.

EXHAUST VALVE REPLACEMENT

INSPECTION

Inspect and clean exhaust valves thoroughly. If valve stem is excessively warped, burned, or worn, the valve must be discarded. When the valve heads are burned, warped, or pitted excessively, replace with new parts. Valves which are not excessively burned, pitted or warped may be refaced as described previously in this section.

INSTALLATION

The valve guides having been checked or replaced and the valves ground, the valves and springs may be replaced as follows:

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

2. Compress the valve springs and insert the spring locks, using tool as illustrated in figures 94 and 95.

EXHAUST MANIFOLD

EXHAUST MANIFOLD

Two exhaust passages from each cylinder lead through a single port in cylinder head to exhaust manifold. Studs in 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 cylinder head by means of special clamp washers and nuts. As a safeguard against exhaust gas leaks, a heat-resisting gasket, supported on the studs, is used between cylinder head and exhaust manifold.

Due to the 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.

REMOVAL

The exhaust manifold will usually be removed along with 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. Remove exhaust pipe.
2. Remove exhaust manifold-to-cylinder head stud nuts, and special washers, then pull exhaust manifold straight out away from engine.

3. Remove manifold gaskets from cylinder head and manifold flanges.

INSTALLATION

When manifold is removed from engine along with 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 drawn up tight against the conical washers.

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 gasket over the studs.
2. Set manifold over studs and next to gasket.
3. Set a clamp washer—dished side toward manifold—over each stud and next to manifold.
4. Replace nuts and tighten evenly to torque recommended in **Specification** section of this manual.

ENGINE TIMING AND BALANCE**ENGINE TIMING AND ENGINE BALANCE****ENGINE TIMING**

When the engine is properly timed, the marked teeth on the timing gears will be matched together as shown in figure 52.

Firing orders for Series 71 Engines are as follows:

R.H. rotation ("R" in model number) 4-71—1-3-4-2; 6-71—1-5-3-6-2-4

L.H. rotation ("L" in model number) 4-71—1-2-4-3; 6-71—1-4-2-6-3-5

CHECKING ENGINE TIMING

When an engine is suspected of being out of time, due to an improperly assembled gear train, a quick check can be made without having to remove the flywheel housing to inspect the gear train markings.

The following procedure may be used on Series "71" engines installed in any unit, provided access to the flywheel or vibration damper is possible. In some instances, it may be necessary to remove the starter to get to the flywheel to "bar" the engine and to mark top dead center indications.

Procedure

1. Remove the cylinder head cover.
2. Select any cylinder for the "timing" check—it is suggested that a cylinder adjacent to one of the cylinder head cover studs be chosen inasmuch as the stud may be used for mounting a dial indicator.
3. Remove the injector fuel jumper lines (at the cylinder selected); make sure that the valve and injector rocker arms are all in the "up" position, then remove the rocker shaft bracket bolts, and swing the rocker arm assemblies back out of the way. Remove the injector assembly as instructed under "Injector Removal" in FUEL INJECTORS section of this manual.
4. Carefully place a length ($\frac{1}{8}$ " x 12") drill rod through the injector hole and on top of the piston. Bar the crankshaft slowly in the direction of rotation, and stop barring when the rod reaches the end of its upward travel. Remove the rod then bar the crankshaft opposite the direction of rotation between $\frac{1}{16}$ and $\frac{1}{8}$ of a turn.
5. Select a dial indicator having .001" graduations and with a spindle movement of at least 1". Use suitable mounting attachments for the indicator so

that it can be mounted over the injector hole in the cylinder head. Provide an extension for the spindle of the indicator. **The extension must be long enough to contact the piston as it approaches its upper position.**

6. Mount the indicator over the injector hole and tighten mountings sufficiently to hold the indicator rigid. The mounting attachments may be threaded into the cover stud; or, the stud may be removed from the cylinder head and the attaching parts threaded into its tapped hole, depending upon the length of the rod used in making-up the mounting parts. Make sure that the spindle extension is free in the injector hole, does not bind, and is free to travel its full 1" movement.

7. Provide a suitable pointer and temporarily attach it to the crankshaft front cover or engine front end plate. Pointer should extend over the vibration damper, or crankshaft pulley, whichever is used.

8. Bar the crankshaft slowly in the direction of rotation until the hand on the dial indicator just stops moving.

9. Continue to bar the crankshaft in the direction of rotation until the indicator hand just starts to move. Reset dial to "0." Continue barring slowly until indicator reading is .010"—then stop turning.

10. Scribe a line on the damper (or crankshaft pulley) at the pointer.

11. Bar crankshaft slowly in the opposite direction of rotation, until the hand on the dial indicator just stops moving. Reset dial to "0." Slowly continue barring until indicator reading is .010"—then stop turning.

12. Scribe a second line on the vibration damper (or crankshaft pulley) in the same manner as in Step 10.

13. Scribe a third line half-way between the first two lines. This is positive TDC (top dead center). Remove the indicator from the engine.

14. Install the injector assembly as instructed under "Injector Installation" in FUEL INJECTORS section of this manual. Swing the injector and valve rocker arms back into position and install rocker arm brackets and tighten bolts to proper torque. Lash the exhaust valves and time the injector as instructed under respective headings in ENGINE TUNE-UP section of this manual. Bar the engine until the exhaust valves in the selected cylinder are open.

15. Install the dial indicator once again so that

ENGINE TIMING AND BALANCE

the spindle of the indicator rests on top of the injector follower. Set indicator dial to "0." Bar the crankshaft slowly in the direction of rotation, and stop when TDC mark on the vibration damper or crankshaft pulley lines up with the pointer.

16. Note the reading on the dial indicator and compare with the following:

1. If the indicator reading is .223" to .233", the engine is in time,
2. If the indicator reading is .188" to .204", timing is one tooth retarded,
3. If the indicator reading is .249" to .257", timing is one tooth advanced.

17. After completing the timing check, remove the dial indicator; install the injector fuel jumper lines, making sure that they are tightened to prevent any leaks; install the cylinder head cover; and, remove the pointer attached to the front of the engine.

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 counterweights on the crankshaft checks. The reciprocating masses (the piston and parts 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.

Balance weights consist of two eccentric weights at each end of the engine, as shown in **CAMSHAFT AND BALANCE SHAFT** section of this manual. 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. 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.

Balance weights at the rear end of the engine are integral and camshaft and balancer shaft drive gears. Weights at 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. One crescent-shaped weight is bolted to each gear for the four-cylinder engine, and one weight attached to each gear for the six-cylinder engine.

Lubrication System

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Engine Oil Recommendations	78	Lubricating Oil Pump	82
Oil Filters and Strainers	79	Oil Pressure Regulator Valve	87

CIRCULATION AND DISTRIBUTION

The full-flow lubrication system, used on all latest engines, is schematically shown in figure 1 and consists of oil pump, oil filter, oil cooler, and by-pass valves around filter and cooler.

The by-pass lubrication system, schematically shown in figure 2, has been superseded by the full-flow type and consisted of oil pump, oil filter, oil cooler, oil strainer (coach only) and cooler by-pass valve.

The oil cooler adapter has a spring loaded by-pass valve which assures continual lubrication even through oil cooler fails to function. Should the oil pressure at cooler inlet become 40 pounds greater than at cooler outlet, the by-pass valve in cooler adapter opens, and oil is then by-passed directly from oil pump to oil gallery. However, under these conditions, the oil is not cooled.

The gallery oil pressure is limited to 45 pounds per square inch by a spring loaded pressure regulator valve at the end of oil gallery. While a part of oil gallery, this regulator is actually located in crankcase, and is integral with pump discharge line.

Continuous filter action is provided by by-passing a portion of the oil through a filter from whence filtered oil is returned to crankcase.

Oil from cooler is conducted through a vertical passage to a longitudinal main gallery on blower side of crankcase. As shown in figures 3 and 4 this gallery distributes the oil, under pressure, to main bearings, and to a horizontal, transverse passage at each end of cylinder block. From these two horizontal passages, two vertical bores at each end of cylinder block carry the oil to end bearings of camshaft and balance shaft, as well as to oil passage in camshaft, which in turn conducts the oil to camshaft intermediate bearings.

Oil for lubrication of connecting rod bearings, piston pins, and the cooling of piston head, is pro-

vided through drilled crankshaft from the adjacent forward main bearings. The gear train is lubricated by overflow of oil from camshaft pocket through a passage into gear train cover. Oil spills into the gear cover from camshaft, balancer shaft, and idler gear bearings. The blower drive gear bearing is lubricated through an external pipe from rear horizontal oil passage of 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 cylinder block. Oil from this gallery enters hollow rocker arm shafts through rocker shaft brackets, hollow capscrews, and lubricates rocker arm bearings and push-rod clevis bearings.

Excess oil from rocker arms lubricates valve ends and push rods, and drains to cam pockets in cylinder head from which cams are lubricated. As shown in figure 5, after reaching a certain level, this oil overflows through two holes at each end of blower housing, providing lubrication for blower drive gears at rear end and governor drive gear at the front. A dam in blower housing cover maintains an oil level which submerges teeth of the lower blower rotor timing gear. A slinger on opposite end of lower rotor throws oil into governor weight assembly. Surplus oil passes from blower to oil pan through drilled holes in cylinder block.

CRANKCASE VENTILATION

Under normal operating conditions, harmful vapors may collect in crankcase and valve compartment. These vapors may, under certain conditions, cause etching of highly finished surfaces and dilution of oil unless withdrawn. The crankcase and valve compartment are continually cleaned of harmful vapors by a breather pipe attached to governor upper housing and venting to atmosphere.

OIL CIRCULATION

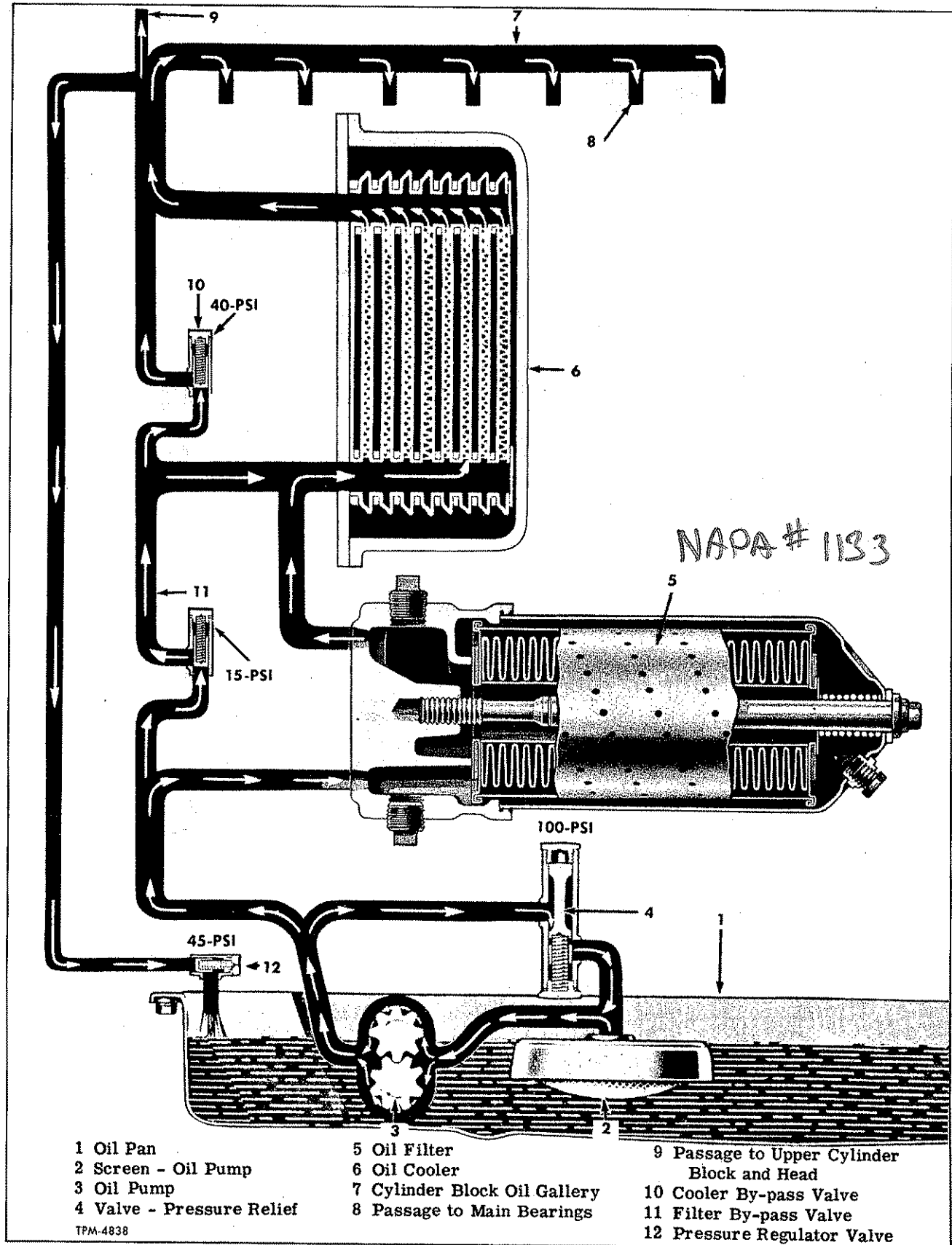


Figure 1—Schematic Diagram of Full-Flow Engine Lubrication System

OIL CIRCULATION

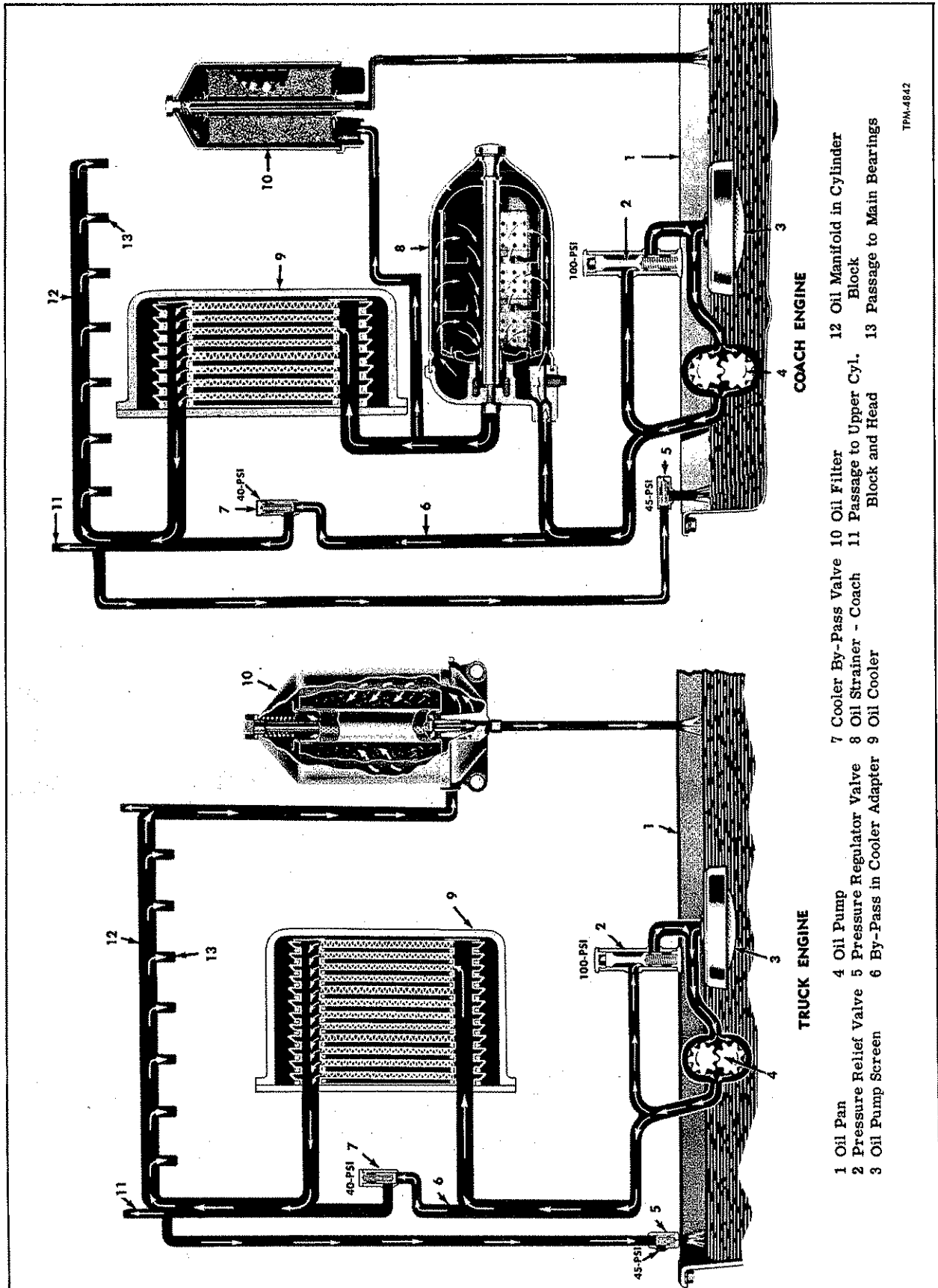


Figure 2—Schematic Diagram of By-Pass Engine Lubrication System

OIL CIRCULATION

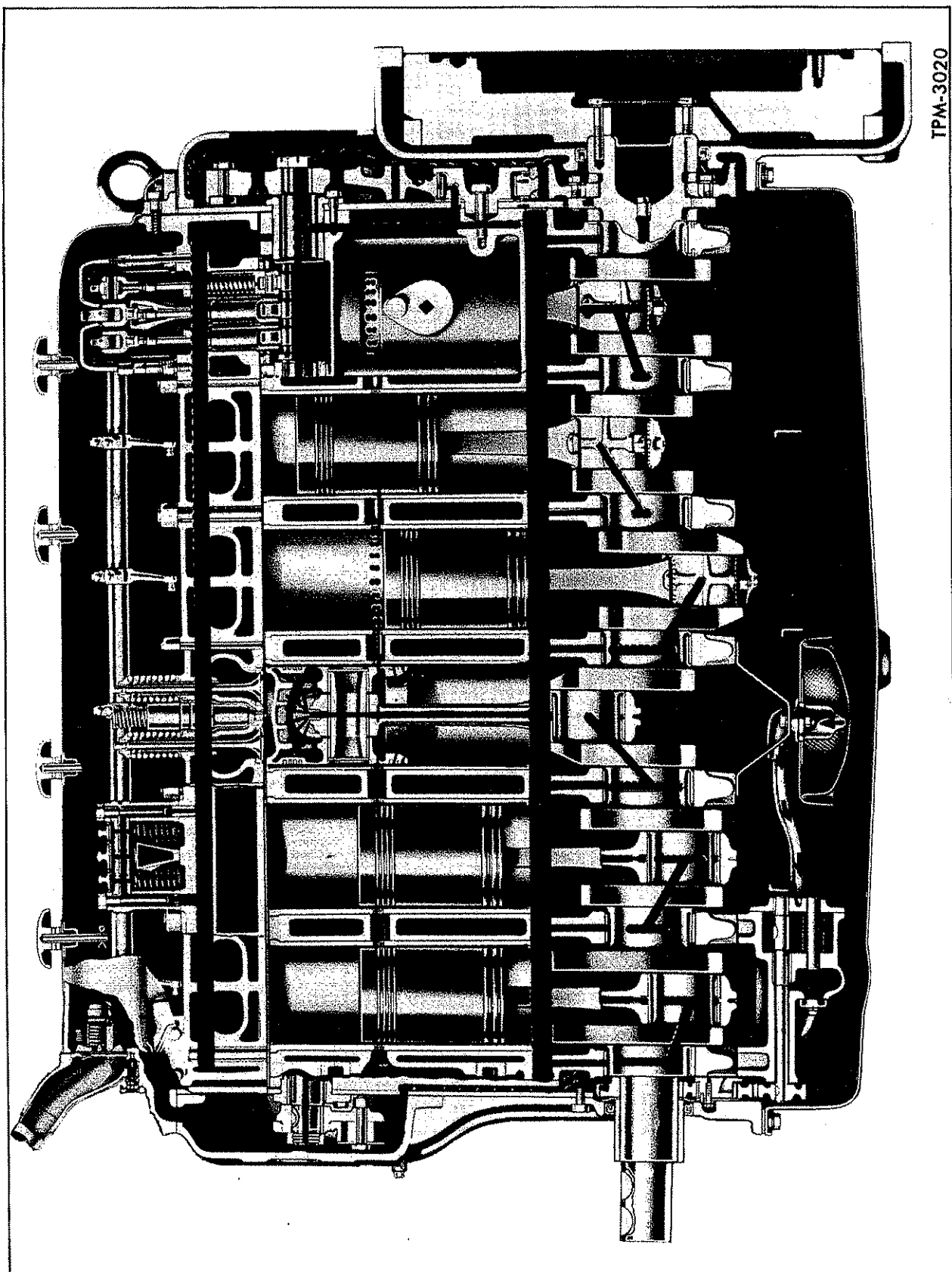


Figure 3—Longitudinal Cross Section of Engine Showing Oil Flow

OIL CIRCULATION

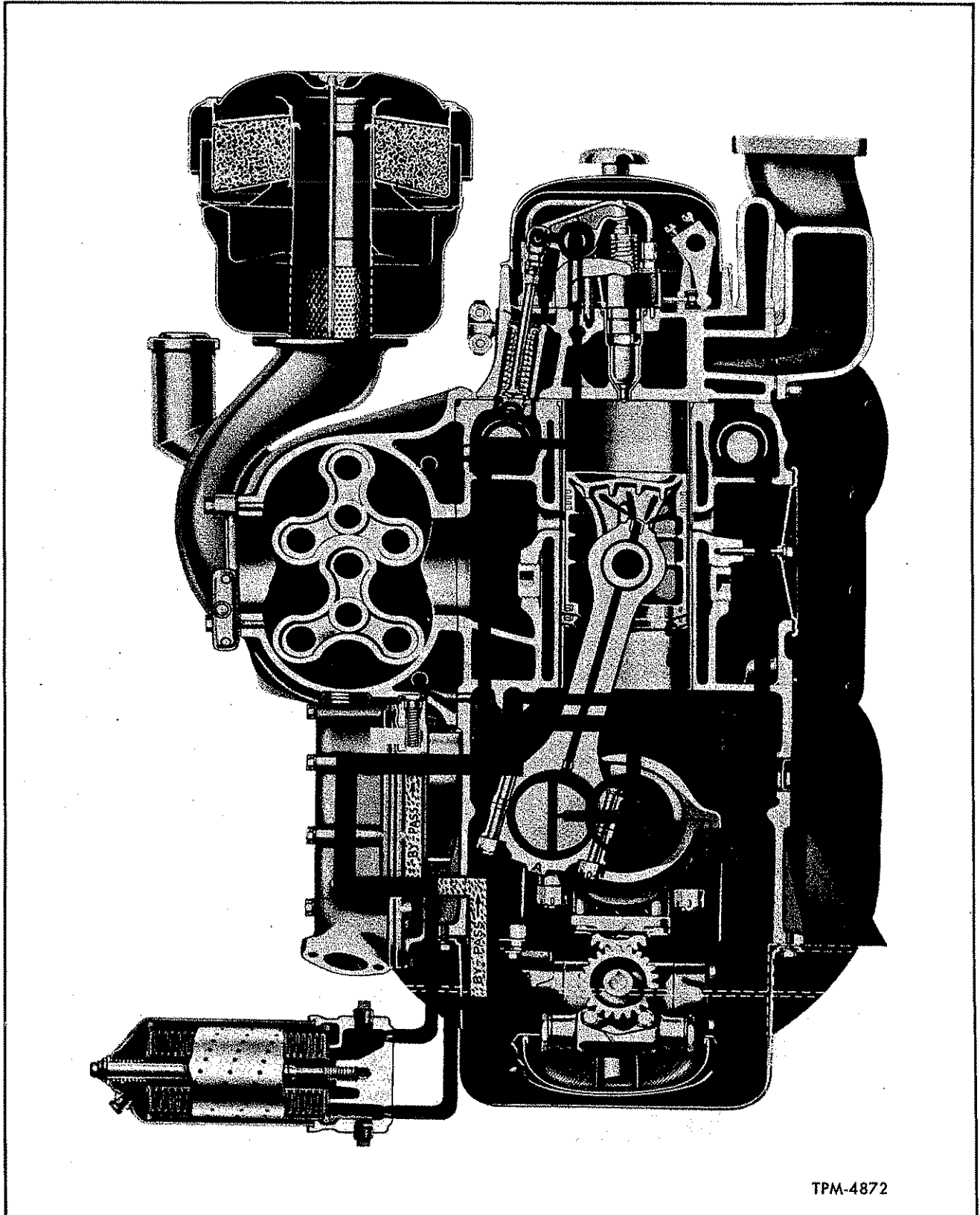


Figure 4—Transverse Cross Section of Engine Showing Oil Flow

OIL CIRCULATION

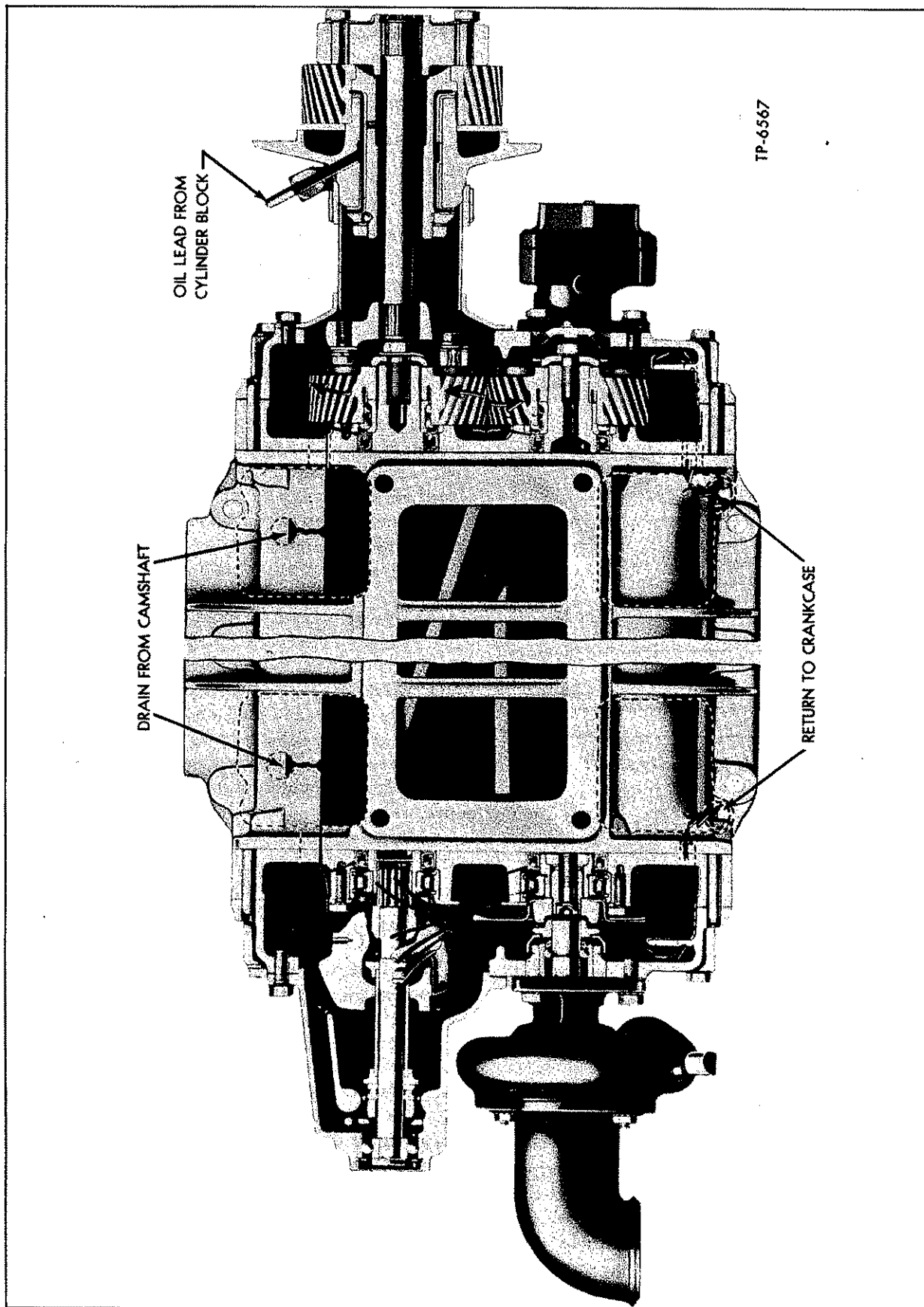
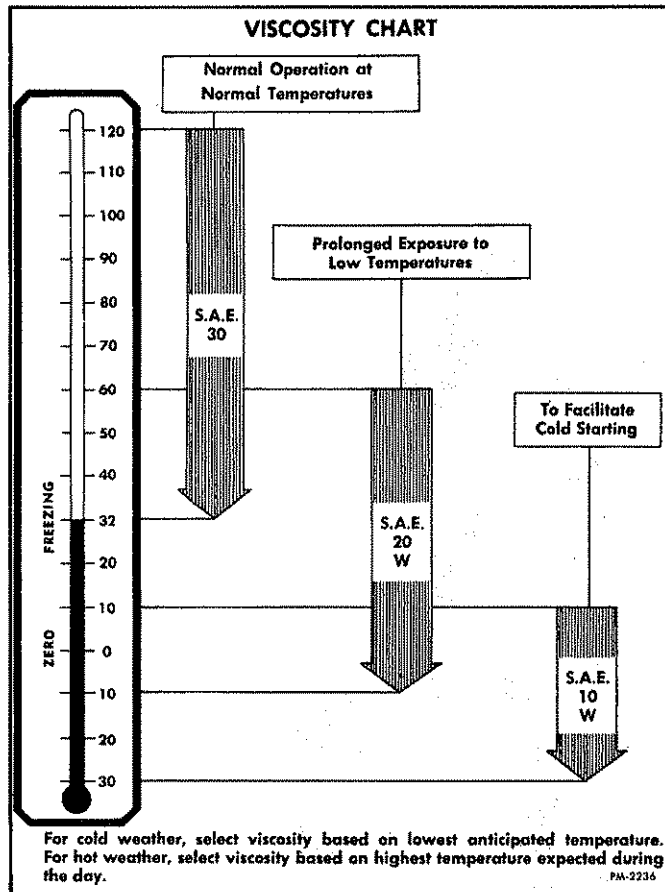


Figure 5—Blower and Accessories Showing Oil Flow

OIL RECOMMENDATIONS**ENGINE OIL RECOMMENDATIONS****Figure 6—Engine Oil Viscosity Chart****TYPES OF OIL**

Crankcase oils in service, unless protected by suitable addition agents, oxidize, form sludge and varnish, and under some driving conditions, corrosive acids may accumulate in the crankcase. Heavy Duty engine oils minimize the formation of these harmful decomposition products and generally aid in obtaining extended trouble free service.

RECOMMENDATIONS

Heavy Duty engine oils designated for service "DG," "DM," or classified as MIL-L-2104A type, Supplement 1 (S-1) and which meet or exceed the MIL-L-2104A specifications are recommended for use in Diesel engines as used in GMC trucks. Regardless of oil type used, reputable oil suppliers

should guarantee the following in furnishing oil for Diesel engines:

1. Good resistance to "scuffing" or excessive wear.
2. Good resistance to low temperature deposits and rust.
3. Good resistance, at high temperature, to formation of deposits, to thinning out, or excessive oil consumption.

CHANGING OIL

It is recommended that engine crankcase oil be drained initially at 500 miles in order that certain oil contaminants such as water, dirt, etc., be removed from engine as soon as possible after the engine is placed in service.

The intervals at which crankcase oil should be changed depend entirely upon the type and quality of oil used, the severity of truck operation, and the mechanical condition of the engine. Oil changing is closely related to filter element and air cleaner element changing. **THE OIL MUST BE CHANGED OFTEN ENOUGH TO KEEP IT NONABRASIVE AND NONCORROSIVE.** It is imperative that regular intervals be established and crankcase oil and oil filter element be changed regularly. The oil supplier will assist in determining fixed oil change intervals from laboratory tests of used oils from the crankcase.

Crankcase should be drained only after a run or when oil is hot.

VISCOSITY

Atmospheric temperatures and severity of service determine the viscosity or grade of oil to use. In cold weather operation, if vehicle is not stored in a heated garage, starting the engine may be difficult, if heavier oil than recommended is used. The use of lighter oils will not only lessen cold weather starting difficulties, but will result in fuel economy and longer engine life. For correct viscosity of oil used at various atmospheric temperatures refer to "Viscosity Chart" shown in figure 1. The S.A.E. viscosity numbers constitute a classification in terms of viscosity or fluidity but with no reference to any other characteristics or properties.

OIL FILTERS AND STRAINERS

CHECKING OIL LEVEL

A bayonet type oil gauge at rear of engine is used to determine the quantity of oil in the engine oil pan. This gauge is marked with two designations, "Low" and "Full." Oil should never be allowed to drop below "Low" mark, and no advantage is gained by having oil above "FULL" mark. Dipstick is ac-

cessible at rear of cab as illustrated in figure 6.

Daily, or oftener if necessary, check level with engine at normal operating temperature and after engine has stopped for 3 to 5 minutes. Remove dipstick, wipe with clean cloth, replace in crankcase and remove again. Note oil on dipstick and, if necessary, add sufficient oil to bring level up to "FULL" mark. Never run engine if oil is below "LOW" mark.

OIL FILTERS AND STRAINERS

Diesel engines are equipped with at least one oil filter. On some coach engines an oil strainer is also used, and some truck engines use two filters.

filter element is carried in applicable maintenance manual.

OIL FILTER

The oil filters incorporate a replaceable, non-cleanable filtering element through which only a metered portion of the circulated oil passes. These filters remove any impurities which may be detrimental to the engine. Filter element must be discarded and replaced with new element at each oil change; otherwise new oil will become contaminated, and eventually flow of oil through filter will cease resulting in possible serious damage to engine.

MAINTENANCE

Several types of oil filters are used on trucks and coaches, depending upon the particular engine, therefore instructions regarding the replacement of

OIL STRAINER

Oil strainer (when used on coach engines) incorporates a cleanable type element through which passes all the oil leaving the oil pump. Strainer removes all particles larger than .005" in diameter.

Strainer element must be thoroughly cleaned at each oil change. If strainer is not cleaned it will eventually become restricted or even clogged; then flow of oil is by-passed around strainer and oil cooler. Under these conditions oil will not be strained or cooled with serious damage to engine resulting.

MAINTENANCE

Refer to applicable maintenance manual covering vehicle being serviced for disassembly, cleaning, and reassembly instructions.

OIL COOLER

Engines are equipped with an oil cooler which not only cools the hot engine, but, by means of the cooling water temperature control, provides a means of rapidly raising the oil temperature during the warm-up period.

The oil cooler is the single-pass, multiple-type, with a corrosion-resistant steel cooling unit con-

tained in a housing. Cooling water drawn through the housing by the water pump completely surrounds the cooling unit. (See fig. 7).

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.

OIL COOLER

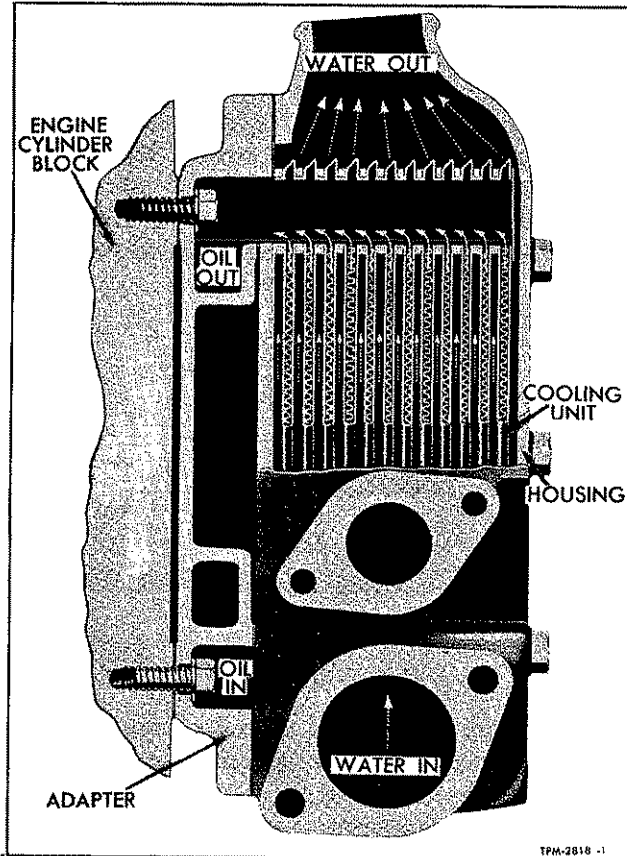


Figure 7—Oil Cooler Assembly

Should the cooler element become clogged, a by-pass valve located in the cooler adapter, bypasses oil around the cooler and directly to the oil gallery in the cylinder block. Refer to figure 8 for method of mounting cooler, filter, and strainer adapter, and by-pass valve for coach engines.

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 housing, the cooling element must be well sealed against water getting into the oil or oil getting into the cooling water. Therefore, special care must be taken at assembly to have the proper gaskets in place and the retaining cap screws tight.

CHECKING COOLER

A definite check for a clogged cooler may be accomplished on engines equipped with an oil strainer by attaching a pressure gauge to the oil strainer

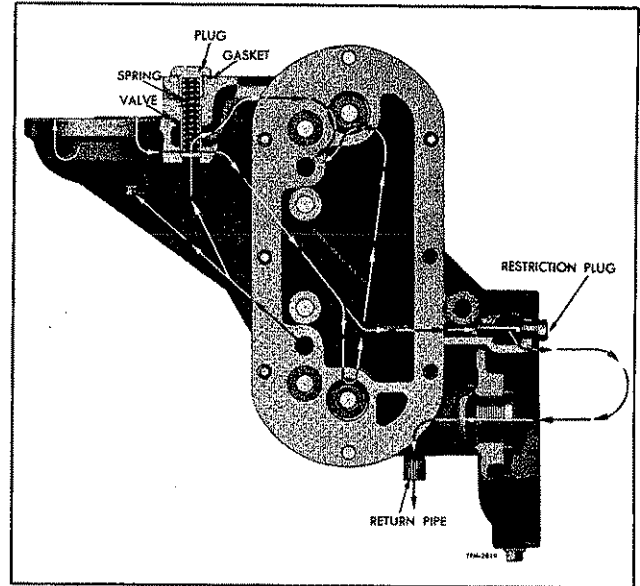


Figure 8—Oil Cooler, Filter, Strainer, and By-Pass Valve Mounting Bracket

drain plug. This gauge will indicate the oil pump pressure. When this pressure is compared with the gallery pressure, the difference should not exceed 25 psi. A pressure drop in excess of 25 psi indicates either a clogged strainer or cooler, both of which should be removed and cleaned.

The same test with a gauge to check for pressure drop can be made on engines with full-flow lubricating system which do not have the oil strainer. A $\frac{1}{8}$ " tapped hole with plug is provided in the side of oil cooler adapter for installation of gauge. On engines without oil strainer, and without the $\frac{1}{8}$ " plug in adapter, gauge can be connected in cylinder block into passage from oil pump to cooler adapter. A tapped hole and $\frac{1}{8}$ " plug are provided for this purpose.

REMOVAL

COACH ENGINE

1. Drain cooling system and oil strainer.
2. Disconnect water connection from radiator at lower end of oil cooler.
3. Break hose clamp connections between the water pump and oil cooler.
4. Remove cap screws which attach oil cooler casting to combination adapter; then remove cover and cooler element as an assembly. Be careful when withdrawing assembly not to drop and damage cooling element.

OIL COOLER

Above operations are necessary to remove oil cooler element; if combination adapter, strainer, and filter are to be removed, then continue as follows:

6. Remove filter and strainer. Remove cap screws that hold adapter to cylinder block then remove adapter.

TRUCK ENGINE

1. Drain cooling system.
2. Disconnect water connection from radiator at lower end of oil cooler.
3. Break hose clamp connection between water pump and oil cooler.
4. Remove cap screws retaining oil cooler cover casting to adapter and remove cover. Be careful when withdrawing assembly not to drop and damage cooling element.

The above operations are necessary to remove oil cooler element; if adapter is to be removed continue as follows:

5. Remove cap screws retaining adapter to cylinder block and remove adapter.

CLEANING

Since the function of the oil cooler is to reduce the engine oil temperature, the oil passages and the water side of the cooler must be kept clean for efficient cooling. The frequency of cleaning will vary depending on the type of lubricating oil used, operating conditions, and the filter medium employed.

When the cooler becomes clogged, the oil pressure on the inlet side of the cooler increases and the outlet pressure decreases, thus causing an increase in the pressure drop across the cooler. When this pressure drop reaches a predetermined value, the oil cooler by-pass valve opens and the oil circulates through the oil cooler by-pass and consequently is not cooled. The gallery oil pressure then becomes less than normal because of the lowered viscosity of the oil due to lack of cooling and the resulting increase in oil temperature.

CLEANING EQUIPMENT

The recommended oil cooler cleaning equipment consists of a gear or centrifugal pump of 25 to 30 gallons per minute capacity and two metal tanks which must be of sufficient capacity to clean the unit or units involved. One tank should contain kerosene, or an equivalent solvent, and the second tank should contain an alkaline base solution, made up in accordance with supplier's recommendations.

CLEANING OPERATIONS

The kerosene, or equivalent solvent, should be circulated through the cooler. If a circulating pump is not available the cooler can be immersed in the solvent for an indefinite period. This will remove some of the dirty oil and sludge and will avoid contamination of the alkaline base solution which is used later to further clean the oil passages. If the cooler is not cleaned immediately after removal from the engine, it should be kept in the solvent solution in order to avoid drying out and hardening of the oil sludge.

The alkaline base solution should be circulated through the oil cooler passages in reverse direction to the normal oil flow. The cooler should be connected with the cleaning solution inlet at the bottom in order to assure that the cooler is filled with the cleaning solution at all times. The cleaning operation usually requires from 20 to 30 minutes, depending on the condition of the unit involved.

Following this operation, the cooler must be thoroughly flushed with clean water and blown dry. If the cooler is not to be reinstalled immediately, some protective measure against rust must be taken.

If the water side of the cooler is coated with mineral deposits, it can be cleaned in a solution of two or three parts muriatic acid to seven or eight parts water, taking care to plug the oil inlet and outlet during this operation in order to avoid the introduction of acid into the oil passages. After the action of the acid on the scale has ceased, the cooler should be thoroughly washed in a neutralizing solution such as ordinary baking soda or soda ash.

REASSEMBLY AND MOUNTING

The lubricating oil cooler is assembled and mounted by reversing the sequence of operations for removal.

1. Clean the old gaskets from the bosses where the oil cooler adapter sets against the crankcase, and affix new gaskets to these bosses.

2. Locate the adapter into place and attach to cylinder block with the cap screws.

3. Clean the old gasket from both sides of the flange on the cooler element, also from the finished face of the adapter and the finished face of the oil cooler cover; then install a new gasket to each flange of the cooler element.

4. Position the cooler element into inside the

OIL PUMP

cover; then set cover with element against adapter and secure with lock washers and cap screws.

5. Install oil filter and strainer.

6. Connect radiator and water pump water connections being sure they are tight to prevent water leakage.

LUBRICATING OIL PUMP

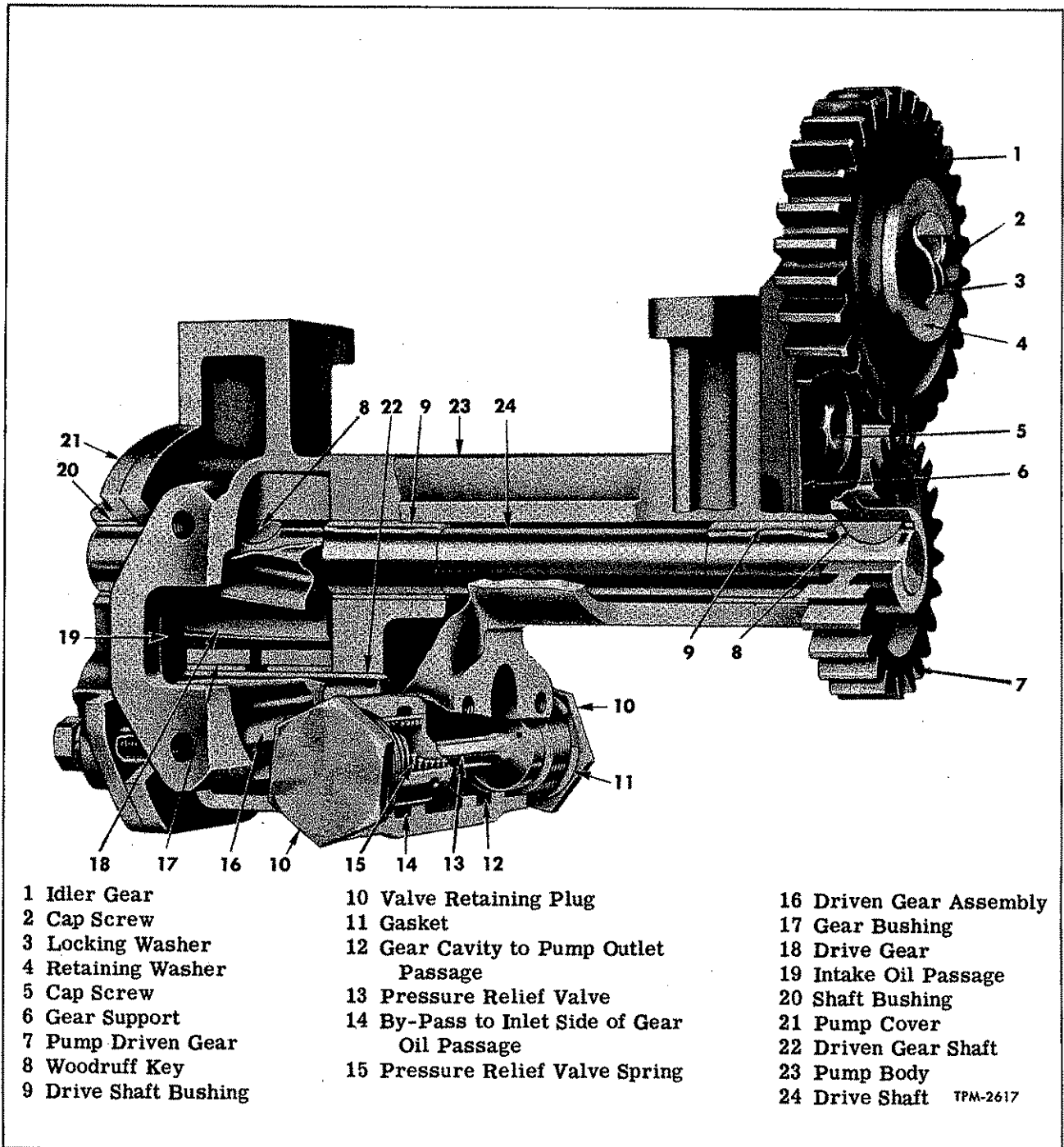


Figure 9—Oil Pump Assembly—RA, RC, and RD Shown

OIL PUMP

CONSTRUCTION

The lubricating oil pump (fig. 9) is gear type and is mounted on main bearing caps (fig. 10). Pump is driven from a gear on crankshaft through an idler gear attached directly to the oil pump assembly.

A plunger type relief valve in the pump body by-passes excess oil to the inlet side of pump when discharge pressure exceeds approximately 100 pounds per square inch.

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 pump housing to opposite side. Pump cover must be properly installed in order

to direct oil intake on correct side of pump gears. Refer to figures 15 and 16.

To protect oil pump gears, and as an insurance against pump losing its prime, a screen assembly of ample size is attached to oil pump suction pipe, and partially immersed in the lubricating oil contained in 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 engine bearings. Clean oil and an occasional overhaul of oil pump if oil becomes sludged, are essential to long engine life.

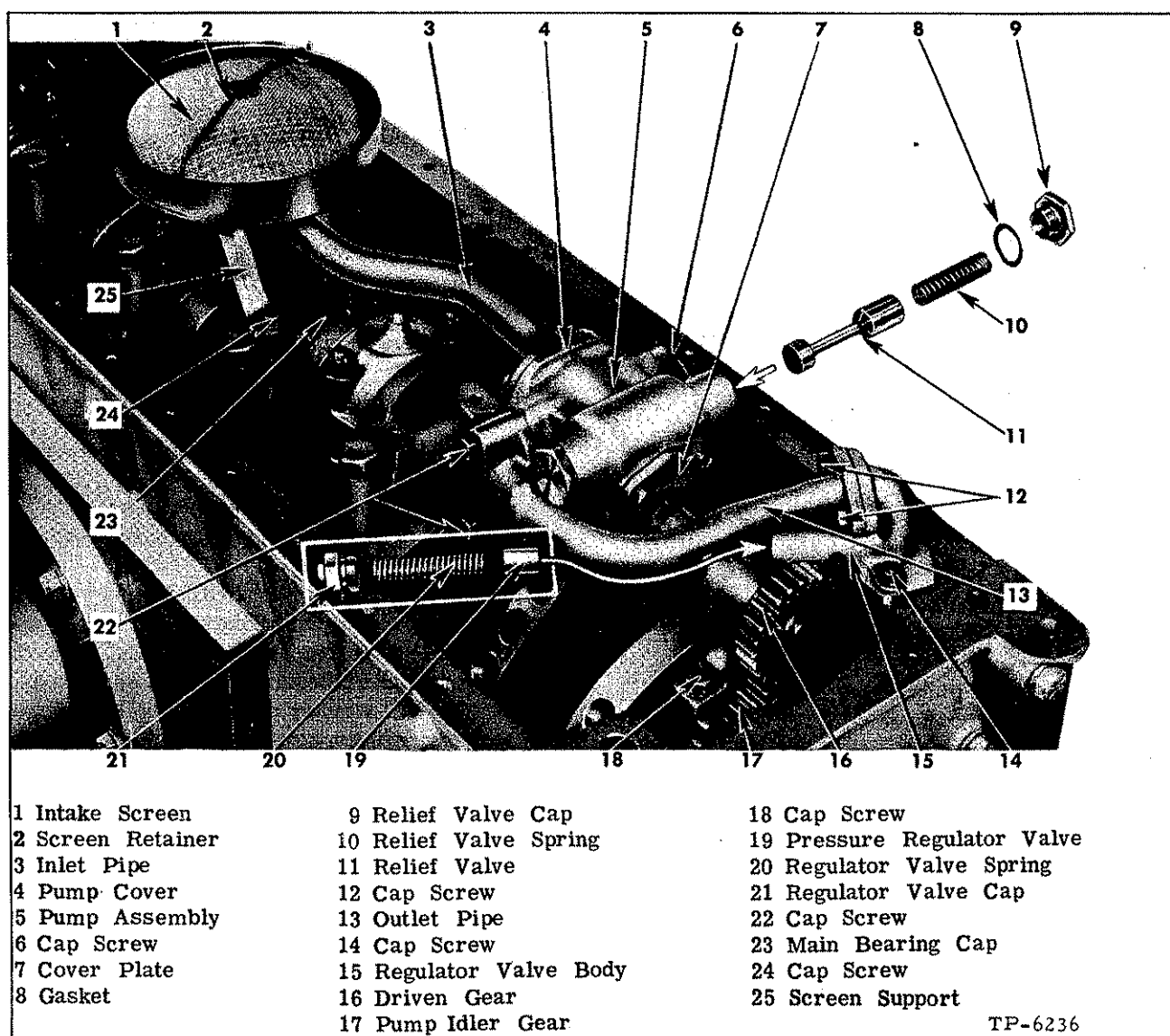


Figure 10—Oil Pump Installed

OIL PUMP

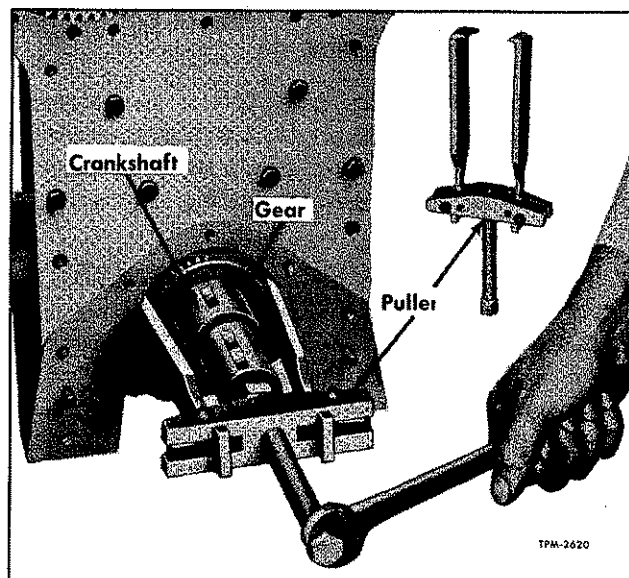


Figure 11—Removing Oil Pump Drive Gear from Crankshaft

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, lubricating oil pump and inlet screen must be removed from main bearing caps.

DRIVING GEAR REPLACEMENT

REMOVAL

1. Remove drive pulley and vibration damper from front end of crankshaft as directed in VIBRATION DAMPER section of this manual.
2. Remove crankshaft front cover as directed in CRANKSHAFT FRONT COVER AND OIL SEAL section of this manual.
3. Remove lubricating oil pump assembly as instructed under "Pump Removal" later in this section.
4. Slide oil slinger and spacer or cone off crankshaft; then with puller pull drive gear off crankshaft (fig. 11).

INSTALLATION

1. The extended-hub side of gear must be next to crankshaft main bearing. Place Woodruff key in crankshaft; then start gear on crankshaft over key. With a suitable pipe for a driver (fig. 12), drive gear tight against shoulder on crankshaft.
2. Place the oil slinger over crankshaft with dished outer diameter away from gear.

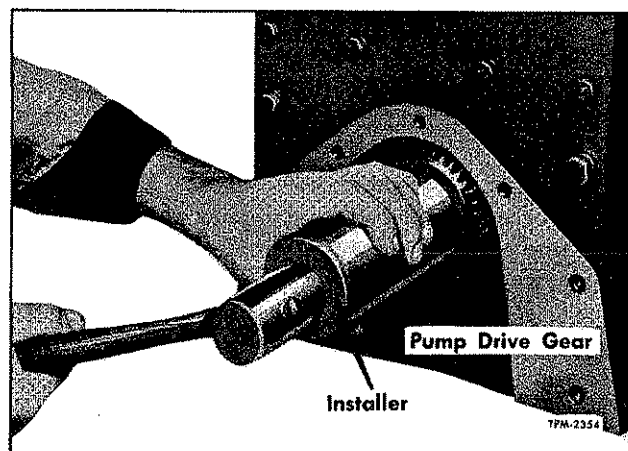


Figure 12—Installing Oil Pump Drive Gear on Crankshaft

CAUTION: Do not install spacer or cone next to oil slinger until after the front cover is in place. The oil seal in front cover may be damaged if forced over the spacer or cone.

3. Install lubricating oil pump assembly as directed under "Pump Installation" later in this section.

4. Install crankshaft front cover as directed in CRANKSHAFT FRONT COVER AND OIL SEAL section of this manual.

PUMP REMOVAL

To remove the lubricating oil pump assembly proceed as follows:

1. Drain oil from pan and remove pan.
2. Remove oil pump screen by removing screen retainer.
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 lock washers attaching regulator valve body to cylinder block; also two cap screws and lock washers retaining oil outlet pipe to pump body and regulator valve. Remove oil outlet pipe assembly, together, with two gaskets.
5. Pump is separated from engine by removing four cap screws, holding pump to main bearing caps.

NOTE: Observe and replace the shims used between legs of oil pump body and main bearing caps.

PUMP DISASSEMBLY

NOTE: Carefully observe relative location and position of relief valve parts (fig. 9) and pump

OIL PUMP

cover markings (figs. 15 and 16) so that these parts can be reassembled to their proper location.

1. Remove two retaining nuts and copper gaskets from each side of pump body; then remove relief valve assembly from body.

2. Remove four cap screws and lock washers; then separate pump cover from body.

3. Remove pump idler gear from stub shaft.

4. Support pump body and drive shaft assembly, including gear, in bench vise; then by means of a gear puller, pull gear from pump shaft, as shown in figure 13. Remove Woodruff key from shaft, and withdraw shaft and gear assembly from pump body.

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.

PUMP INSPECTION

Wash all lubricating oil pump parts in cleaning solvent to remove all accumulated deposits, before inspection.

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, impurities 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 filters, oil strainers, and air cleaners.

Before assembling pump, inspect gear teeth, inside of gear housing, and body bushings for wear. If gear teeth are scored, or worn appreciably they should be replaced. If gear housing is scored, the pump body and cover should be replaced.

Oil pump gears must be smooth, and without scratches or score marks on their sides. Also, teeth must be smooth without nicks or rough spots. Clearance between gears and housing should be within limits given in **SPECIFICATIONS** section of this manual.

Inspect seat and plunger of relief valve, and change if necessary.

PUMP ASSEMBLY

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 crank-

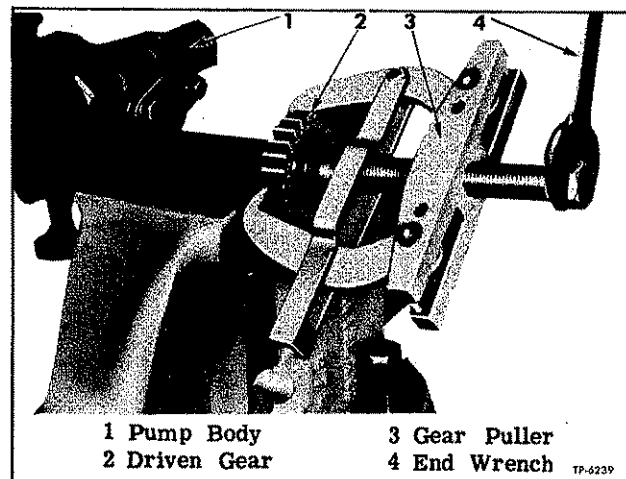


Figure 13—Removing Driven Gear from Pump Shaft

shaft rotation differ in two respects:

1. The location of the pump intake or pump cover.
2. The position of the relief valve relative to the pump intake.

When viewing the oil pump from the drive gear end, the shaft revolves clockwise on right-hand engines, and counterclockwise on left-hand engines.

Again, as viewed from the drive end, the intake opening will be positioned on left and relief valve spring on same side of pump for right-hand rotating engines, and on the right for left-hand rotating engines.

With the above identification features in mind, and by reference to figures 15 and 16 assemble the oil pump, as follows:

1. The pump gear end of drive shaft has a keyway about $1\frac{3}{32}$ " 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

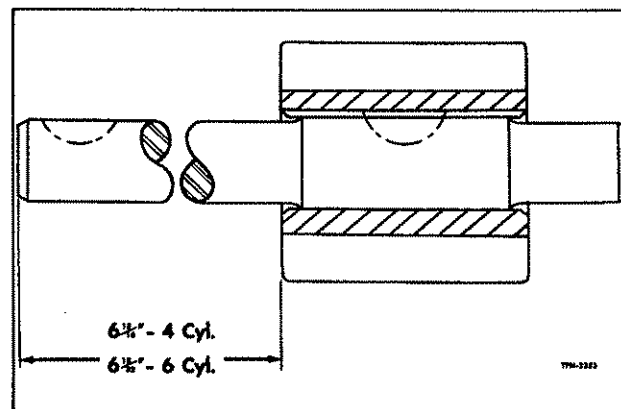


Figure 14—Oil Pump Drive Gear and Shaft Assembly Dimensions

OIL PUMP

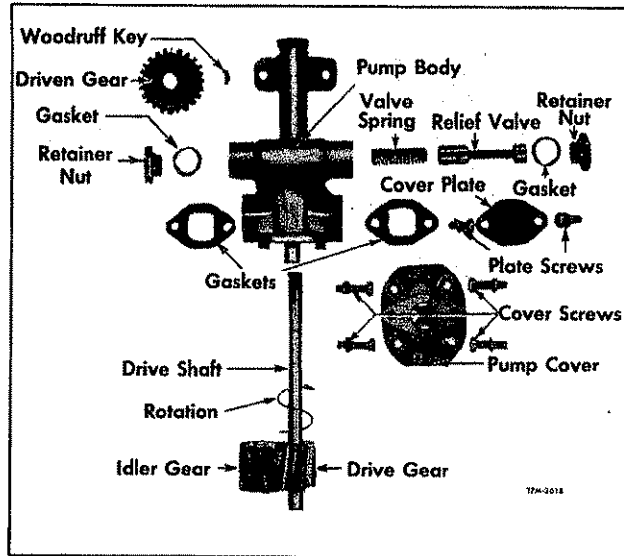


Figure 15—Oil Pump Details—RA, RC, RD, RB

onto shaft with arbor press until dimension from end of shaft to gear is as shown in figure 14.

2. Lubricate shaft with engine oil, and insert into pump body.

3. Install idler gear support over pump body and secure with cap screw.

4. Install Woodruff key at drive gear location, align keyway with key and start gear onto shaft with flat face facing pump body. Support pump gear end of shaft on bed of arbor press and press gear onto shaft to within .005" of pump body.

5. Lubricate and position pump idler gear onto

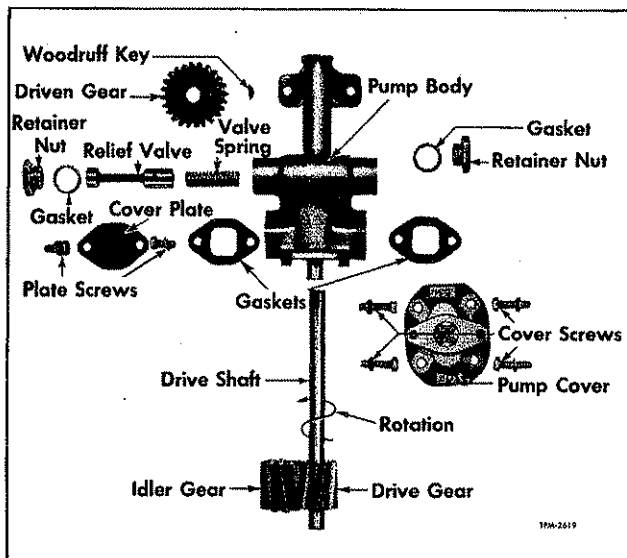


Figure 16—Oil Pump Details—LA

stub shaft in body.

6. 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 lock washers and cap screws.

NOTE: No gasket is used at this joint.

7. Position idler gear on support and install retaining washer, locking plate and cap screw. Be sure retaining washer is over support dowel; then tighten cap screw.

8. Note on what engine model the pump is to be used, then refer to figures 15 and 16, and assemble the relief valve in the pump body. As viewed from gear end of pump, the intake opening in body cover and relief valve spring will both be on left side of pump for right-hand rotating engines, and on right side of pump for left-hand rotating engines. Body end covers are marked "RH" or "LH" and "TOP." Cover marked "RH" must always be used with right-hand rotation engines, while cover marked "LH" must be used with left-hand rotations. Cover marked "TOP" must always be so installed.

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

PUMP INSTALLATION

When main bearing caps are in place and the pump driving gear is on the crankshaft the lubricating oil pump may be installed as follows:

1. Position oil pump assembly against main bearing caps so that idler gear meshes and is flush with

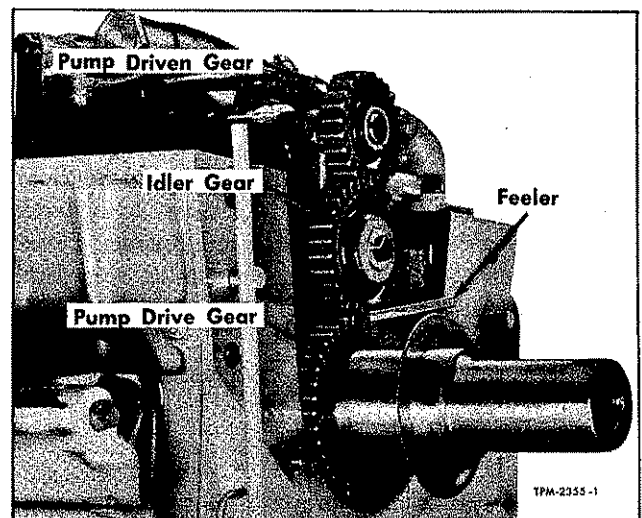


Figure 17—Checking Clearance Between Oil Pump Drive Gears

PRESSURE REGULATOR VALVE

driving gear at crankshaft.

2. Secure pump mounting feet to main bearing caps, using cap screws and lock washers.

3. Check clearance between gears using feeler gauge (fig. 17). Refer to **SPECIFICATIONS** section of this manual for backlash dimension.

4. Shims are used between the pump mounting feet and main bearing caps when necessary to make an adjustment to obtain backlash. Equal shim pack thickness must be used under each foot. Each .005" shim removed or added changes the backlash .0035".

5. Using new gasket at each end, attach oil outlet pipe to pressure regulator valve and oil pump body, with two lock washers and cap screws at each end.

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

7. Position screen supports on the two correct main bearing caps with lock washers on cap screws, start bolts in place. Do not tighten.

8. Using new gasket at pump end, secure oil inlet pipe to pump.

9. Set screen cover (screen side facing oil pan) over casting at outer end of oil inlet pipe and cap screws to outlet pipe casting and screen supports. Tighten screen supports to bearing caps.

10. Attach oil screen and lock in place with wire retainer.

11. Re-check all cap screws for tightness to make sure there will be no oil leaks in connection with the pump installation.

12. Install new gasket to oil pan, then install pan to cylinder block. Tighten all bolts evenly and securely but not excessively.

OIL PRESSURE REGULATOR VALVE

Stabilized lubricating oil pressure is maintained within engine at all speeds, regardless of oil temperature by means of a pressure regulator valve located at end of the oil gallery and integral with oil pump discharge line, as shown in figures 1 and 2, and installed as illustrated in figure 10.

The regulator valve assembly consists of a hollow piston-type valve, a compression spring, a plug to retain the spring, and a valve body. Details of oil pressure regulator valve is shown in figure 18.

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

MAINTENANCE

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

Whenever lubricating oil pump is removed for inspection, regulator valve and spring assembly

should be removed also; thoroughly cleaned in fuel oil and inspected for wear.

REMOVAL

Valve assembly may be removed from cylinder block and valve from body as outlined below:

1. Remove oil pan.

2. Remove capscrews retaining valve body to cylinder block, and oil pump outlet pipe assembly

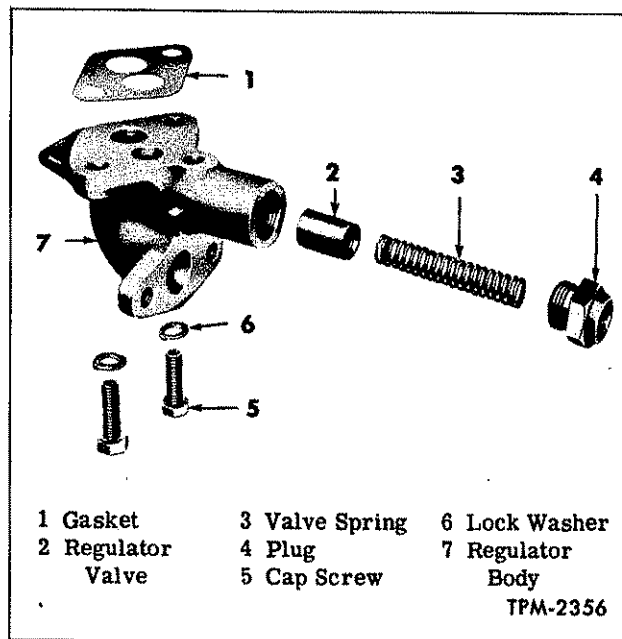


Figure 18—Lubricating Oil Pressure Regulator

PRESSURE REGULATOR VALVE

to oil pump.

3. Strike lower end of valve body lightly to separate body from gasket and cylinder block. Remove and discard gasket.

DISASSEMBLY

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, regulator valve body and parts should be thoroughly cleaned, parts and passages dried with compressed air, then parts inspected before assembly.

Oil passages must be open and the valve free from score marks. Valve must move freely in valve body. Check free length of valve spring. Refer to **SPECIFICATIONS** section of this manual for spring specifications.

REASSEMBLY

All parts having been cleaned and inspected, assemble as follows:

1. Apply clean engine oil to outside of valve; then position in valve body with open end of valve toward threaded end of valve opening.
2. Position spring inside valve, and while compressing spring, start plug into valve body. Tighten plug.

INSTALLATION

After assembly, the 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 to regulator valve body so that opening in gasket registers with hole in body.
3. Position regulator valve body and oil pump outlet pipe assembly to cylinder block and oil pump, and secure with capscrews.

Cooling System

Control of engine temperature is accomplished by means of a thermostat directing the flow of cooling liquid within a sealed cooling system. A sealed system utilizes a pressure valve which maintains a slight pressure within the system when engine is running at normal operating temperature, thus raising the efficiency of the system. A condensing tank or surge tank, permits expansion of cooling liquid without loss from the system.

Cooling liquid is circulated by means of a centrifugal pump driven from the blower. Pump draws cooling liquid through radiator and oil cooler, discharging it into lower part of cylinder block. Openings in water jackets around cylinder bores connect with corresponding openings in cylinder head, circulating liquid around exhaust valves and fuel injectors. A water manifold bolted to cylinder head, discharges cooling liquid into radiator where it is

then cooled by action of fan.

During the engine warm-up period, action of thermostat closes off flow of cooling liquid into radiator, directing the flow of cooling liquid through a by-pass tube. This arrangement permits circulation of liquid within the engine warming the engine and shortening the warm-up period. As engine reaches normal operating temperature, thermostat valve opens gradually, allowing cooling liquid to flow through radiator, thus maintaining an efficient operating temperature.

Thermostatically controlled radiator shutters automatically assist engine thermostat in controlling engine operating temperature.

Refer to applicable vehicle maintenance manual for specific, thermostat and radiator shutter information; also for information regarding other cooling system units as used on specific vehicles.

WATER PUMP

DESCRIPTION

A centrifugal type water pump (fig. 2) is used for circulating the cooling liquid through the engine. A bronze impeller with straight blades is pressed and pinned onto one end of a case-hardened steel shaft, and a pump drive coupling and oil slinger is pressed onto the opposite end. Oil slinger shrouds inner end of pump body flange to prevent oil from seeping along shaft and through shaft bearing. Shaft is supported at drive end on a sealed, double-row combination radial and thrust ball bearing. Shaft is prevented from moving endwise by staking pump housing at the inner end of the bearing.

A spring loaded carbon and Neoprene seal, retained in impeller by a steel stamping, prevents water from seeping along shaft from impeller end. The slinger is fitted on shaft between pump housing and ball bearing to prevent moisture from creeping along shaft to the bearing. As shaft serves as inner race of ball bearing pump shaft, bearing and slinger constitute one assembly and are serviced as such.

Water pump ball bearing is of the "Sealed" type and filled with lubricant when assembled, requiring no further lubrication.

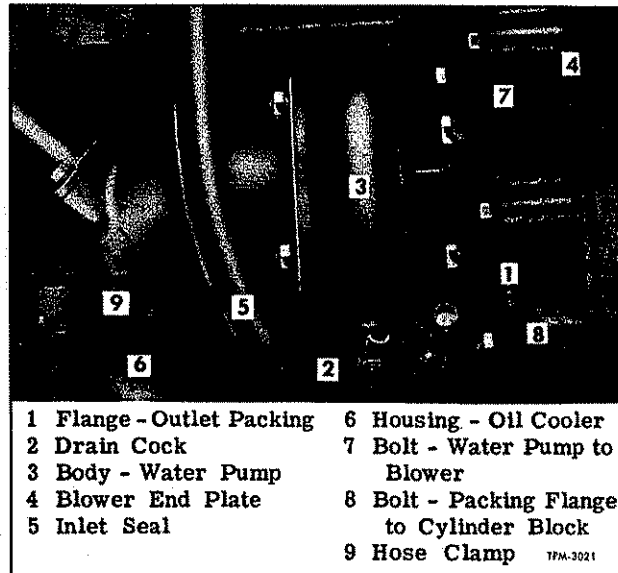
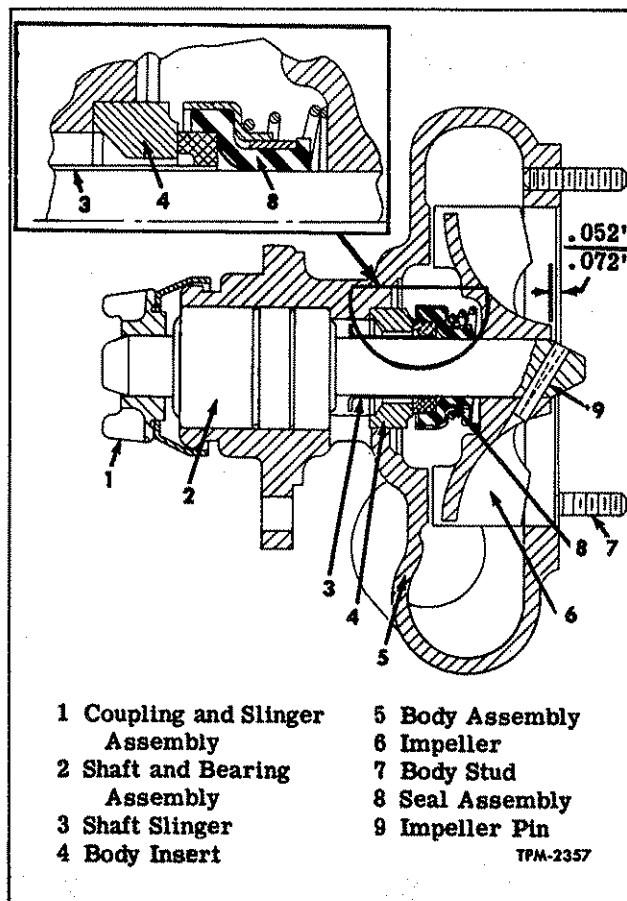
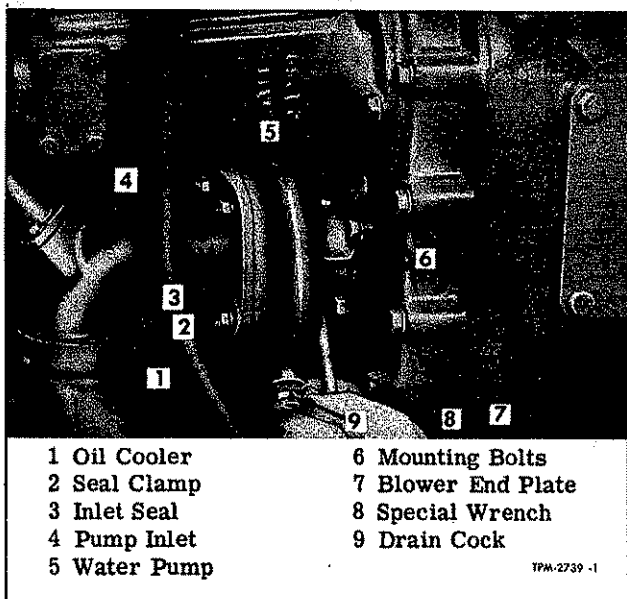
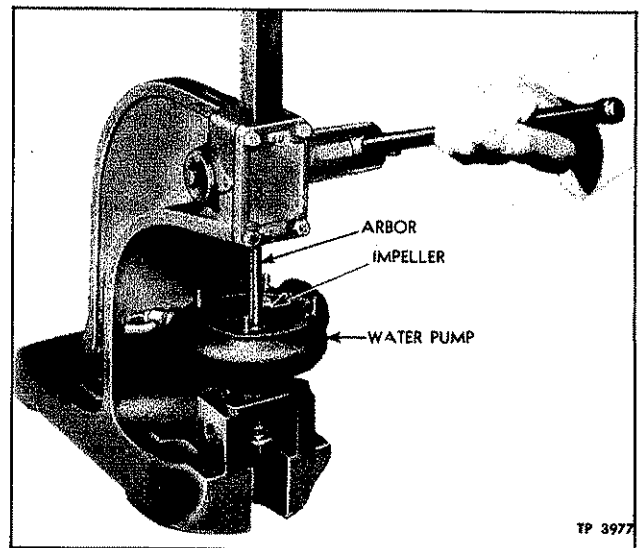


Figure 1—Water Pump Installed—Typical

REMOVAL

Refer to figure 1 and remove water pump in the following manner:

1. Drain cooling system.

WATER PUMP**Figure 2—Water Pump Assembly****Figure 3—Water Pump Mounting and Use of Special Wrench****Figure 4—Pressing Water Pump Impeller from Drive Shaft**

2. Loosen clamp (9); then slip inlet seal (5) down on oil cooler neck.

3. Remove two cap screws (8) and loosen flange (1) which holds pump outlet to cylinder block. Move flange and packing towards pump body.

4. Remove cap screws (7) which holds pump to blower. The inner cap screw can be removed by using a special wrench as shown in figure 3.

5. Remove water by-pass tube from water pump inlet.

6. Loosen pump by jarring with palm of hand, then rotate assembly until pump will clear the governor drive housing and oil cooler housing neck.

DISASSEMBLY

If removal of the spring seal assembly or the impeller is necessary, the following sequence of operation will apply:

1. Remove pump cover or inlet from body.

2. Drive out pin retaining impeller to shaft.

3. Support the water pump in an arbor press flange down as shown in figure 4 and press the shaft through the impeller. Shaft and bearing assembly will also be removed from the pump body during this operation.

4. 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 is furnished complete with spring.

5. If further disassembly is necessary the pump

WATER PUMP

drive coupling and slinger assembly may be driven from the shaft in manner illustrated in figure 5.

CLEANING AND INSPECTION**CLEANING BEARINGS**

Water pump bearings are sealed type. No attempt should be made to clean or lubricate these bearings as they have been packed at time of manufacture with sufficient lubricant to last throughout life of bearings. To clean properly, use cloth moistened in cleaning fluid and wipe off any surplus lubricant or foreign matter on bearing or shaft. NEVER immerse water pump bearing in cleaning fluid as this will dissolve lubricant and render bearings unfit for further service.

INSPECTION

1. Replace bearing and shaft assembly if distorted, noisy, lumpy or rough.
2. Inspect steel insert in pump body against which seal turns. Surface must be smooth and free from scores. If inspection indicates necessity replace insert and check squareness of body with insert face which should be within .0004" total indicator reading.

ASSEMBLY

1. Press slinger onto pump shaft with the flanged end towards bearing. Slinger should be pressed onto

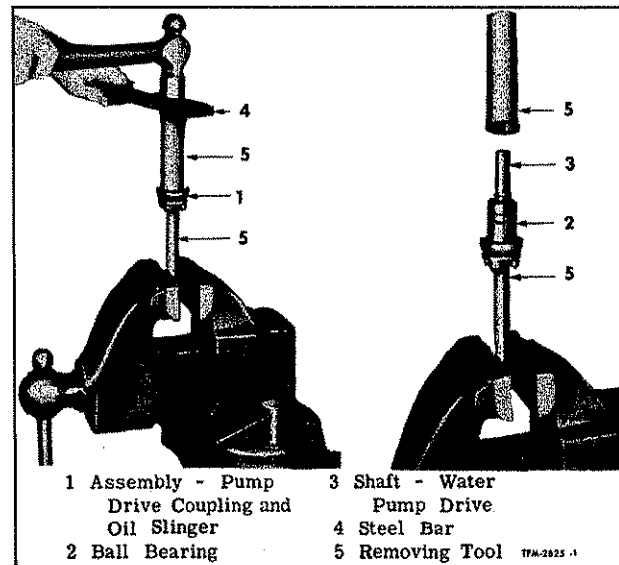


Figure 5—Removing Water Pump Coupling from Impeller Shaft

shaft until dimension between face of slinger and bearing is $\frac{3}{16}$ ".

2. Support pump body and install shaft and bearing assembly into pump body by pressing against the outer race of the bearing. Outer end of bearing should be flush with face of pump body when installed. Stake the pump body in three places to hold bearing in place.

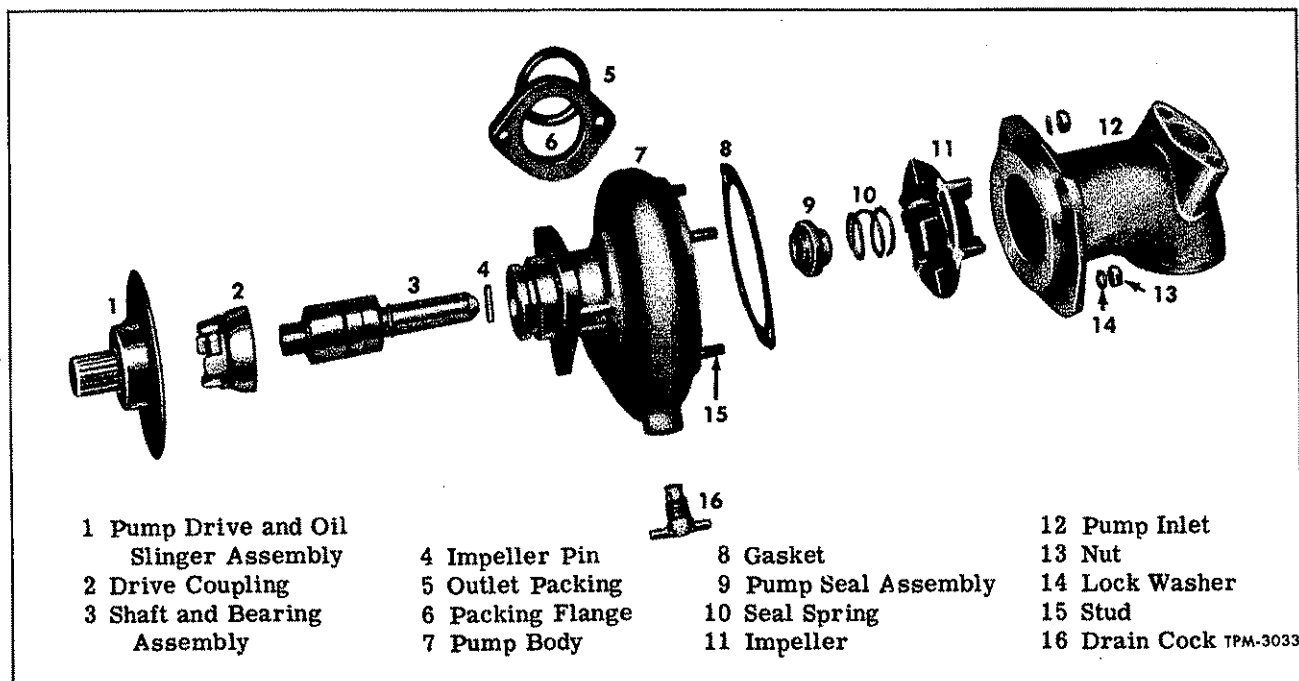


Figure 6—Water Pump Details

WATER PUMP

3. Coat shaft and insert with Lubriplate or equivalent. Carefully position seal assembly over bearing shaft and slinger. Install spring over seal, with large end of spring toward impeller.

4. With pump set in press so it is supported on the outer end of pump shaft, press impeller onto pump shaft.

CAUTION: Be sure assembly is supported properly to prevent damage to bearing and staking.

5. Press impeller onto shaft until outer face of impeller hub is .052"-.072" below face of pump body (fig. 2). Impeller must be positioned on shaft so pin hole in shaft is located midway between blades of impeller. Rotate impeller to be sure clearance exists between face of impeller blades and pump body.

6. Using the hole in the pump shaft as a jig, drill a .184" diameter hole through impeller hub. Hole should be located approximately midway between impeller blades. Drive pin into hole through shaft and impeller.

7. With pump positioned in press so it is supported on the impeller end of pump shaft, drive coupling and slinger assembly on opposite end of shaft until coupling is flush with end of shaft. Coupling must be a tight press fit on shaft since no drive key is used.

8. Position gasket to pump body at bolting flange for combination inlet and cover. Install cover over studs and up against body, with elbow pointing down, and pump outlet toward cylinder block. Tighten cover in place with nuts and lock washers. Test bind between impeller and cover by turning

pump shaft by hand.

9. If pump drive coupling and slinger assembly was removed from the blower shaft, insert splined end of coupling into mating splines of blower shaft. Insert the screw tightly to hold coupling. Be sure coupling is fully in place before tightening screw; otherwise a preloading of the water pump bearing may cause damage.

INSTALLATION

1. Place water pump outlet packing flange over pump outlet, with flat machined face away from pump body. Place packing over outlet next to flange.

2. With inlet elbow opening pointing down, install hose clamp and water pump inlet seal over inlet elbow.

3. Position pump assembly at end of blower cover so that lugs register on the two drive couplings. In this position pump will be correctly positioned with respect to cylinder block and oil cooler. Secure with cap screws and lock washers.

4. Install water outlet packing and packing flange against cylinder block; then secure with cap screws and lock washers.

5. Slide pump inlet seal and hose clamp in place at junction of oil cooler and pump inlet elbow; then tighten clamp screws.

6. If water by-pass tube is attached to inlet it must be reconnected using new gasket and cap screws.

7. Fill cooling system and check for water leaks.

HYDRAULIC DRIVEN FAN

DESCRIPTION

A thermostatically-controlled hydraulic-driven fan that operates only when engine cooling is needed is used as standard on truck engines and as optional on coach engines. Two types of mounting are used—one at balance weight cover (fig. 7) and the other at front of crankshaft (fig. 8). The arrangement shown in figure 7 is driven by conventional belts and pulleys, while type shown in figure 8 is driven directly from crankshaft.

The fan drive consists of a driving and a driven torus member enclosed within an aluminum housing. Speed of fan is variable, depending upon operating temperature. When engine is cool, little or no power is transmitted to the driven torus and fan idles or may stop. When engine is hot, full power is transmitted to the fan to assist in cooling the engine.

OPERATION

A thermostatically-operated valve is installed in water return between radiator and oil cooler (fig. 9). The amount of oil retained in the torus housing is controlled by the valve, which is actuated by water temperature.

Under cold conditions, the valve is open permitting oil to return to the crankcase and no power is transmitted to fan by torus driven member. As the temperature of the coolant reaches a predetermined setting the valve starts to close, retaining oil in torus housing and power is gradually transmitted to fan.

The fan speed varies with the amount of oil retained in the coupling as determined by the temperature of water. The fan speed is varied gradually as temperatures change due to operating conditions.

HYDRAULIC FAN**REMOVAL AND DISASSEMBLY**

The following instructions apply only to the type of fluid fan drive mounted on engine balance weight cover as shown in figure 7.

1. Remove cap screws (26) attaching fan blades (1) to fan hub (2), then remove blade assembly.
2. Remove cotter pin and hex nut securing fan hub (2) to torus driven member shaft (8). Remove hub with puller.

3. Remove cap screws (3) and lock washers attaching pulley (5) to torus driving member hub (4), then remove pulley. Remove woodruff key from driven shaft.

4. Remove cap screws (11), plain washers, and lock washers attaching driving torus member housing (21) to balance weight cover (15).

5. Pull entire assembly straight outward and away from balance weight cover. Remove thrust washer (14). Place assembly on bench for further disassembly.

6. Pull torus driven member and drive shaft assembly (19) from torus driving member hub. Remove thrust washer (13) used between two torus members.

7. If inspection indicates necessity, torus driven member (19) can be pressed from drive shaft (8).

8. Remove 6 set screws (10) attaching driving torus member (20) to torus driving member hub (4), then remove torus from hub.

9. Torus driving member hub (4) with hub oil seal (25) and sealing ring (6) can now be removed from torus housing assembly (21).

10. If inspection indicates necessity, remove sealing ring (6), oil seal assembly (25), and bushings (22) from torus driving member hub (4).

11. If inspection indicates necessity, remove bushing (7) and oil seal assembly (24) from torus housing (21).

ASSEMBLY AND INSTALLATION

The following instructions apply only to the type of fluid fan drive mounted on engine balance weight cover, as shown in figure 7.

1. If removed, press new bushing (7) into torus housing. Inner edge of bushing must not protrude beyond housing. Machine and polish bushing to dimension given in SPECIFICATIONS section of this manual, also chamfer outer end of bushing to an angle of 30 degrees for a distance of 0.060".

2. Coat outer surface of lip type oil seal assembly (24) with Permatex to prevent leaks, then press seal into housing with lip toward housing bushing. Outer

edge of seal is to be flush with housing.

3. If removed, install two bushings (22) in torus driving member hub (4) with edge of bushings flush with end of hub. Line ream to dimension given in SPECIFICATIONS section of this manual.

4. If removed, press oil seal bushing (23) onto torus driving member hub (4). Bushing is properly located when a dimension of 3.495"-3.505" is obtained between end of hub and edge of bushing.

5. Coat outer surface of lip type oil seal assembly (25) with Permatex to prevent leaks, then press seal into torus driving member hub (4) until edge of seal is flush with hub.

6. Install sealing ring (6) in groove in torus driving member hub (4).

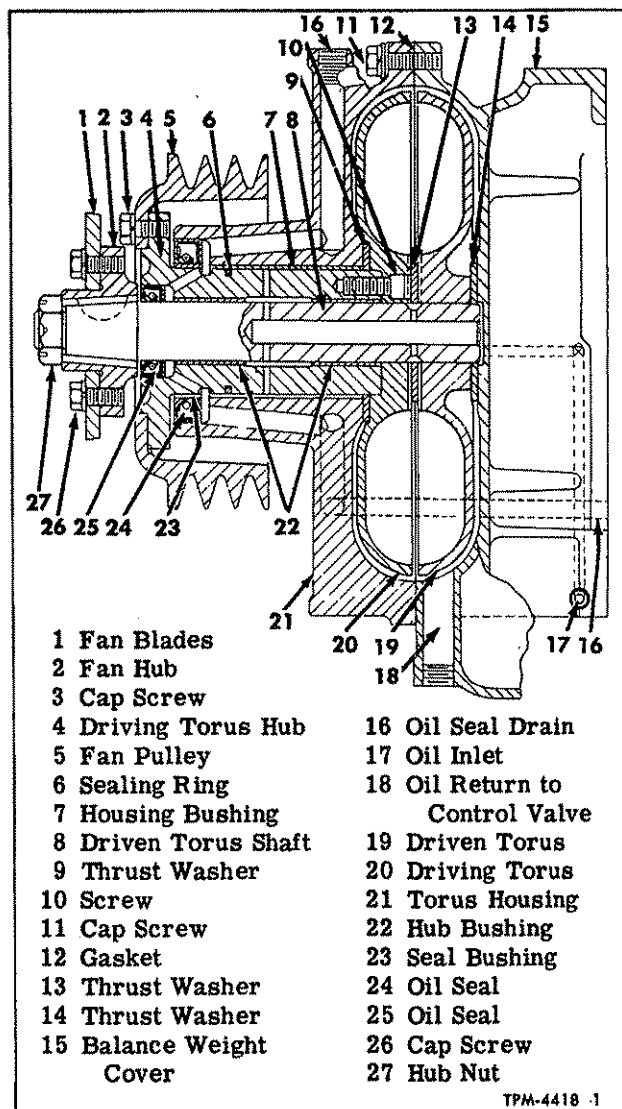


Figure 7—Fluid Driven Fan—Balance Cover Mounted Type

HYDRAULIC FAN

7. Apply engine oil liberally to oil seal, bushings, and sealing ring. Install torus driving member hub (4) into housing (21) using care that sealing ring (6) is not damaged.

8. Install thrust washer (9) over hub (4) and against housing (21). Position torus driving member (20) to hub (4) and secure with six screws (10). Tighten screws evenly and alternately.

9. Install fan pulley (1) to driving hub (4) using six cap screws and lock washers. Tighten cap screws evenly and alternately.

10. Press torus driven member (19) onto drive

shaft (8) with drilled oil hole in shaft in alignment with oil slot in torus member. Shaft should protrude through torus member .168"-.188" when properly positioned.

11. Coat oil seal and bushings in torus driving member hub liberally with engine oil. Install thrust washer (13) onto drive shaft, then position drive shaft through driving hub.

12. Install woodruff key in shaft, then install fan hub (2) and secure with nut (27) and cotter pin.

13. Lubricate thrust washer (14) and position over end of drive shaft.

14. Position assembly to balance weight cover, using new gasket (12), and secure with cap screws (11), plain washers, and lock washers. Tighten cap screws evenly and alternately.

15. Install fan blade assembly on fan hub using cap screws and lock washers.

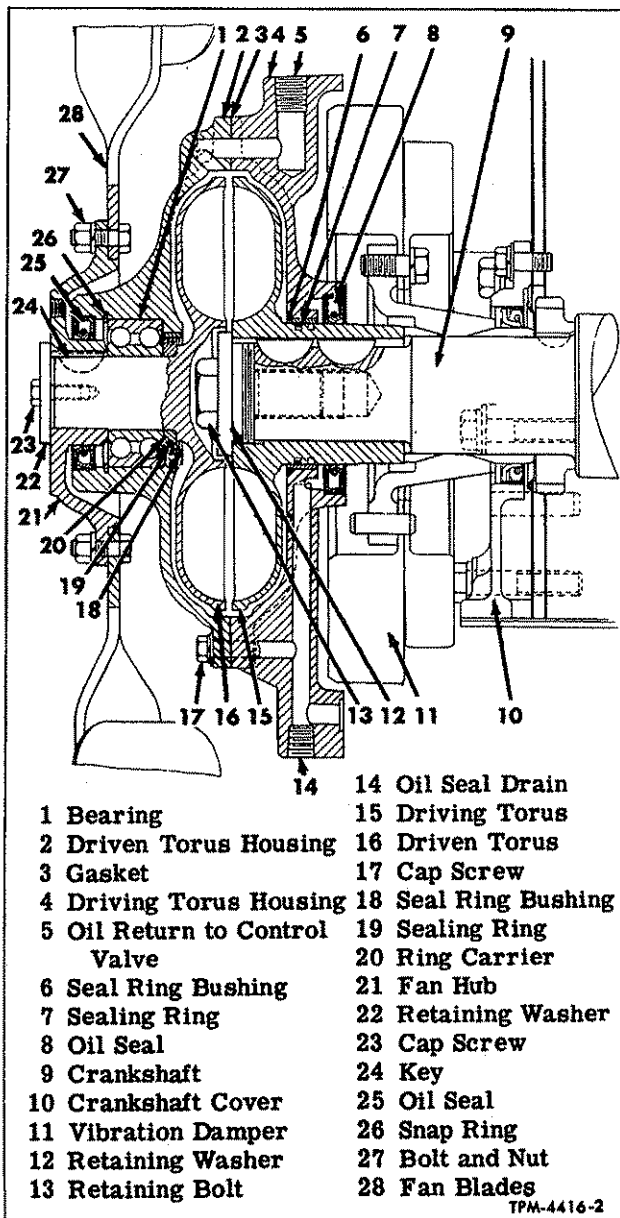


Figure 8—Fluid Driven Fan—Crankshaft Mounted Type

REMOVAL AND DISASSEMBLY

The following instructions apply only to the type of fluid fan drive mounted on engine crankshaft, as shown in figure 8.

1. Remove two cap screws (23) and washer (22) retaining fan hub (21) to driven torus.

2. Using two tapped ($\frac{3}{8}$ "-16) holes, install puller at fan hub (21), then pull hub with blades from driven torus (2).

3. Remove inlet and outlet oil lines from torus housing.

4. Remove 18 cap screws (17), plain washers, and lock washers attaching two halves of torus housing to each other. Mark driven and driving torus housings for reassembly reference.

5. Remove driven torus housing (2) with driven torus (16), bearing (1), and seals from driving torus housing. Remove and discard gasket (3).

6. Remove key (24) from driven torus stub shaft. Press driven torus (16) from ball bearing.

7. Remove lip type oil seal assembly (25) from driven torus housing.

8. Remove snap ring (26) then press ball bearing (1) from driven torus housing.

9. If inspection indicates that sealing ring bushing (18) should be replaced it can be pressed out of driven torus housing.

10. Remove sealing ring (19) and carrier (20) from driven torus by using suitable puller.

11. Remove retaining bolt (13) and washer (12) from end crankshaft.

HYDRAULIC FAN

12. Use puller #80-0041 to pull driving torus (15) from crankshaft.

13. Remove four bolts, lock washers, and plain washers attaching driving torus housing to crankshaft front cover, then pull housing from cover.

14. Remove lip type oil seal assembly (8) from driving torus housing.

15. If inspection indicates that sealing ring bushing (6) should be replaced it can be pressed out of driving torus housing.

ASSEMBLY AND INSTALLATION

The following instructions apply only to the type of fluid fan drive mounted on engine crankshaft, as shown in figure 8.

1. If removed, press sealing ring bushing (6) into driving torus housing. Bushing must be positioned so that one edge is flush with chamfer in housing bore. Machine and polish seal ring bushing to dimension given in **SPECIFICATIONS** section of this manual. Inner diameter of bushing at torus side must be chamfered to 20 degrees, which facilitates assembly of torus to housing without damage to sealing ring.

2. Coat outer surface of lip type oil seal assembly (8) with Permatex to prevent oil leaks, then press seal into housing with lip toward torus member side.

3. Install oil sealing ring (7) in groove provided in driving torus member.

NOTE: Sealing ring can be positioned in opposite groove of driving torus when groove is worn or bushing is rough.

4. Install two woodruff keys in keyways of crankshaft.

5. Lubricate lip type oil seal assembly and sealing ring thoroughly with engine oil. Insert driving torus (15) into driving torus housing (4), using extreme caution so as not to damage either of the seals.

6. Position driving torus and housing assembly onto crankshaft with housing dowels in alignment with crankshaft front cover.

7. Start 4 cap screws, lock washers, and plain washers attaching housing to cover.

8. Coat retaining washer (12) and bolt (13) on crankshaft side with Permatex to prevent oil leaks, then install at end of crankshaft. Tighten bolt to 180-200 ft. lbs. torque. Tighten 4 cap screws attaching torus housing to crankshaft front cover.

9. If removed, press oil seal bushing (18) into driven torus housing. Bushing must be positioned so that edge is flush with undercut on bearing side.

10. Support driven torus housing (2) at center

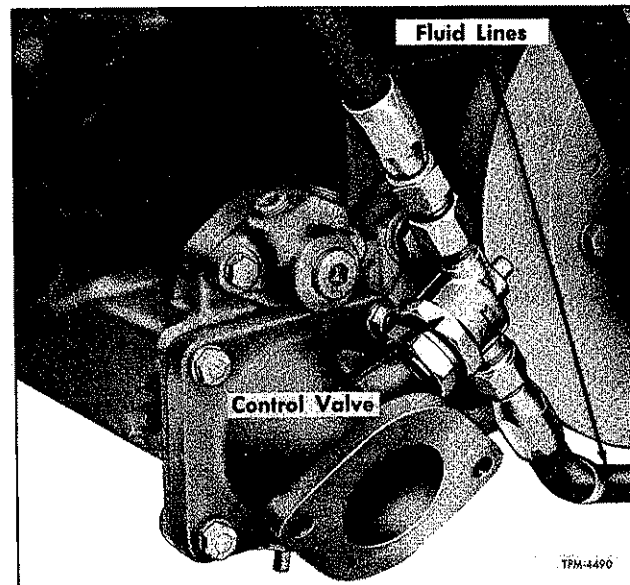


Figure 9—Hydraulic Fan Fluid Control Valve Mounting

and install bearing (1), with shielded side toward bushing. Install bearing retaining snap ring (26).

11. Install oil sealing ring (19) in ring carrier (20). Position carrier and ring assembly in driven torus housing against ball bearing, with large chamfer on inside diameter of carrier away from bearing.

12. Support torus driven housing on inner race of ball bearing, then press driven torus (16) through ring carrier (20) and bearing (1) until ring carrier and bearing are tight on torus member.

13. Install woodruff key in driven torus member. Coat outer surface of oil seal assembly (25) with Permatex to prevent oil leaks, then press seal into housing with lip toward bearing. Remove excess Permatex and lubricate lip of seal with engine oil.

14. Position driven torus and housing assembly to driving torus housing, using new gasket and aligning the two housings as indicated by marks made at time of disassembly. Install 18 cap screws with lock washers and plain washers. Tighten evenly and alternately until tight.

15. If removed, attach fan blades to fan hub (21). Install blades and hub assembly to torus member shaft. Coat inner side of retaining washer (22) and two cap screws (23) with Permatex to prevent oil leaks. Tighten two cap screws until hub is fully seated against bearing.

FLUID CONTROL VALVE

A fluid control valve (fig. 10) is mounted in water return between radiator and engine oil cooler (fig. 9). Purpose of valve is to control flow of oil from torus

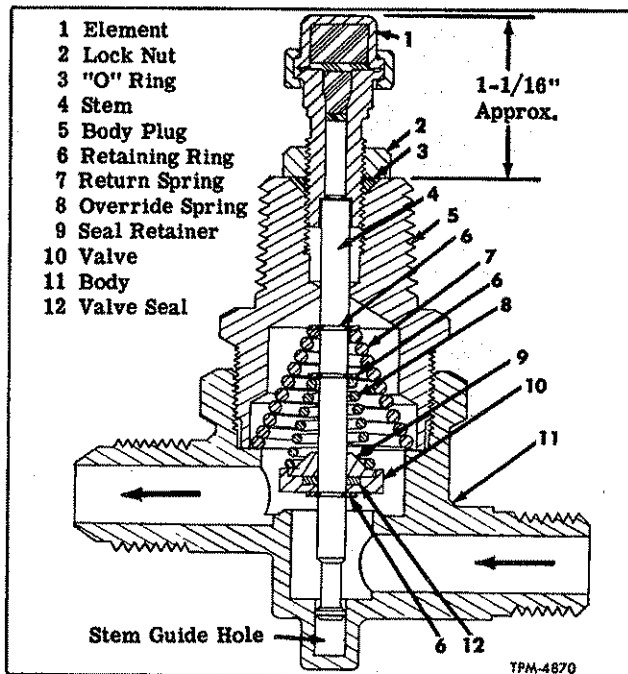
HYDRAULIC FAN

Figure 10—Sectional View of Hydraulic Fan Control Valve

housing. When temperature of water is such that cooling is required, the valve starts to close, thus flow of oil from torus is restricted. Speed of fan is variable depending upon the amount of oil being restricted in torus.

MAINTENANCE

Ordinarily valve requires only a minimum amount of maintenance.

1. After prolonged use, wear within element may occur, resulting in the valve closing at a slightly higher temperature. Should this occur it may be advisable to readjust as directed under "Adjusting Valve."

2. Whenever it is believed that valve is not seating, due to dirt or other foreign matter, the inlet and outlet lines can be disconnected and valve flushed with fuel oil and blown out with compressed air.

ADJUSTING VALVE

Suitable test equipment must be available, which provides water under pressure, also a means of immersing element in water heated to at least 175°F.

1. Connect valve inlet to water source which will provide 30 psi pressure.

2. Immerse power element in water heated to 172°F.-174°F.

3. Maximum leakage past valve should be 1 pint per minute with element heated to 172°F.-174°F., and with 30 psi pressure at inlet.

4. Should adjustment be necessary, loosen element

lock nut (2) and turn element (1) in to decrease or out to increase closing temperature. **CAUTION:** Use wrench on flats of element stem. Do not grasp element with pliers. Each full turn of element changes the operating temperature about 5°F.

REPLACE ELEMENT

1. Loosen lock nut (2) then thread element out of body plug (5) and remove "O" ring (3) also lock nut (2) from element.

2. Apply thin coating of thread compound on element threads, then thread nut and "O" ring onto element.

3. Thread element into body plug. When element projects $1\frac{1}{16}$ " above plug it is in its approximately correct location. Adjust as previously instructed under "Adjusting Valve."

DISASSEMBLY

1. Loosen lock nut (2), then thread element (1) out of body plug (5).

2. Temporarily place assembly in vise while body plug (5), is loosened.

3. Remove body plug (5) from body, then lift valve, stem, and springs from body.

4. Remove three retaining rings which will permit removal of springs, valve, seal, and valve retainer from stem.

ASSEMBLY

1. Install retaining ring (6) in center groove of stem then install small spring (8) with small end of spring against ring.

2. Install seal retainer (9) over stem with flat side down, then install seal (12), and valve (10). Compress spring and secure these parts to stem using retainer ring (6) in stem lower groove.

3. Position large spring (7) over small spring and valve and secure with retaining ring (6) in stem upper groove.

4. Place body in vise, then position stem and spring assembly in body. Apply thin coating of thread compound, then thread body plug into body until it can be felt that lower end of stem is bottoming in body, then back off plug slightly.

5. Using a small ($\frac{1}{8}$ ") rod press down on upper end of stem until it can be felt that lower end of stem is entering guide hole in bottom of body. While holding stem down, tighten body plug.

6. Again press down on upper end of stem to be sure it is free to move up and down.

7. With lock nut (2) and "O" ring (3) in place on element stem, thread element into body plug. When element projects $1\frac{1}{16}$ " above plug it is in approximately the correct location.

8. Adjust as previously instructed under "Adjusting Valve" in this section.

Air Intake System

BLOWER

DESCRIPTION AND OPERATION

In the scavenging process employed in GM 71 Series two cycle engines, air is forced into cylinders by blower which thoroughly sweeps out all of the burnt gases through the exhaust valve ports, and also helps to cool internal engine parts, particularly exhaust valves. (See fig. 1.) At the beginning of compression stroke, therefore, each cylinder is filled with fresh, clean air, which permits highly efficient combustion.

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 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 in a twisted or helical form.

NOTE: Two types of blowers are described and illustrated in this section. Standard type, illustrated in figure 3, is used on most applications and has a speed ratio of 2 to 1 of engine speed. Type illustrated in figure 2 has a reduced ratio of 1.69 to 1, on "E" Series and 1.55 to 1 on "T" Series engines. Reduced ratio is accomplished by the addition of a pair of gears (fig. 2). By the addition of these gears the drive is through the lower rotor gear instead of the upper; therefore, rotor clearance "C" becomes "CC," likewise "CC" becomes "C" when checking this type blower.

The air entering the blower inlet from air cleaner is picked up by the lobes and carried to discharge side of blower as indicated by arrows in figure 1. The continuous discharge of air from blower creates air pressure in cylinder block air chamber of about $4\frac{1}{4}$ pounds @ 2000 rpm for standard blower or $3\frac{3}{4}$ pounds @ 2000 rpm for blower used on "E" and "T" Series engines.

Air sweeps through intake ports, which start to open before bottom dead center, and close after bottom dead center. The angle of intake ports imparts a rotational motion to the intake air as it

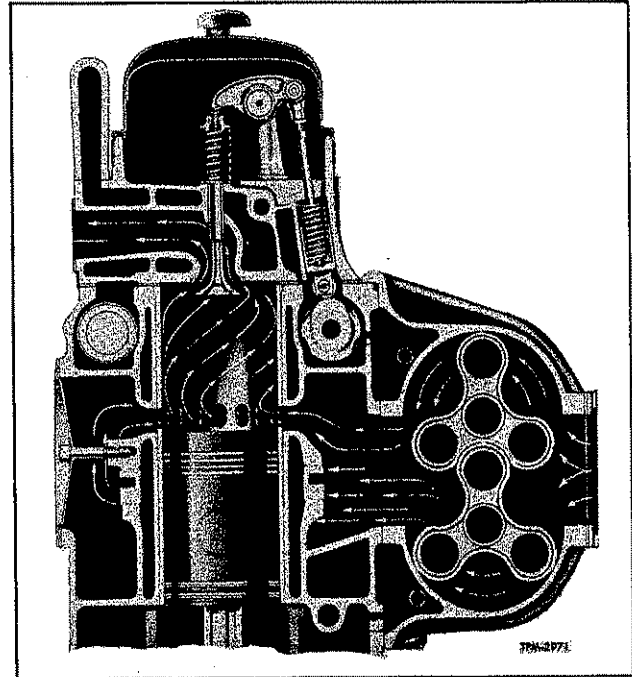


Figure 1—Air Intake System Through Blower and Engine

enters the cylinder. This rotation persists throughout compression stroke and improves combustion.

Two steel timing gears on drive end of rotor shafts space rotor lobes with a slight clearance. Consequently, as rotors do not touch each other at any time, they require no lubrication. Highly effective seals prevent air leakage at ends of the lobes, and also prevent oil, used for lubricating timing gears and rotor shaft bearings, from entering rotor compartment.

The flexible coupling which prevents transmission of torque fluctuations to blower is formed by an elliptical cam driven by two bundles of leaf springs. Each rotor is supported in doweled end plates of blower housing by straight roller bearings at front end. Rear end of rotors are carried on double row radial and thrust ball bearings.

For Description and Service Information on AIR CLEANERS and ENGINE EMERGENCY STOP, refer to applicable Vehicle Maintenance Manuals.

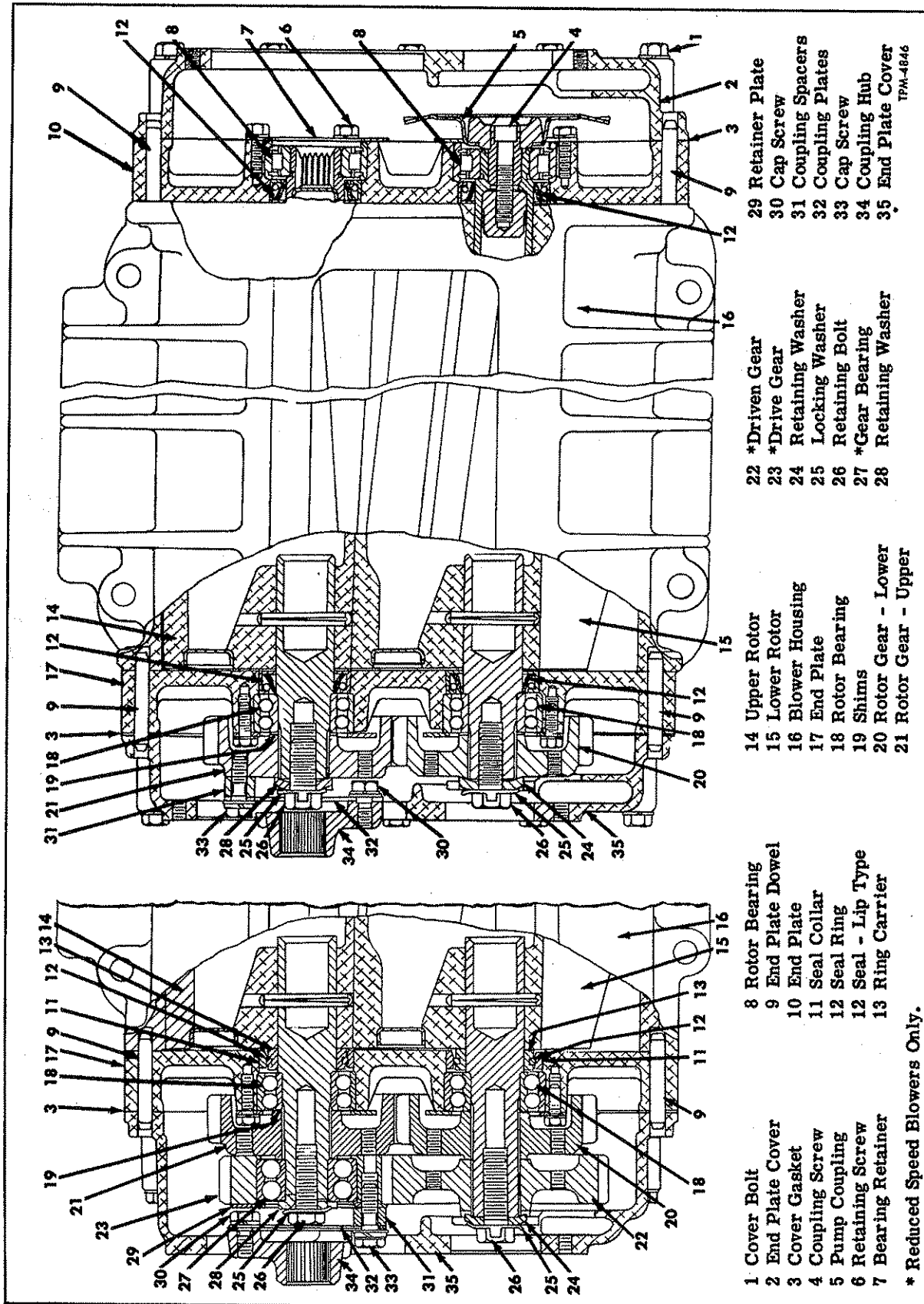
BLOWER

Figure 2—Reduced Speed Type
Figure 3—Standard Type
 Sectional View of Blower Assembly

BLOWER

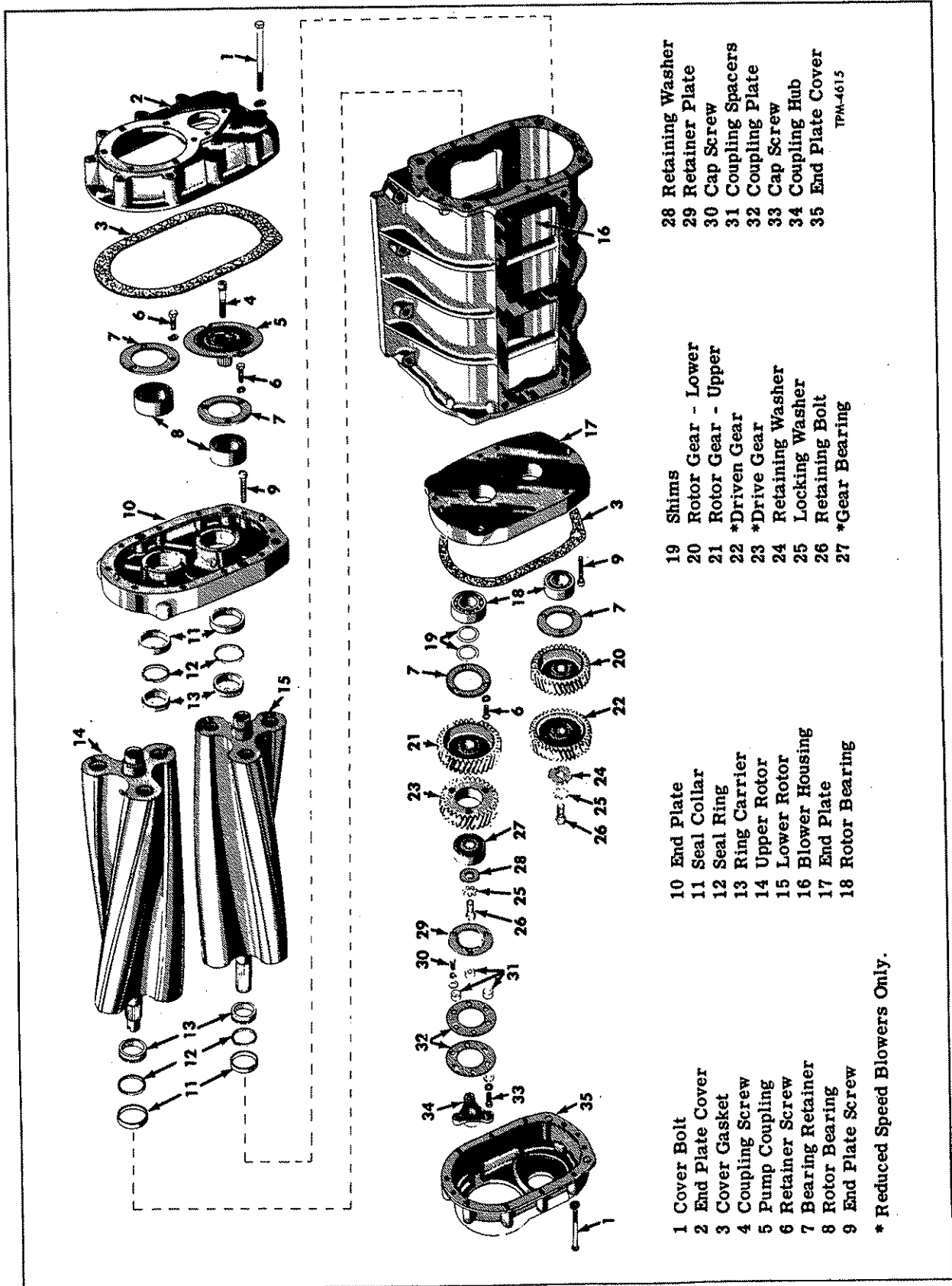


Figure 4—Blower Details and Relative Location of Parts (Reduced Speed Type Shown)

BLOWER**LUBRICATION**

The blower gears and bearings are lubricated by oil which drains from valve operating mechanism on cylinder head and into camshaft or balance shaft gallery pockets. After this oil reaches a certain level in pockets, it overflows through two holes at each end of blower housing, providing lubrication for blower drive gears at rear end, and governor and water-pump drives at front end. A dam in blower housing cover maintains an oil level which submerges the teeth of blower lower rotor timing gear. A slinger on opposite end of lower rotor throws oil into governor weight assembly. Surplus oil passes from blower to oil pan through drilled holes in cylinder block.

AIR BOX DRAINS

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 block and openings in the side of the engine block below the air box floor.

Pipes from the air box drain openings lead to atmosphere beneath vehicle.

Air box drains should be open at all times. Examine the openings at regular intervals and, if necessary, clean the passages. An indication of plugged drains 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, blow out with compressed air.

CAUTION: Remove or at least loosen an air box hand hole cover, or end plate gaskets may be damaged by excessive air pressure. Remove pipe connectors from block and clean connectors and pipes, thoroughly blowing out drains with compressed air.

Under normal conditions only a small amount of waste drains from air box.

INSPECTION

Because of the important part blower plays in efficient operation of the Diesel engine, an inspection of unit at regular intervals is recommended.

When operating under adverse conditions inspection should be accomplished at more frequent intervals. If this practice is followed, minor irregularities can usually be detected and corrected before more serious difficulties develop. Every 100,000

miles, the blower should be removed, inspected, and overhauled.

A blower may be inspected for defective conditions without being removed from engine. If, however, inspection reveals that blower has been damaged or worn sufficiently to impair its efficiency, then remove from engine and either overhaul or replace.

Before examination of blower on engine for any unusual conditions, remove air cleaners, blower air inlet housing, or any other parts interfering with the air inlet system.

WARNING

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 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.

Scuffing Caused by Dirt or Chips

Dirt in blower invariably causes deep scratches in housing around intake and on rotor tips. Blower should be removed to bench and reconditioned. Eliminate dirt leak and service air cleaners.

Leaky Oil Seals

If oil is present on rotors or in housing, run engine at approximately 1000 rpm and observe inside of end plate with a strong light. A thin film of oil will spread around a leaking oil seal. Replace defective seals.

NOTE: Oil on rotors may also be the result of pull-over from air cleaners that are filled above oil level marks; therefore, the two conditions, oil seal leak and pull-over from air cleaners, should not be confused.

Loose Rotor Shaft or Defective Bearings

If contact has been made at any point on rotors or housing, it is an indication of rubbing and scoring between crowns or rotor lobes and mating rotor roots; between rotors and end plates; or between rotors and housing. Generally a combination of these conditions exist and are usually caused by the following:

1. A loose shaft usually causes rubbing between rotors and end plates. Worn or unsatisfactory bearings will cause rubbing between mating rotor lobes

BLOWER

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.

2. Excessive backlash in blower timing gears usually results in rotor lobes rubbing throughout their entire length.

To correct either of the above conditions the blower must be removed from engine, and either repaired or replaced.

Broken or Cracked Parts

If inspection reveals any defective parts, blower should be repaired before operation.

Noisy or Jammed Blower

If blower develops a harsh metallic sound, clearances have taken up and adjustments or repairs are necessary. If blower does not turn over, do NOT attempt to run engine. Remove blower for overhaul.

Defective Blower Drive

Operate engine at idling speed. Defective coupling will cause loose rattling sound within blower.

NOTE: A loose water pump coupling will sometimes cause a similar noise. Check movement of rotors at lobe tips. Rotors should move $\frac{3}{8}$ " to $\frac{5}{8}$ " with a spring-like action. When released, they should spring back at least $\frac{1}{4}$ ". If this test indicates necessity, repair coupling as instructed in GEAR TRAIN section of this manual.

Rotor Clearances

Blower clearances are given in figure 24. If rotors bind on feeler in any of the following tests, blower must be removed, disassembled, and repaired. Make preliminary check of rotor lobe clearance as follows:

1. Insert feeler between lobes of rotors as shown in figure 25 for "C" clearance, and as shown in figure 26 for "CC" clearance.

NOTE: When checking "C" clearance, do not insert feeler too far as "CC" clearance will be obtained instead. Also, when measuring clearances greater than .005," laminated feelers made up of .002", .003" or .005" are more practical than one single thick feeler.

2. Turn engine slowly with bar while feeler position is changed to located tight spots. Check clearance at several points along length of each rotor.

3. Now insert feeler between lower rotor and housing to check for "D" clearance.

4. Insert feeler between upper rotor and housing to check for "D" clearance in same manner.

REMOVAL

Removal of the blower assembly together with governor drive, water pump, fuel oil pump, and blower drive shaft cover, will be found advantageous in most cases. For removal of this assembly the following may be used as a guide:

1. Drain water from cooling system as instructed in manual covering respective vehicle.

2. Remove the governor control housing assembly as directed in respective GOVERNOR in FUEL SYSTEM section of this manual.

3. Disconnect fuel lines at fuel pump.

4. Remove water pump connections at oil cooler and cylinder block as directed under WATER PUMP in COOLING SYSTEM section of this manual.

5. If engine is equipped with the hand control emergency stop, disconnect Bowden wire control at valve shaft lever-located at lower rear corner of blower air inlet housing. If engine is equipped with electrically operated stop solenoid, disconnect wires.

6. Remove air cleaners and blower air inlet housing, including striker plate and blower screen which are mounted between inlet housing and blower.

7. Loosen blower drive tube seal clamp. 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. Then pull blower assembly (including accessories) forward withdrawing blower drive shaft cover and seal on drive gear housing. Remove drive shaft from coupling attached to blower upper rotor timing gear.

DISASSEMBLY**TOOLS REQUIRED**

Certain special tools are required for disassembly and assembly of blower. For information relative to vendor of such tools, refer to SPECIAL TOOLS section of this manual.

ACCESSORY REMOVAL

After the blower assembly has been removed from engine, the various accessories may be removed as follows, before the blower is disassembled.

1. Remove cap screws attaching fuel pump to blower end cover plate, then remove fuel pump and drive coupling.

2. Remove cap screws attaching blower drive shaft cover to blower cover plate, then remove cover.

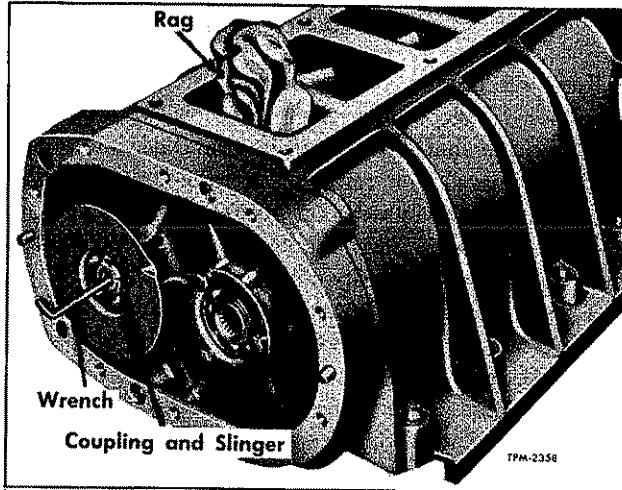
BLOWER

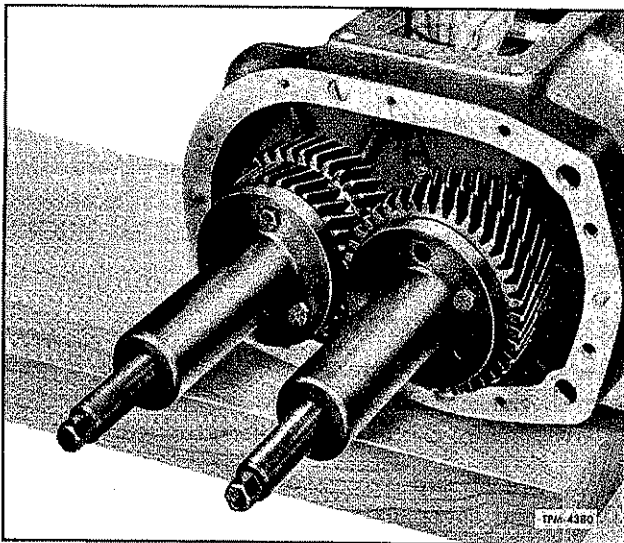
Figure 5—Removing Water Pump Coupling Screw

3. Remove cap screws attaching water pump to blower cover plate, and remove pump by tapping pump housing lightly with copper hammer.

4. Remove six cap screws attaching governor weight housing to blower cover plate, and withdraw governor drive shaft and weight housing from blower rotor shaft.

DISASSEMBLY PROCEDURES

Clean exterior surfaces of blower. Do not use a hot solvent which may destroy oil seals. Mark end of blower housing and end plates so that unit may be assembled correctly. Disassemble blower in following manner: Refer to figures 2, 3, and 4.



**Figure 6—Removing Blower Reduction Gears
(Reduced Speed Blowers)**

Remove End Covers

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, as this will damage gasket surfaces.

Remove Water Pump Coupling

Using a $\frac{3}{16}$ " Allen Wrench, loosen bolt, at center of front end of blower lower rotor shaft, and withdraw water pump coupling from shaft. Refer to figure 5.

Remove Drive Shaft Hub

Remove capscrews retaining drive shaft hub, spacers and drive plates on drive gear. Tap hub to loosen and remove.

Remove Gear Retainers

Wedge folded cloth between rotors to prevent rotors turning. At upper and lower drive gears remove gear retaining screw, locking washer, and retaining washer.

Remove Drive or Rotor Gears

1. On reduced speed blowers, used on "E" and "T" Series engines, install puller tool 6270-1 on each gear in manner illustrated in figure 6, then pull gears from rotor shaft. Gears can be removed separately if desired.

2. Install puller tool 6270-1 at each rotor drive gear in manner illustrated in figure 7, then turn puller bolts uniformly so that both gears are withdrawn from rotor shafts simultaneously.

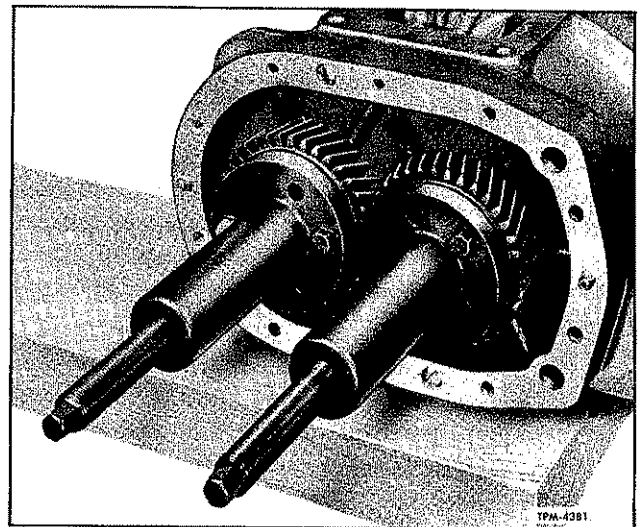


Figure 7—Removing Blower Rotor Gears

BLOWER

3. Remove shim pack (if used) from each rotor shaft and tag for identification, so that they can be replaced in their original location.

Remove Bearing Retainers

Remove three cap screws and lock washers at each rotor shaft bearing retainer, then remove retainers.

Remove End Plates

1. Loosen (do not remove) two fillister head screws attaching front end plate to housing.
2. Install puller tool J-6270-1 at rear end plate in manner illustrated in figure 8.
3. Turn puller screws evenly and alternately until front end plate is loose.
4. Remove two fillister head screws attaching rear end plate to housing.
5. Turn puller screws evenly and alternately until rear end plate is removed.
6. At blower front plate, remove the two fillister head screws which were previously loosened.
7. Install puller tool J-6270-1 at front end plate, then turn puller screws evenly and alternately until front end plate is removed.

Remove Rotors

In most instances rotors may be pulled out of housing, however a burr sometimes may interfere. If necessary, remove burrs so that rotors can be removed without interference.

Remove Seal Ring and Carrier

1. Use special pliers to spread seal ring and permit removal from ring carrier (fig. 9).

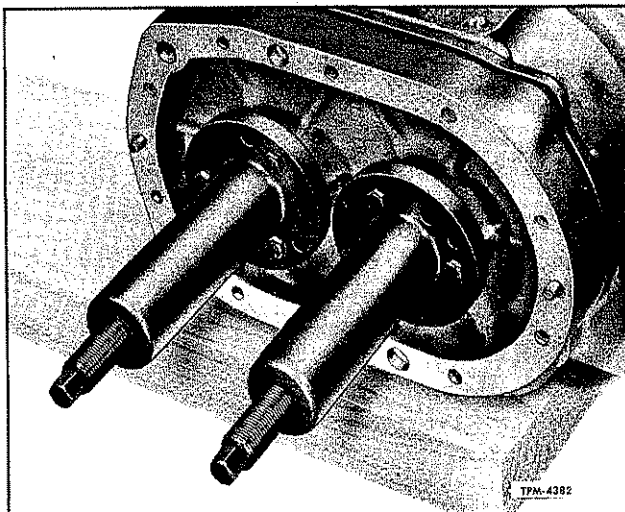


Figure 8—Removing Blower End Plates

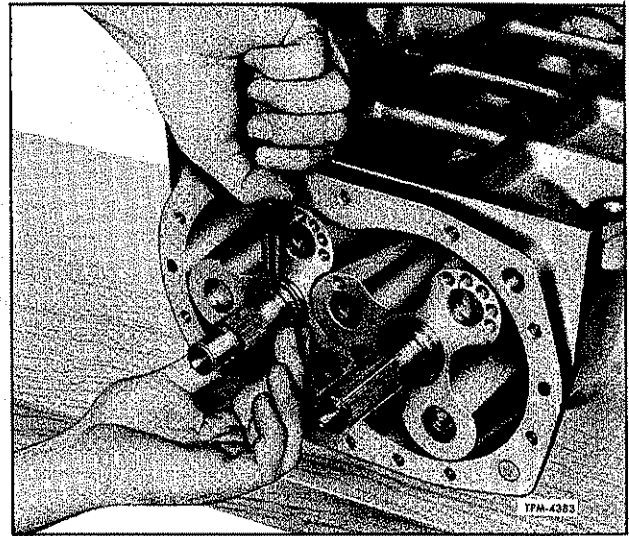


Figure 9—Removing Seal Ring

2. If inspection indicates necessity, remove seal ring carriers from rotor shaft by use of puller J-6270-1 and adapter J-6270-2. Application of tools is illustrated in figure 10.

Remove Seal and Bearing

NOTE: Removal of seal collar (or rubber seal) is not necessary unless leaks are indicated. However, if rubber seal is brittle or charred, or if seal collar is worn these parts must be replaced.

Support end plates on wood blocks in arbor press while bearing, collar (or rubber seal) are pressed from plate. Use remover tool J-6270-3 in manner illustrated in figure 11.

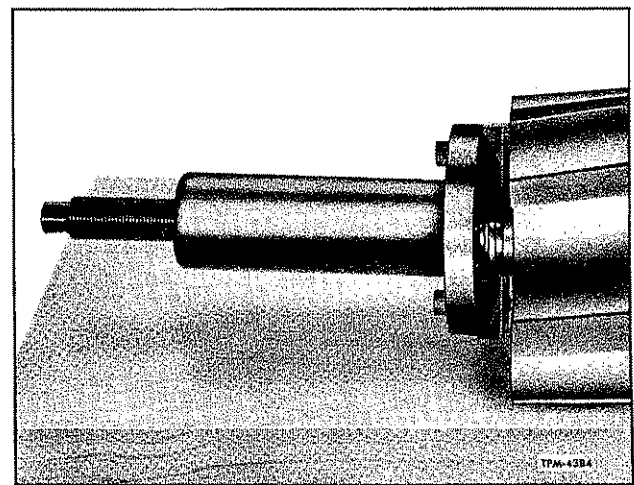


Figure 10—Removing Seal Ring Carrier

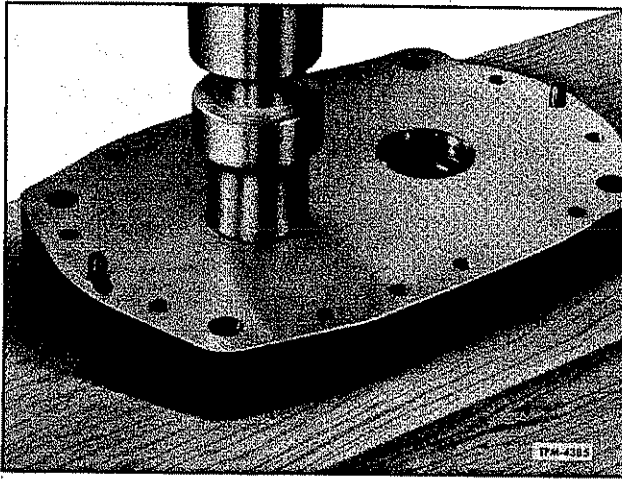
BLOWER

Figure 11—Removing Seal Collar (or Lip Type Seal) and Bearing from End Plate

INSPECTION

(On Bench)

After blower has been completely disassembled, remove old gaskets and clean all parts thoroughly. **DO NOT** use wire brush or emery cloth. Blower parts must be handled carefully as aluminum parts are easily dented or burred.

Housing

Rotor bores must be smooth; end plate flanges must be smooth and flat. Cylinder block flange must be flat. Remove all rough spots or burrs with fine mill file or scraper. Replace housing if badly scored, warped or cracked.

Rotor Assemblies

Rotors must be smooth without burrs. All shafts must fit **TIGHTLY** in rotors. Rotor shaft pins must

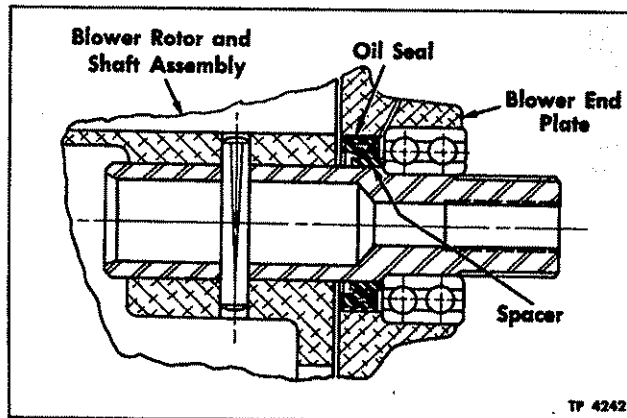


Figure 12—Oversize Lip Type Oil Seal and Rotor Shaft Spacer Installed

be tight in rotors. Internal splines in front rotor shafts must not be excessively worn. Oil seal wiping surfaces on shafts must be smooth without sharp edges. Remove all high spots and burrs from rotors with fine mill file or scraper. Replace rotor assemblies in a scored condition, or with loose shaft, pins, or badly worn shaft splines.

Bearings

When washed clean and lubricated with light oil, bearings should roll smoothly. Replace loose, rough, or over-heated bearings.

Rotor Gears

Maximum allowable backlash is .004". Teeth must be in good condition and splines not worn. Use new gears if these conditions do not obtain.

Oil Seals

Seal lip must be smooth, pliable and leak-proof. Replace all oil seals which have been removed from end plates, or are brittle thin or cut. On blowers using piston ring type seals, inspect ring type seal bushing in end plate and replace if rough or worn. Also, inspect seal ring and ring carrier at rotor shaft for wear or damage and replace if necessary.

End Plates

End plates must be free from cracks (check closely about bearing bosses and bearing retainer bolt holes.) Flat faces of plates must be true, smooth and un-scored. Counterbores for bearings must not be worn or ridged. Bearings must fit counterbore with light push or tap fit. Oil seals must not project above flat surface of end plate. Remove all burrs or minor local score marks by filing or scraping **CAREFULLY**. Replace plates that are cracked, badly scored, distorted, or have worn bearing counterbores.

SPECIAL SEAL AND SPACER INSTALLATION

NOTE: The following information is applicable only to lip type flexible seals.

In some instances blower inspection may reveal that seal contact surface at blower rotor shaft is worn and unsatisfactory for further use. In such instances a special spacer and oil seal is available and may be installed to permit further use of such rotor and shaft assemblies. Proceed as follows:

1. Inspect rotors, which have shaft end seal surfaces worn, to be sure they are otherwise in usable

BLOWER

condition. If so, remove burrs and roughness from end shaft, but do not grind.

2. Press special spacer on rotor shaft until outer edge of spacer is flush with the bearing shoulder using J6270-6 installing tool (fig. 12). Spacer should be .001" press fit on shaft. Use caution when pressing spacer on shaft to prevent distortion of rotor where shaft is pinned in place.

3. Install special seal in same manner as described for standard seal, except that special installing tool (J1682-13) should be used.

BLOWER ROTOR SHAFT REPLACEMENT

In the past, whenever the rotor drive shaft serrations became worn it was necessary to replace the complete rotor. Method of removing and installing the rotor shaft is described in the following paragraphs.

REMOVAL

1. Remove core plug in rotor lobe directly opposite visible tapered pin hole.

2. Drive tapered pin back as shown by dotted lines in figure 13, then, bend and repeat process until pin drops into rotor body.

3. Remove plug from rotor shaft by driving plug thru into rotor body.

4. Clamp rotor assembly firmly in vise, using soft wood blocks to prevent damage to rotors.

5. With segments held in retracted position insert puller shaft into stub shaft until segments are beyond stub shaft splines. (Figure 13).

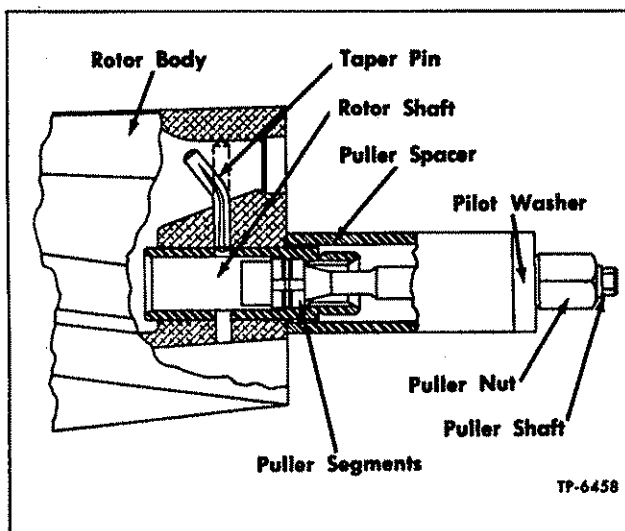


Figure 13—Blower Rotor Shaft Removal

6. Slide expander tube over puller shaft and push segments onto large diameter of puller stud, then remove expander tube.

7. Install puller spacer over puller shaft also install pilot washer and puller nut. Coat threads and pilot washer with extreme pressure lubricant.

8. Turn puller nut until stub shaft is pulled from rotor. (Nut torque may reach 100 ft. lbs.)

9. Shake core plug and stub shaft plug from rotor.

INSTALLATION

1. Coat the shaft with lubriplate to facilitate easy installation. Press new shaft and plug assembly to height of installing spacer.

2. Drill and ream new pin hole (.250 dia. 2 3/8" deep) 120° from existing pin hole. Drive new pin into hole until 1/16" below rotor surface.

3. Install new core plug in rotor lobe.

4. Stake pin and core plug to prevent loosening. Remove any existing raised burrs.

ASSEMBLY

Blower assembly must be made on a clean bench, with all clean parts, in the following manner:

INSTALL SEAL RING AND CARRIER

1. Position seal ring carrier over end of rotor shaft, then use tool J-6270-4 and hammer in manner illustrated in figure 14, to drive carrier solidly into place.

2. Use special pliers to spread seal ring sufficiently to permit installation in ring carrier groove. Refer to figure 9.

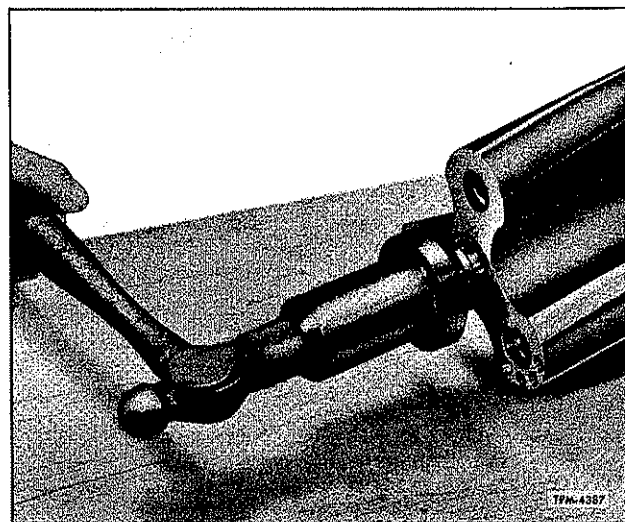


Figure 14—Installing Seal Ring Carrier

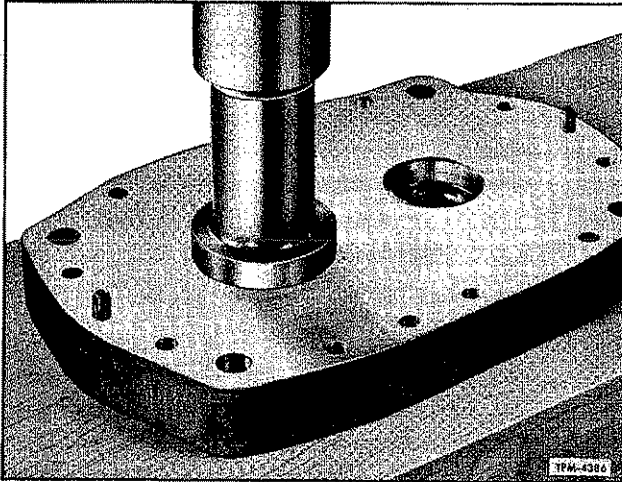
BLOWER

Figure 15—Installing Oil Seal Collar in End Plate

INSTALL PLATE SEAL

1. Support end plate on wood blocks in arbor press and using replacer tool J-6270-4 press seal collar (Fig. 15) into plate until tool bottoms against plate. Use of tool properly locates collar the required 0.002" to 0.008" below surface of plate. Taper, at inner diameter of collar, must be toward inside.

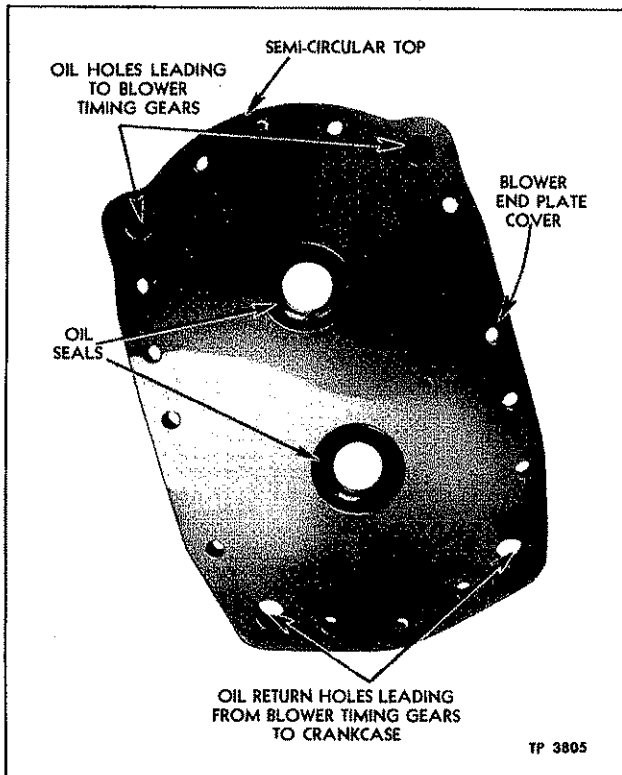


Figure 16—Blower End Plate

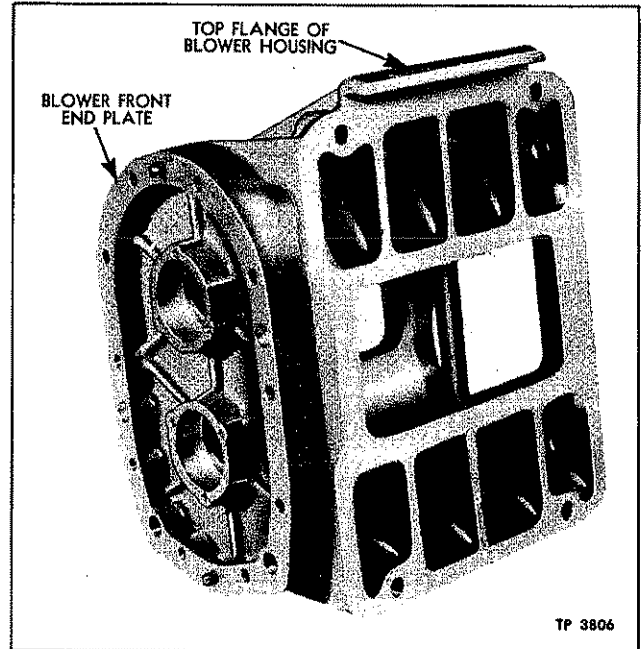


Figure 17—Position of Blower Front End Plate—RC, RD

2. Lip type rubber seals are installed in the same manner as described above for ring type seals, except; that replacer tool J-6270-3 must be used. Lip of seal must be toward outside.

INSTALL FRONT END PLATE

The top of the blower housing may be identified by the flange which extends along the top 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 figure 16 and is also marked "TOP" on outer, ribbed side.

When viewing blower housing from cylinder block (outlet) side, the end plate for the front will be assembled to the right-hand end of the housing for RB, and LA model engines, and to the left-hand end for RC, and RD model engines, as shown in figures 17 and 18.

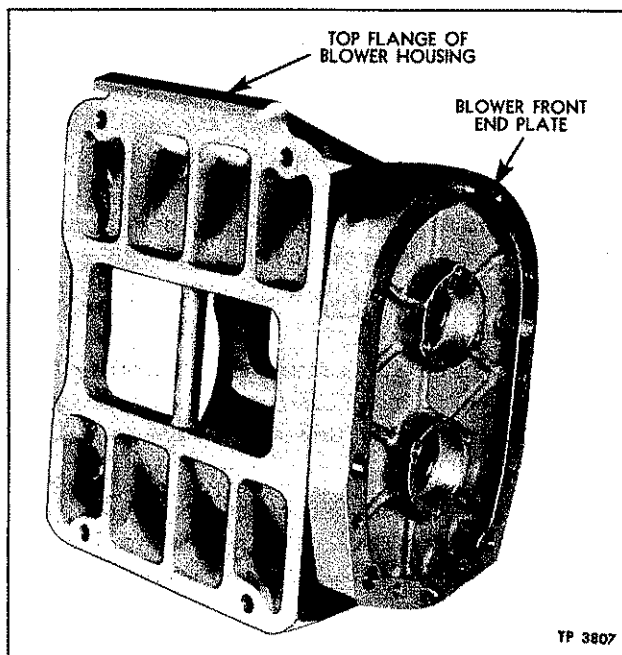
With these identifications clearly in mind, proceed as follows:

1. 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: No gaskets are used between end plates and housing, therefore mating surfaces must be perfectly flat and smooth.

2. Lock end plate securely to housing with two fillister head screws. No lock washers.

BLOWER



**Figure 18—Position of Blower Front End Plate—
RA, RB, LA**

3. Inspect and see that dowels project $\frac{3}{8}$ " beyond outer face of end plate.

INSTALL ROTORS

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 helixes are the upper units in the blower; and those parts with left-hand helixes the lower units. Rotors and gears are marked with the words "Upper" and "Lower." The identification marks are on the top of one 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. Gear must be placed on the shafts with the serrations in registrations. 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 bench; likewise the left-hand rotor and gear, as shown in figure 19. With identification in mind, as outlined above proceed as follows:

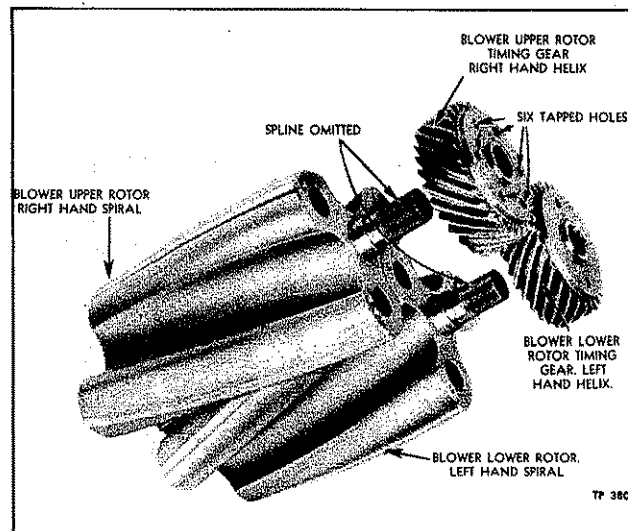


Figure 19—Relative Position of Upper and Lower Rotors and Gears

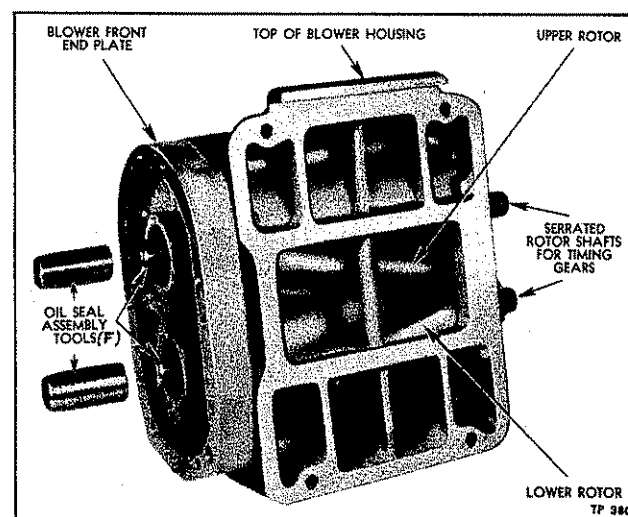
1. Install one oil seal pilot over short end (non-splined) of each rotor shaft and with rotors in mesh and omitted serrations toward top of blower housing, slip rotors into housing. See fig. 20.)

NOTE: When blower rotor shaft special spacer and seal (fig. 12) is used it is necessary that a special Oil Seal Pilot be used when installing rear end plate over blower shafts.

2. Remove oil seal pilots.

INSTALL REAR END PLATE

With rotors positioned in housing as above:



**Figure 20—Installing Rotors in Housing, Using
Oil Seal Tools**

BLOWER

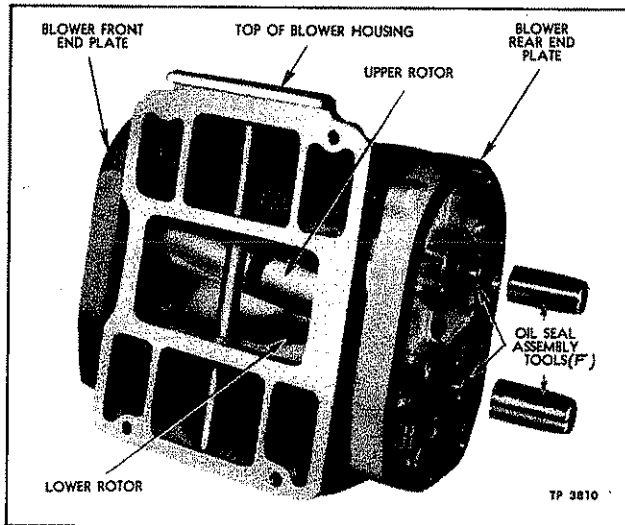


Figure 21—Use of Oil Seal Tools When Installing Rear End Plate

1. If lip type seals are being used, install one oil seal pilot over serrated end of each rotor shaft. (See fig. 21.)
2. Identify top and bottom of end plate as previously described, and shown in figure 17, start end plate dowels into dowel holes in blower housing. Tap dowels lightly to fit end plate to housing.
3. Lock end plates securely to housing with two fillister head screws. No lock washers.
4. Inspect and see that dowels project $\frac{3}{8}$ " beyond outer face of end plate.
5. Remove oil seal pilots, if used.

INSTALL FRONT BEARINGS

Straight roller bearings are used at the front end of the blower rotor shafts and double-row ball bear-

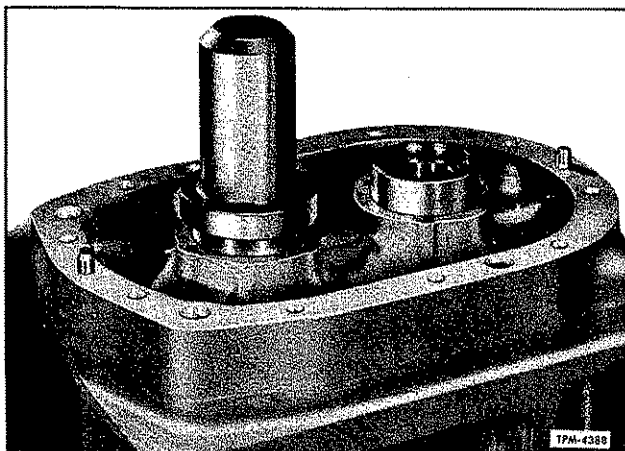


Figure 22—Installing Rotor Shaft Bearings

ings at the rear (serrated) end. The bearing number is stamped at one end of the ball race only. When assembling the markings are away from blower housing. Straight roller bearings are installed with side having inner and outer races flush toward the oil seal.

1. Start the straight roller bearings onto front end of rotor shafts (short end with internal splines).
2. Using tool J6270-4 shown in figure 22, tap bearings into end plates.

NOTE: When installing straight roller bearings it is recommended that the inner and outer races be pressed alternately to prevent damage to bearing assembly.

3. Retainers for straight roller bearings are flat and can be installed with either side toward bearing. Lock each retainer with three cap screws and lock washers.

INSTALL REAR BEARINGS

Install the rear rotor shaft bearings in exactly the same manner the fronts were installed except use tool J6270-7. Be sure markings on bearing race are away from blower housing.

NOTE: Rotor to housing and rotor to end plate clearances may be checked at this time, as described under "Rotor Timing and Clearances" later in this section.

INSTALL ROTOR GEARS

If blower once used is being reassembled shims were no doubt used back of one, or perhaps both blower rotor (timing) gears—they should be installed

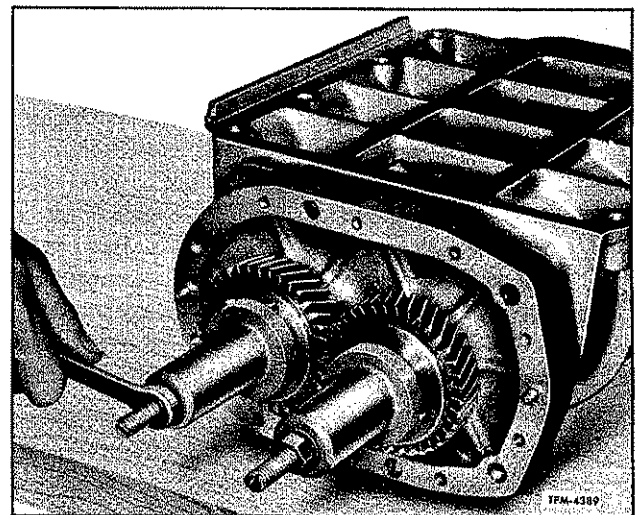


Figure 23—Installing Blower Rotor Gears

BLOWER

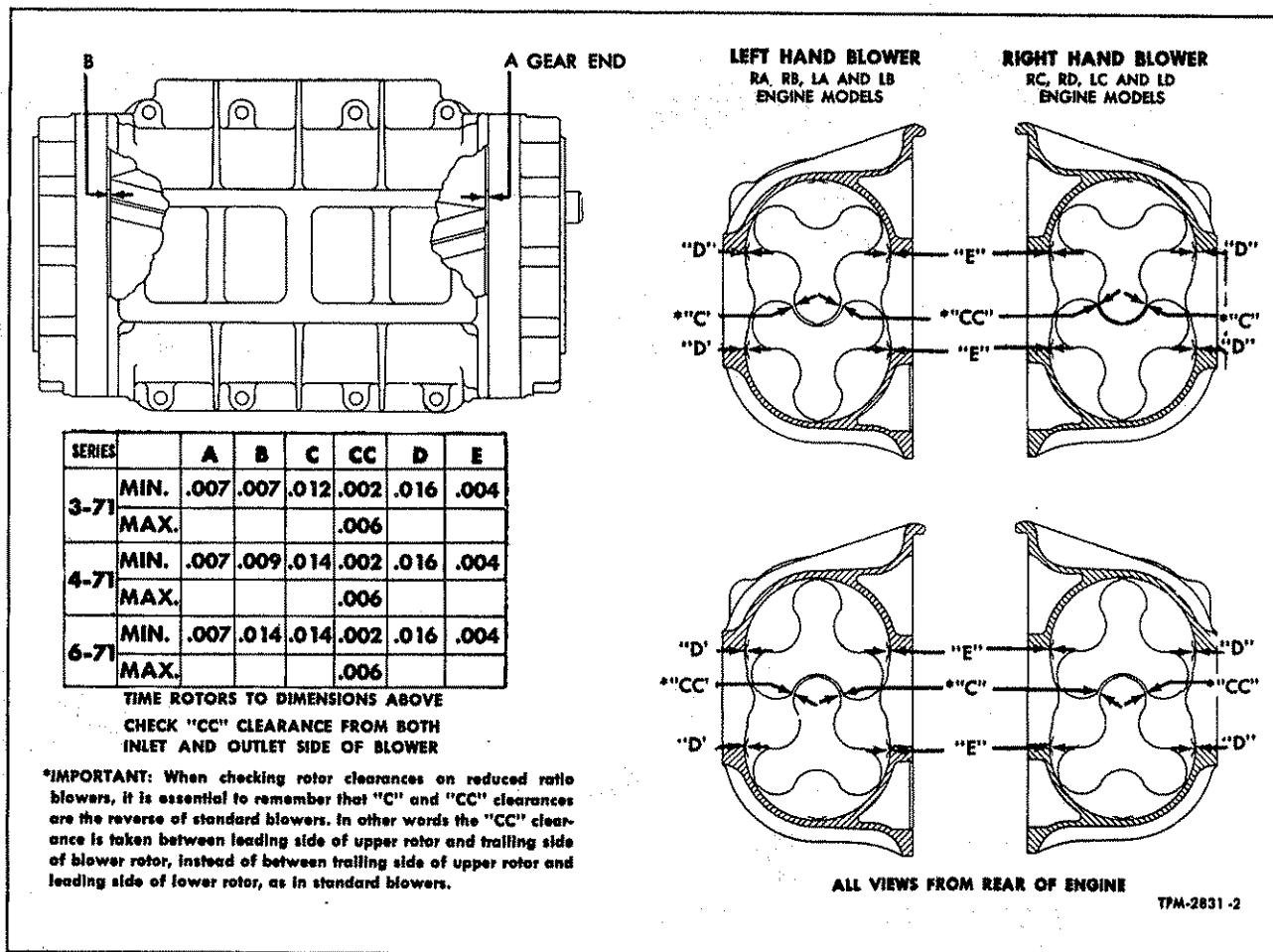


Figure 24—Diagram of Blower Clearances

in their original positions before pressing gears onto shafts. If new gears or rotors are used, assemble without shims, and use later if necessary when timing rotors.

NOTE: Rotor timing gears are matched. Replace as a complete set when necessary.

1. Be sure that both rotor shafts with the omitted serrations, as shown in figure 19, point toward top of blower; that the gear with six tapped holes in hub, is located on the upper rotor shaft; and, if old parts are being reinstalled that original shims are placed on their respective shafts.

2. 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.

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.

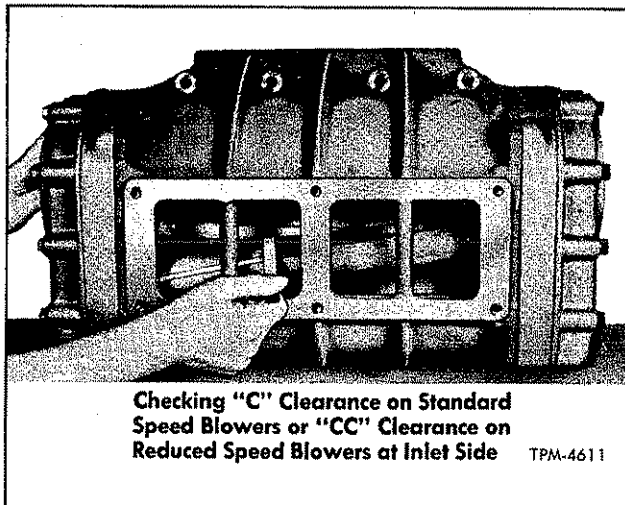
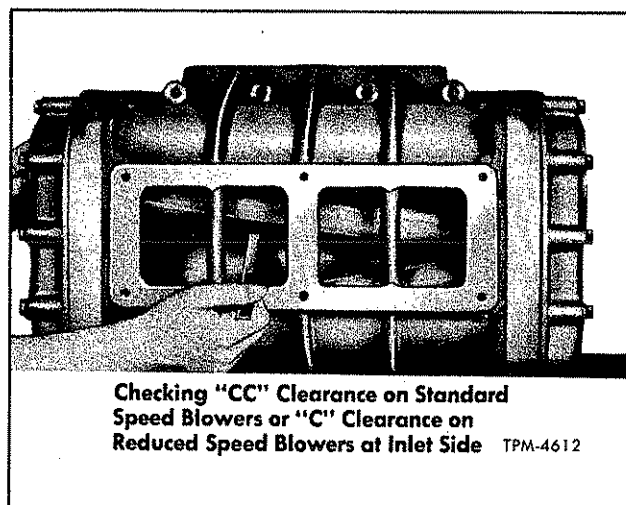
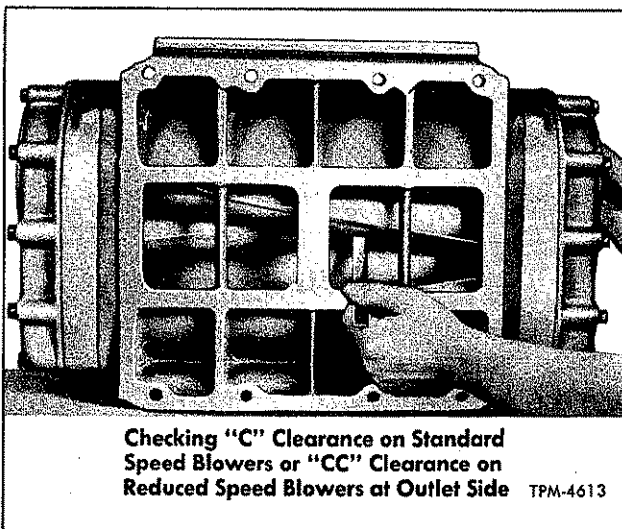
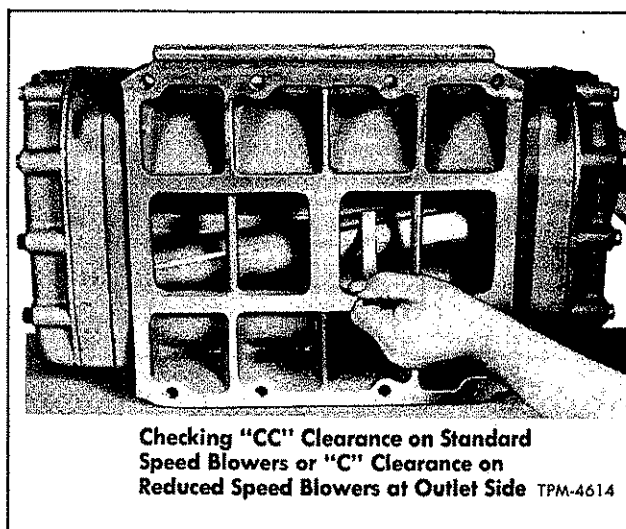
3. Attach blower gear installing tools J-6270-6 and J-6270-7 with puller screws J-6270-8 and J-6270-9 threaded into blower shafts as illustrated in figure 23. Install lower gear first until $\frac{1}{8}$ " of splines protrude.

4. Turn puller screw nuts evenly and alternately until gears are tight against bearing inner races. Torque puller screw nuts to 55-65 ft. lbs. to be sure that gears are fully seated.

ROTOR TIMING AND CLEARANCES

At this stage of the blower assembly, the blower rotors must be timed.

The three lobes on each blower rotor are spiral (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 (fig. 19).

BLOWER**Figure 25—Checking Rotor Clearance****Figure 26—Checking Rotor Clearance****Figure 27—Checking Rotor Clearance****Figure 28—Checking Rotor Clearance**

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 counterclockwise 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.

Blower rotors to be efficient must rotate within the clearance specified in figure 24. Check and time blower in the following manner:

IMPORTANT: WHEN CHECKING ROTOR CLEARANCES ON REDUCED RATIO BLOWERS (FIG. 3), IT IS ESSENTIAL TO REMEMBER THAT "C" AND "CC" CLEARANCES ARE THE REVERSE OF STANDARD BLOWERS. IN OTHER WORDS THE "CC" CLEARANCE IS TAKEN BETWEEN LEADING SIDE OF UPPER ROTOR AND TRAILING SIDE OF LOWER ROTOR, INSTEAD OF BETWEEN TRAILING SIDE OF UPPER ROTOR AND LEADING SIDE OF LOWER ROTOR, AS IN STANDARD BLOWERS.

BLOWER

ROTOR TO ROTOR CLEARANCES "C" AND "CC"

Rotor lobe clearance is greater between the leading side of the upper rotor and the trailing side of the lower rotor, than between the trailing side of the upper rotor and the leading side of the lower rotor. These clearances are designated as "C" and "CC" respectively. Refer to figure 24 for specified clearances and to figures 25, 26, 27, and 28 for method of checking.

NOTE: Do not insert feeler too far when checking "C" clearance, or "CC" clearance will be measured. (See fig. 25.) Also when measuring clearances greater than .005", laminated feelers made up of .002", .003", or .005" are more practical than a single thick feeler. Adjustment is made as described under "Adjust Rotor Clearance" in text following.

ROTOR TO HOUSING CLEARANCE "D" AND "E," (FIG. 24).

This clearance is not adjustable. If rotors bind, disassemble to determine cause.

ROTOR TO END PLATE CLEARANCE "A" AND "B"

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. Refer to figure 24 for dimensions. This clearance is not adjustable. If rotors bind, disassemble to determine cause.

ADJUST ROTOR CLEARANCE

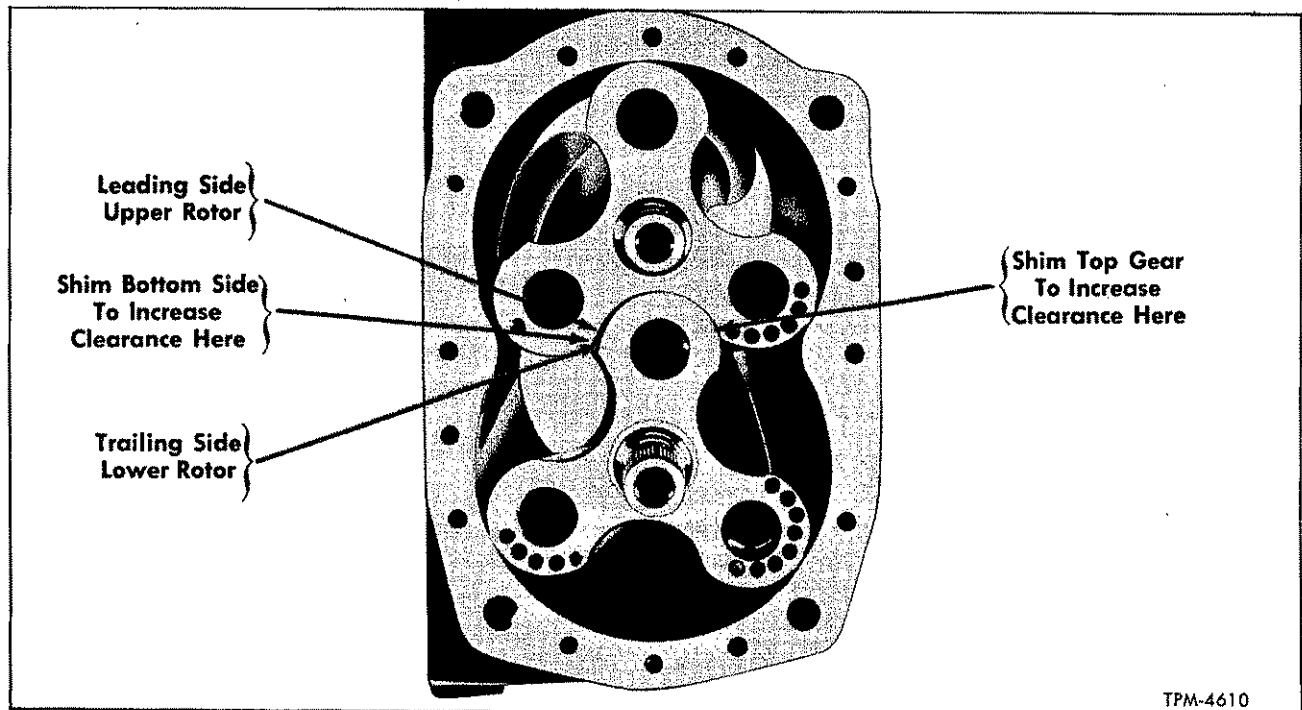
Adjustment is made by removing or adding shims behind either upper or lower gear. Refer to figures 25, 26, 27 and 28. Check clearances at several points along the length of each rotor lobe. Always determine point of minimum clearance and adjust for that point.

NOTE: Three .002" thickness shims are required to revolve rotor .002".

Having determined the amount one rotor must be revolved to produce the proper clearance observe engine model on which the blower is to be used and add shims back of either the upper or lower gears, as shown in figure 29, to produce the desired result.

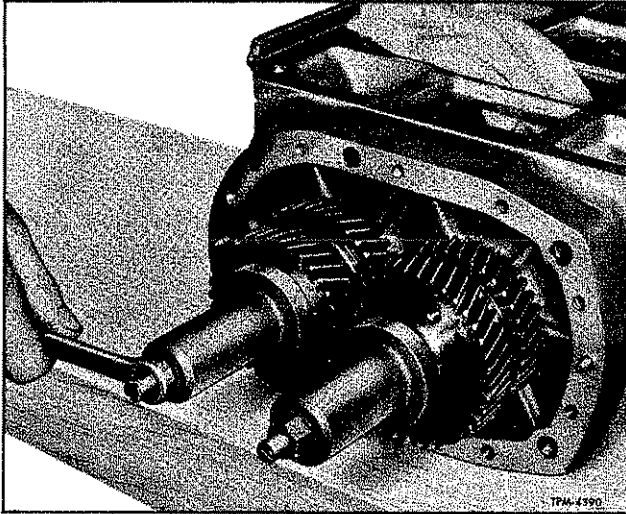
When additional shims are required, both gears must be pulled from the rotors, as directed under "Remove Rotor Gears" previously in this section.

Install the required thickness of shims back of the proper gear and next to the bearing inner race, and again press the gears tightly in place. Recheck clearances between rotor lobes.



TPM-4610

Figure 29—Diagram Showing Proper Location of Shims for Correct Rotor Lobe Clearances

BLOWER

**Figure 30—Installing Blower Reduction Gears
(Reduced Speed Blowers)**

COMPLETE THE ASSEMBLY**Install Reduction Gears**

The following information is applicable only to reduced ratio blowers, shown in figure 3.

1. Position lower reduction gear on splined rotor shaft, making sure that wide serration on gear matches missing serration on shaft.

2. Use J-6270-7 installer and J-6270-8 screw to force lower reduction gear (fig. 30) solidly against inner drive gear.

3. Install double row ball bearing in upper reduction gear. Use J-6270-7 installer and J-6270-8 screw to force upper reduction gear bearing against upper drive gear.

Secure Gears

Secure gears in place by installing special locking washer and retaining washer with washer lugs engaging slots in gear hub and lock washer ears engaging washer and cap screws.

Install Fuel Pump Coupling

Install locking plate and fuel pump coupling disc on retaining bolt with tangs of disc engaging slot in gear hub and locking plate ear engaging slot in coupling disc. Tighten retaining bolt to recommended torque.

Install Drive Hub

Assemble plate to hub using special cap screw, lock washer and flat washer between plate and lock washer. Attach plate to gear using spacer between

gear and plate also flat washer between plate and lock washer.

Install Water Pump Coupling

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 $\frac{3}{16}$ " wrench.

Install End Plate Covers

Install a new gasket to each blower end plate cover. Attach both end plate covers using cap screws and washers.

NOTE: Foreign matter inside the blower will ruin the unit. After blower has been assembled, temporarily attach the gasket and cover over the air openings of the blower housing to prevent foreign matter entering blower.

INSTALL ACCESSORIES

Time may be saved and operations simplified if the various accessories are assembled to blower before the unit is attached to engine.

1. Install 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 lock washers and cap screws.

2. Install 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 lock washers and cap screws.

3. Using new gasket and lock washers with cap screws, attach blower drive shaft 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 be set next to the cylinder block.

CAUTION: Be sure driving fork is fully on fuel pump shaft.

5. Install a new gasket to pump bolting flange. With pump drive coupling on pump shaft so that arms are directed away from pump, and intake and discharge openings at bottom and markings on pump cover toward cylinder block, attach pump to lower rear cover at lower rotor shaft, using lock washers

BLOWER

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.

INSTALLATION

Attach blower assembly including blower, fuel pump, blower drive shaft sleeve, water pump, and governor weight housing to cylinder block in the following manner:

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 blower may score rotors and impair blower efficiency. Install a new gasket to cylinder block at blower pad.

2. Slip water pump outlet packing flange—flat face out—and packing over pump discharge, also hose clamp and seal over pump inlet.

CAUTION: The blower will slide into position easily if the blower drive shaft 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.

3. Check carefully and note if blower drive shaft is in position inside of blower drive flexible coupling. Avoid damage to gasket at blower pad on cylinder block.

4. Slide the blower assembly into position with blower drive shaft registering with serrations in drive shaft flange, and shaft sleeve and seal assembly sliding over blower drive gear housing. Attach blower housing securely to cylinder block with washers and cap screws. Tighten drive shaft sleeve seal retainer clamp.

5. Connect water pump intake to oil cooler housing and cylinder block.

6. 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 items in mind, attach fuel lines to pump.

7. Install governor as directed in respective "Governor" under **FUEL SYSTEM** section of this manual.

Diesel Fuel Oil Should Meet Specifications Recommended in Service Bulletins, Which Will Be Furnished Upon Request.

Use Care in Storing and Dispensing Diesel Fuel to Prevent Contamination by Dirt and Water.

Fuel System

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DESCRIPTION

Fuel system includes fuel pump, fuel filters, fuel lines, fuel oil manifold, and injectors.

Fuel is drawn from vehicle fuel tank, through primary filter by the fuel pump which is driven from rear end of blower lower rotor shaft. From the pump, fuel is forced through secondary filter and to fuel intake manifold which supplies the injectors. Surplus fuel, flowing through injectors, is returned through fuel outlet manifold to vehicle fuel tank.

To insure 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 called an injector.

Before injection can be effected, the fuel pressure must be higher than that of the air charge in the combustion chamber. Consequently, the fuel injector performs a quadruple duty: 1st, metering and injecting fuel; 2nd, creating high fuel pressure; 3rd, atomization; 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 parts necessary to perform the above functions, thus providing a complete and independent injection system for each engine cylinder.

FUEL OIL RECOMMENDATIONS

It is recommended that only completely distilled fuel oil, such as number one grade fuel oil or kerosene be used, because, residual (undistilled) fuel oil contains high amounts of sediment and sulphur.

SELECTION OF FUEL

Selection of fuel is a very important factor in the successful operation of Diesel engines in coach and truck service. Good quality and suitability of the fuel oil will lead to economical and satisfactory performance in the over-all operation and maintenance program. Quality however, is the responsibility of the individual refiner or marketer. Therefore, his reputation is the best indication of quality.

FUEL CHARACTERISTICS

Cetane Number

The cetane number of a fuel oil is an index to its ability to burn smoothly and start easily, both improving with an increase of the cetane number. Ignition quality of a Diesel fuel can be accurately

determined only by an engine test. Although 45 minimum cetane number is approved for fuels for use in GM Diesel engines, higher cetane fuels are desirable from the standpoint of smooth operation and easy cold starting.

Pour Point

Pour point of a fuel is of importance with respect to bulk handling, pumpability in engine, and fuel filter performance. Pour point and cetane number are sometimes related, low pour points often indicating low ignition quality. The pour point should therefore not be specified lower than necessary, although for best results it should be at least 10°F. below the lowest atmospheric temperature to which the fuel will be exposed for any considerable length of time.

Volatility

Volatility of a fuel oil determines degree to which vaporization takes place before injected fuel ignites. Fuel cannot ignite and burn cleanly until vaporized.

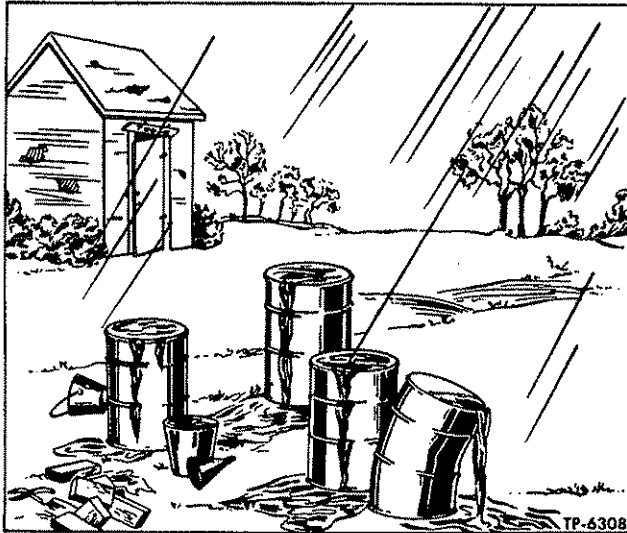
FUEL OIL

Figure 1—Do not Store Fuel Oil in Unprotected Containers

Normally, temperatures of air within combustion chambers are high enough for complete vaporization but incomplete vaporization is liable to occur during cold weather, light load operation or during periods of idling. Fluid fuel drops impinging on the relatively cool combustion chamber walls will cause incomplete combustion accompanied by blue or dark gray exhaust smoke, and by formation of excessive deposits within the engine. Heavier fuels of low volatility form deposits more rapidly than do lighter or highly volatile fuels.

Suitability of the fuel depends, very much, on the engine operating conditions. When frequent speed and load changes are encountered, cleaner burning fuels should be chosen rather than those satisfactory for constant speed operation.

Storage and Handling

It is important that extreme care be exercised in the handling and storage of all diesel fuel oil, as absolute cleanliness is essential to satisfactory engine operation. The following recommendations apply to the storage and handling of diesel fuel.

Wherever fuel oil is stored, adequate filtering equipment should be provided. It is suggested that the fuel oil be specially filtered or strained between storage tank and dispenser to remove all moisture and sediment.

Approximately every ten days a hand pump should be inserted in lowest portion of storage tank to remove accumulated water and sludge. Some layouts, for removal of dirt and water, may include a sludge collection pan, eliminating need for hand pump.

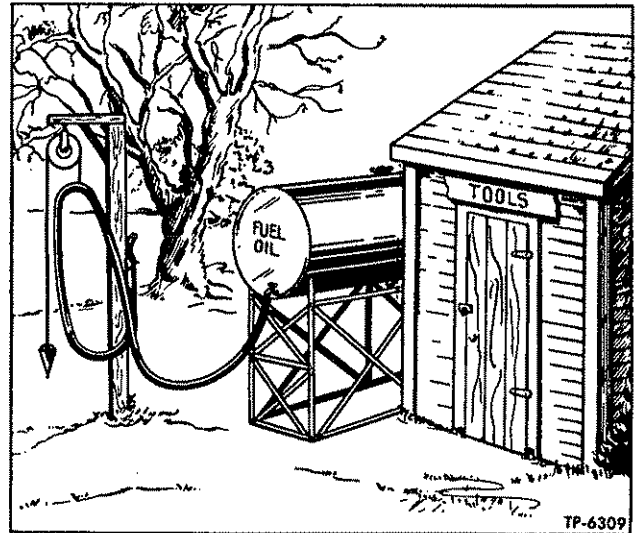


Figure 2—Typical Approved Method of Outside Storage

Should small amounts of water be carried into the fuel system of an engine and remain there during a shut-down period, there is danger of corroding fuel pump parts, injector plunger and bushings, and other parts of the fuel system. If a considerable portion of water is injected into the combustion chamber of an engine, power and performance will fall off and rough or irregular running may be noted. Pistons, exhaust valves and piston rings may become coated with deposits from erratic combustion due to the water in the fuel. In winter there is also danger of water in the system freezing and obstructing the passage of fuel into the engine.

Keep water out of the fuel oil by preventive maintenance. Regularly drain the fuel filters and syphon or pump water from the storage tank. A few suggestions are:

1. Buy fuel oil only from a reputable supplier.
2. Have fuel oil delivered directly from truck to tank, if possible.
3. Drain, syphon or pump water caused by condensation out of tank regularly.

Delivery of diesel fuel oil in barrels or drums is not as desirable as having the suppliers truck pump the fuel into the customer's large storage tank. Even though the barrels are clean, this necessitates extra handling, additional containers, and added precautions, which are easily overlooked.

Delivery of fuel oil in barrels is also more expensive as compared with delivery from tank truck to storage tank.

The least desirable method of receiving fuel oil from the oil supplier is to have the fuel pumped

FUEL INJECTORS

from the tank truck into the customer's upright barrels or drums (fig. 1). Clean fuel quickly becomes contaminated because of scale, dirt, and water which collects in fuel oil barrels over a period of time. Upright storage of fuel oil barrels is to be avoided as much as possible since water will stand in the tops of the barrels after a rain or a snow and may later seep into the barrel through the plugged opening, thus contaminating the fuel. Barrels used for supplying daily fuel oil requirements should be

stored horizontally, with the outlet end slightly higher than the other end, in order to allow sediment and water to settle out.

If storing of fuel oil above ground is unavoidable, operators are cautioned to use containers horizontally and protect them as much as possible from weather (fig. 2). The last few gallons remaining in barrels should then be dumped into a separate collecting barrel where accumulation can be allowed to settle, thus permitting salvage of useable oil.

FUEL INJECTORS

DESCRIPTION AND OPERATION

The cross section of the injector illustrated in figure 5, shows the various fuel injector parts. Fuel oil supplied to injector enters the drop-forged steel body at the top through the filter cap. After passing

through the filter element in inlet passage, the fuel oil fills the supply chamber between bushing and spill deflector. The plunger operates up and down in this bushing, the bore of which is connected to fuel supply by two funnel-shaped ports.

Motion of injector rocker arm is transmitted to

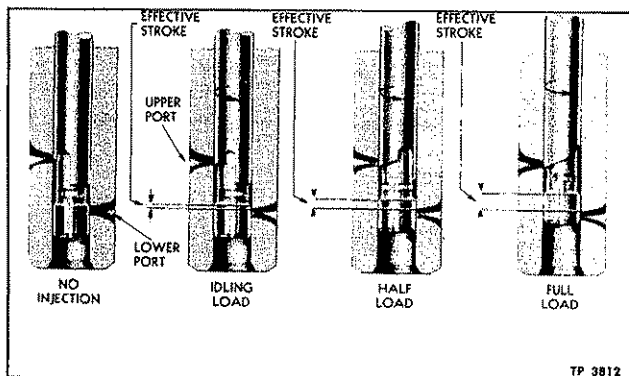


Figure 3—Fuel Metering Produced by Rotating Plunger

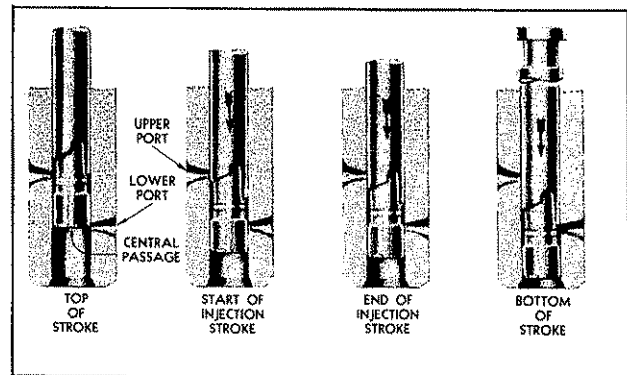


Figure 4—Injector Operation by Vertical Travel of Plunger

FUEL INJECTORS

plunger by follower which bears against plunger spring. Follower is positioned in body by a follower stop pin. In addition to up and down motion, the plunger can be rotated, in operation, around its axis by gear, which is in mesh with control rack. The fuel is metered by an upper helix and lower helix which are machined into lower end of plunger. The

relation of these helices to the two ports changes with the rotation of the plunger. As plunger moves downward, fuel oil in high-pressure cylinder or bushing is first displaced through the ports back into supply chamber until lower edge of plunger closes the lower port. Remaining oil is then forced upward through center passage in plunger into recess be-

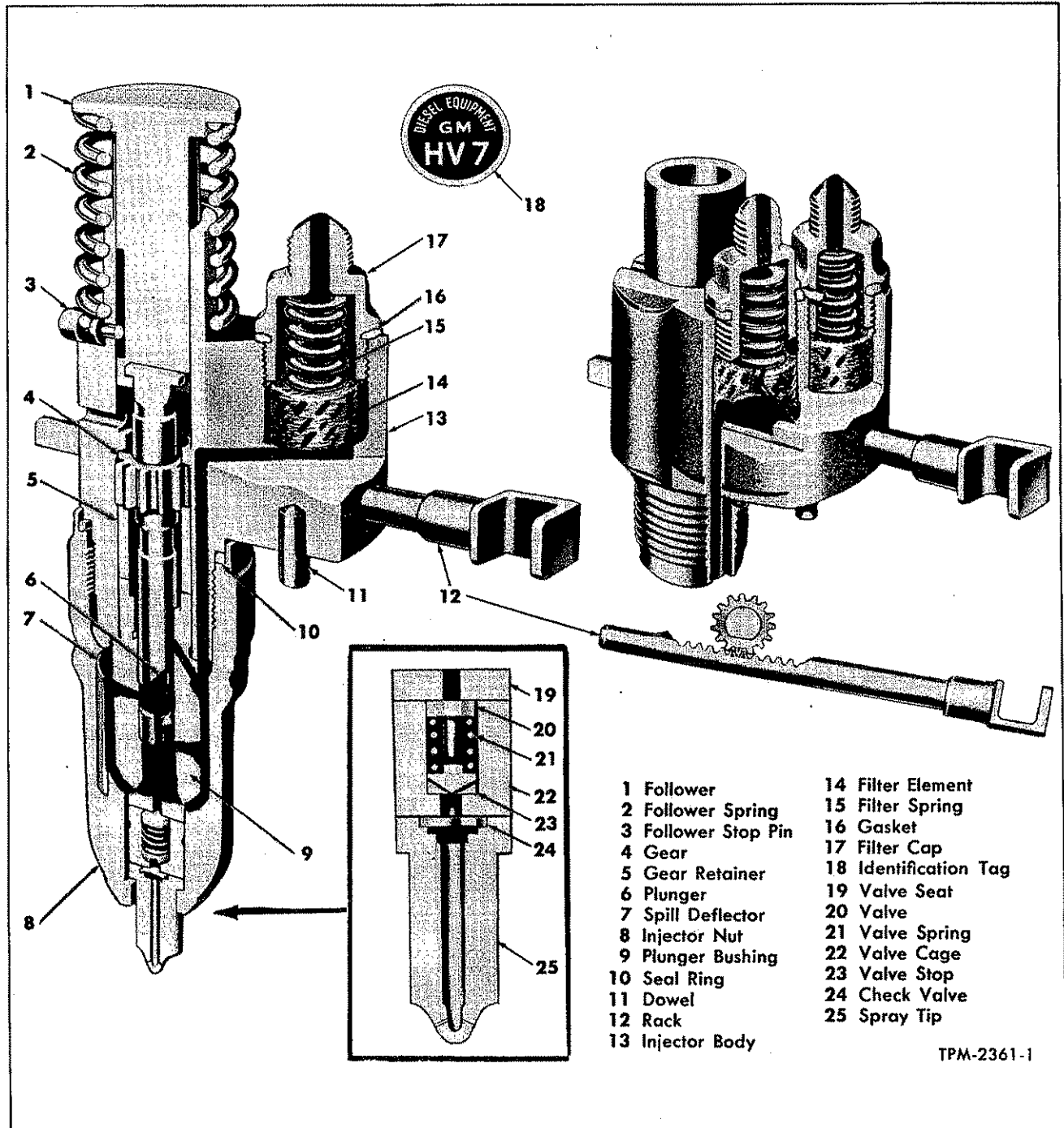


Figure 5—Fuel Injector Assembly Shows Fuel Flow (in Red)

FUEL INJECTORS

tween upper helix and the lower cut-off from which it can still flow back into supply chamber until helix closes upper port. Rotation of plunger, by changing position of helix, retards or advances the closing of the ports and beginning and ending of injection period, at the same time increasing or decreasing desired amount of fuel which remains under plunger for injection into the cylinder.

Figure 3 shows the various plunger positions from NO INJECTION to FULL INJECTION. With control rack pulled OUT completely (no injection), upper port is not closed by helix until after lower port is uncovered. Consequently, with control rack in this position, all of the fuel charge is forced back into supply chamber, and no injection of fuel takes place. With the control rack pushed IN completely (full injection), upper port is closed shortly after 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 closing of ports and beginning of injection.

Figure 4 shows four positions for downward travel of plunger, rack fixed. On downward travel of plunger, the metered amount of fuel is forced through center passage of the valve assembly, through check valve, and against spray tip valve. When sufficient fuel pressure is built up, valve is forced off its seat and fuel is forced through small orifices in spray tip and atomized into the combustion chamber.

Check valve prevents air leakage from combustion chamber into the fuel system.

On return upward movement of plunger, the high-pressure cavity at lower end of bushing is again filled with fuel oil through the ports. Constant circulation of fresh, cool fuel through the injectors, which renews the fuel supply in the chamber, helps to maintain even operating temperatures of injectors, and also effectively removes all traces of air which might otherwise accumulate in system and interfere with accurate metering of fuel.

The fuel injector outlet opening, which returns the excess fuel oil supplied by fuel pump, is directly adjacent to inlet opening.

Injector used in Series 71—GM Diesel Engines may be one of five different types, each designed for

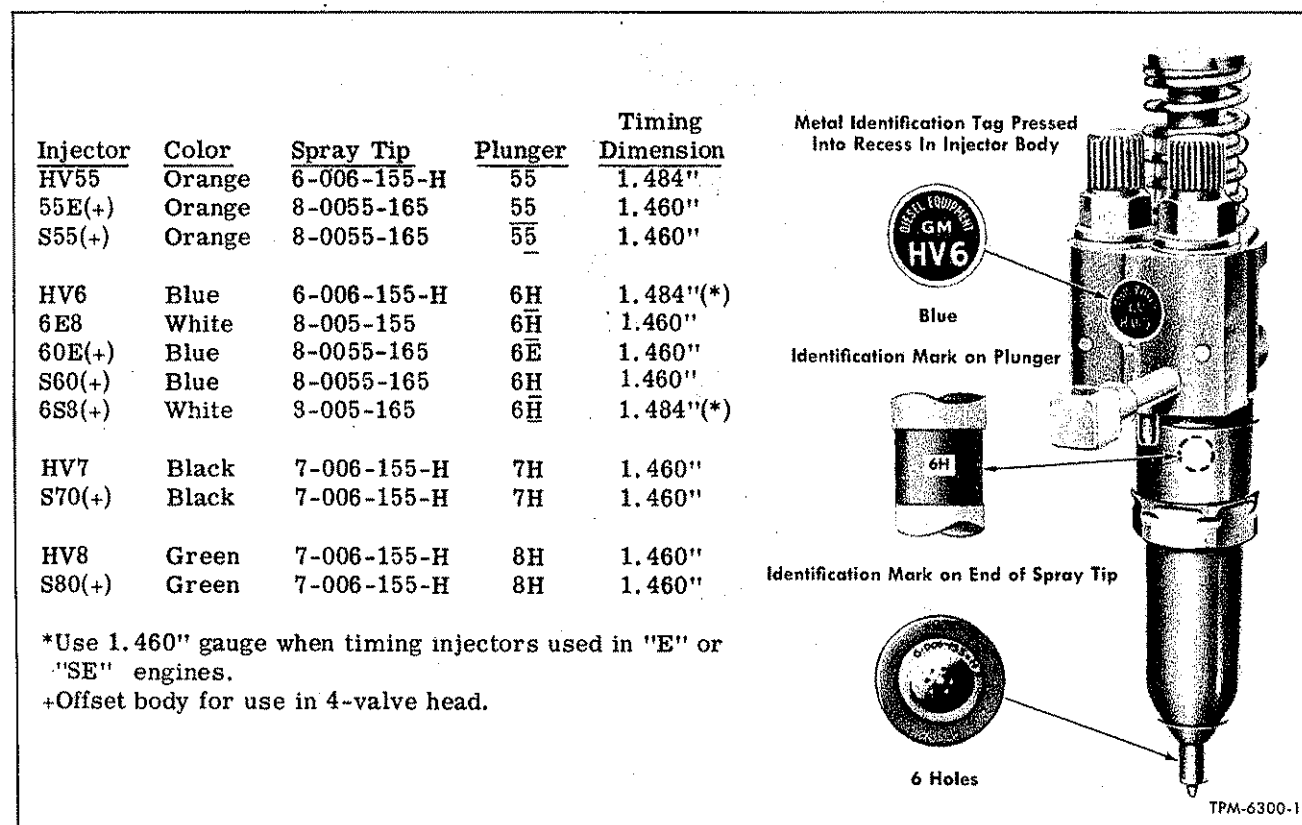


Figure 6—Fuel Injector Identification

FUEL INJECTORS

a specific requirement. Refer to figure 6 for injector identifying marks. The correct injector must be used and type can be determined by checking injector in engine for number which appears on color tag pressed into body.

INJECTOR MOUNTING

The injectors are mounted in the cylinder head, with their spray tips projecting slightly below top of inside surface of combustion chambers as shown in figure 7. A clamp, bolted to cylinder head and fitting into a machined recess in each side of injector body, holds injector in place in a water-cooled copper tube which passes through cylinder head. A dowel pin in injector body registers with a hole

in cylinder head for accurately locating injector assembly.

A copper tube is installed in 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 injector seats in copper tube, forming a tight seal to withstand the high pressure inside combustion chamber.

INJECTOR SERVICE

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 combustion chamber. Due to the fact that injector works against high com-

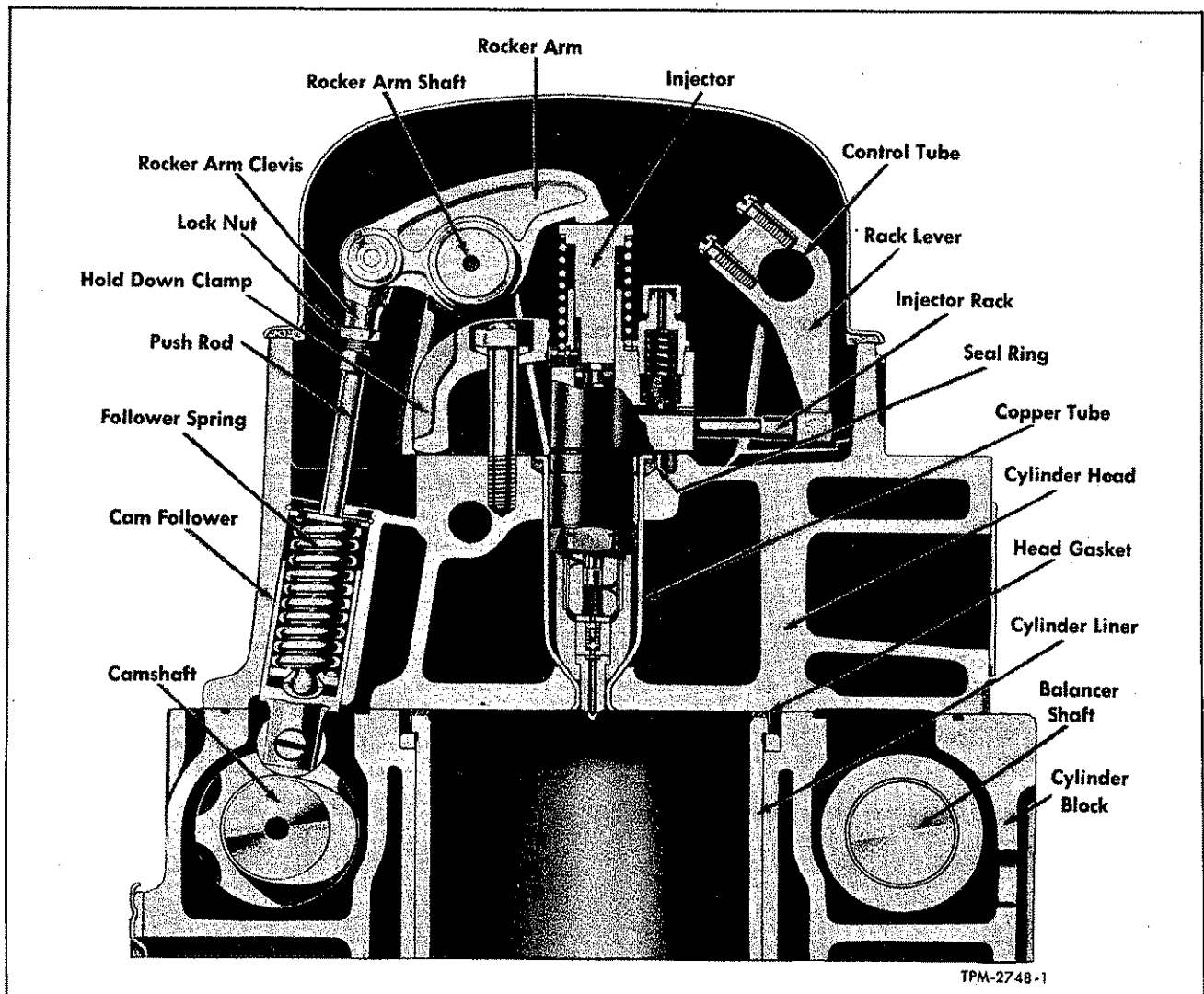


Figure 7—Fuel Injector and Operating Mechanism Installed

FUEL INJECTORS

pression in 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 injector, and intelligent care when servicing unit. No service operations should be attempted on injector without first acquiring a complete understanding of its construction and operation. This section of text thoroughly describes the working principle, shows the construction, and explains how to service unit.

While a skilled mechanic may intelligently service injectors, using the instructions in this section as a guide, time and expense may be saved by changing 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 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 other foreign matter.

When preparing to assemble an injector, it is absolutely essential to wash the hands thoroughly and to clean all 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 passages in injector body and all drilled holes, slots, etc., in injector parts. Waste or rags should never be used for cleaning injector parts, since this would leave lint and other particles which could collect and clog parts of injector when assembled.

Toilet tissue is a good and inexpensive material for wiping an injector part, or on which to place injector parts after cleaning with liquid and blowing dry with air. After liquid wash and subsequent drying with air, it is essential that parts be placed in a clean location until assembled. Clean, light oil should be used liberally on injector parts during assembly to protect them from rust in case injector is not used immediately and to provide initial lubrication when engine is started.

CARE OF INJECTOR (When Replacing)

Because of important part the injectors play in operation of engine, the necessity for proper care and cleanliness of these units cannot be overemphasized. Instructions below should be carefully followed:

1. Whenever the fuel lines are removed from an injector which is installed in engine, protect the two

fuel fittings with shipping cap, part No. 5226414, to exclude dirt.

2. Do not dismantle an injector in dirty surroundings or on a dirty workbench. Use clean paper on the bench, and, after parts have been removed from injector, store 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 parts of each injector separate. The plunger must be fitted, always with the same bushing. It is advisable to keep the parts of tip assembly spring, stop, spray tip valve and seat, as a unit, as it insures that "pop" pressure and calibration built into 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 injector when injector is in engine. If filter caps or filters are to be removed, injector must be completely disassembled and cleaned.

5. Whenever an injector has been removed and reinstalled, or a new injector installed in engine, the injector must be timed and racks positioned. Refer to "Control Rack Positioning" later in this section, also to "Timing Injector" in **ENGINE TUNE-UP** section of this manual.

6. Whenever an injector is to be out of service for an extended period, the injector should be purged as outlined under "Storing Injectors" later in this section.

7. Before installing any used or rebuilt injectors in an engine, test each injector. See "Injector Tests," later in this section.

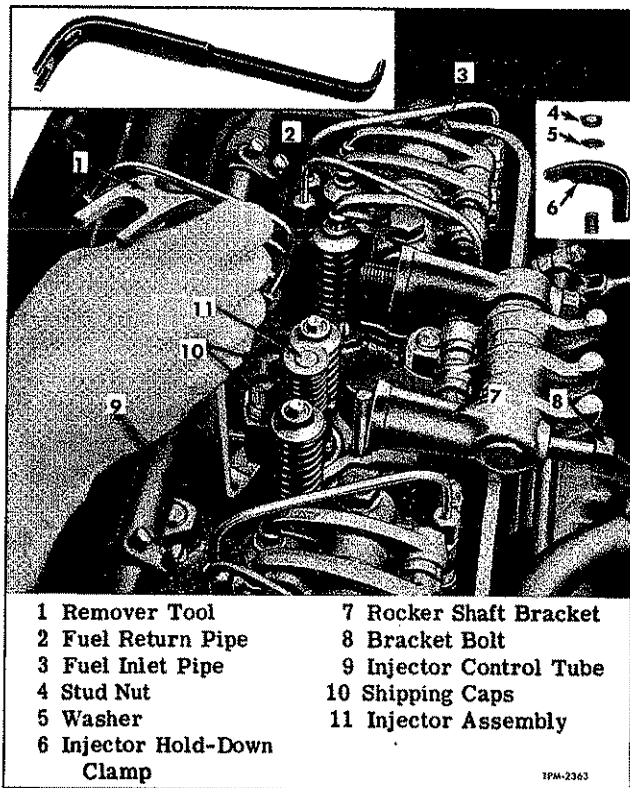
INJECTOR REMOVAL

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 fuel lines from an injector, the two fuel feed fittings should be protected with shipping cap, part number 5226414, to prevent dirt entering injector.

3. If necessary, crank engine with the starter or a bar at flywheel ring gear until the three rocker arm

FUEL INJECTORS**Figure 8—Removing Injector from Cylinder Head**

clevis pins, at outer end of arms, are in line.

4. Loosen two rocker arm bracket bolts holding brackets to cylinder head and swing rocker arm assembly over away from valves and injector.

5. Remove injector hold-down stud nut, special washer, and injector clamp.

6. Using tool as illustrated in figure 8, pry injector from its seat.

7. Lift injector from seat, at the same time disengage control rack linkage.

INJECTOR TESTS

After removing the injector from the engine and cleaning the exterior, inspect the injector. If inspection does not reveal any external damage, then a series of tests may be made to determine the condition of the injector to avoid unnecessary overhauling. Use injector testing and popping fixture and injector comparator (if available), in determining the condition of the injector.

An injector that passes tests outlined below may be considered to be satisfactory for service without disassembly, other than the visual check of the plunger.

However, an injector that does not pass one or more of the tests is unsatisfactory and the faults should be corrected. **ALL OF THE TESTS** should be performed before disassembling an injector to correct any one condition.

Identify each injector and record its pop pressure and fuel output as indicated by the following tests:

CHECK INJECTOR RACK AND PLUNGER MOVEMENT

Purpose of the check is to see if plunger works freely in its bushing and whether the control rack moves back and forth freely.

1. Free movement of a plunger may be checked by placing the injector against a bench, as shown in figure 9, and depressing the follower to the bottom of its stroke while moving the rack back and forth. Failure to produce a free rack indicates that the internal parts of the injector are damaged or dirty. **CAUTION:** The injector must always be held in such a way as to prevent any fuel spray from penetrating the skin. Fuel oil which enters the blood stream may cause serious infection.

VALVE OPENING (POP PRESSURE) TEST

Purpose of the pop pressure test is to determine the pressure at which the valve opens and injection begins.

1. Place the injector in testing and popping fixture, figure 10, with dowel on underside of injector located in the proper slot of the set. When testing offset body injectors, install adapter plate on the test fixture. Position injector support plate and popping handle support to the proper height.

CAUTION: The injector must always be in the proper position in relation to the spray deflector before it is tested, in order to prevent the fuel spray from penetrating the skin. Fuel oil which enters the blood stream may cause a serious infection.

2. Close clamp with inlet tube on injector. Operate pump handle until all air is purged from the test fixture and injector. Then close the outlet clamp.

3. With the injector rack in **FULL FUEL** position, pump handle of test fixture with smooth even strokes (fig. 11) and record the injector valve opening (pop) pressure, indicated when injector sprays fuel. The pop pressure should be 450 to 850 psi. If the pop pressure does not fall within the above range, refer to "Low or High Pop Pressure" chart at end of this section.

FUEL INJECTORS

VALVE HOLDING PRESSURE TEST

The valve holding pressure test will determine whether the various surfaces in the injector are sealing properly.

1. Operate the pump handle to bring the pressure up to a point just below the injector pop pressure.
2. Close the fuel shut-off valve and note the pressure drop. The time for a pressure drop from 450 psi to 250 psi should not be less than 40 seconds.
3. If the injector pressure drops from 450 psi to 250 psi in less than 40 seconds, the injector should be checked as follows:
 - a. Thoroughly dry the injector with compressed air.
 - b. Open test fixture fuel valve and operate pump handle to maintain the testing pressure.
 - c. Observe for a leak at the injector rack opening. If this occurs, a poor bushing-to-body fit is indicated.
 - d. A leak around the spray tip or seal ring is usually caused by a loose injector nut, a damaged seal ring, or a brinelled surface on the injector nut or spray tip.
 - e. A leak at the filter cap indicates a loose filter cap or damaged filter cap gasket.
 - f. A "dribble" at the spray tip orifices indicates a leaking valve assembly due to a damaged surface or dirt. Leakage at the tip will cause preignition in the engine.

NOTE: A drop or two of fuel at the spray tip is only an indication of the fuel trapped in the spray

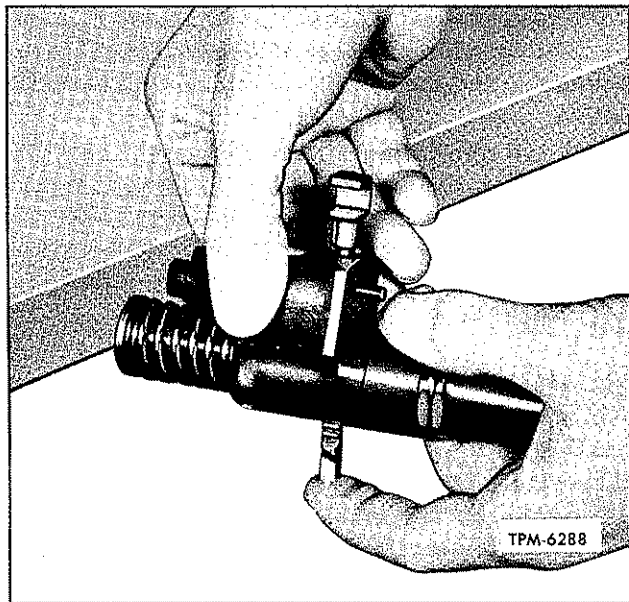


Figure 9—Checking Rack Freeness

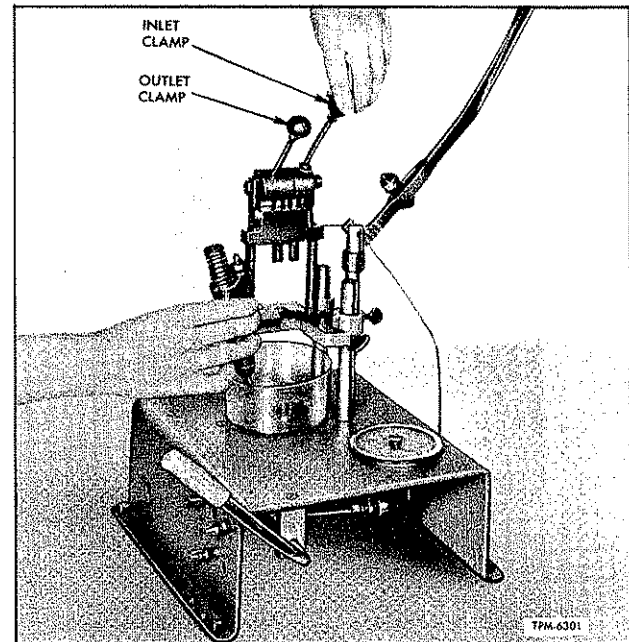


Figure 10—Installing Injector in Testing and Popping Fixture

tip at the beginning of the test and is not detrimental as long as the pressure drop specified is not less than 40 seconds. If the holding pressure does not fall within the above limits refer to "Insufficient Injector Holding Time" chart at end of this section.

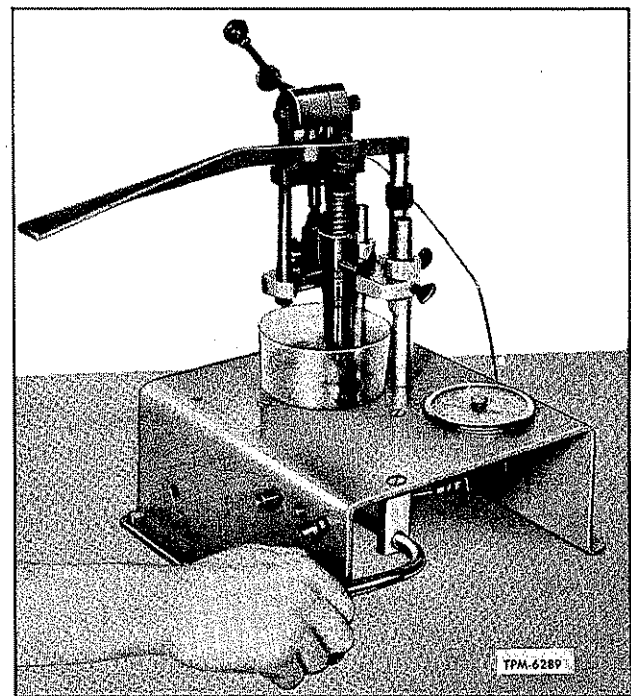
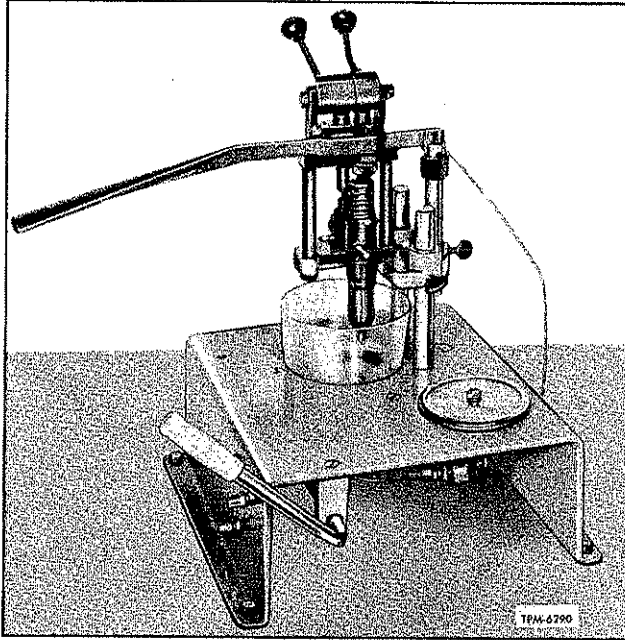
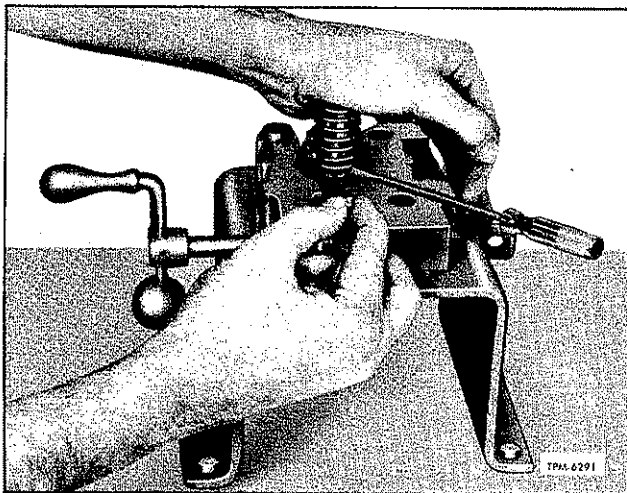


Figure 11—Pumping Up Testing and Popping Fixture

FUEL INJECTORS**Figure 12—Injector High Pressure Test****HIGH PRESSURE TEST**

This test is performed to discover any fuel leaks at the injector filter caps, body plugs, nut seal ring and internal lapped surfaces which did not appear during the valve holding pressure test. The high pressure test also indicates whether or not plunger and bushing clearances are satisfactory.

1. Thoroughly dry the injector with compressed air.
2. Check fuel connections for leaks and tighten if necessary. If leaks have occurred, dry injector again.

**Figure 13—Removing Injector Follower Stop Pin**

3. With injector rack in **FULL FUEL** position and popping handle locked in position by means of the handle lock (fig. 12), operate pump handle to build up and maintain pressure.

4. Use adjusting screw in the popping handle to depress the injector plunger just far enough to close both ports in the injector bushing. The point at which both ports are closed may be easily ascertained by the fact that injector spray will decrease appreciably and a rise in pressure will occur.

5. At this time, the condition of the plunger and bushing may be established. If there is excessive clearance between the plunger and bushing, the operator will be unable to pump up pressure beyond normal valve opening (pop) pressure. Replacement of the plunger and bushing assembly is then required.

6. Pump up test fixture and maintain a pressure of 1400 to 2000 psi and inspect for leaks at the injector filter cap gaskets, body plugs, injector nut seal ring area, and injector rack hole. If any of these conditions exist, refer to "Insufficient Injector Holding Time" chart at end of this section.

CAUTION: Do not permit the pressure in the test fixture to equal or exceed the capacity of the pressure gauge.

SPRAY PATTERN TEST

1. With the injector rack in **FULL FUEL** position, operate pump handle to maintain a fuel pressure just below the valve opening (pop) pressure. Pop the injector several times with the popping handle and observe the spray pattern emitted from the spray tip orifices. Fuel should be discharged from each orifice and the spray should produce a uniform pattern.

2. If the spray tip does not produce a uniform pattern, clean the orifices in the spray tip, using a .005" diameter wire for spray tips with .005" or .0055" diameter holes, or a .006" wire for tips with .006" diameter holes. Refer to "Incorrect Fuel Output" chart at end of this section.

VISUAL INSPECTION OF PLUNGER

An injector which passes all of the previous tests should have the plunger checked visually, under a magnifying glass, for excessive wear or a possible chip on the bottom helix. There is a small area on the bottom helix and lower portion of the upper helix, if chipped, that will not be indicated in any of the tests. Remove plunger from the injector as follows:

FUEL INJECTORS

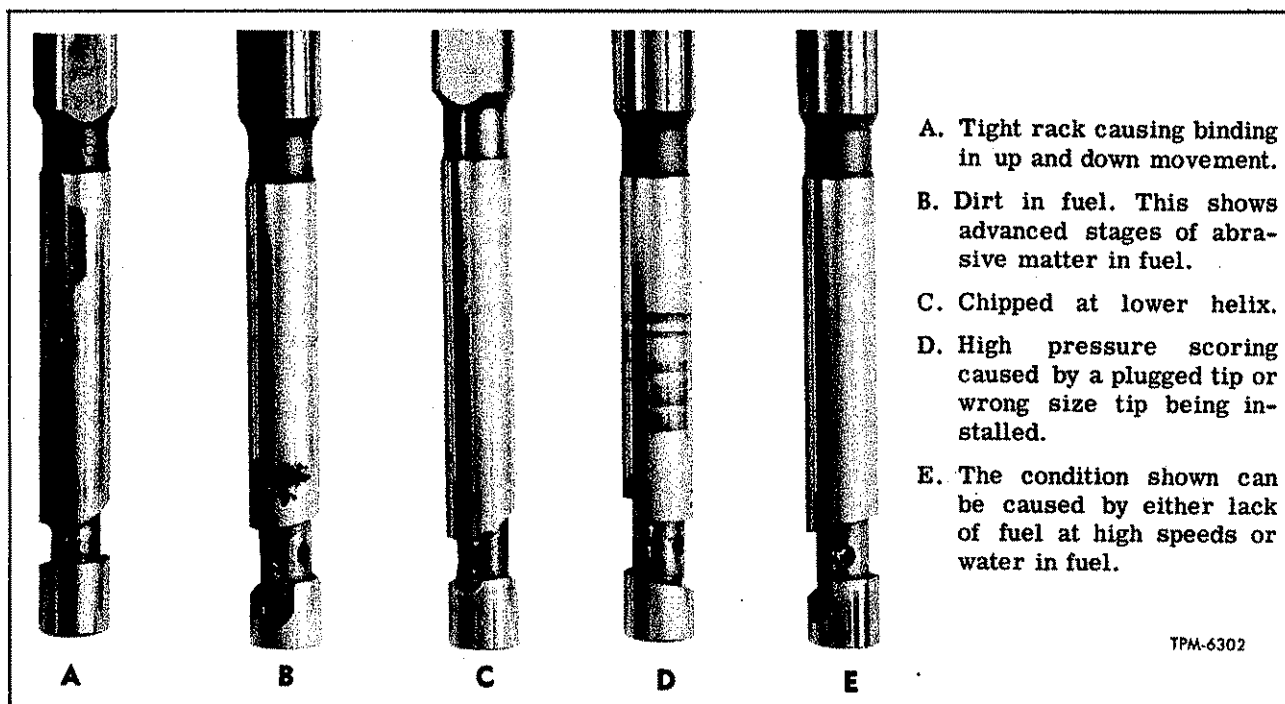


Figure 14—Damaged and Unusable Plungers

1. Support injector, right side up in holding fixture.

2. Compress follower spring. Then, using a screwdriver, raise spring above stop pin and withdraw the pin, as shown in figure 13. Allow plunger spring to rise gradually.

3. Remove injector from holding fixture and turn injector upside down, to prevent entry of dirt in injector, and catch spring and plunger in hand.

4. Inspect plunger and, if chipped, the plunger and bushing should be replaced after fuel output check is performed. Figure 14 illustrates unusable plungers.

FUEL OUTPUT TEST

Operate injector in GM Diesel injector comparator (fig. 15) to check the fuel output as follows:

1. Place injector in comparator and seal firmly.
2. Pull rack out to NO FUEL position.
3. Start comparator by turning on switch shown in figure 15.
4. After comparator has started, push injector rack to FULL FUEL position.
5. Let injector run for approximately 30 seconds to purge air that may be in the system.
6. After 30 seconds, press fuel flow start button. This will start the flow of fuel into the vial. The

comparator will automatically stop the flow of fuel after a thousand strokes.

7. After fuel stops flowing into the vial, pull rack out to NO FUEL position.

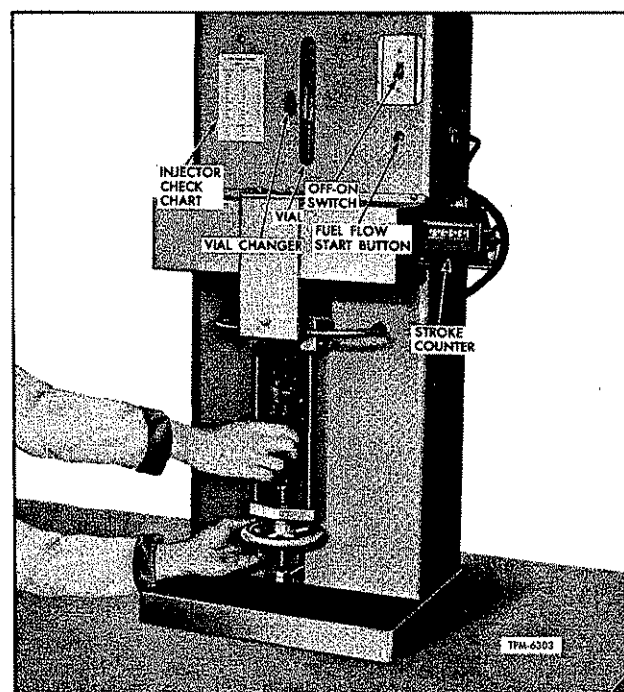


Figure 15—Injector Comparator

FUEL INJECTORS

8. Turn comparator off.
9. Reset counter.
10. Observe reading on vial.
11. Refer to chart on comparator, and check if injector fuel output falls within its specified limits. If the quantity of fuel in the vial does not fall within the specified limits, refer to "Incorrect Fuel Output" chart at end of this section for cause and remedy.

The comparator may be used to check and select a set of injectors which will inject the same amount of fuel in each cylinder at a given throttle setting, thus resulting in a smooth running, well balanced engine.

An injector which passes all of the above tests may be put back into service. However, an injector which fails to pass one or more of the tests must be disassembled and rebuilt.

Any injector which is disassembled and rebuilt must be tested again before being placed in service.

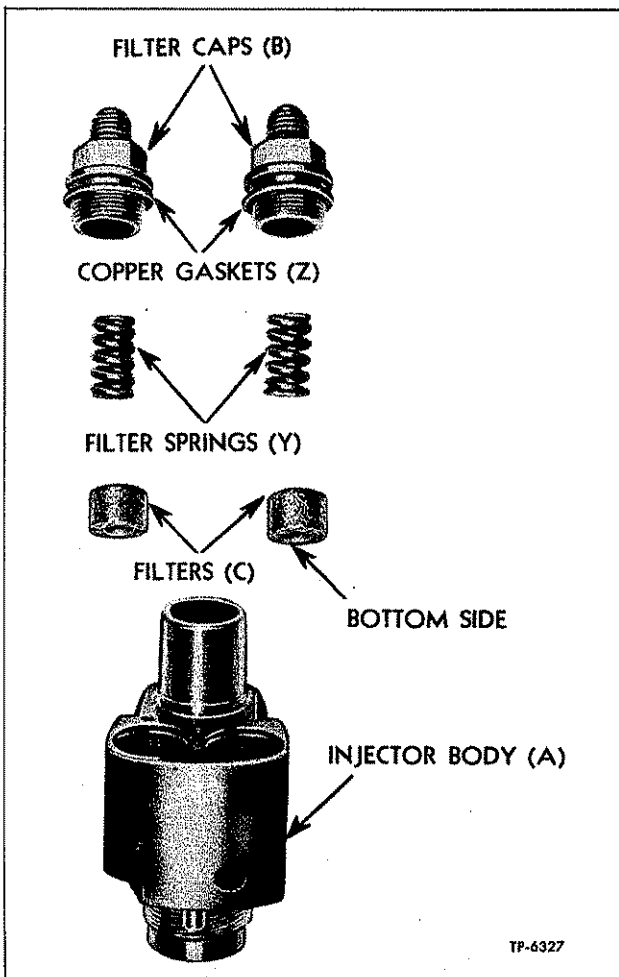


Figure 16—Injector Filters, Springs, and Caps

INJECTOR DISASSEMBLY

If required, the injector may be disassembled in the following manner:

1. Support injector upright in injector assembly fixture, and remove filter caps, springs, filter elements and gaskets (fig. 16).

NOTE: Whenever injector is disassembled, filter elements and gaskets should be discarded and replaced with new filters and gaskets.

2. Compress follower spring as shown in figure 13. Then, using a screwdriver, raise spring above stop pin and withdraw pin. Allow follower spring to rise gradually.

3. Refer to figure 17 for details and remove plunger follower, spring and plunger as an assembly (fig. 18).

4. Reverse the injector in the fixture and, using socket wrench, loosen nut from injector body (fig. 19).

5. Lift injector nut straight up by hand, being

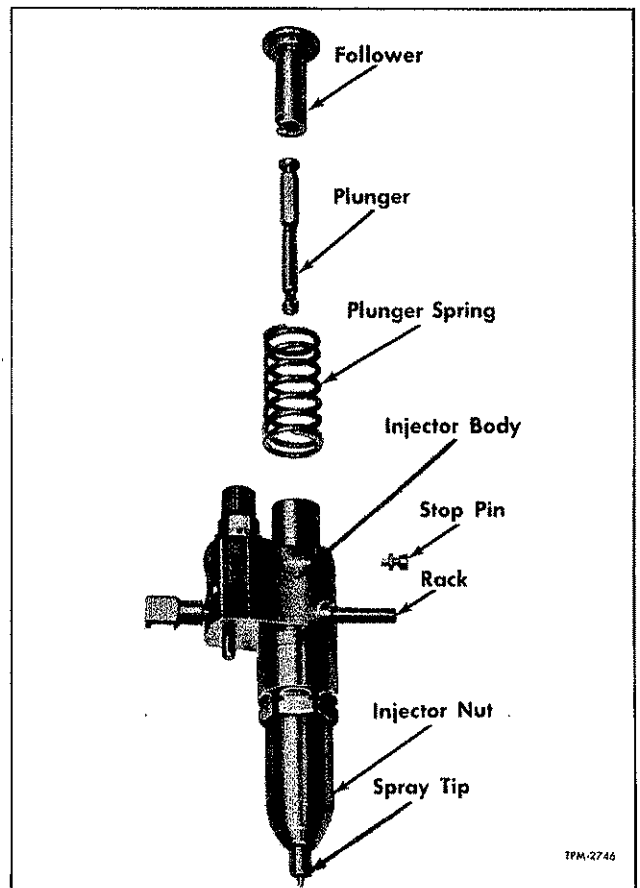


Figure 17—Injector Plunger and Follower Details

FUEL INJECTORS

careful not to dislodge the spray tip and valve parts. Remove the spray tip and valve parts off bushing and place in a clean receptacle until ready for assembly.

6. When an 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, support the nut on a wood block and drive the tip down through the nut, as shown in figure 20, using recommended tool.

7. Remove spill deflector, and seal ring, from injector nut (fig. 21).

8. Remove plunger bushing, gear retainer, and gear from injector body (fig. 21).

9. Withdraw injector control rack from injector body (fig. 21).

CLEANING INJECTOR PARTS

Since most injector difficulties are the result of dirt particles, it is essential that a clean area be provided on which to place injector parts after cleaning and inspection.

1. Wash all parts with clean fuel oil or a suitable cleaning solvent and dry with clean, filtered compressed air. Do not use waste or rags for cleaning purposes. Be sure to clean out all passages, drilled holes and slots in all injector parts.

2. Spray tip should be cleaned with reamer (fig.

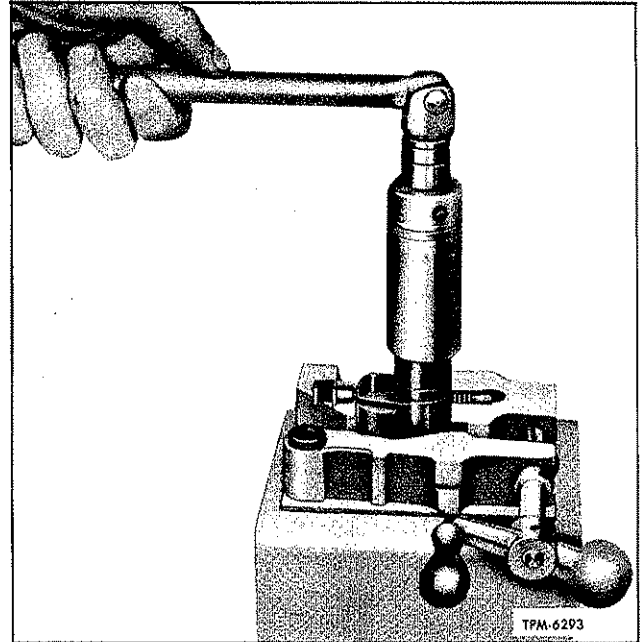


Figure 19—Removing Injector Nut

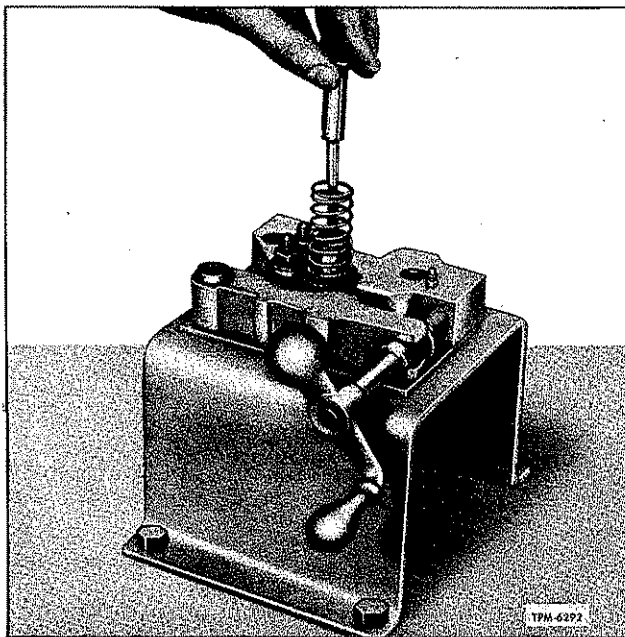


Figure 18—Removing or Installing Injector Follower Spring and Plunger

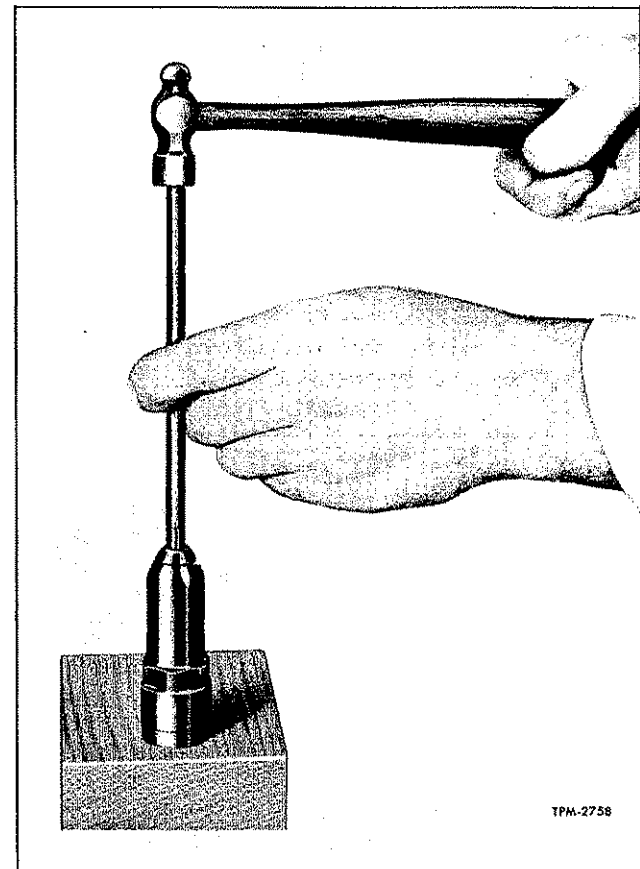
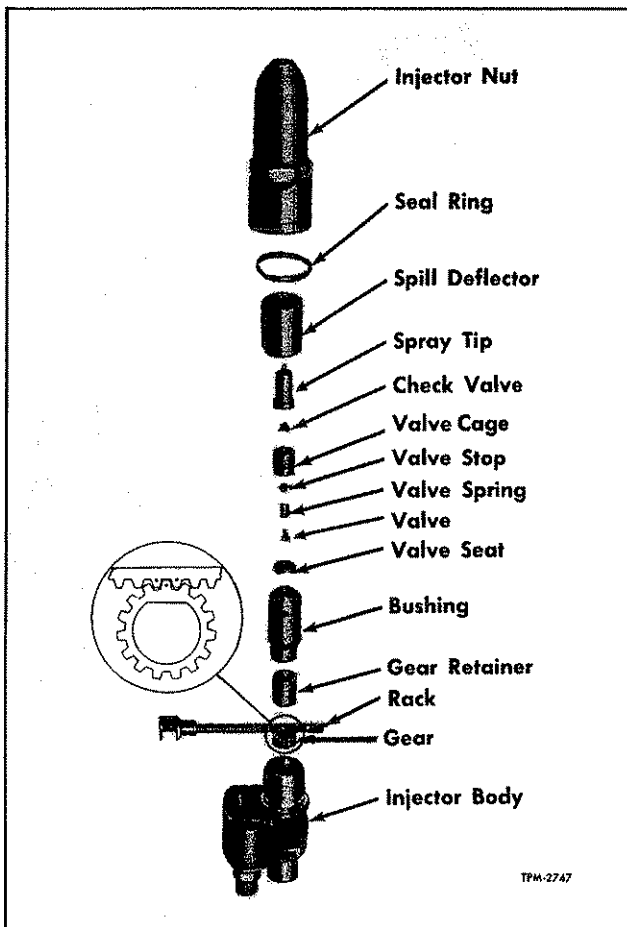
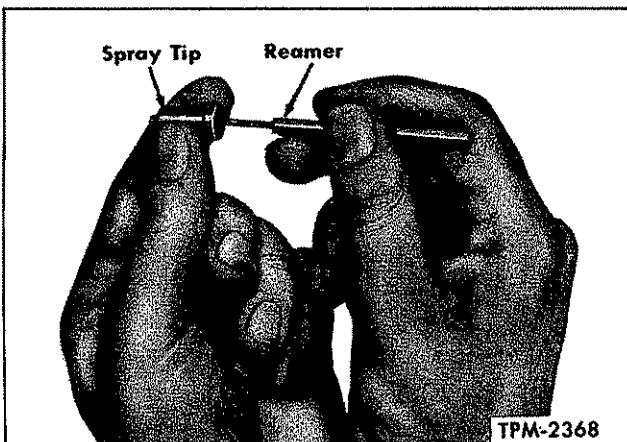


Figure 20—Removing Spray Tip From Injector Nut

FUEL INJECTORS**Figure 21—Injector Rack, Gear, and Spray Tip Details**

22). Turn reamer in a clockwise direction to remove carbon deposits. Wash spray tip and dry with compressed air. Clean spray tip orifices, using a .005" diameter wire for tips with .005" or .0055" diameter

**Figure 22—Reaming Injector Spray Tip**

holes, or a .006" diameter wire for tips with .006" diameter holes (fig. 23).

3. Before using wire, hone the end of wire until it is smooth and free of burrs, using stone. Wash spray tip in clean fuel oil and dry with compressed air.

4. Clean and brush all passages in injector body, using fuel hole cleaning brush and rack hole cleaning brush. Blow out passages and dry with compressed air.

5. Carefully insert reamer in injector nut as shown in figure 23A. Turn reamer in a clockwise direction to remove carbon deposits. Use care in reaming to prevent removing any metal or setting up burrs on the spray tip seat. Then, wash in clean fuel oil and dry with compressed air. Carbon deposits on the spray tip seating surface of the injector nut will result in poor sealing and consequently fuel leakage around the spray tip.

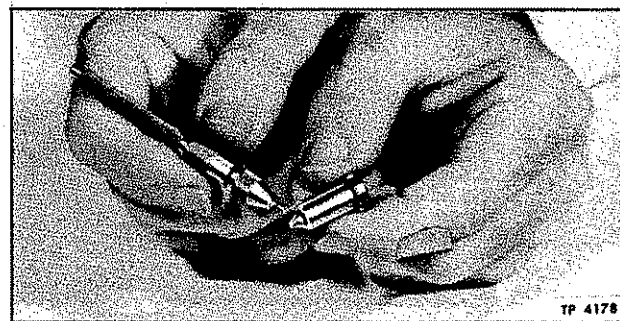
6. When handling the injector plunger, do not touch finished plunger surfaces with the fingers. Wash plunger and bushing with clean fuel oil and dry with compressed air (fig. 23B). Final cleaning may be accomplished with soft tissue paper. Wrap tissue paper around bushing cleaner tool and clean out bushing bore (fig. 23B). Keep plunger and bushing together as they are mated parts.

7. After washing, submerge parts in clean receptacle containing clean fuel oil. Keep parts of each injector assembly together.

INSPECTION

1. Inspect teeth on control rack and control rack gear for excessive wear or damage. Also, check for excessive wear in bore of gear. Replace if damaged or worn.

2. Inspect both ends of spill deflector for sharp edges or burrs which could create burrs on the in-

**Figure 23—Cleaning Spray Tip Orifices**

FUEL INJECTORS

jector body or injector nut and cause particles of metal to be introduced into the spray tip and valve parts. Burrs may be removed with a medium stone.

3. Inspect plunger spring for defects and check in spring tester. The plunger spring has a free length of 2.039". A load of 38 ± 3 lbs. is required to compress the spring to a length of 1.027". The spring should be replaced when a load of less than 30 lbs. will compress it to the 1.027" length.

4. Check the seal ring area in the injector body for burrs or scratches. Also check the surface which contacts the injector bushing for scratches, scuff marks or other damage. If necessary, lap this surface as outlined below. A faulty sealing surface at this point will result in high fuel consumption and contamination of the lubricating oil.

5. Inspect injector plunger for scoring, erosion, chipping or wear at helix (fig. 14). Check for sharp edges on that portion of plunger which rides in gear. These sharp edges may be removed with a 500 grit stone. Wash plunger after stoning. Inspect plunger bushing for cracks or chipping. Slip plunger straight into bushing and check for free movement. Badly worn, chipped, or scored plunger and/or bushing must be replaced. Plungers and bushings are mated parts and must be replaced as an assembly.

6. Examine spray tip seating surface of injector

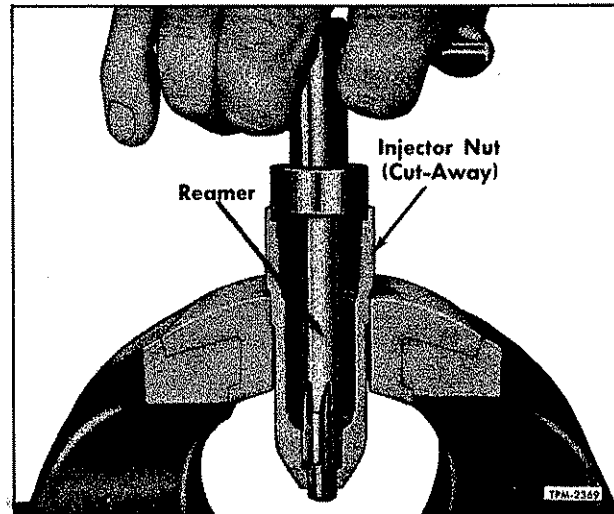


Figure 23A—Cleaning Injector Nut Tip Seats

nut for nicks or burrs or brinelling. Reseat surface or replace nut if severely damaged.

7. The injector valve spring plays an important part in establishing the valve opening (pop) pressure of the injector assembly. Replace a worn or broken valve spring. When compressed to a length of .240", the valve spring has a loading of $5\frac{1}{2} \pm \frac{1}{2}$ lbs. The spring should be replaced when a loading

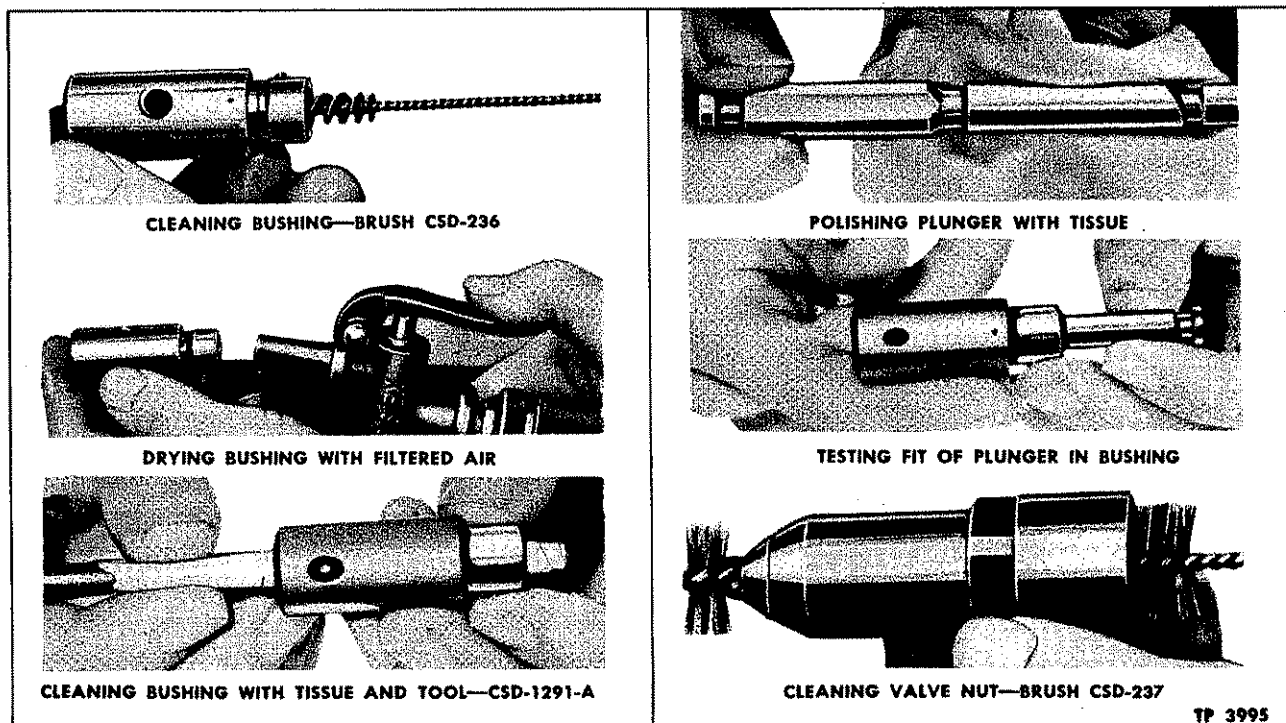
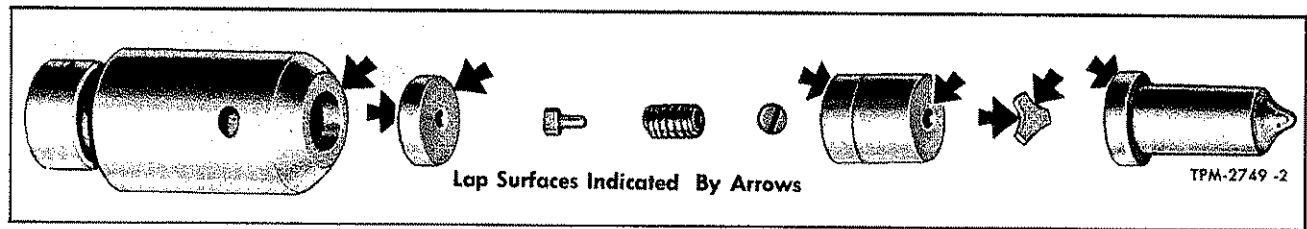


Figure 23B—Cleaning Plunger, Bushing, and Nut

FUEL INJECTORS**Figure 23C—Sealing Surfaces of Injector Parts Requiring Lapping**

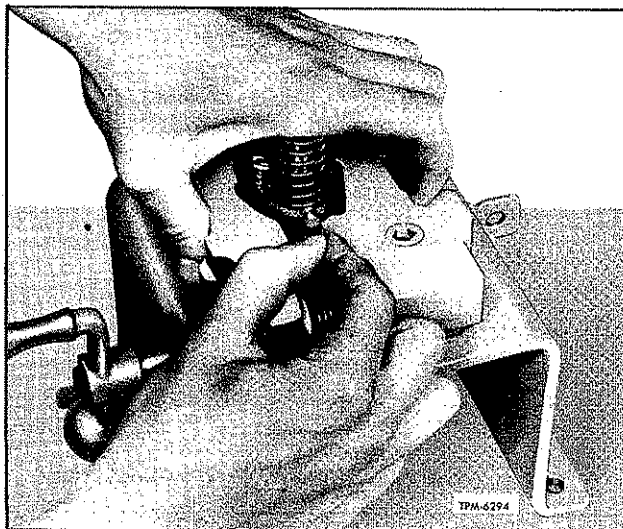
of less than $4\frac{1}{4}$ lbs. will compress it to the .240" length.

8. Inspect the sealing surfaces of the spray tip and valve parts indicated in figure 23C. The sealing surfaces should be examined with a magnifying glass, for even the slightest imperfections will prevent the injector from operating properly. Check for burrs, nicks, erosion, cracks, chipping and excessive wear. Also, check for enlarged orifices in spray tip. Replace damaged or worn parts.

9. If inspection reveals the injector body, injector bushing, spray tip, and valve assembly seating surfaces require reconditioning, it should be carried out as outlined under "Lapping Injector Parts" following.

10. When reinstalling used valve parts in an injector, all the sealing surfaces (fig. 23C), with the exception of the crown valve, must be lapped as outlined under "Lapping Injector Parts" following.

11. Due to the possibility of parts being burred or nicked during handling, it is good practice to lightly lap the sealing surfaces (with the exception noted above) on new valve parts before installing in an injector assembly.

**Figure 23D—Installing Injector Follower Stop Pin****LAPPING INJECTOR PARTS**

Lapping of the sealing surfaces may be carried out as follows:

1. Clean the lapping blocks with compressed air. Do not use a cloth or any other material for this purpose.

2. Spread a good quality, 600 grit dry lapping powder on one of the lapping blocks.

3. Place the part to be lapped flat on the block and, using a figure eight motion, move it back and forth across the block. Do not press on the part, but use just enough pressure to keep the part flat on the block.

It is important that the part be kept flat on the block at all times.

4. After each four or five passes, clean the lapping powder from the part by drawing it across a clean piece of tissue placed on a flat surface and inspect the part. Do not lap excessively.

5. When the part is flat, wash in cleaning solvent and dry with compressed air.

6. Place the dry part on the second lapping block. After applying lapping powder, move the part lightly across the block, in a figure eight motion, several times to give it a smooth finish. Do not lap excessively. Again wash part in cleaning solvent and dry with compressed air.

7. Place the dry part on third block. Do not use lapping powder on this block. Keep the part flat and move it across the block several times, using the figure eight motion. Lapping the dry part in this manner gives it the "mirror" finish required for perfect sealing.

8. Since only the edge of the hole in the crown valve seat contacts the valve, this edge must be nearly perfect, must be a true circle, and present an unbroken surface. Examine the edge of the hole under a magnifying glass for chipping or cracks. If edge of hole shows small irregularities, the hole should be lapped with deburring tool.

FUEL INJECTORS

9. Mount deburring tool in drill motor and place a small amount of lapping powder and oil mixture on the tool. Place valve seat over pilot of tool and start drill. Holding valve seat with fingers, touch it lightly against rotating lapping tool so as to produce a uniform seat at the hole. After lapping the edge of the hole in this manner, flat lap the face of the seat lightly, then clean and examine the width of the edge. Width of the chamfer produced at the edge of the hole should be within .002" to .005". A width in excess of these limits, due to excessive lapping, will lower the pop pressure of the injector.

10. Wash all the injector parts that were lapped in clean fuel oil or suitable cleaning solvent and dry with compressed air. Clean the inside of the injector bushing by wrapping clean tissue around bushing cleaner tool, and rotate in and out through bushing as shown in figure 23B.

INJECTOR ASSEMBLY

Before starting to assemble an injector, it is necessary to have an extremely clean bench on which to work and place the parts. Refer to figures 16, 17, and 21 for proper relative positions of the injector parts and the methods for their assembly prior to proceeding with assembly. Since the plunger and bushing are matched parts, they must be considered as one piece and, if one is replaced, both must be replaced.

For purposes of simplicity, the injector assembly has been subdivided into four sub-assemblies and will be so treated in the assembly procedure. These sub-assemblies are: (1) Filter assembly, (2) Rack and gear assembly, (3) Valve and related parts assembly, (4) Plunger and follower assembly.

ASSEMBLE INJECTOR FILTERS

New filters and gaskets should always be used when reassembling injectors.

1. Holding the injector body right side up, place a filter in each of the fuel cavities in the top of the injector body (fig. 16). The fuel entering the inlet side of the injector body surrounds the filter element, passes through the element, and is discharged through the bottom of the filter. The flow is in the reverse direction on the outlet side of the injector. Note that the fuel filters have a dimple in one end. When assembling the filters, always have the dimple at the bottom.

2. Place a spring above each filter, a new gasket up against the shoulder of each filter cap, lubricate the threads, and tighten the filter cap in place in the

injector body to a torque of 65 to 75 ft.-lbs., using a $\frac{9}{16}$ " deep socket wrench. It is important that the filter caps be tightened securely so as to compress the gaskets and effect a good seal with the injector body. Also, when the caps are tightened, they compress the filter springs which hold the filters securely in place so all fuel entering the injector is properly filtered.

3. Install shipping caps on injector filter caps to prevent any dirt particles from entering injector. Be sure shipping caps are clean.

ASSEMBLE RACK AND GEAR

Refer to figure 21 and note that two of the teeth of the injector rack have a drill spot mark; also note one tooth of the mating gear is similarly marked. When rack and gear are assembled, the marked tooth of the gear must be engaged between the two marked teeth on the rack.

1. Hold the injector body bottom end up and slide the rack through the proper hole in the body. The two marked teeth can then be observed when looking into the bore for the gear from the bottom of the injector body. The injector rack can be placed in the injector body in only one position and have the tooth marks show in the opening for the gear.

2. Holding the rack in position so the tooth marks show, slide the gear into proper engagement with the rack.

3. Slide gear retainer down on top of gear; then place plunger bushing down onto retainer with locating pin in bushing guided into slot of injector body.

ASSEMBLE INJECTOR VALVE AND RELATED PARTS

After having lapped and cleaned the injector valve and related parts, refer to figures 5 and 21 and assemble in the following manner:

1. Support the injector body in injector assembly fixture, bottom end up.

2. Locate seal ring on shoulder of body. Slide spill deflector over barrel of bushing.

3. Place valve seat on end of bushing. Insert stem of valve in one end of valve spring and valve stop in opposite end of spring. Lower valve cage over this assembly so that stop seats in cage, as shown in figure 5, then position the valve cage assembly on valve seat.

4. Locate the check valve centrally on cage, and place spray tip over check valve and against cage.

5. Lubricate threads and carefully pilot nut over the spray tip and check valve assembly. The tip will

FUEL INJECTORS

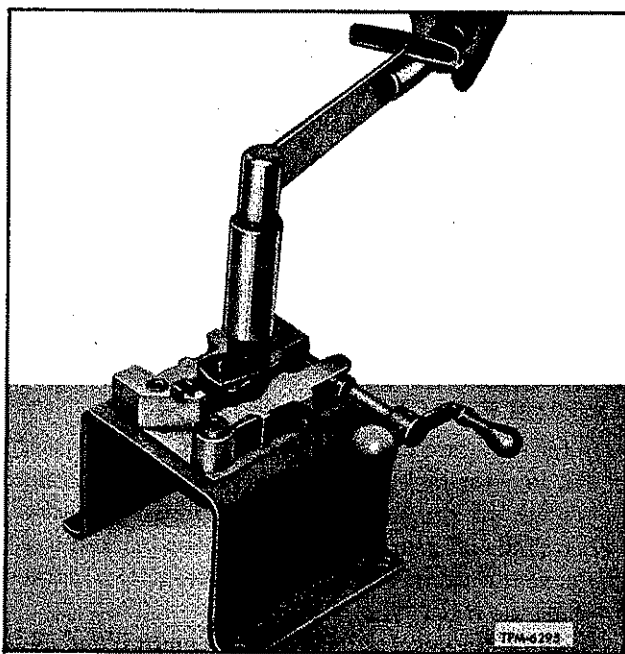


Figure 23E—Tightening Injector Nut with Torque Wrench

slide through the hole in the small end of nut.

6. Screw the nut in place by hand making sure that the valve assembly does not shift. Do not use a wrench to tighten nut at this time. If the valve parts are not centrally located on the end of the bushing, they will not enter the counterbore of the injector nut. To facili-

tate assembly in such case, turn the end of spray tip with the fingers while screwing the nut onto the body by hand.

ASSEMBLE PLUNGER AND FOLLOWER

1. Refer to figure 18, and slide the head of plunger into the follower. Insert this assembly through plunger spring for assembly to injector.

2. Invert the injector in the assembly fixture—connector side up—and push the rack all the way IN; then insert free end of plunger into top of injector body.

3. Refer to figure 23D and start the stop pin into position in injector body so that bottom coil of follower spring rests on the narrow flange on the stop pin. Then, with slot in the follower and hole in the injector body in alignment for the stop pin and flat side of plunger positioned to engage flat 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 the slot in follower and hole in injector body come in alignment. When in place, the spring will hold the stop pin in position.

4. Invert the injector assembly in the assembly fixture, and by means of socket wrench and torque wrench (fig. 23E) tighten injector nut to torque of 55 to 65 ft.-lbs. Do not exceed specified torque, otherwise plunger will bind in bushing.

CHECK SPRAY TIP CONCENTRICITY

The spray tip and injector nut **MUST** be concentric within .008" to ensure correct alignment of the spray tip hole of the cylinder head (or injector hole tube).

1. Place the injector in concentricity gauge as shown in figure 23F.

2. Adjust dial indicator to "O." Rotate injector 360° and note total run-out as indicated on dial. If the total run-out exceeds .008", remove injector from gauge. Loosen injector nut, re-center spray tip, tighten nut, and recheck concentricity. If, after several attempts, the spray tip cannot be positioned satisfactorily, the assembly of the complete injector must be checked.

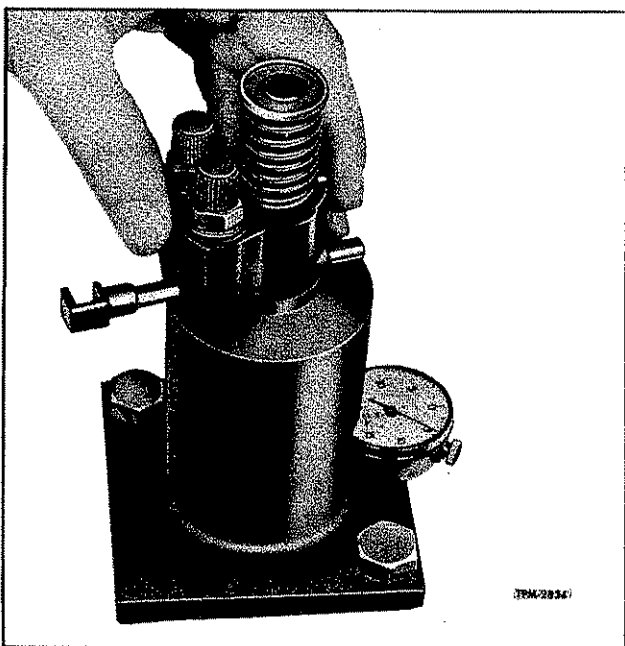


Figure 23F—Checking Injector Spray Tip Concentricity

FINAL TESTING

1. Before placing a reconditioned injector in service, all of the tests (except the visual inspection of the plunger) previously outlined in this section under "Injector Tests" must be performed again.

FUEL INJECTORS

2. If the injector passes these tests, it is satisfactory for further use. However, failure to pass any one of the tests indicates that defective or dirty parts have been assembled. In this case, the injector must be disassembled again, cleaned, inspected, reassembled, and tested again.

3. If an injector is not to be used immediately, shipping caps should be installed on the injector caps. The injector test oil remaining in the injector after the fuel output test will serve as a rust preventive while the injector is in storage.

INJECTOR INSTALLATION

Before installing a new or reconditioned injector in an engine, the carbon deposits must be removed from the beveled seat of the injector hole tube in the cylinder head. If this carbon is not removed, the injector may be cocked during installation resulting in undue stresses being exerted against the spray tip. This could ultimately result in a fractured spray tip.

Injector tube bevel seat reamer should be used to clean the carbon out of the tube before installing the injector. Refer to "Reaming" in "CYLINDER HEAD" section of this manual. Care must be exercised to remove **ONLY** the carbon so that the proper clearance between the injector body and cylinder head is maintained. The flutes of the reamer should be packed with heavy grease to retain the carbon removed from the tube.

1. Refer to figure 7 and insert the injector into the injector tube with the locating dowel registering with the locating hole in the cylinder head and with the pin on the injector control tube lever registering with the injector control rack lever.

2. Place injector clamp over stud. Install special washer and nut and tighten nut to torque of 20 to 25 ft.-lbs. Check to make sure clamp does not interfere with valve or injector springs.

NOTE: Check injector rack for free movement. Excess torque will cause the injector control rack to stick or bind.

3. Move rocker arm assembly into position and secure rocker arm bracket bolts to torque of 90 to 100 ft.-lbs. (fig. 8).

4. Connect fuel pipes (fig. 8) to injector and fuel connectors.

5. As a precautionary measure against any possibility of scoring injector parts upon initial installation due to lack of lubrication, any entrapped air should be bled from the injector before tightening the connections on the fuel outlet side of the injector. This

may be accomplished by cranking the engine briefly with the injector rack in the **NO FUEL** position and then tightening the fuel pipe connection.

6. When installing injector fuel lines, connections should be tightened only enough to prevent leakage of fuel. Excess tightening may result in the flared end of the fuel line being twisted or fractured. When all injector fuel lines are installed, the engine should be run long enough (during tune-up procedure) to check for leaks. Should leaks occur, the connections should be tightened only enough to stop the leak.

7. Following installation of the injectors in the engine, a complete engine tune-up should be performed. However, if only one injector has been removed and replaced, and other injectors and the governor adjustment have not been disturbed, it will only be necessary to adjust the clearance of the valves, valve bridge, and time the injector for the one cylinder, and position the control rack on the cylinder involved to correspond with that of the other racks.

CONTROL RACK POSITIONING

1. Whenever injector control tube has been removed, care should be exercised when replacing assembly to be sure that no bind exists between tube levers and injector racks to hamper free operation of the latter. The levers are free to move endwise on tube a limited distance.

2. Whenever the adjusting screw and the levers are tightened, levers should be so positioned on tube that operating lug at lower end of lever does not bind in slot of injector rack. Furthermore, the brackets holding tube assembly to cylinder head should be so positioned that coil spring on control tube will return injector racks to **NO FUEL** position freely.

3. Control tube and bracket assembly may be shifted by loosening bracket-to-cylinder head bolts and tapping brackets lightly to change their positions on cylinder head, then retightening 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 injector has been used over a long period of time without cleaning.

4. If no bind exists between rack control tube and injectors, and the tension spring on control tube fails to return racks freely to **NO FUEL** position when control tube is disconnected from governor fuel rod, the cause may be due to a sticking injector rack. A sticking injector rack may be located by checking each injector as follows:

FUEL INJECTORS

a. Loosen adjusting screws in all but one of the rack control levers.

b. Turn engine crankshaft so exhaust valves are closed and injector in non-injection position (the three rocker arms in line) on cylinder in which adjusting screws were not loosened.

c. Press down on injector follower with screwdriver and at same time move injector rack of cylinder being checked in and out by means of control tube lever. Control tube and injector rack must operate freely. After checking loosen adjusting screw.

5. The following four operations are involved to position the injector control racks:

a. Make preliminary rack setting so engine can be safely started and run.

b. Set the governor spring gap to obtain full engine power. Refer to respective **GOVERNOR** section of this manual.

c. Position injector racks to full fuel position (engine not running). Refer to respective **GOV-**

ERNOR section of this manual.

d. Set governor idling speed. Refer to respective **GOVERNOR** section of this manual.

THROTTLE DELAY CYLINDER

The function of throttle delay cylinder unit (used only on transit type coaches equipped with hydraulic transmission) is to momentarily retard full fuel injection when accelerator is depressed. This aids in reducing exhaust smoke on acceleration and in reducing overall fuel consumption. The throttle delay cylinder is mounted at the center of the injector rack and operates by oil supplied to the cylinder through a drilled opening in the throttle delay cylinder hold down bolt. Surplus oil flows from the cylinder to the engine cam pockets.

An oil bleed hole together with a check valve are installed in the end of the bracket assembly and control the movement of the throttle delay piston during acceleration of the engine. Refer to "Engine Tune-up" for adjustment procedure.

FUEL INJECTORS

INJECTOR TROUBLE SHOOTING
LOW OR HIGH POP PRESSURE

LOW POP PRESSURE

WORN OR ERODED VALVE SEAT—Valve seat may be lapped, but not excessively as this would reduce thickness of valve and cause a deviation in valve stack up dimension.

VALVE SEAT CHIPPED AT POINT OF CONTACT—When seat is chipped, lap surface of seat and I.D. of hole. Do not lap excessively.

CRACKED VALVE SEAT—Replace valve seat.

WORN OR BROKEN VALVE SPRING—Replace spring. Check valve cage and valve stop for wear.

LOW POP PRESSURE—Cont.

WORN VALVE OR VALVE STOP—Replace parts.
DIRT OR FOREIGN MATERIAL IN INJECTOR—Disassemble injector and clean.

WORN VALVE STOP SEAT IN CAGE—Replace.

HIGH POP PRESSURE

CARBON OR FOREIGN MATERIAL IN SPRAY TIP—Remove and clean with tip reamer.

CARBON IN TIP ORIFICES—Remove and clean with proper size wire.

INSUFFICIENT INJECTOR HOLDING TIME

POOR BUSHING TO BODY FIT—Lap injector body.

INJECTOR NUT NOT TIGHT—Tighten nut to recommended torque. Do not exceed.

CRACKED VALVE PARTS—Replace parts.

VALVE SEAT CHIPPED AT POINT OF CONTACT—When seat is chipped, lap surface of seat and I.D. of hole. Do not lap excessively.

WORN OR ERODED VALVE SEAT—Valve seat may be lapped, but not excessively as this would reduce thickness of valve and cause a deviation in valve stack up dimension.

WORN OR BROKEN VALVE SPRING—Replace spring. Check valve cage and valve stop for wear.

WORN VALVE—Replace.

DEFECTIVE SEAL RING—Replace.

BODY PLUG LEAKS—Plug body.

FILTER GASKET LEAKS—Replace gaskets and tighten caps to recommended torque.

LEAK AT FUEL FITTINGS SEAL SURFACES—Clean sealing surfaces or replace filter caps.

DIRT OR FOREIGN MATERIAL IN INJECTOR—Disassemble injector and clean.

INCORRECT FUEL OUTPUT

SPRAY TIP OR ORIFICES PARTIALLY PLUGGED—Remove and clean with proper size wire.

SPRAY TIP ORIFICES ENLARGED—Replace spray tip.

CARBON IN TIP ORIFICES—Remove and clean with tip reamer.

WORN PLUNGER AND BUSHING—First check for incorrect or faulty spray tip, also try changing spray tip. Replace plunger and bushing if output still does not fall within limits.

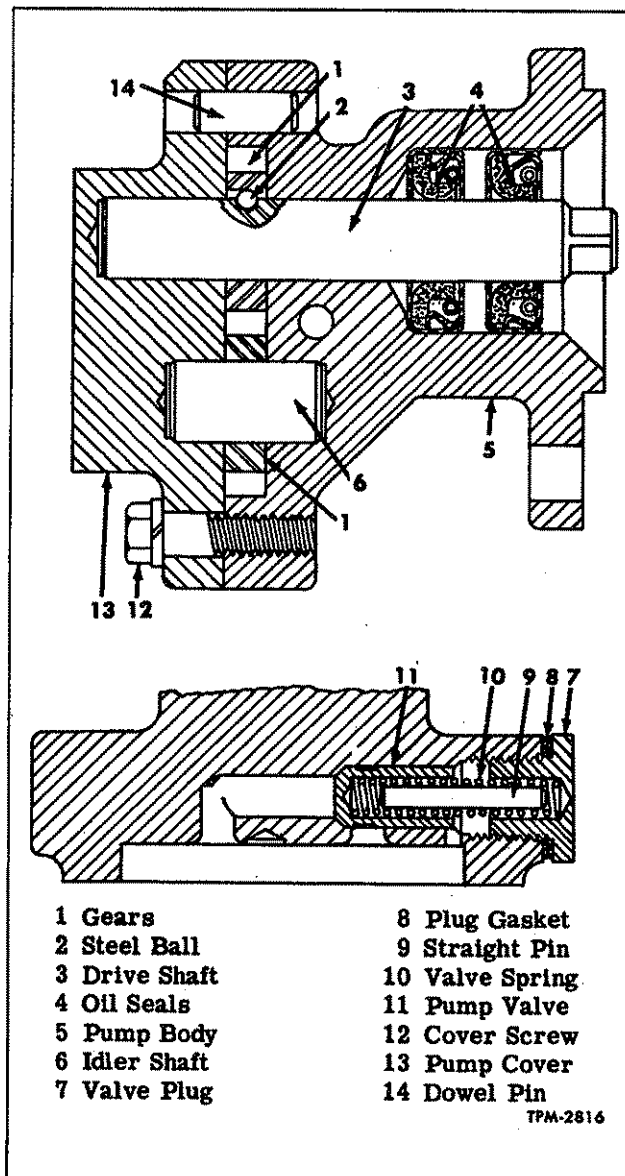
CRACKED VALVE PARTS—Replace parts.

CRACKED BUSHING—Replace plunger and bushing.

POOR LAPPED SURFACES—Re-lap sealing surfaces.

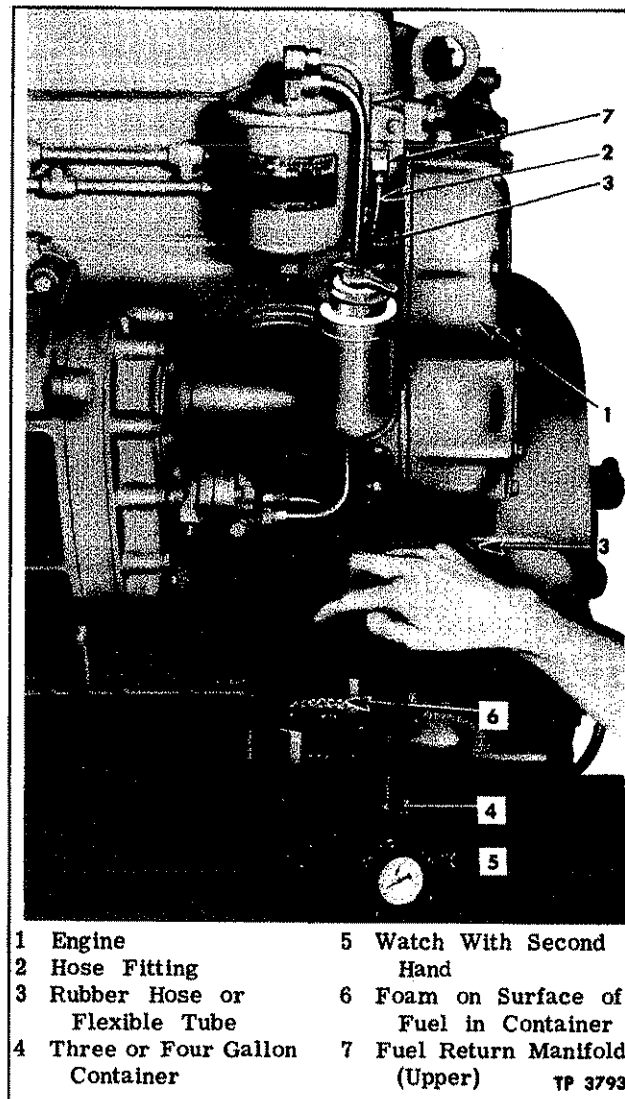
FOREIGN MATERIAL BETWEEN VALVE AND SEAT—Disassemble injector and clean.

RACK AND GEAR NOT IN TIME—Reassemble with spot on tooth between marks on rack.

FUEL OIL PUMP**FUEL OIL PUMP****Figure 24—Fuel oil Pump Assembly**

The fuel pump shown in figure 24 is positive displacement gear type.

Pump is bolted to blower rear end plate cover and is driven from lower blower rotor shaft through a U-shaped steel stamping which acts as a universal joint. Drive shaft and idler shaft are supported by pump body and cover. Cover and body are held in alignment by straight dowel pins. Drive gear and idler gear are supported by respective shafts. Drive gear is locked to shaft by a small steel ball, and driven gear is pressed onto idler shaft.

**Figure 25—Measuring Fuel and Checking Air in Fuel System**

Two oil seals are used inside the flange at end of drive shaft. Lip of both seals is toward blower and effectively prevents lubricating oil in blower compartment from creeping along pump shaft. Seals are located so that a drain hole, located between the two seals, vents to atmosphere and permits any fluid passing lip of seal to be drained away.

Fuel oil entering the pump on the suction side fills the space between gear teeth and pump body. The gear teeth then carry the fuel oil to the discharge side, where oil is forced out of the outlet

FUEL OIL PUMP

as teeth of gears come together during rotation.

Relief valve normally does not open since its purpose is to relieve excessive pump pressure in case any of fuel lines or filters become plugged and build up an extremely high pressure in pump. If valve opens, fuel passes from the discharge side (pressure side) to the suction side of pump.

TESTS

Uneven running, excessive vibration, stalling when idling, and a loss of power, may be caused by an insufficient fuel supply to injectors due to one of the following conditions:

1. Clogged primary or secondary fuel filter element.
2. Air in the system.
3. Clogged injector fuel filters.
4. Partially plugged fuel lines.
5. Defective fuel oil pump.

The various conditions may be checked by conducting either a flow test of fuel being returned from injector fuel return manifold or checking fuel pressure in the return manifold at end opposite to the fuel line leading back to fuel tank. A screw plug at that location may be removed to attach a pressure gauge. If gauge shows a reading of 10 or more pounds at 600 to 800 engine rpm, flow tests outlined below need not be run.

CLOGGED FUEL FILTER AND AIR IN SYSTEM

1. After connecting one end of rubber hose or flexible tube to fuel return (upper) manifold and immersing other end in a large container as illustrated in figure 25, start engine and run at 1200 engine rpm. Measure fuel being returned from manifold, which should be approximately one-half gallon per minute; also observe if air is being pumped through fuel system as will be indicated by air bubbles appearing as foam on fuel in container.

2. 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.

3. Stop engine and remove element from primary fuel oil filter and again run flow test as in (1). An increased flow of fuel with filter element removed indicates proportionate clogging of element. In such cases element should be cleaned.

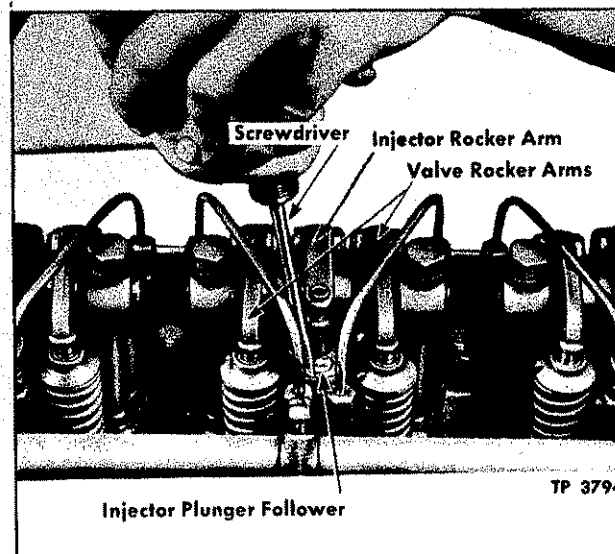


Figure 26—Cutting Out an Injector

CLOGGED INJECTOR FUEL FILTER

If engine still runs "ragged" with suitable fuel return, one or more injector filters may be faulty, in which case:

1. 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, as illustrated in figure 26, while engine is running.
2. Stop engine and remove fuel line between return manifold and injector.
3. 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.

PUMP REPLACEMENT

REMOVAL

Whenever pump fails to rotate when blower is running, the cause may be due to a broken drive fork on end of fuel pump shaft. Remove pump from blower as follows:

1. Disconnect both intake and discharge fuel lines from the pump.

2. Remove the three pump flange-to-blower end cover cap screws. Cap screw next to the cylinder block can be removed readily with special wrench or, if not available, a similar tool as illustrated in figure 27. Withdraw pump straight out from rear blower end plate cover.

3. After the pump has been removed, rotate shaft

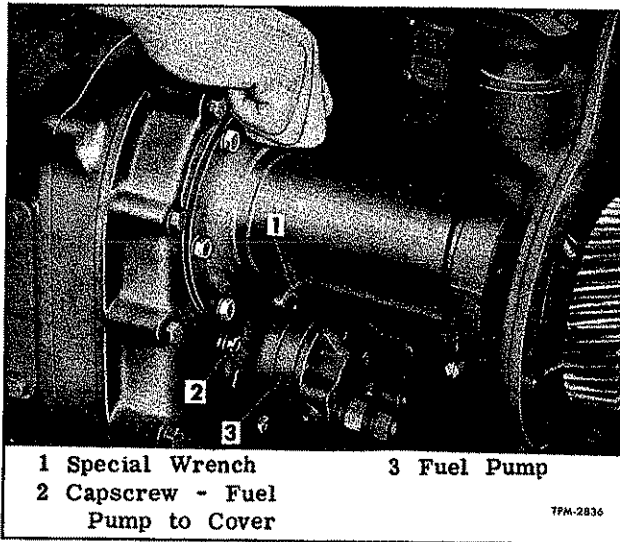
FUEL OIL PUMP

Figure 27—Fuel Pump Mounting and Use of Special Wrench

by hand to see if parts rotate freely. If pump is binding or sticking, it should be replaced.

INSTALLATION

The fuel oil pump is attached to the engine at the rear of the blower as follows:

1. Select the correct type pump for the engine on which it is to be installed. "A" and "B" model engines use a pump stamped "LH" on pump cover, while "C" and "D" model engines use a "RH" stamped pump.

2. Install pump drive coupling fork (arms out) on square outer end of pump rotor shaft and a new gasket on pump flange.

NOTE: Pump is installed with relief valve retainer screw toward cylinder block.

3. Set the pump assembly up against blower end plate cover so that lugs of coupling fork register with slots in coupling disc which is attached to end of lower blower rotor shaft. When lugs of fork are correctly engaged, pump will slide readily into place tight against the end plate cover.

4. Recheck to ascertain markings on pump cover, and relief valve as described above, are nearest the cylinder block; then attach pump securely to cover with capscrews.

5. Connect fuel inlet and outlet lines to pump.

DISASSEMBLY

Refer to figures 24 and 28, then proceed as follows:

1. Remove eight screws retaining cover to body. Tap cover lightly with soft hammer to loosen from dowels, then lift cover from body.

2. Remove idler gear and shaft from pump body. Do not remove gear from shaft unless either part is to be replaced.

NOTE: The drive shaft must not be pulled from seals in pump unless special tool is available for guiding drive shaft back into seals. If tool is not used to guide shaft through seals, end of shaft will

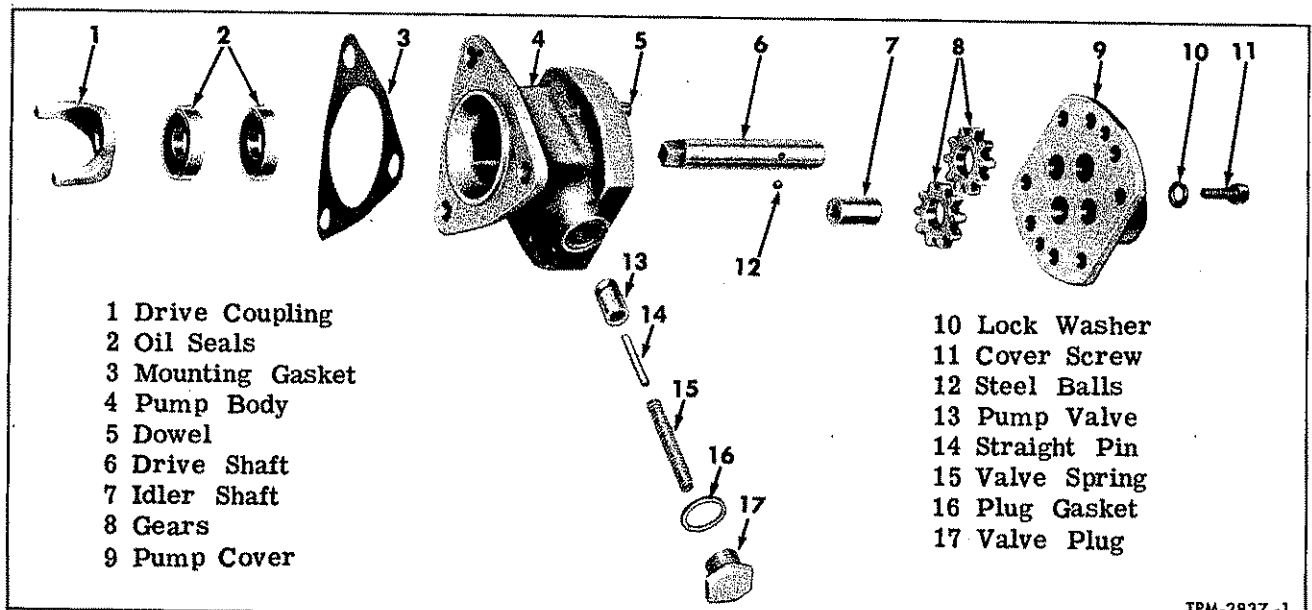


Figure 28—Fuel Oil Pump Details

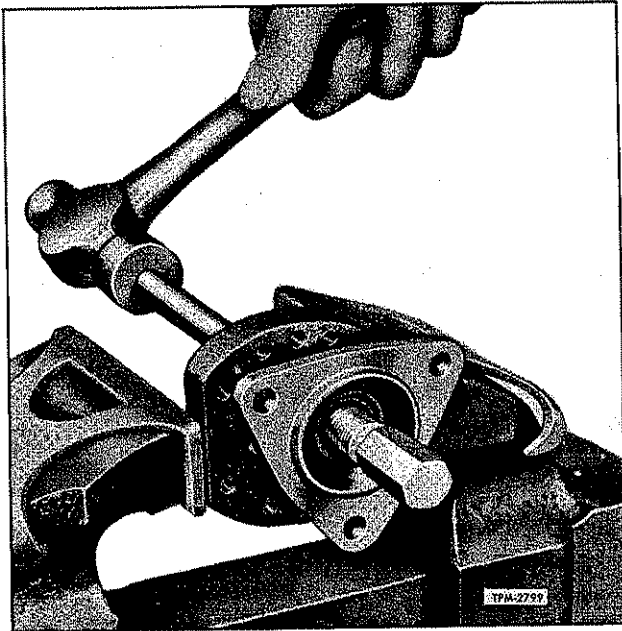
FUEL OIL PUMP

Figure 29—Removing Oil Seals from Pump Body

destroy sealing edges of seals and pump will leak excessively.

3. If oil seal pilot tool is not available, drive shaft must not be removed. Pull shaft from body only until steel ball can be removed from between gear and shaft, then remove gear from shaft.

4. Remove relief valve retaining plug and gasket. Remove relief valve, spring and pin from pump body.

5. Using seal remover tool as shown in figure 29, screw threaded end of tool shaft into outer oil seal. Tap end of tool with hammer and remove seal. Repeat this operation to remove the inner seal.

INSPECTION

1. All pump parts should be washed in fuel oil and carefully inspected before assembly. The oil seals, once pulled from the body cannot be used again. If the feather edges of the 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.

2. Carefully inspect cover and body for evidence of wear at areas contacted by gears and shafts. Replace parts showing evidence of wear.

3. Position gears on shafts and install in body to check radial clearance between gears and body.

4. Check width of gears for excessive wear.

5. Check drive shafts for wear at area connected

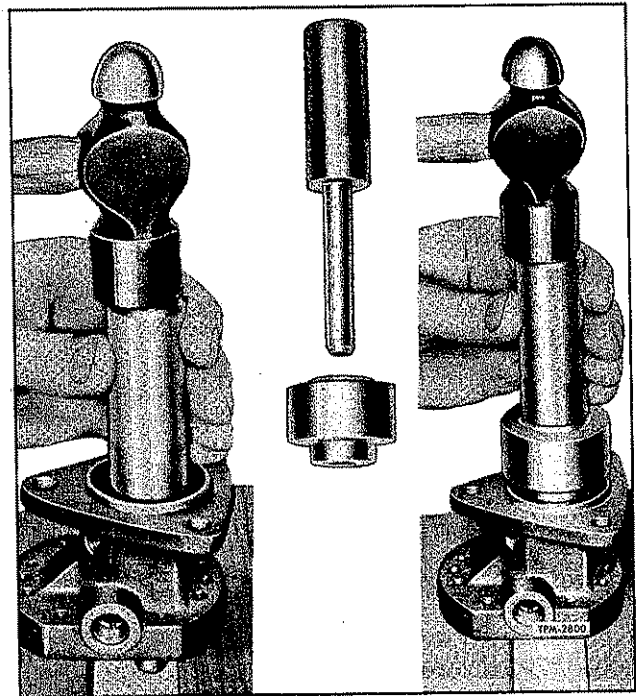


Figure 30—Installing Inner and Outer Seal in Pump Body

by oil seals. Shafts must be smooth and free of any imperfections that may impair efficiency of oil seals.

REASSEMBLY

Refer to figures 24 and 28, then proceed as follows:

1. Use installer tool and adapter and install both seals with lip of seals pointing away from pump body or toward the blower. Use of installer tool correctly positions seals $\frac{1}{16}$ " apart. (Fig. 30).

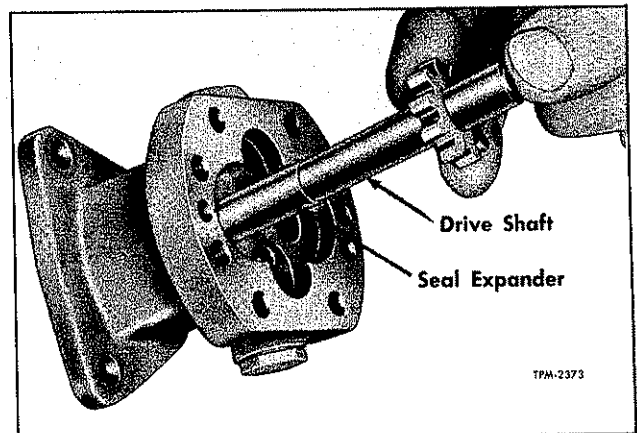


Figure 31—Inserting Fuel Pump Drive Shaft Through Oil Seals

FUEL MANIFOLDS

2. Support holding fixture in bench vise, set pump body on three pins of fixture.

3. Place oil seal pilot over square end of gear drive shaft. Lubricate pilot tool with clean engine oil and insert pilot and shaft carefully into seals. (Fig. 31).

4. Position drive gear over drive shaft with open end of ball slot toward cover. (Fig. 24).

5. Locate steel ball in indent of shaft and in alignment with slot in gear. Press shaft into place, with steel ball locking gear to shaft.

6. Press driven gear onto idler shaft until gear is in exact center of shaft. Install in pump body.

7. Position cover to body with inlet "IN" opening on same side as relief valve. Install lock washers and cap screws attaching cover to body. Tighten screws finger tight, then tighten alternately and evenly.

8. Install valve, spring and straight pin into pump body then install gasket and retaining plug (Fig. 24). Tighten plug.

FUEL MANIFOLDS

Two types of manifolds have been used, some are external type as illustrated in figure 32; others are internal type which are simply drilled passages in cylinder head.

Fuel injectors are supplied with fuel oil by the pump through fuel manifolds located on side of cylinder head and connected to injectors by short steel lines, as shown in figure 32.

INTERNAL TYPE

Since internal fuel manifolds are drilled passages in the cylinder head no maintenance is required. Access to drilled passage is gained through several plug open-

ings. Upper passage serves as fuel inlet and lower is outlet. Connectors (fig. 34) must be tight and new gasket should be used whenever installing a connector.

EXTERNAL TYPE

Upper manifold returns excess fuel from injectors through tubing to fuel tank. Both manifolds are locked in position at side of cylinder head by fuel connectors which set into tapered seats in manifold fittings.

Since manifolds are positioned and locked with tapered-seat fuel connectors, care must be exercised

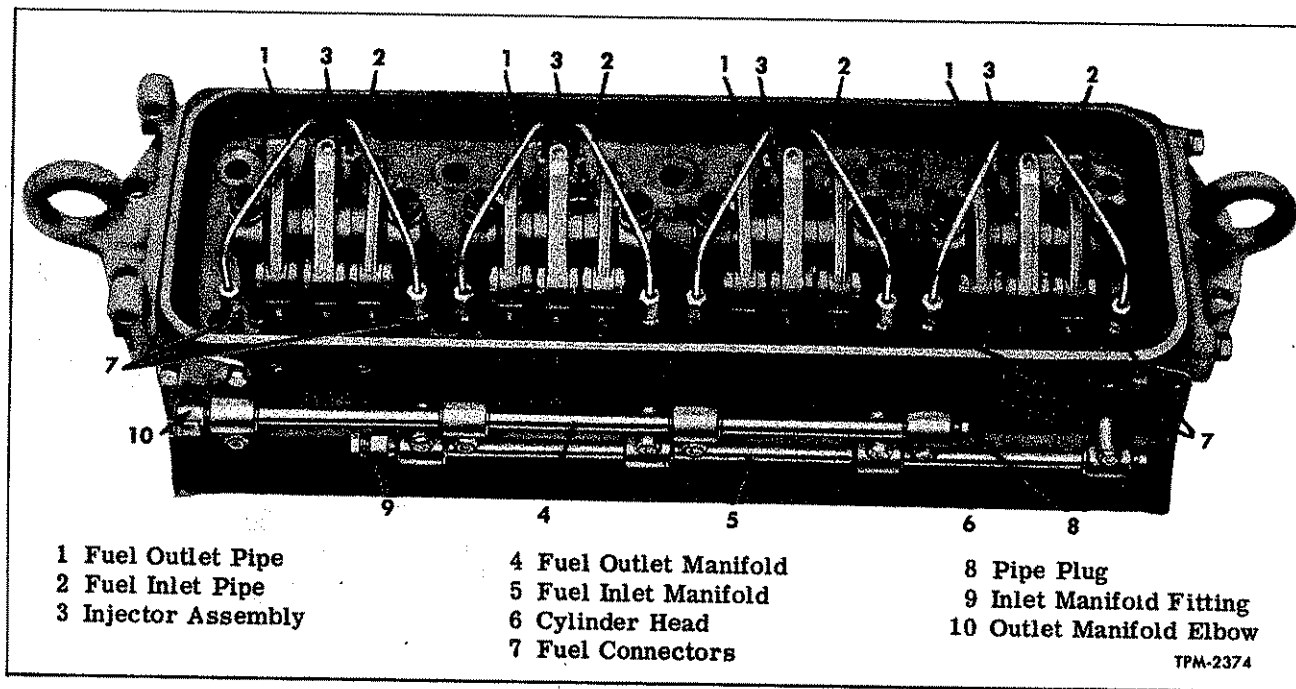
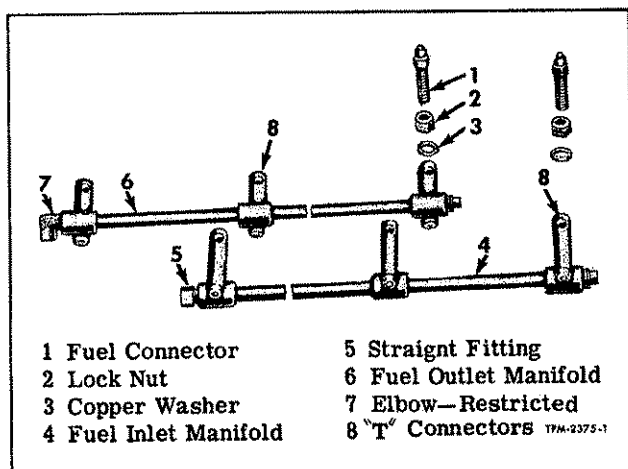


Figure 32—External Fuel Manifolds and Jumper Lines at Cylinder Head

FUEL MANIFOLDS**Figure 33—External Fuel Manifold Details**

when a connector is removed, to see that tapered seats are perfectly clean and properly positioned in manifold fittings.

REMOVAL

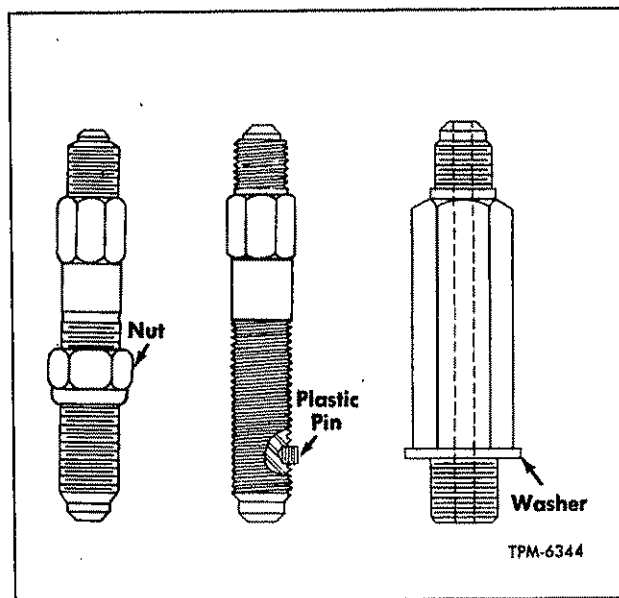
When occasion requires, either fuel oil manifold may be removed. However, before removing, refer to figures 32 and 33 for assembly and relative location of parts; then proceed as follows:

1. Remove valve rocker cover.
2. Disconnect fuel inlet and outlet pipes (jumper lines) between injectors and fuel connectors.
3. Install shipping caps at two injector filter caps to prevent entry of dirt.
4. Disconnect inlet and outlet fuel lines from inlet and outlet manifolds.
5. Loosen lock nuts (if used) on connectors, a few turns.
6. Unthread connectors from head and (if used) discard copper washer.
7. Remove manifold, being careful that tee connectors do not bind in head.

INSTALLATION

Refer to figure 33, and note that the "T" connectors on the manifolds leading into cylinder head are on top side of lower (inlet) manifold and on bottom side of upper (outlet) manifold. These manifolds are not interchangeable, due to location of tapered hole.

NOTE: Several types of fuel connector arrangements may be used. One type uses a lock nut and

**Figure 34—Types of Fuel Connectors**

copper washer to prevent fuel oil leaks at connector, another type uses a plastic button at connector threads and nut is eliminated. Refer to figure 34.

1. Use compressed air to clean holes in cylinder head for fuel connectors and manifold fittings.

2. Guide manifold "T" connectors attached to fuel manifold, into openings at side of cylinder head so that tapered seat is in approximate alignment with hole in top of head for fuel connector.

3. Centralize "T" connectors with fuel connectors 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 (30-35 ft. lbs.) and secure lock nuts against new copper washer (if used).

5. Attach fuel inlet and outlet lines at fuel connectors and injectors.

6. Connect fuel lines (inlet and outlet) to respective manifolds.

IMPORTANT: 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.

7. 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 MODULATING GOVERNOR**FUEL MODULATING GOVERNOR****DESCRIPTION**

The "Fuel-Modulator" governor (fig. 35) has been developed to improve combustion and fuel economy during low-speed full-throttle operation. This "Fuel-Modulator" incorporated with the mechanical limiting speed governor automatically controls the fuel input to assure complete combustion, thus providing maximum fuel economy, clean exhaust, and longer engine life. This control is assured regardless of the throttle setting maintained by the operator.

The governor includes a low speed spring, a high speed spring, a set of low speed weights, and a set of high speed weights, similar to those included in limiting speed mechanical governor.

In addition, the governor incorporating the "Fuel Modulator" includes a fuel modulator spring (55), which provides governor control for the purpose of gradually reducing the fuel input in the fuel modulating range. Over this speed the forces of the low speed and modulator springs react against the force of the high speed weights.

As the engine speed decreases below top modulator range, the gradual reduction in high speed weight force permits the force of the low speed (59) and modulating spring (55) to open the fuel modulator gap in the governor by moving the low speed spring cap (61) back away from the high speed spring plunger (39). The movement of the low speed spring cap moves the operating lever (31) --- and the operating lever carries the differential lever (35) toward the engine, causing the differential lever to rotate around the pin which connects it to the operating lever. The rotation of the differential lever is restricted by the engagement of the roller (34), on the bottom of the lever, with the fuel modulator cam (47). The cam causes the differential lever to rotate in a direction which pulls the governor link back into the governor and thus pulls the injector racks out from the full fuel position.

During this time the differential lever torsion spring (36) opposes the above rotation with a light tension and maintains the roller (34) in its proper position against the fuel modulator cam (47). It is this differential lever torsion spring which allows the "Fuel-Modulator" to operate regardless of the throttle position maintained by the operator.

The fuel modulator spring tension is set so that

injector racks start to leave the "full in" position as engine speed is reduced. Engine speed at which this occurs is controlled by the rate and tension of modulating spring used. Fuel modulating action begins at approximately 200 rpm below the fuel modulating gap closing speed with 80 cu. mm. injectors, and approximately 300 rpm below fuel modulating gap closing speed with 70 cu. mm. and 60 cu. mm. injectors. Delay in modulating action with 70 cu. mm. and 60 cu. mm. injectors is due to helix design on injector plunger, which does not reduce the fuel input until after .075" rack movement.

The following chart specifies proper fuel modulating and high speed spring combination to be used with each size injector at desired full load engine rpm.

Engine RPM, Injector, and Spring Combinations

RPM*		Injector	Fuel Modulating Spring	High Speed Spring
Max.	Min.			
2300	2075	70	225# (W)	55# (Y)
2300	2075	80	225# (W)	55# (Y)
2300	1975	70	175# (G)	55# (Y)
2300	1865	70	150# (B)	55# (Y)
2000	1650	60	70# (Y)	50# (R)

*RPM given is full load--to obtain no-load (floor setting) speed, add 125 RPM.

When engine is equipped with rubber damper full load speed must not exceed 2000 RPM. When full load speed in excess of 2000 RPM is desired engine must be equipped with fluid (viscous) damper.

Color Stripe--(W) white, (G) Green, (B) Brown, (Y) Yellow, (R) Red, (A) Aluminum.

DISASSEMBLY

Governor can be completely or partially disassembled by accomplishing one or more of the following sub-assembly disassembly procedures.

Refer to figure 35 for all nomenclature references in following text.

CONTROL HOUSING COVER

1. Disconnect external control linkage connected to governor control levers. Remove four cap screws and lockwashers, then lift cover (7) and lever assembly from control housing.

2. Remove pin clip and flat washer, then loosen

FUEL MODULATING GOVERNOR

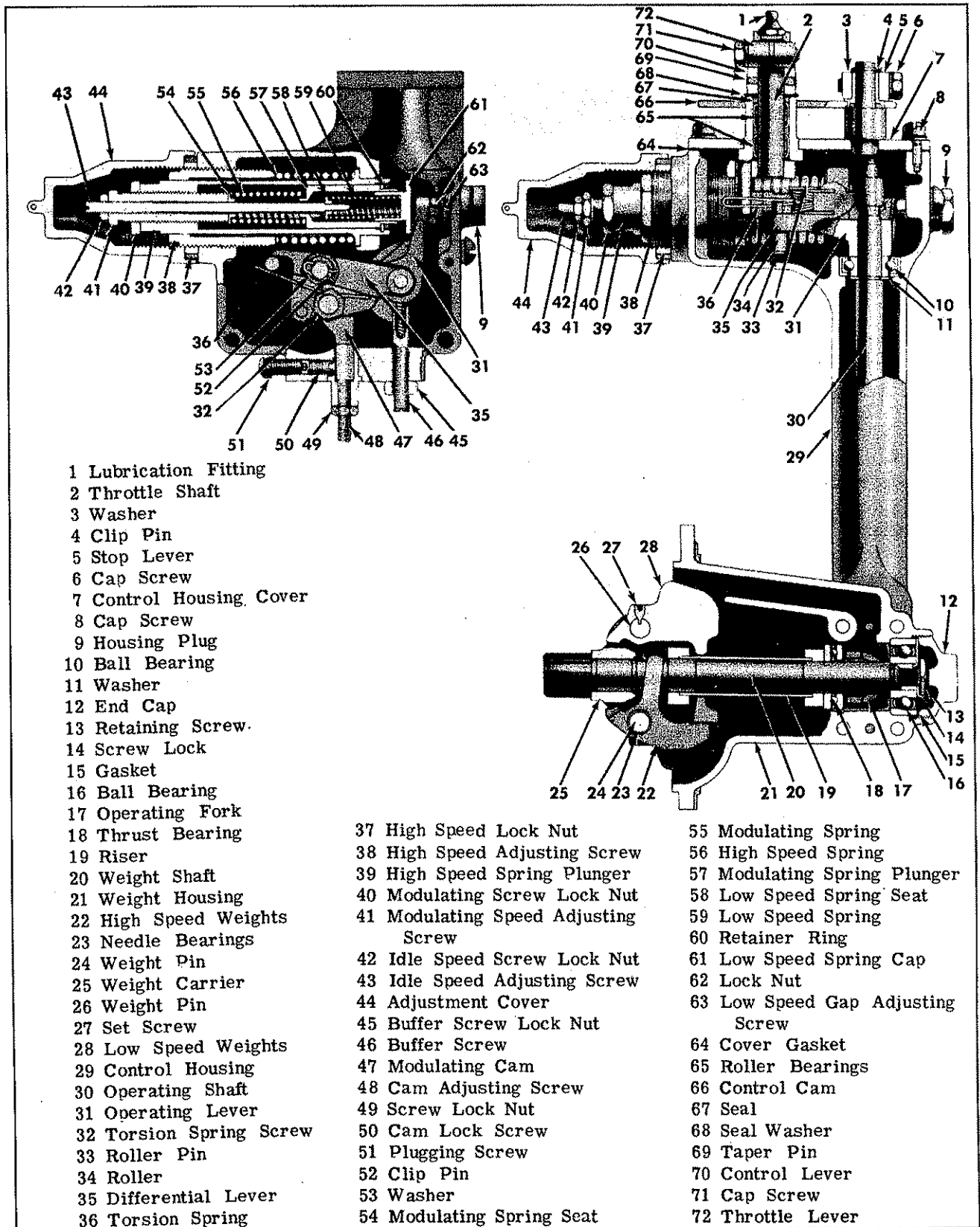


Figure 35—Fuel Modulating Governor Assembly

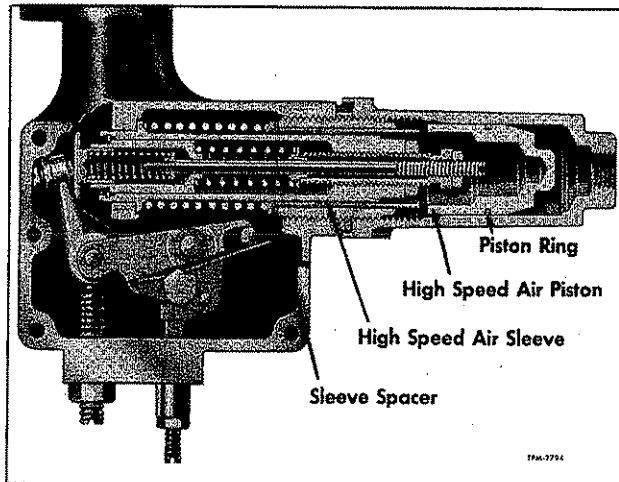
FUEL MODULATING GOVERNOR

Figure 36—Governor High Speed Air Piston, Ring, Sleeve, and Spacer (PD-4501)

clamp bolt and lift stop lever (5) and cam (66) from cover stud.

3. Remove lubrication fitting from throttle shaft. Loosen clamp bolt and lift throttle lever (72) from shaft.

4. Use small punch and hammer, to remove taper pin (69) from throttle control lever (70) and throttle shaft.

5. Pull throttle shaft assembly (2) down through bottom of cover. Lift washer (68) and seal (67)

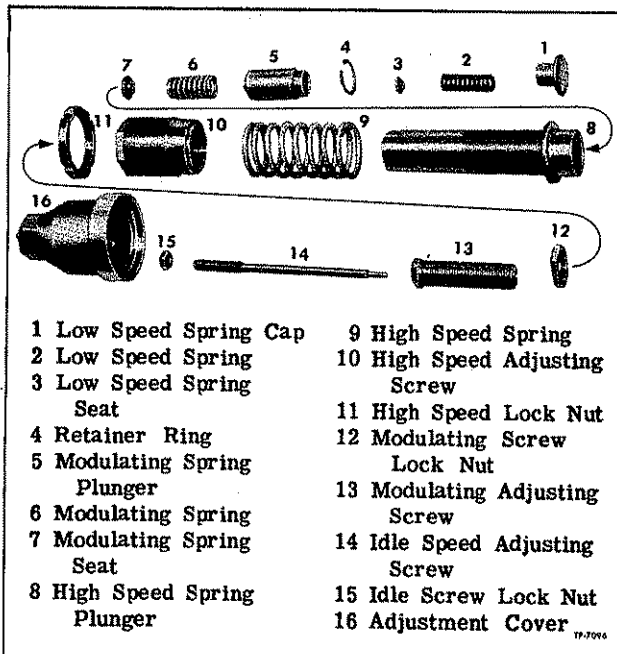


Figure 37—Governor Springs, Plungers, and Adjusting Screws (Standard)

from cover.

6. Wash cover and bearing assembly in fuel oil and inspect bearings for damage or wear. If bearings are satisfactory for further use, removal is unnecessary.

7. If bearing removal is necessary, support cover in soft jaws of bench vise or support on a work bench. Then, use a small punch and hammer to drive lower bearing down and upper bearing up until removed from cover.

SPRINGS, PLUNGERS AND ADJUSTING SCREWS

Springs, plungers and adjusting screws (Fig. 37) can be removed from control housing as an assembly with governor either installed or removed; however, it is necessary that control housing cover (7) and levers assembly be removed.

1. Remove adjustment cover (44). Loosen high speed adjusting screw lock nut (37) using spanner wrench. Use end wrench to thread high speed adjusting nut (38) out of control housing. When adjusting nut is free of housing entire assembly of springs and plungers can be removed and placed on bench for further disassembly.

NOTE: On Coach Model PD-4501 a high speed air piston, ring, sleeve, and spacer are also incorporated (fig. 36) which functions to reduce engine rpm when operating in third overdrive.

2. Remove low speed spring cap (61), low speed spring (59), and low speed spring seat (58).

3. Loosen idle speed adjusting screw lock nut (42), also modulating speed spring adjusting screw lock nut (40).

4. Remove idle speed adjusting screw (43), also modulating spring adjusting screw (41).

5. Use sharp-nose pliers and remove modulating spring plunger retainer ring (60) from high speed spring plunger.

6. Remove modulating spring plunger (57), modulating spring (55) and modulating spring seat (54) from inside high speed spring plunger.

CONTROL HOUSING

With control housing removed from weight carrier housing and with springs, plungers, and adjusting screws removed, the housing may be further disassembled as follows:

1. Remove pin clip (52) and washer, then lift

FUEL MODULATING GOVERNOR

differential lever (35) assembly from operating lever (31).

2. Remove special screw (32) retaining torsion spring (36) to differential lever, then remove spring from screw.

3. Remove lock screw, lock washer and plain washer holding upper bearing (10) in control housing.

4. Remove expansion plug at lower end of control housing, using sharp punch and hammer.

5. Remove set screw attaching operating fork (17) to operating shaft (30).

6. Invert housing and drive operating shaft, operating lever and bearing from control housing, using long drift pin and hammer at lower end of shaft.

7. Remove operating fork (17) through opening at lower end of control housing.

8. If inspection indicates necessity, use long drift pin and hammer to drive lower bearing down and out of control housing.

9. If inspection indicates that upper ball bearing and operating lever requires replacement, the operating lever can be removed by pressing shaft from lever and tapping ball bearing from shaft.

WEIGHT AND HOUSING

Before removing any part from weight housing assembly, the unit should be thoroughly washed in cleaning solvent, dried with compressed air, and then inspected for worn, damaged, or binding parts. If all parts are in good working order, disassembly will be unnecessary. If bearings only need replacing, then removal of weights from carrier will not be necessary. Complete disassembly is as follows:

1. Support the governor weight housing in a vise and remove bearing end cap (12). A hex wrench head on the cap makes removal a simple operation. A gasket between bearing outer race and plug prevents oil seeping through the threads.

2. Straighten lip on lock and remove retaining screw (13) from outer end of weight carrier shaft (20).

3. Using a $\frac{5}{16}$ "-24 bolt, thread bolt into tapped hole at end of weight carrier shaft, then remove shaft from bearing by tapping on bolt head. Use a bolt of sufficient length, so bolt head will not interfere with bearing inner race before the shaft leaves the bearing.

4. Remove the thrust ball bearing (18) and riser (19) from the weight carrier shaft.

5. Mark weights and carrier with center punch for identification, also note position of thin washers between weights, so parts can be replaced in their

original locations; then remove Allen set screws, weight pivot pins and weights from carrier. The governor weight carrier is only serviced with the shaft and should not be removed.

6. Press ball bearing from housing. Usually only slight pressure is required to remove bearing.

CLEANING AND INSPECTION**CLEANING**

Immerse all governor parts in suitable cleaning fluid to loosen and remove all accumulations of foreign material. Use bristle brush and compressed air as necessary to assure absolute cleanliness of all parts.

INSPECTION

The function of the governor is to control the fuel injection by means of linkage within the governor and inter-connecting linkage between governor and injector. It is extremely important that all moving parts be absolutely free and that no binding exists under any condition of operation.

Inspect all bearings to be sure that they are absolutely free of corroded or pitted surfaces and that they are otherwise satisfactory for further use.

Inspect spring seats, plungers, adjusting screws, lock nuts, and other parts of control housing for defects that might effect governor operation.

Inspect governor weights, weight pins, shaft and carrier for excessive wear or other damage. Weights should be assembled and checked for free movement.

ASSEMBLY

Key numbers in text refer to figure 35.

WEIGHT AND HOUSING

1. Using wood block, tap annular ball bearing (16) into outer end of weight housing.

2. Observe marks previously placed on governor weights and carrier, also noting position of washers between weights, attach weights (22 and 28) to weight carrier (25) with pins (24 and 26) and lock each pin with the Allen set screw (27). Stake Allen screws at two places after replacing.

3. Support serrated end of shaft (20) vertically in vise between copper jaws and slip riser (19), then thrust bearing (18) onto upper end of shaft. Drop carrier housing (21) over shaft, then using block of wood on inner race of ball bearing, drive

FUEL MODULATING GOVERNOR

shaft through bearing tight against shoulder on shaft.

4. Thread lock screw (13) through lock (14) and into end of weight shaft (20). Tighten screw and bend tang of lock over flat of screw head. Install new gasket (15) and install end cap (12).

CONTROL HOUSING

1. If operating lever (31), bearing (10) and washer (11) were removed from operating shaft install washer over shaft and against shoulder. Tap or press bearing onto shaft then press operating lever onto shaft, until lever is against bearing inner race.

2. If lower bearing has been removed, tap new bearing into housing until seated against shoulder in housing. Install expansion plug at lower end of housing.

3. Lubricate ball bearing also needle bearings. Insert operating shaft assembly (30) into housing until lower end is through lower bearing. Install operating fork (17) to operating shaft (30) so that machined surfaces of fork will bear against thrust bearing washer (18).

4. Push fork (17) onto shaft until seated against shoulder on shaft. Install set screw retaining fork to shaft and tighten with Allen wrench. Stake walls of fork against set screw, using pointed anvil and punch.

5. When installation of shaft assembly is complete, hold operating lever (31) and force operating fork (17) in direction of normal load in order to properly seat lever and fork on the shaft. A torque of 250-300-inch pounds should be applied.

6. Install flatwasher, lockwasher and screw retaining shaft ball bearing (10) in housing. Tighten screw securely.

7. Install torsion spring (36) to differential lever (35) using special screw. Tighten screw (32) securely.

8. Install differential lever assembly (35) to operating lever (31) and secure with flat washer (53) and pin clip (52). Check differential lever for free movement on operating lever.

SPRINGS, PLUNGERS AND ADJUSTING SCREWS (Figs. 35 and 37)

1. Thread idle speed adjusting screw (43) into modulating spring adjusting screw (41), then thread these two pieces into high speed spring plunger (39).

2. Install modulating spring seat (54), modu-

lating spring (55), and modulating spring plunger (57), into high speed spring plunger (39). Seat shoulder must be toward spring.

3. With modulating spring seat, spring, and plunger installed in high speed spring plunger, install retainer ring (60) in groove—near end of high speed spring plunger (39). Be sure ring is fully seated in groove.

4. Install low speed spring seat (58), low speed spring (59), and low speed spring cap (61) into high speed spring plunger (39). Seat shoulder must be toward spring.

5. Slide high speed spring (56) and high speed adjusting screw (38) over high speed spring plunger (39).

NOTE: On governor having air piston and associated parts (Fig. 36), install high speed sleeve and spacer after high speed spring is installed, then install high speed adjusting screw over high speed sleeve.

6. Hold assembly while being positioned in control housing with high speed spring plunger against support in housing. Thread high speed spring adjusting screw into housing sufficiently to retain assembly.

7. Thread high speed adjusting screw (38) into housing until end of screw is approximately $\frac{3}{4}$ " from spanner lock nut (37). Thread modulating spring adjusting screw (41) in until end of screw is approximately $1\frac{1}{2}$ " from spanner lock nut.

CONTROL HOUSING COVER

1. If throttle shaft bearings were removed from cover, start bearings straight in the cover by hand, then use a block of wood on end of bearing while being pressed into place. Install opposite bearing in same manner.

NOTE: Lower bearing is pressed flush with cover hub. Upper bearing is pressed $\frac{1}{8}$ " below cover hub.

2. Lubricate roller bearings with grease, then slide throttle shaft (2) through bearings from the bottom of cover.

3. Install seal (67) over throttle shaft and into cover counterbore at top of upper bearing, then install flat washer (68) over shaft as a seal retainer.

4. Lubricate shaft and install cam (66) over shaft with cam boss away from cover. Install stop lever (5) over cam boss and tighten only sufficiently to hold lever. Install washer (3) and clip pin (4).

5. Install control lever (70) over throttle shaft with lever pin inside cam. Install taper pin (69) attaching lever to shaft and seat pin securely.

FUEL MODULATING GOVERNOR

6. Install throttle lever (72) to throttle shaft and tighten clamp screw only sufficiently to hold lever to shaft.

7. Install gasket to housing (64). Install cover assembly to control housing, being sure that throttle shaft fulcrum pin is between differential lever fork (35) and torsion spring (36). Install and tighten four cap screws and lockwashers attaching cover to housing.

INSTALLATION

Difficulties encountered in installing governor will be minimized if control housing is separated from weight housing.

1. Position gasket to governor weight housing flange, then locate housing assembly against blower end plate with governor weight shaft splines meshing with splines in hollow blower shaft. Install attaching bolts finger tight.

2. Position the control housing assembly to weight housing assembly using a new gasket between these parts.

NOTE: Be sure that operating fork is assembled with machined faces bearing on outer thrust washer and not between the washer and balls.

3. Install weight housing cover and gasket and secure control housing to weight housing, using cover cap screws and lockwashers.

4. Using a new gasket, attach control housing to cylinder head with cap screws and lockwashers.

5. Tighten bolts, previously installed finger tight, securing weight housing to blower.

6. Perform complete governor adjustment as instructed under "Governor Adjustments" following in this section of this manual.

GOVERNOR ADJUSTMENTS

Governor adjustments should not be performed until the following engine tune-up procedures have been accomplished.

1. Start engine and operate at part throttle until engine is thoroughly warmed up and water temperature is at least 160°F.

2. Adjust valve lash (.009" hot—.012" cold).

3. Time injector—use timing gauge and adjust follower height in accordance with approved practice described in **ENGINE TUNE-UP** section of this manual.

Governor adjustment procedures should be performed in the following step-by-step sequence. Any deviation from the following order may result in an improperly adjusted governor.

Prior to adjustment the service man should read the following instructions, study the illustrations, and familiarize himself with the general design, also nomenclature and location of various parts. **REFER TO FIGURE 35 FOR ALL NOMENCLATURE REFERENCES IN FOLLOWING TEXT.**

ADJUSTMENT SEQUENCE

The following 7 basic steps in setting a fuel modulating type governor, must be performed in the order listed.

Setting No. 1. Set fuel modulating spring tension.

Setting No. 2. Set low speed spring gap.

Setting No. 3. Check fuel modulating gap closing space.

Setting No. 4. Set fuel modulating cam.

Setting No. 5. Set injector racks.

Setting No. 6. Set no load high speed.

Setting No. 7. Set idle speed.

Only settings 1, 3 and 4 are new and peculiar to the fuel modulating governor. Settings 2, 5, 6 and 7 are the same as or somewhat similar to those of the limiting speed governor; however, the following adjustment procedures should be thoroughly studied and carefully followed.

These seven basic settings are set forth in bold face type in the following pages. The adjustments required before each of these seven settings can be made are set forth prior to each setting and are listed as "Preliminary Adjustments" to step 1, 2, 3, etc.

No. 1—FUEL MODULATING SPRING TENSION SETTING**Preliminary Procedures**

A. Remove governor adjustment cover (44), control housing cover (7), housing plug (9) and copper gasket. Disconnect governor external control linkage and remove cylinder head cover.

B. Loosen idle speed screw lock nut (42) and back out idle screw (43) until low speed spring (59) exerts no pressure on low speed spring cap (61). This may be determined by moving low speed cap in and out. Use care not to back the screw out too far as it is possible to turn it completely out of the low speed spring seat (58).

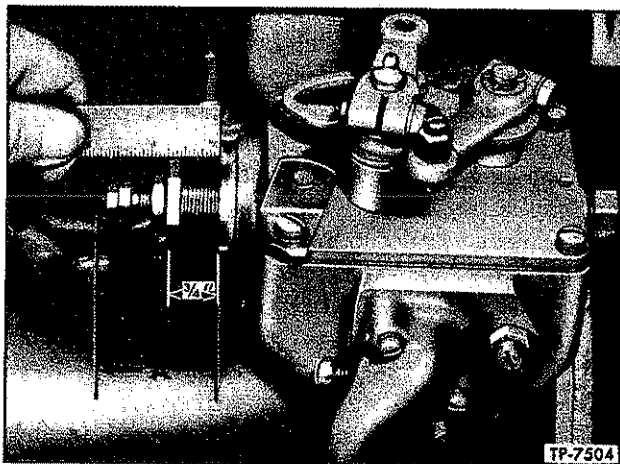
FUEL MODULATING GOVERNOR

Figure 38—Preliminary Adjustment of Low and High Speed Springs

NOTE: If type of fuel modulating spring (55) is not known (70, 150, 175 or 225 lbs. per inch) the high speed plunger assembly should be removed from the governor, retainer ring (60) removed and the type of spring determined by color code (see chart) before proceeding with preliminary adjustment "C" below.

C. Loosen high speed lock nut (37) and turn high speed adjusting screw (38) into body until flats on end of high speed spring plunger (39) are fully exposed.

D. Loosen modulating screw lock nut (40) and turn screw (41) out by hand until modulating plunger (57) may be moved back toward the high speed plunger $\frac{1}{16}$ " before touching spring.

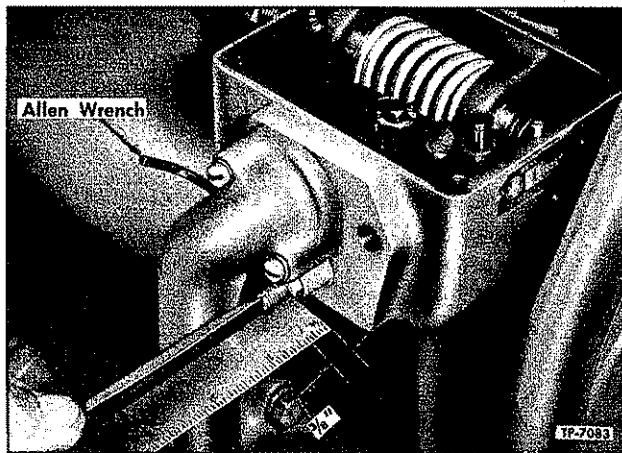


Figure 39—Preliminary Adjustment of Modulating Cam

Adjustment No. 1

Turn screw (41) in by hand until resistance indicates that spring has forced plunger forward to contact retainer ring (60). Repeat as necessary until sure that plunger is just contacting ring with no tension on spring, then turn modulating adjusting screw (41) in $\frac{1}{8}$ of a turn (one flat). Lock adjusting screw in position with locknut (40).

CAUTION: The high speed plunger (39) and the fuel modulating spring adjusting screw (41) should both be held securely in position with two wrenches when tightening fuel modulating adjusting screw locknut (40) to prevent screw and plunger relationship from being disturbed.

No. 2—LOW SPEED SPRING GAP SETTING**Preliminary Procedures**

A. Reset idle adjusting screw (43) to 2" projection ("A" Fig. 38) and replace control housing cover, attaching with two screws.

CAUTION: Be sure that throttle shaft pin is positioned between torsion spring (36) and end of differential lever (Fig. 35).

B. Start engine and make preliminary idle speed setting by setting speed at 385 RPM with low speed screw (43) and advancing speed to 400 RPM by turning in buffer screw (46). Tighten low speed locknut (42).

C. Stop engine.

D. Remove governor control housing cover (7) and lever assembly. Remove cover gasket. Disconnect link rod between differential lever and injector control tube lever, then remove link thru governor.

E. Thread buffer screw (46) outward 4 or 5 turns.

F. Loosen cam adjusting screw locknut (49). Remove plugging screw (51), and use Allen wrench to loosen cam lock screw (50) approximately $\frac{1}{8}$ turn, to permit cam to be moved in and out without allowing it to turn in housing.

G. Thread cam adjusting screw (48) into housing until screw extends $\frac{3}{8}$ " beyond locknut when nut is against sleeve (Fig. 39). Tighten cam lock screw with Allen wrench to hold cam in position until adjusted later.

H. Start engine and operate between 600 and 700 RPM using tachometer.

FUEL MODULATING GOVERNOR

NOTE: Governor to control tube link is removed and engine speed must be controlled by hand or temporary adjustable link and spring at control lever tube. (Figs. 40 and 41.)

Adjustment No. 2

Check gap between low speed spring cap (61) and modulating spring plunger (57) with .0015 feeler gauge (fig. 42), or by using oil bead method.

If gap is not within .001"-.002" at 600-700 RPM, loosen locknut (62) and turn low speed gap adjusting screw (63) as necessary to obtain proper gap. Tighten lock nut (62) and recheck gap.

No. 3—CHECKING FUEL MODULATING GAP CLOSING

Preliminary Procedures

A. If adjustable link has been used it should be removed (Figs. 40 and 41).

B. Install control link between differential lever and injector control tube lever. Link is secured at governor end with flat washer and hair pin clip. Straight pin and cotter pins are used at control tube. Link must be free with no binding.

C. Start engine and control speed manually by exerting force against torsion spring (36) with finger.

CAUTION: Care should be exercised to avoid over-speeding engine.

Adjustment No. 3

Advance engine speed gradually until low speed spring cap (61) contacts high speed plunger (39). Do not exceed 2100 RPM. Gap closing speed should be checked by a .0015" feeler between mating surfaces of (61) and (39), or by oil bead method and will vary according to following table:

F. M. Spring	Closing Speed Range
225 #/inch-WHITE	1950-2040
175 #/inch-GREEN	1850-1940
150 #/inch-BROWN	1750-1840
70 #/inch-YELLOW	1525-1625

If closing speed does not fall in correct range then recheck setting No. 1—or preliminary "B" to setting No. 2—or check for correct fuel modulating spring. (See chart.)

If, after rechecking adjustments as indicated above, closing speed still does not fall within specified range, modulating spring should be replaced.

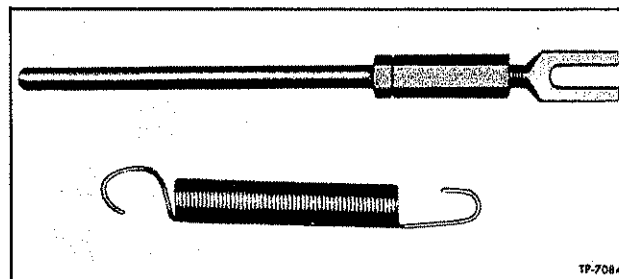


Figure 40—Adjustable Injector Rack Control Link and Spring

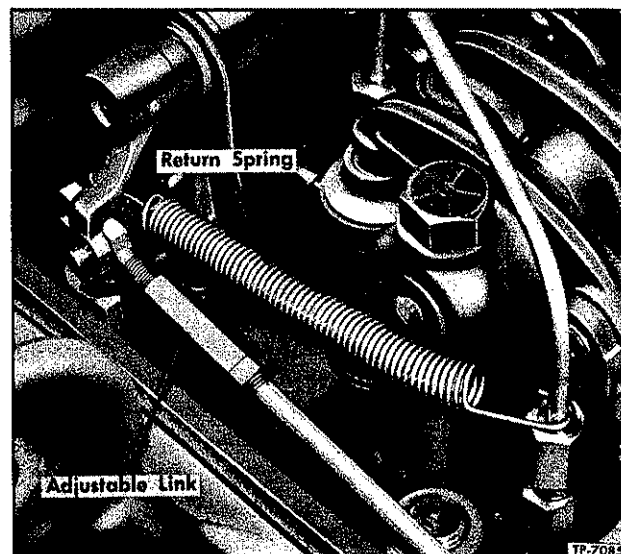


Figure 41—Injector Rack Adjustable Link and Spring Installed

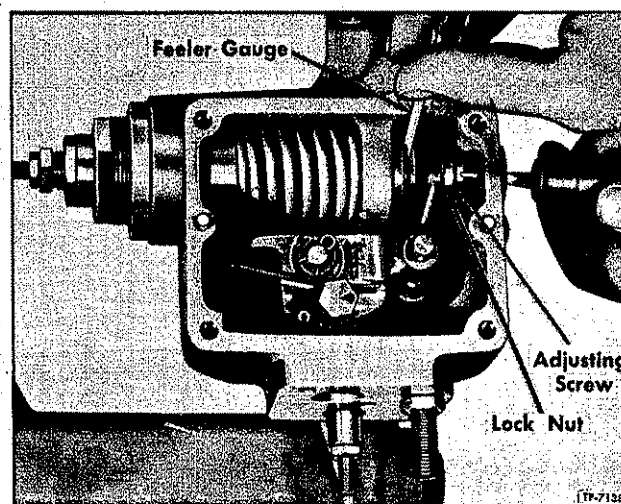


Figure 42—Low Speed Spring Gap Adjustment

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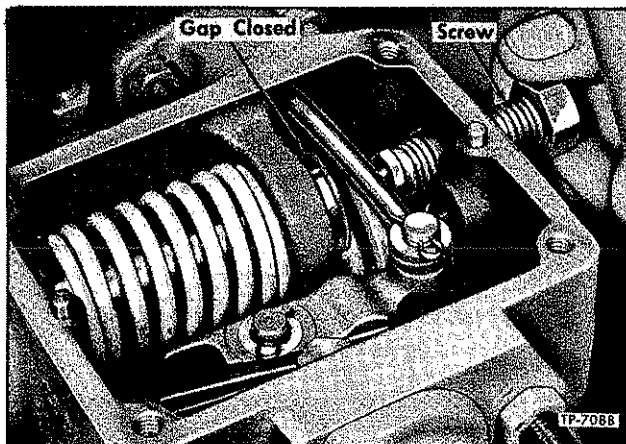


Figure 43—Closing Modulator Gap With Special Screw

No. 4—FUEL MODULATING CAM SETTING

Preliminary Procedures

- A. Stop engine.
- B. Set high speed adjusting screw (38) to extend $\frac{3}{8}$ " beyond high speed screw locknut (37) when nut is tight against housing (29) (Fig. 38).
- C. Temporarily install cap screw ($\frac{1}{2}$ -13 x 2") into front of control housing and thread screw inward until gap between low speed cap (61) and high speed spring plunger (39) just closes (Fig. 43) being careful that high speed spring plunger is not moved.

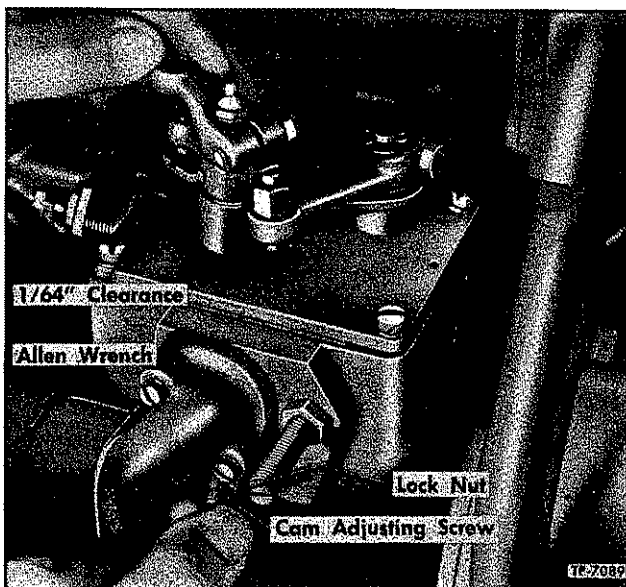


Figure 44—Modulating Cam Adjustment

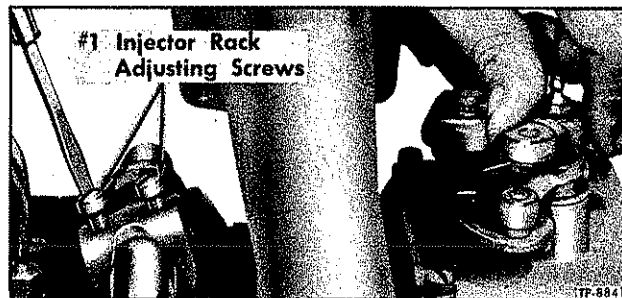


Figure 45—Adjusting No. 1 Rack to Governor

D. Loosen inner and outer adjusting screws at each control rack lever until each lever is free on control tube.

E. Install cover to governor control housing gasket (64). Install control housing cover assembly (7), being sure that throttle shaft pin is between differential lever (35) and torsion spring (36). Secure cover with four screws and lockwasher.

Adjustment No. 4

Use Allen wrench and loosen cam lock screw (50) only sufficiently ($\frac{1}{8}$ turn) to permit turning cam adjusting screw (48) with fingers. If lock screw is backed out further, cam may be released and turned by its own weight out of the operating position.

With control lever in full throttle position (Fig. 44), thread cam adjusting screw (48) outward with finger tips until cam (47) can be felt bottoming against roller (34) on the bottom of the differential lever (35). Thread cam adjusting screw outward an additional $\frac{1}{8}$ turn to provide positive engagement between differential lever roller and cam. After making contact it may be necessary to turn the screw very slightly in or out to produce the final $\frac{1}{64}$ " clearance illustrated in figure 44 which is required after the Allen screw has been tightened. Tighten lock nut (49); also install plugging screw (51).

CAUTION: The adjustment of the modulating cam is extremely important and must be carefully and accurately performed.

No. 5—INJECTOR RACK SETTING

Preliminary Procedure

A. Manually hold control lever in full throttle position (fig. 45).

Adjustment No. 5

Adjust No. 1 injector rack lever (fig. 45) so that

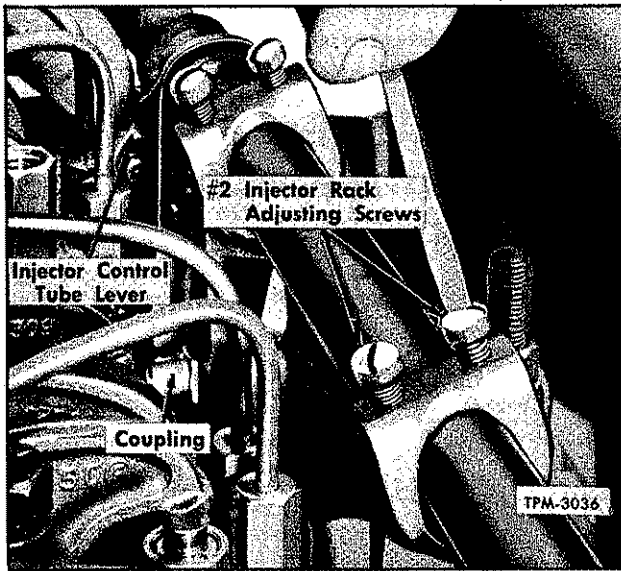
FUEL MODULATING GOVERNOR

Figure 46—Adjusting No. 2 Rack to No. 1 Rack

very light finger tip pressure at coupling will produce a tendency to roll, but coupling should not be loose.

CAUTION: Do not set No. 1 or any other rack too tight as this will produce clearance between the cam and differential roller and will result in delay and reduction of the fuel modulating action.

Hold injector control tube lever for "feel," while adjusting remaining control rack couplings (fig. 46). Adjust No. 2 rack control lever so that it has the same "feel" as No. 1 coupling. Repeat this procedure on all remaining racks. That is, compare No. 3 rack with No. 1, etc., making certain no other injector is tighter than No. 1.

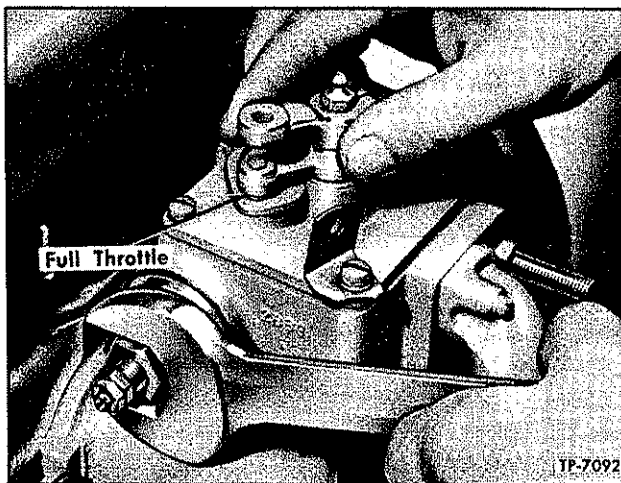


Figure 47—Adjusting High Speed

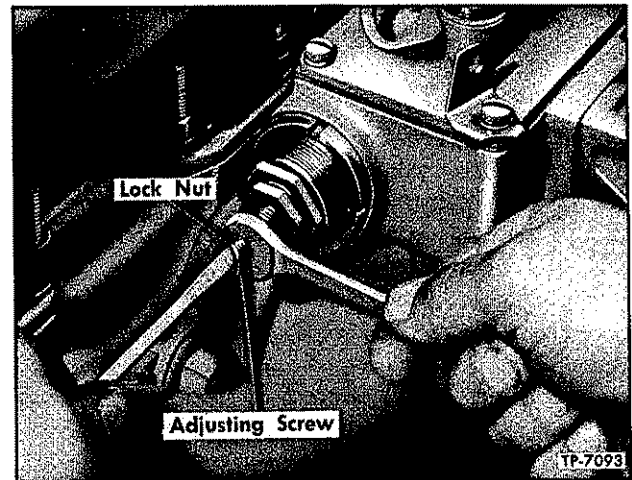


Figure 48—Adjusting Idle Speed

No. 6—NO-LOAD HIGH SPEED SETTING

Preliminary Procedures

- A. Remove temporarily installed cap screw then install control housing plug (9) with gasket.
- B. Loosen high speed adjusting screw locknut if tight.
- C. Install cylinder head cover.

Adjustment No. 6

Start engine and move throttle lever toward full fuel position while observing tachometer. Avoid overspeeding engine more than 100 RPM above desired speed.

Turn high speed adjusting screw (39) until desired (see table) speed is obtained with throttle lever in wide open position (fig. 47). Lock nut (37).

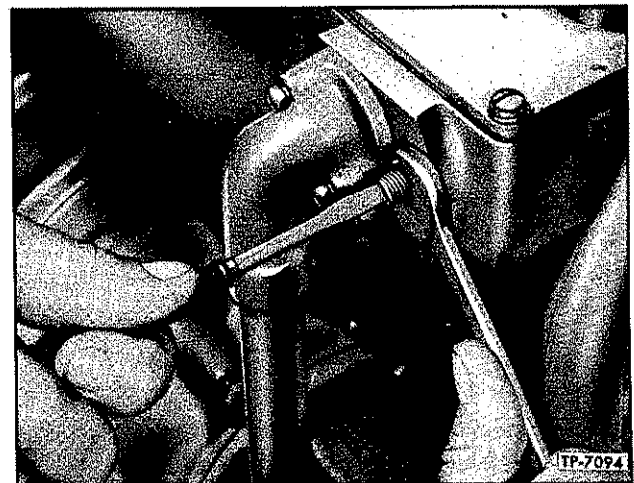


Figure 49—Adjusting Buffer Screw

LIMITING SPEED GOVERNOR**No. 7—IDLE SPEED AND BUFFER
SCREW SETTING****Adjustment No. 7**

With engine running at idle speed, observe engine RPM at tachometer, then loosen locknut (42) and thread idle adjusting screw (43) in to increase or out to decrease until 385 engine RPM is obtained (fig. 48). Tighten locknut.

With engine running at idle speed, thread buffer screw (46) in until "surge" or "roll" of engine just disappears, but not higher than 400 RPM. Variation from this speed will affect fuel modulating action.

Do not raise engine speed more than 20 RPM with the buffer screw, otherwise it may not be possible to stop the engine. Hold screw (46) and tighten locknut (fig. 49). Stop and start engine several times to be sure of its stopping.

INSTALL REMOVED PARTS

1. Install and tighten governor adjustment cover (44).
2. Connect throttle control rod to throttle control lever at governor cover.
3. Connect linkage to engine stop lever at governor cover.

LIMITING SPEED GOVERNOR**GENERAL**

Requirements on the engine continually vary, due to fluctuating loads, therefore some means must be provided to control the amount of fuel required for idling, intermediate, and full throttle operation. A no fuel position in a cam for stopping the engine is used on trucks. To accomplish this control, a governor is inserted in the linkage between the manual throttle control and the fuel injectors.

In the governor, force is transmitted from hinged, mechanical rotating weights through the governor operating mechanism to the injector control racks, which are connected to the governor by a link. Forces created by the rotating weights are counter-balanced by springs in the governor, tension of which determines engine speed.

This governor has the following characteristics:

- (a) Controls the engine idling speed.
- (b) Limits maximum engine speed.
- (c) Manual control between maximum engine speed and idling.
- (d) Permits return of injectors to no fuel position at speeds above idling range.

NOTE: All illustrations in this section show the governor for LA engine models, unless otherwise specified.

DESCRIPTION

The limiting speed governor (figs. 51, 52 and 55) incorporates two high speed and two low speed weights; each set of weights having a fixed stop for the inner and outer positions. A high and low speed spring is also employed in this governor; the former

works in conjunction with the high speed weights to limit the maximum engine speed, the latter works in conjunction with both the low and high speed weights to control the engine idling speed.

The motion produced by the travel of the governor weights, between their inner and outer positions, is transmitted to the injector racks by a system of cams and levers on which can be superimposed a manual control.

The governor, which is mounted at front of blower as shown in fig. 50, is divided into two main assemblies embodied in separate housings. These assemblies are: Governor control housing and governor weight and lower housing, and the cover.

The two sets of weights are carried on a horizontal shaft inside governor weight housing. Weight carrier shaft is mounted on an annular ball bearing at one end and opposite end is supported inside and driven by hollow blower upper rotor shaft. The blower end of governor shaft is serrated and engages with corresponding serrations inside blower shaft, which drives the governor shaft and weights.

Control mechanism transmits motion of governor weights to the injector racks. This mechanism consists of a vertical shaft mounted inside a housing, with a fork or yoke fixed at lower end, an operating lever fixed at upper end, and a high and low speed governing spring with suitable adjustments. The vertical shaft is mounted on an annular ball bearing at upper end and a bushing at lower end.

The motion of the governor weights is transmitted to the vertical shaft through a movable riser on the weight carrier shaft and the fork on the lower end of the vertical shaft. This motion is, in turn, transmitted to the injector control tube by means of the

LIMITING SPEED GOVERNOR

operating and differential levers on the upper end of the vertical shaft.

The cover assembly serves as a carrier for the throttle control lever, stop lever, control cam, and covers the top of the control housing.

The lower portion of governor is lubricated by means of a slinger attached to front end of blower lower rotor shaft. This slinger dips into a well of oil dammed up in blower housing cover and throws the oil onto all parts within governor weight housing. The upper portion of the governor, including the vertical shaft bearings and the control mechanism, is lubricated partly by splash from oil slinger on weight carrier shaft and partly by return oil through the vertical shaft housing from cylinder head.

OPERATION

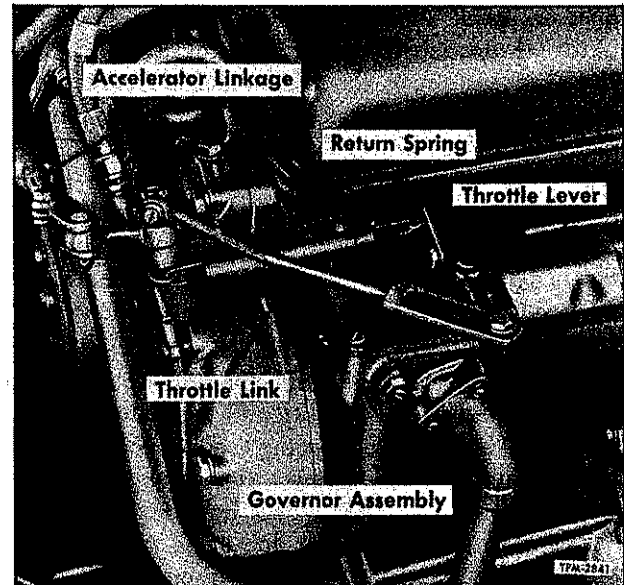
The limiting speed mechanical governor provides full fuel for starting when the throttle control lever is in the idle position. Immediately after starting, the governor moves the injector racks out to the position required for idling. Engine speed may then be manually controlled, within the governed limits, by the operator.

In the low speed range the governor weights operate against the low speed spring. The engine idle speed is determined by the engine speed required to rotate the governor weights with sufficient force to form a balance with the low speed spring. Adjustment of the low speed spring adjusting screw will change the compression of the low speed spring and thus raise or lower the engine idle speed.

An increase in engine speed will continue to rotate the weights faster and compress the low speed spring until the spring cap is tight against the spring plunger. This removes the low speed spring from operation and the governor then is in the intermediate speed range where speed control is entirely manual.

When engine speed is increased until rotation of the weights overcomes the pre-load on the high speed spring the governor will retard the injector racks and engine speed will be reduced to the maximum governed speed. Adjustment of the high speed spring retainer will change the compression of the high speed spring and, thus, will raise or lower the maximum governed speed of the engine.

The outward motion of the governor weights, is changed into linear motion by the bell crank extension on each weight and is applied to the riser. The riser transmits this force through the ball thrust bearing



**Figure 50—Limiting Speed Governor Mounting—
Transit Coach**

to a forked lever on the lower end of the vertical shaft. An operating lever is secured to the other end of the vertical shaft. One end of this operating lever bears against the high and low speed springs as described above, while the other end provides a changing fulcrum for the differential lever. The differential lever permits both manual and governor control of the injector racks. Thus, the limiting speed governor will control the idle and maximum engine speed while permitting manual control of engine speeds in the intermediate range.

MAINTENANCE ON VEHICLE

Governor faults are usually manifest in speed variations of the engine, but it does not necessarily follow that all such speed variations indicate governor faults. Therefore, when improper speed variations appear, the following procedure should be carried out.

1. Check the load to be sure that speed changes observed are not the result of load fluctuations.
2. If the load is uniform, carefully check engine to be sure that all cylinders are firing properly.
3. See that no bind exists in any of the governor mechanism or operating linkage between governor and engine; also, that no bind is manifest in injector control rack shaft or its mounting brackets.

If all cylinders are not firing properly, remove and check the injector from the faulty cylinder. The

LIMITING SPEED GOVERNOR

injector check should consist of "popping" the injector as described under "Injector Tests" in INJECTOR section of this manual. If this test shows any of the holes in spray tip to be plugged, remove and clean tip as described under "Spray Tip Cleaning." With governor control link connected to injector rack control shaft, the mechanism should be free from bind throughout entire travel of injector racks. Should friction exist in the mechanism, it may be located and eliminated as follows:

1. Injector racks may stick or move too hard. This may be due to the injector hold-down clamp being too tight or not positioned properly, and can often be eliminated by tapping the foot of the clamp lightly with a small hammer and a long punch or screwdriver. An injector which has been in service a long time may get sticky due to an accumulation of foreign material. This can be corrected by washing in a pail of clean gasoline.

2. Injector rack may stick due to being cramped by the rack control lever being out of position or cocked. Loosen screws in rack control lever, and if this relieves binding, move lever endways on control tube until rack control lever no longer cramps injector rack. Cocking of rack control lever may also be due to damage to ends of adjusting screws or surfaces which they contact, and may be corrected by filing. After trouble has been remedied, rack control lever must again be adjusted for proper position.

When injector rack control tube is free from bind, shaft should return freely to no-fuel position by tube return spring only. Whenever control tube bearing supports have been loosened, adjustment of rack control lever should be checked.

CAUTION: Never stretch or tamper with rack control spring to change tension. If spring is distorted, replace.

3. Control tube may have too much friction due to bent control tube spring. Replace with a new spring.

4. Pin in link connecting governor to control tube may be binding in control tube lever. Remove bind.

Having made all the above checks and governor still fails to control engine properly, governor may be worn or otherwise unfit for further use until unit has been completely torn down, inspected, and rebuilt or replaced.

If removal and overhaul of governor is necessary, instructions given below will simplify and shorten operations.

REMOVAL

1. Remove engine valve rocker cover.
 2. Disconnect control rods at governor throttle and stop levers on governor control housing cover.
 3. Remove screws attaching governor control housing cover to control housing then remove cover.
 4. Disconnect governor to injector control tube link from both the differential lever and control tube lever then remove link.
 5. Remove two screws which attach governor control housing to cylinder head.
 6. Remove four cap screws which attach cover and control housing to weight carrier housing and remove cover plate.
- NOTE:** Two dowels are used at junction of vertical housing and weight housing. Do not bend upper housing too far away from cylinder head without removing lower end at same time.
7. Remove cap screws which attach weight carrier housing to front end of blower and separate governor shaft from front blower shaft by pulling straight out. The rear cap screw may be easily removed by using the special wrench required for removing fuel pump inner cap screw.

DISASSEMBLY

For purposes of simplicity, the governor assembly described has been divided into subassemblies and illustrated as follows:

1. Control housing cover assembly.
2. Springs and plunger assembly.
3. Control housing assembly.
4. Weight and housing assembly.

CONTROL HOUSING COVER

With governor cover removed from control housing, proceed with following necessary operations:

1. Remove pin clip and special washer from control camshaft. Loosen clamp bolts on both operating and stop lever, then remove the two levers.
2. Using small punch and hammer, remove taper pin from pedal control lever hub then remove lever.
3. Remove control cam assembly.
4. Pull throttle shaft assembly down through bottom side of cover. Remove two plain washers and packing washer. At this stage of disassembly, wash cover and roller bearings (bearings assembled in cover) thoroughly in cleaning solvent or fuel oil and inspect bearings for wear or damage. If bearings are satisfactory for further use, removal is unnecessary.

LIMITING SPEED GOVERNOR

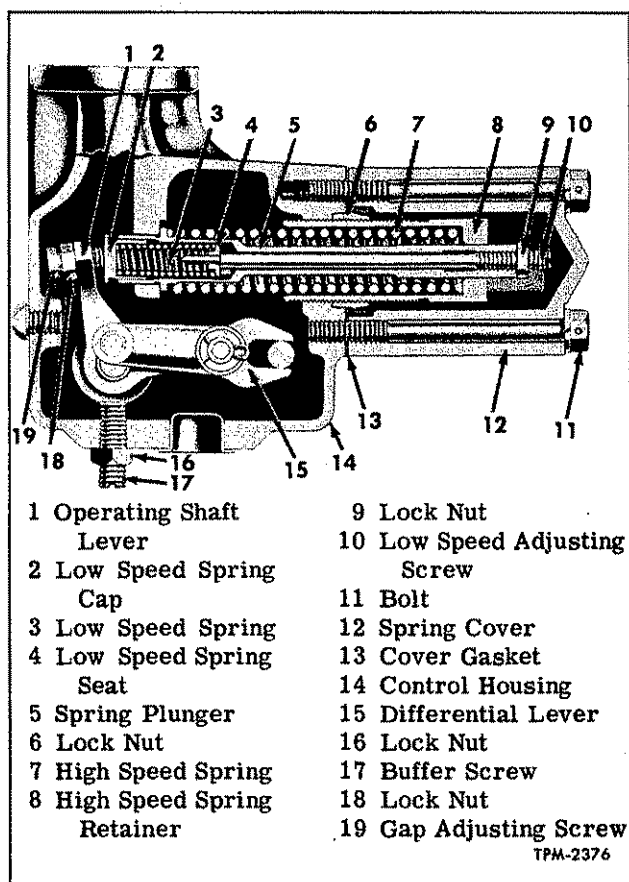


Figure 51—Governor Control Mechanism

5. If bearing removal is necessary, support cover in soft jaws of bench vise or suitably on a work bench. Then by means of a small punch and hammer, drive lower bearing down through bottom of cover and upper bearing out through top of cover.

SPRINGS AND PLUNGER

With the governor control housing detached from the weight housing, the springs and plunger can be removed from the control housing. Refer to figures 51 and 53.

1. Remove two bolts and lock washers attaching spring cover to control housing. Remove cover and gasket.

2. Loosen low speed spring adjusting screw lock nut, then loosen adjusting screw to relieve tension on low speed spring.

3. Loosen high speed spring retainer lock nut, then thread high speed spring retainer out of control housing. This will permit removal of low speed spring cap, spring, seat, adjusting screw, lock nut, and retainer. Refer to figure 53.

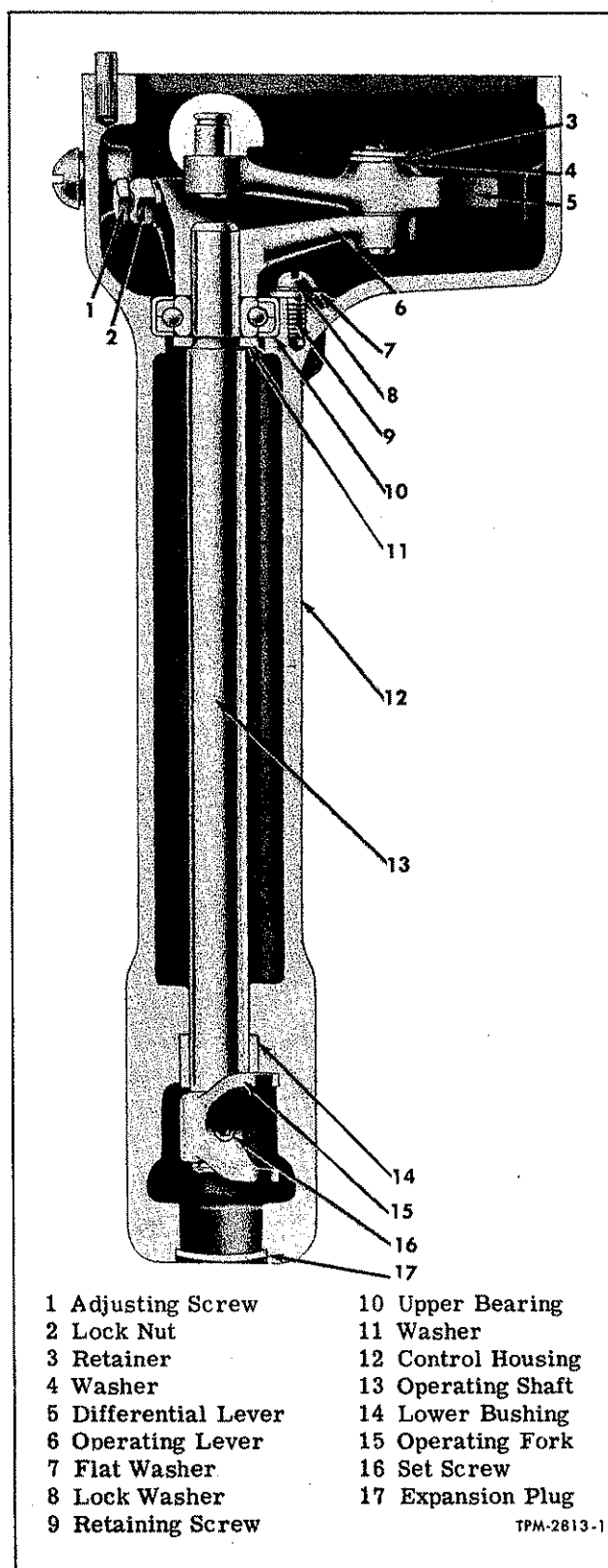


Figure 52—Governor Control Housing Assembly

LIMITING SPEED GOVERNOR

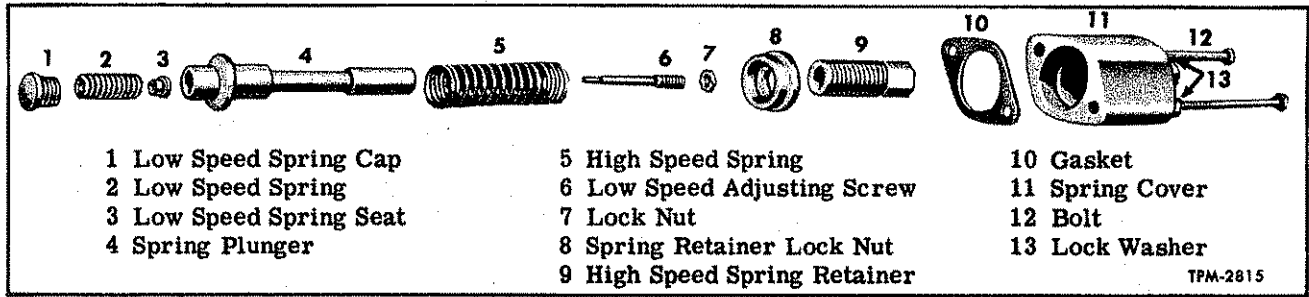


Figure 53—Relative Location of High and Low Speed Springs, Plunger and Seats

CONTROL HOUSING

With control housing removed from weight carrier housing, and spring and plunger assembly removed, the operating shaft and associated parts (fig. 52) may be removed as follows:

1. Remove pin clip, washer, and differential lever off lever pin of the operating shaft.
2. Remove screw, lock washer, and plain washer retaining ball bearing in control housing.
3. Remove operating shaft yoke set screw. Remove expansion plug at bottom of control housing.
4. Invert control housing and drive shaft from fork as shown in figure 54.
5. If control housing bushing requires replacement it can be removed by driving with a long rod

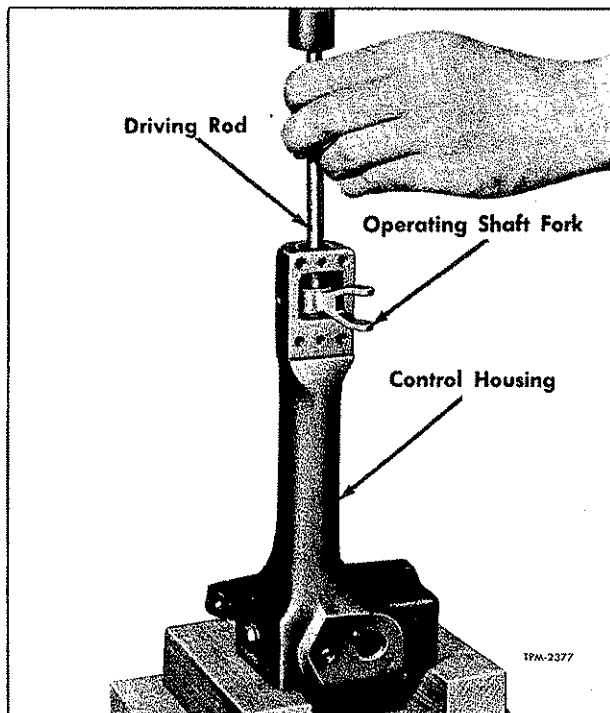


Figure 54—Removing Operating Fork from Governor Operating Shaft

and hammer.

6. Ball bearing can be removed, if necessary, by pressing shaft from lever and bearing.

WEIGHT AND HOUSING

Before removing any part from weight housing assembly, (fig. 55) the unit should be thoroughly washed in cleaning solvent or fuel oil, dried with compressed air, and then inspected for worn, damaged, or binding parts. If all parts are in good working order, disassembly will be unnecessary. If bearings only need replacing, then removal of weights from carrier will not be necessary. Complete disassembly is as follows:

NOTE: Governor assemblies have a threaded cap screwed into the bearing end of the weight carrier housing. This threaded cap screws tight against the bearing outer race thus cap serves as a bearing retainer.

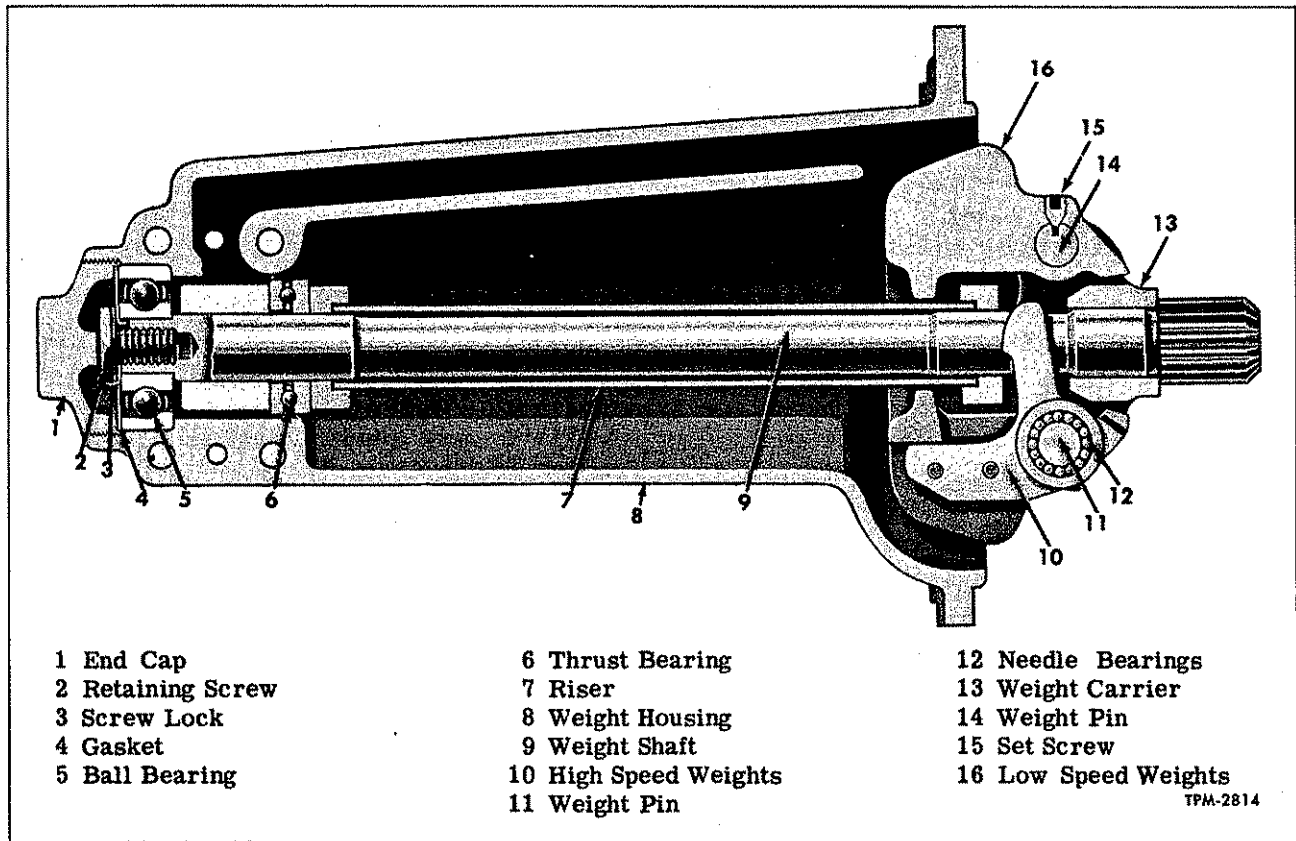
1. Support the governor weight housing in a vise and remove bearing cap. A hex wrench head on the cap makes removal a simple operation. A gasket between bearing outer race and plug keeps oil from seeping through the threads.

2. Straighten lip on locking washer and remove lock screw from outer end of weight carrier shaft.

3. Using a $\frac{5}{16}$ "-24 bolt, thread bolt into tapped hole at end of weight carrier shaft, then remove shaft from bearing by tapping on bolt head. Use a bolt of sufficient length, so bolt head will not interfere with bearing inner race before the shaft leaves the bearing.

4. Remove the thrust ball bearing and riser from the weight carrier shaft.

5. Mark weights and carrier with center punch for identification, also note position of thin washers between weights, so parts can be replaced in their original locations; then remove Allen set screws, weight pivot pins and weights from carrier. The governor weight carrier is only serviced with the shaft

LIMITING SPEED GOVERNOR**Figure 55—Governor Weight and Lower Housing Assembly**

and should not be removed.

6. Press ball bearing from housing. Usually only slight pressure is required to remove bearing.

INSPECTION

All the governor parts having been washed in cleaning solvent or fuel oil and dried with compressed air, the parts may be inspected for wear and fitness for further use.

Since the function of governor is to control fuel injection by means of suitable linkage within the governor and inter-connected linkage between governor and injector control, absolute freedom of all moving parts within governor, as well as the inter-connecting linkage, is of utmost importance.

When inspecting governor parts, therefore, bear in mind that all parts must work freely with their mating parts.

Revolve outer race of annular bearing slowly for any indication of rough spots. Replace pitted or corroded balls and races.

At lower end of control housing examine bushing

for wear, and replace if necessary.

Examine journals on shafts at bearing locations, and if journals are worn excessively, replace shafts.

Examine all sleeves, pins, shaft journals, and links for wear; also for fits, and, if necessary, dress with crocus cloth for proper fit. The weights should be suspended in their carrier sufficiently free to fall from the extended to the inner position by their own weight, and the suspending pins should not be used if worn more than .002" out-of-round.

ASSEMBLY

The governor may be assembled by reversing the sequence of operations for disassembly. The work will be much simplified by close reference to the various detailed illustrations accompanying the following text. Having thoroughly inspected each part and by reference to the various illustrations, governor may be assembled as follows:

WEIGHT AND HOUSING

Refer to figure 55 and proceed as follows:

LIMITING SPEED GOVERNOR

1. Using wood block, tap annular ball bearing into outer end of weight housing.

2. Heeding marks previously placed on governor weights and carrier, also noting position of washers between weights, attach weights to carriers and lock each pin with the Allen set screw. Stake Allen screws at two places after replacing.

3. Support serrated end of shaft vertically in vise between copper jaws and position riser and thrust bearing onto upper end of shaft. Drop carrier housing over shaft, then using block of wood on inner race of ball bearing, drive shaft through bearing tight against shoulder on shaft.

4. Thread lock screw through lock plate and install in end of weight shaft. Tighten screw and bend tang of lock plate over flat of screw head. Install new gasket and install end cap.

CONTROL HOUSING

Due to the flatted shaft ends and the "D" holes in the hub of both the lower forked lever and the upper operating lever, these parts are properly located. Through this method of establishing the proper relationship between operating lever, shaft, and yoke, any one of the three pieces may be replaced without changing the relationship of the system. Refer to figure 52 and proceed as follows:

1. If operating lever, bearing, and washer were removed from the shaft, set the washer in place against shaft shoulder, tap or press bearing onto shaft then, using an arbor press, replace operating lever against ball bearing inner race.

Install new expansion plug.

2. Lubricate ball bearing and insert operating shaft assembly down through bushing. Position the fork lever (yoke) so machined surfaces of fork will bear against ball bearings thrust washer. When lower end of control shaft appears through the lower bushing put fork in position and slide shaft assembly down through hub of fork.

3. Push forked lever onto shaft just far enough to contact the bushing, then back off just enough to make the shaft movement perfectly free. Tighten set screw securely with an Allen wrench. The walls of the forked lever should be staked down tight against the set screw using a pointed anvil and a pointed punch. After the installation of the shaft and levers in the housing is completed, hold the upper operating lever and with the heel of the hand, gently force the lower operating fork in the direction of normal loading in order to properly seat the operating lever and fork on the shaft. A torque of about 300 inch

pounds should be applied to the shaft.

4. Install differential lever to operating shaft lever and secure with washer and clip.

SPRING AND PLUNGER

Refer to figures 51 and 53 and proceed as follows:

1. Position one end of low speed spring into spring cap, then place spring seat on opposite end of spring. Install this assembly into governor spring plunger.

2. Install this assembly into position through opening in control housing.

3. Install high speed spring over end of plunger. **NOTE:** Loosely wound end of spring **MUST** be against shoulder of plunger.

4. Thread lock nut about half way down on high speed spring retainer. Position retainer over high speed spring, then thread into housing until against nut.

5. Thread lock nut about halfway down on low speed adjusting screw, then thread screw into housing until against nut.

6. If governor is to be placed in stock install gasket and spring cover and secure with two bolts.

CONTROL HOUSING COVER

1. If bearings for throttle shaft were removed from cover, start either upper or lower bearing straight in the cover by hand; then, using a block of wood on end of bearing, press into position. Install other bearing in the same manner.

NOTE: Lower bearing is pressed in flush with lower end of bearing boss. Upper bearing is pressed in flush with counterbore in cover.

2. Lubricate roller bearings with a liberal amount of good cup grease, slide thin plain washer over the throttle shaft next to eccentric shoulder on lower end of shaft, and slide shaft through bottom of cover into position through bearings.

3. Insert seal washer into counterbore for roller bearing at upper side of cover. Install plain washer over shaft and next to seal.

4. Lubricate camshaft and install cam over shaft with boss on cam directed away from cover. Position stop lever over operating cam assembly and insert bolt and washer. Install plain washer over shaft and insert clip lock. On installations or models on which the stop lever and cam are not used disregard these instructions.

NOTE: After governor has been attached to the engine, and the engine stop mechanism is about to

LIMITING SPEED GOVERNOR

be connected, it may be necessary to reposition stop lever. Do not tighten bolt too securely.

5. Align holes in throttle shaft and pedal control lever and press lever onto upper end of shaft with pin at outer end of lever down in slot of cam. Lock lever to shaft with taper pin.

6. Position control lever on shaft over pedal control lever, and lock with clamp bolt.

INSTALLATION

Difficulties will be encountered in attempting to install complete governor assembly to engine without first separating the control housing from the weight housing. Therefore, if a replacement governor, as received from stock, is to be installed on engine, the two housings must be separated. If a governor being rebuilt is to be installed, installation may be carried out before the two housings are joined together, as follows:

1. Position a gasket to the governor weight housing attaching flange, and slide housing assembly up against front end of blower with splined end of governor shaft entering hollow upper blower rotor shaft. Put attaching bolts in place finger tight only.

2. Using a gasket between the two assemblies, set the control housing and shaft assembly on dowels and against the weight housing; then put weight carrier housing cover and gasket in position, and lock cover, gaskets and the two housings together with cap screws and lock washers.

IMPORTANT: Be sure that forked lever is assembled with machined faces bearing on outer thrust washer and NOT between washer and balls.

3. Using a new gasket, attach upper end of housing to cylinder head with cap screws and lock washers.

4. Tighten the bolts that attach weight housing to end of blower, using the special wrench, for tightening the inner bolt.

5. Pour at least $\frac{1}{2}$ pint of engine oil into top of governor, lubricating all parts thoroughly.

6. At this stage of the governor assembly and before replacing the cover, the low-speed spring plunger gap-space between the spring plunger and the low-speed spring cap may be checked and if necessary adjusted. When the engine is not running this space should be approximately .170". To adjust the gap, if necessary, proceed as directed under "Adjust Low-Speed Spring Gap," later in this section.

7. Install governor control link using clevis pin and cotter pins at injector control tube, and plain

washer and pin clip at governor control lever.

8. Affix gasket to cover bolting flange then; set cover on control housing over dowels with pin on lower end of throttle control lever engaging with slot in the differential lever. Replace cover screws and lock washers.

9. Attach throttle control link to governor operating lever and engine stop mechanism to governor stop lever. The position of the operating and stop levers may be changed if necessary to facilitate these connections.

ADJUSTMENTS

Five adjustments are necessary on the limiting speed governor, and should be performed in the following sequence.

1. Adjust engine idling speed.

2. Adjust gap between low speed spring cap and spring plunger.

3. Perform injector rack to injector positioning adjustment.

4. Adjust high speed spring setting for the particular maximum engine rpm for which the unit is used.

5. Adjust buffer spring tension for limiting OFF travel of differential lever.

As previously stated under "Maintenance On Vehicle" in this section, governor faults are usually manifest in speed variations of the engine, but it does not necessarily follow that all such speed variations indicate governor faults. Therefore, before adjusting the governor to correct speed variations, first carry out the instructions for checking the engine as previously described under "Maintenance On Vehicle." These checks should also include:

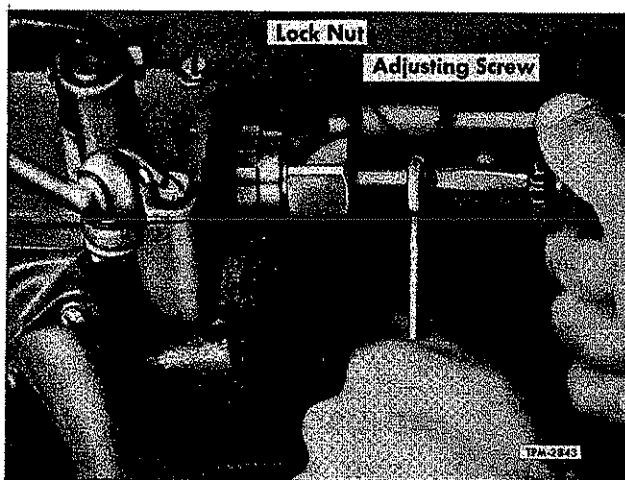
1. Lash valves as outlined under "Valve Lash" in **ENGINE TUNE-UP** section of this manual.

2. Retime injectors as outlined under "Timing Injectors" in **ENGINE TUNE-UP** section of this manual, also position injector control racks as directed under "Positioning Injector Rack" later in this section.

IDLE SPEED ADJUSTMENT

The desirable idling speed is 360 to 375 rpm with hydraulic or 400 rpm with mechanical transmission.

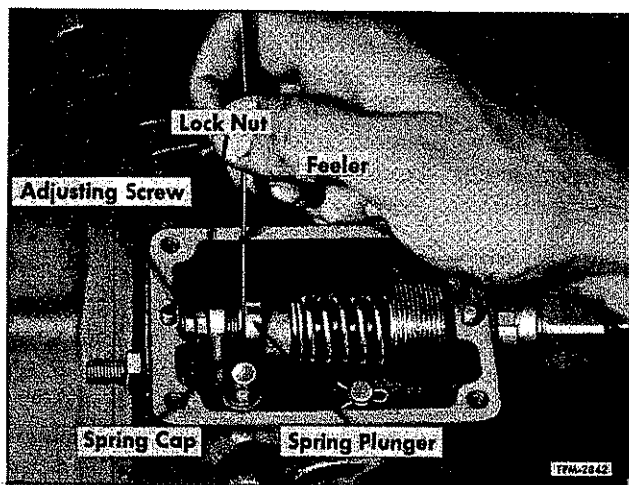
Even though the low-speed adjustment is set at the factory before the engine is shipped, it may be desirable either to raise or lower the idling speed of the engine, in which case the adjustment is made as follows: The engine should be at operating temperature while making this adjustment.

LIMITING SPEED GOVERNOR**Figure 56—Adjusting Engine Idle Speed**

1. Remove two bolts and lock washers attaching governor spring cover to control housing then remove cover.
2. Loosen lock nut and turn buffer screw OUT until screw projects about $\frac{3}{8}$ " beyond lock nut.
3. Start engine and operate at idle speed while observing RPM at tachometer.
4. If necessary to adjust, loosen lock nut and turn idle adjusting screw IN to increase or OUT to decrease speed (fig. 56). Lock adjusting screw with lock nut when idle speed is approximately 15 RPM below desired setting.

ADJUST LOW-SPEED SPRING GAP

Once this adjustment is properly established no further attention should be necessary until the governor assembly is repaired or replaced. When

**Figure 57—Adjusting Low Speed Spring Gap**

the adjustment is required it may be carried out as follows:

1. Remove governor control housing cover by removing four screws and lock washers, then lift cover and levers assembly from housing.
2. Remove connecting link between governor and injector control tube lever.
3. Start engine, then by hand, move control tube so as to operate engine at approximately 700 to 800 RPM.

WARNING: DO NOT OVER-SPEED ENGINE AS GOVERNOR IS NOW DISCONNECTED AND CANNOT CONTROL ENGINE SPEED.

4. Measure gap between low speed spring cap and plunger (fig. 57). If gap is not between .001" to .002", loosen lock nut and turn adjusting screw until desired gap is obtained, then tighten lock nut. Recheck gap after tightening lock nut.
5. Stop engine. Install connecting link between governor and injector control tube lever. Install control housing cover, being sure that throttle shaft pin engages differential lever fork.

POSITIONING INJECTOR RACK

The position of the injector racks must be correctly set in relation to the governor. Their position determines the amount of fuel injected into each cylinder and insures equal distribution of load. Refer to figure 58 and proceed as follows:

1. Adjust No. 1 injector rack control lever first in order to establish a guide for adjusting the remaining injector rack control levers.
2. Loosen locknut and back out buffer screw (fig. 60) until it projects about $\frac{3}{8}$ " from the governor housing.
3. Loosen inner and outer adjusting screws (fig. 58) of all injector rack control levers several turns. Be sure all levers "swing freely" on injector control tube.
4. On coaches using hydraulic transmission a yield link is used between governor and injector control rack (fig. 58). Whenever positioning injector rack on vehicles equipped with yield link it is necessary that a small "C" clamp be used at the rod shoulder to provide a temporary solid rod. This is important since it prevents possibility of compressing yield link spring.
5. Move governor control lever into full fuel position and hold by hand.
6. Turn down inner adjusting screw at No. 1 in-

LIMITING SPEED GOVERNOR

jector rack control lever until governor control lever starts to move away from full fuel position.

7. Tighten outer adjusting screw to lock rack control lever in position. This should accomplish the desired setting of No. 1 injector rack control lever.

8. Check the adjustment, holding governor control lever in full open position, then pull injector control tube lever towards governor. Movement should not exceed $\frac{1}{64}$ " (max.).

9. If movement is in excess of $\frac{1}{64}$ ", it will be necessary to readjust "setting" of No. 1 injector rack control lever.

10. After No. 1 injector rack control lever is once correctly set, **IT MUST NOT BE CHANGED THROUGHOUT ADJUSTMENT OF REMAINING INJECTOR RACK CONTROL LEVERS.**

11. With governor control lever held in full fuel position, note rotary movement of No. 1 injector rack to lever coupling. Pressure of finger tip will produce a tendency to rotate, but coupling should not be loose. All injector rack control levers must now be adjusted to the same "feel" at coupling to insure same amount of fuel injected into each cylinder at full load as follows.

12. Hold governor control lever in full fuel position. Adjust No. 2 injector rack control lever by turning down inner adjusting screw while finger tip is touching No. 2 injector rack coupling. When coupling loses its rotary movement, tighten outer adjusting screw.

13. "Feel" No. 2 and No. 1 injector rack couplings with finger tip to check rotary movement.

14. If No. 1 injector rack coupling now feels loose, No. 2 injector rack coupling is too tight. Correct No. 2 injector rack adjustment by loosening inner adjusting screw and tightening outer adjusting screw.

15. If No. 2 injector rack coupling feels loose, correct by loosening outer adjusting screw slightly and tighten inner adjusting screw.

16. When No. 2 injector rack coupling "feels" the same as No. 1, repeat this procedure (operations 12, 13, 14, 15) on all remaining injector racks. That is compare No. 3 injector rack coupling with No. 1, etc.

17. Recheck idle speed as previously instructed in this section.

NOTE: An accurate rack setting in "full fuel" position will result in balanced injection throughout the entire operating range. Therefore, a "rough" idle after tune-up calls for a check of governor, injectors and related controls. Do not attempt to change rack position with engine idling or operating at any

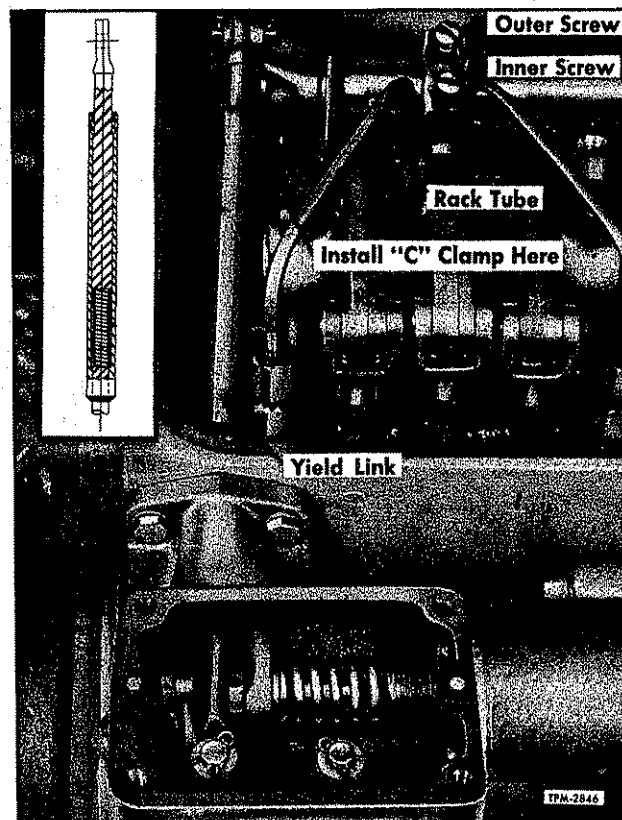


Figure 58—Governor to Injector Rack Yield Link

speed. When one rack is adjusted "in" more than the others, only that one injector rack can reach "full fuel" position. As a result, maximum output of the engine will be reduced.

HIGH SPEED NO-LOAD ADJUSTMENT

At time of vehicle delivery governor is adjusted to maximum specified speed and further adjustments

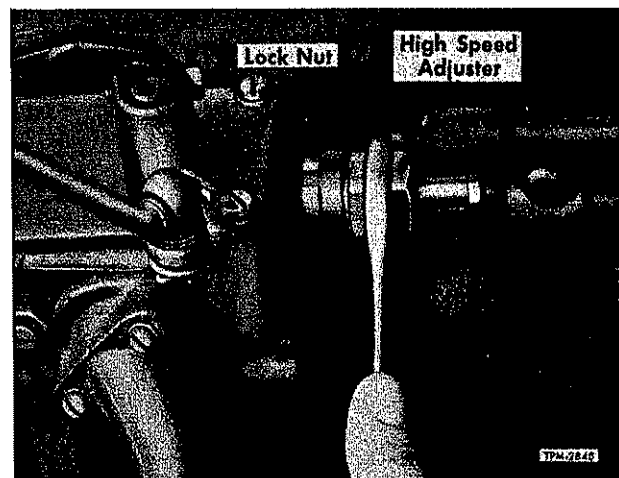
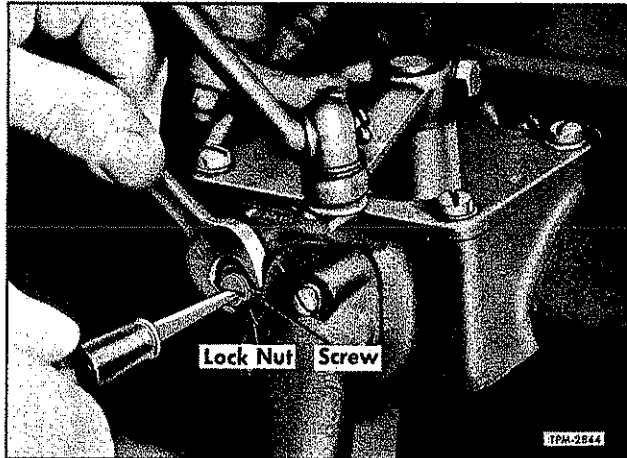


Figure 59—Adjusting No-Load High Speed

LIMITING SPEED GOVERNOR**Figure 60—Buffer Spring Screw Adjustment**

are ordinarily unnecessary. However, in the event of a governor change, it may be necessary to adjust the maximum no-load speed. Whenever it is necessary to adjust, the engine should be at operating temperature and the following procedure used:

1. Remove two bolts and lock washers attaching governor spring cover to control housing, then remove cover.
2. Loosen the high speed spring retainer lock nut using a spanner wrench.
3. Start engine and operate at maximum speed.

CAUTION: THERE MUST BE NO LOAD ON ENGINE DURING THE MAXIMUM NO-LOAD SPEED ADJUSTMENT.

Observe engine RPM at tachometer.

4. Turn high speed spring retainer IN to increase or OUT to decrease speed (fig. 59) until desired no-load setting is obtained.
5. Hold high speed spring retainer, then tighten lock nut, using spanner wrench.
6. Recheck and if necessary readjust after tightening lock nut.
7. Install governor spring cover and secure with two bolts.

BUFFER SPRING ADJUSTMENT

Governors are equipped with buffer springs, the purpose is to prevent low speed engine "roll" or "stalling," which is manifest on some engines and absent on others.

To adjust after the screw has been backed out as directed for the low speed adjustment, turn screw IN until engine idling speed, is increased slightly (not over 20 rpm), thus insuring spring contact with the differential lever (fig. 60).

NOTE: Accelerate and decelerate engine several times. If smoke is visible in exhaust when engine is decelerated, check buffer spring to make sure injector racks are returning to No-Fuel position.

ECONOMY-RANGE LIMITING SPEED GOVERNOR

A limiting speed economy-range type governor is used on some trucks. This governor is essentially a limiting speed type and in many respects is the same as previously described under heading "Limiting Speed Governor." However, an air operated piston is added, which provides two high speed ranges (fig. 61).

When vehicle is being operated in the reduced transmission and axle ranges, air is present at governor and engine is permitted to operate at maximum RPM. When transmission is in 4th or 5th speed and rear axle is in high range, air is shut off from governor and piston returns to a position which reduces engine approximately 200 RPM.

REPLACEMENT

Instructions given previously in this manual covering removal and installation are also applicable to economy range governor.

SPRINGS AND PLUNGERS REMOVAL

Governor springs, plungers, seats, and retainers (fig. 62) located in control housing (fig. 61) can be removed and installed while governor is installed or at bench, as follows:

1. Remove two bolts attaching piston housing to control housing, then remove housing, with cover, piston, and sleeve.
2. Remove cover from housing, then push piston, sleeve, and seal from housing.
3. Remove spring retainer nut from control housing, using nut wrench J-1652-01. Spring seats, springs, plunger, adjusting screw, and spring cap can now be removed from control housing. Refer to figure 62 for arrangement of these parts.

SPRINGS AND PLUNGERS INSTALLATION

Refer to figure 62 and proceed as follows:

1. Position one end of low speed spring into cap,

GOVERNOR—ECONOMY RANGE

then place spring seat on opposite end of spring. Install this assembly into governor spring plunger.

2. Thread low speed adjusting screw into spring plunger.

3. Install this assembly into position through opening in control housing.

4. Install high speed spring and spring guide over plunger.

5. Thread spring retainer into housing (fig. 63) and tighten with nut wrench.

6. If sleeve and piston have been separated they should be threaded together until a preliminary measurement of $\frac{25}{32}$ " for 6-71 or $\frac{19}{32}$ " for 4-71 engines is obtained (fig. 64).

7. Install piston, sleeve, and seal ring assembly in piston housing.

8. Secure piston housing and piston assembly to control housing, using new gaskets at each end of housing.

CONTROL HOUSING

Disassembly, maintenance, repair, and reassembly of control housing is described previously in this section.

WEIGHTS AND HOUSING

Disassembly, maintenance, repair, and reassembly of weights and housing is described previously in this section.

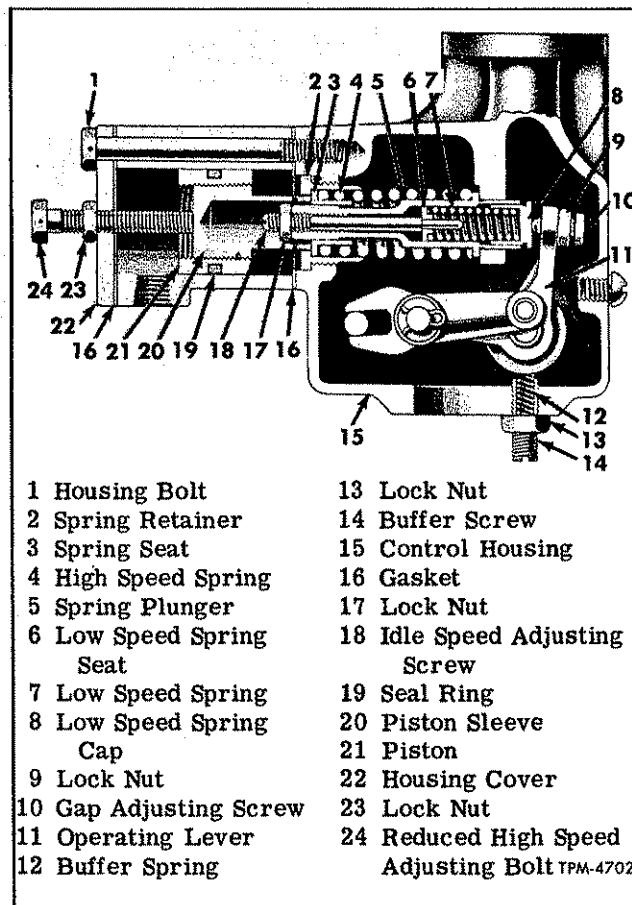


Figure 61—Economy-Range Governor Control Mechanism

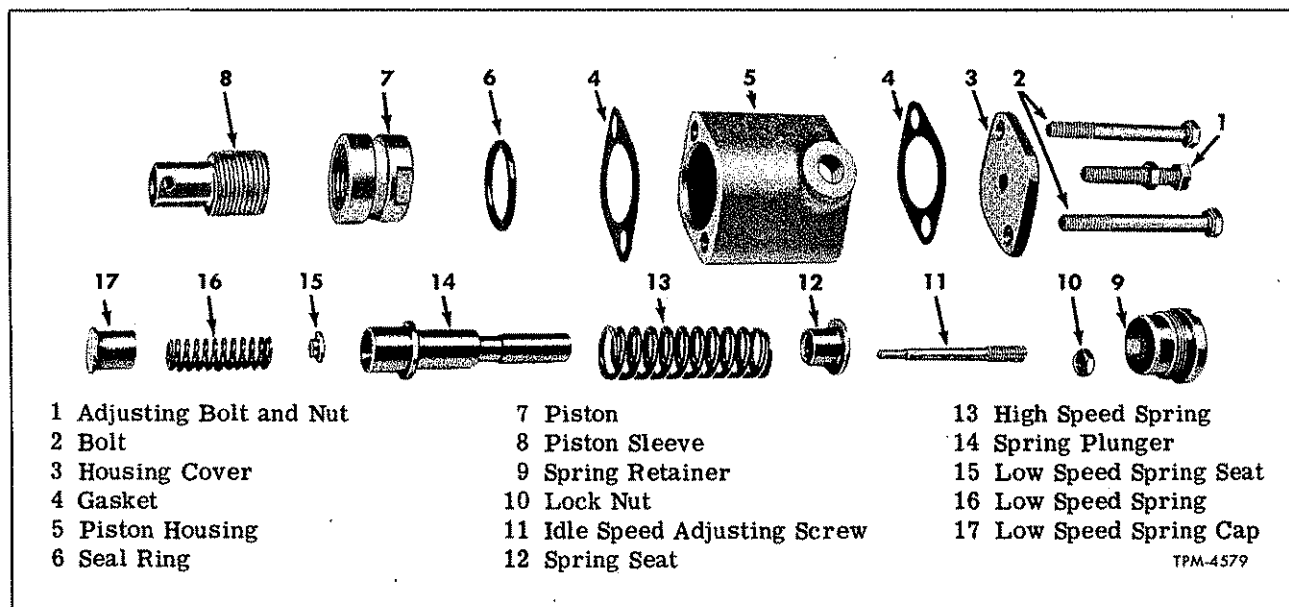


Figure 62—Relative Location of Governor High and Low Speed Springs, Plunger, Seats, and Piston

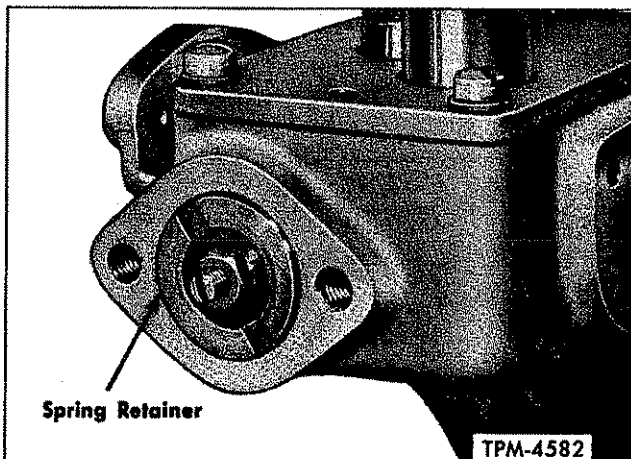
GOVERNOR—ECONOMY RANGE


Figure 63—High Speed Spring Retainer Installed

ADJUSTMENTS

Seven adjustments are necessary on limiting speed economy-range type governor, and should be performed in the following sequence:

1. Adjust engine idling speed (preliminary).
2. Adjust gap between low speed spring cap and spring plunger.
3. Perform injector rack to injector positioning adjustment,
4. Adjust high speed piston for maximum engine RPM.
5. Adjust high speed piston for reduced speed RPM.
6. Adjust engine idling speed (final).
7. Adjust buffer spring tension.

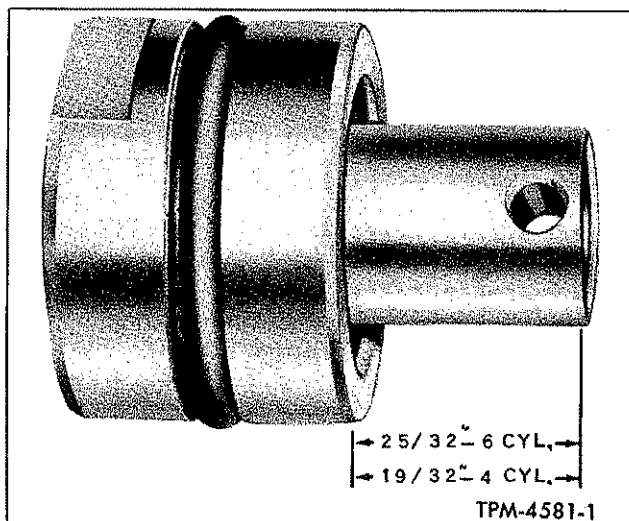


Figure 64—High Speed Piston Preliminary Setting

IDLE SPEED ADJUSTMENT

Even though the low-speed adjustment is set at the factory before the engine is shipped, it may be desirable either to raise or lower the idling speed of the engine. The engine should be at operating temperature, while adjustment is being made as follows:

1. Remove two bolts attaching piston housing to control housing, then remove housing and piston assembly.
2. Loosen lock nut and turn buffer screw OUT until screw projects about $\frac{5}{8}$ " beyond lock nut.
3. Start engine and operate at idle speed while observing RPM at tachometer.
4. If necessary to adjust, loosen lock nut and turn idle screw IN to increase or OUT to decrease speed (fig. 65). Lock adjusting screw with lock nut when idle speed is approximately 15 RPM below desired setting.

ADJUST LOW-SPEED SPRING GAP

Once this adjustment is properly established no further attention should be necessary until the governor assembly is repaired or replaced. When the adjustment is required it may be carried out as follows:

1. Remove governor control housing cover by removing four screws and lock washers, then lift cover and levers assembly from housing.
2. Remove connecting link between governor and injector control tube lever.
3. Start engine, then by hand, move control tube so as to operate engine at approximately 700 to 800 RPM.

WARNING: DO NOT OVER-SPEED ENGINE AS GOVERNOR IS NOW DISCONNECTED AND CANNOT CONTROL ENGINE SPEED.

4. Measure gap between low speed spring cap and plunger (fig. 57). If gap is not between .001" to .002", loosen lock nut and turn adjusting screw until desired gap is obtained, then tighten lock nut. Re-check gap after tightening lock nut.
5. Stop engine. Install connecting link between governor and injector control tube lever. Install control housing cover, being sure that throttle shaft pin engages differential fork.

POSITION INJECTOR CONTROL RACKS

The position of the injector racks must be correctly set in relation to the governor. Their position determines the amount of fuel injected into each

GOVERNOR—ECONOMY RANGE

cylinder and ensures equal distribution of the load.

A fuel modulator assembly is installed in cylinder head on turbocharged engines. This unit is controlled by air box pressure and operates in such a manner as to retard fuel injector racks as air pressure drops, due to reduced engine rpm. In addition, injector racks cannot move into full speed position, until air box pressure is sufficient to provide proper combustion.

When adjusting the fuel control racks on engines equipped with a fuel modulator, be sure no interference is encountered from the fuel modulating device. This may be assured by loosening the fuel modulator lever "U" bolt and moving the modulator lever along the injector control tube to avoid contact with modulator cam or adjacent cylinder head stud nut.

NOTE: When the modulator lever is in position, it may strike the cylinder head stud nut when the rack is moved toward the OFF position. The NO FUEL position is reached before this contact takes place and should therefore cause no concern.

No. 1 injector rack control lever must be adjusted first to establish a guide for adjusting the remaining injector rack control levers.

1. Disconnect any linkage attached to governor throttle lever.

2. Loosen lock nut and back out buffer screw approximately $\frac{5}{8}$ "

3. ON ENGINES EQUIPPED WITH FUEL MODULATOR, loosen lock nut and back out idle speed adjusting screw until $\frac{1}{16}$ " of thread projects beyond lock nut. **NOTE:** This lowers the tension on the low speed spring permitting the governor gap to close completely without overcoming the control tube fuel modulating spring.

4. Loosen all injector control rack inner and outer adjusting screws, as shown in Figure 66. Be sure all control levers are free on the injector control tube.

5. Move governor throttle control lever to the FULL FUEL position as shown in Figure 66. Turn inner adjusting screw down until a slight movement of the control tube is observed or a step up in effort is noted. This will place No. 1 injector rack in the FULL FUEL position. Turn down outer adjusting screw until it bottoms lightly on the injector control tube. Then alternately tighten both the inner and outer adjusting screws until tight.

PARAGRAPHS 6 AND 7 FOLLOWING ARE APPLICABLE ONLY TO ENGINES EQUIPPED WITH FUEL MODULATOR.

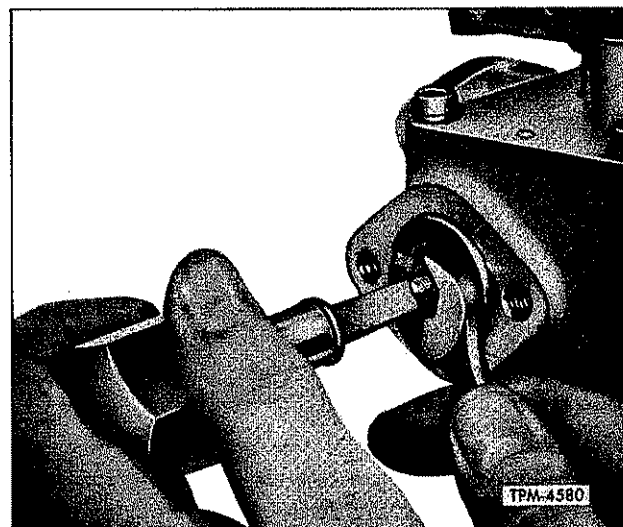


Figure 65—Adjusting Idle Speed

6. Check the setting of No. 1 injector rack by moving the governor control lever toward the NO FUEL position while holding the governor to control tube link, with light finger pressure, in a direction toward the governor. This pressure will retain the low speed spring gap in the closed position when the throttle control lever is moved from the full speed position toward the idle position. A proper rack setting will be indicated by an immediate corresponding movement of the No. 1 injector rack from the FULL FUEL position when the governor control lever is moved away from the FULL SPEED position.

7. If no immediate corresponding movement of the injector rack is observed in Step 6, back off inner adjusting screw approximately $\frac{1}{8}$ of a turn and

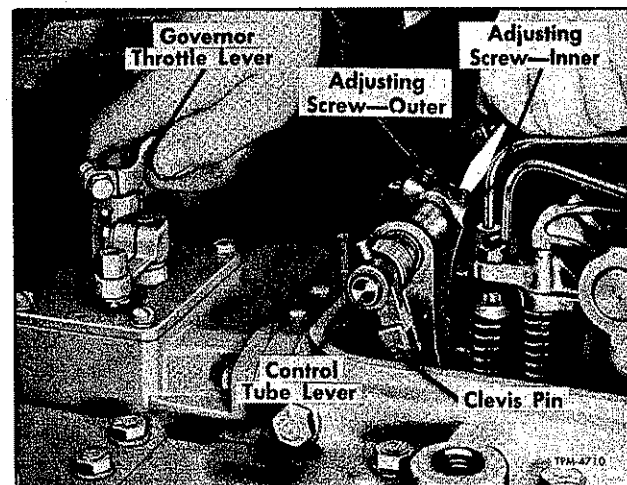


Figure 66—Positioning Injector Control Rack

GOVERNOR—ECONOMY RANGE

tighten outer adjusting screw. When the setting is correct, the injector rack will be snug on the pin of the rack control lever and still maintain the movement specified on item 6.

PARAGRAPHS 8 AND 9 FOLLOWING ARE APPLICABLE ONLY TO ENGINES NOT EQUIPPED WITH FUEL MODULATOR.

8. With the governor control lever held in the **FULL FUEL** position, check for movement of the injector control tube lever. There should be a slight movement not to exceed .005".

9. If no movement is observed, back off inner adjusting screw approximately $\frac{1}{8}$ of a turn and tighten outer adjusting screw. If the movement exceeds that specified, back off outer adjusting screw approximately $\frac{1}{8}$ of a turn and tighten inner adjusting screw. When the setting is correct, the injector rack will be snug on the pin of the rack control lever and still maintain the movement specified in item above.

10. Remove clevis pin between the fuel rod and the injector control tube lever. See Figure 34.

11. Manually hold No. 1 injector in the **FULL FUEL** position and turn down inner adjusting screw of No. 2 injector until the injector rack of No. 2 injector has moved into the **FULL FUEL** position and the inner adjusting screw is bottomed on the injector control tube. Turn outer adjusting screw

down until it bottoms lightly on the injector control tube. Then alternately tighten both the inner and outer adjusting screws until tight.

12. Recheck No. 1 injector fuel rack to be sure that it has remained snug on the pin of the rack control lever while adjusting No. 2 injector. If the rack of No. 1 injector has become loose, back off slightly on the inner adjusting screw on No. 2 injector rack control lever. Tighten outer adjusting screw. When the settings are correct, the racks of both injectors must be snug on the pin of their respective rack control levers.

13. Position the remaining control rack levers as outlined in items 11 and 12.

14. Insert the clevis pin between the fuel rod and the injector control tube lever.

15. Reset idle speed adjusting screw until it projects $\frac{3}{8}$ " beyond the lock nut. Tighten lock nut.

HIGH SPEED ADJUSTMENT

This type governor has two high speed no-load adjustments (1) maximum high speed (2) reduced high speed. Each of these adjustments is accomplished separately and in the following order:

Maximum High Speed Adjustment

1. Start engine and operate at full speed. Be sure air is supplied to governor. No load speed is 125-150 RPM above full load speed shown on chassis serial number plate on cab door hinge pillar.

2. Remove two bolts attaching piston housing to governor control housing, then remove housing and piston assembly.

3. Remove piston and sleeve assembly with seal ring from piston housing.

4. Measure distance from end of piston to end of sleeve (fig. 64). This dimension should be approximately $2\frac{5}{32}$ " for 6-71 or $1\frac{13}{32}$ " for 4-71 engines.

5. Should it be necessary to increase engine RPM the dimension, shown in Figure 64, should be increased. Also, when necessary to decrease engine RPM the dimension, shown in Figure 64, should be decreased. **NOTE:** Each full turn of piston and sleeve will change engine approximately 100 RPM.

6. Install piston and sleeve assembly in piston housing, then install piston housing to governor control housing.

7. Check for proper setting and readjust as necessary.

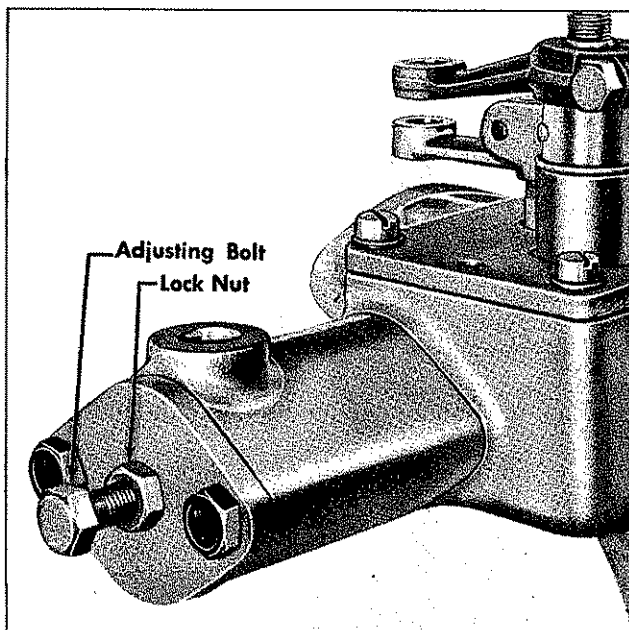


Figure 67—Reduced High Speed Adjustment

GOVERNOR—ECONOMY RANGE

Reduced High Speed Adjustment

1. Disconnect wire at governor air supply solenoid so as to prevent air reaching governor.
2. Start engine and operate at full speed while observing RPM at tachometer. Proper adjustment is approximately 200 RPM below maximum no-load speed.
3. Loosen lock nut and turn adjusting bolt (fig. 67) as necessary to obtain proper reduced high speed RPM. Lock screw with nut when proper adjustment is obtained.
4. Should it be necessary to increase engine RPM turn adjusting bolt (fig. 67) in to increase, or out to decrease engine RPM.
5. Reconnect wire to solenoid when adjustment is completed.

READJUST IDLE SPEED

With the no-load maximum high speed and re-

duced high speed properly adjusted, the idle speed should be readjusted as recommended under heading "Idle Speed Adjustment" in this section.

ADJUST BUFFER SCREW

1. Maximum no-load speeds and idle speed must be in proper adjustment as previously described.
2. Start engine and operate at idle speed. Turn buffer screw in so that it contacts the differential lever as lightly as possible and still eliminates the engine roll. Buffer screw final adjustment should be made after engine has thoroughly warmed after several hours of operation.
3. Recheck maximum no-load speeds. If it has increased more than 25 RPM from the speeds previously set, back off buffer screw until increase is less than 25 RPM.

**All Tune-up Operations and Adjustments
Should Be Performed Carefully and In
Proper Sequence**

Engine Run-in and Tune-up

ENGINE RUN-IN SCHEDULE

Engines in which new pistons or piston rings, cylinder liners, main bearings, or connecting rod bearings have been installed, should be operated on a RUN-IN schedule prior to release for service.

The purpose of the RUN-IN schedule is to assure proper alignment and seating of parts before the engine is subjected to FULL-LOAD operation.

When filling the lubrication system, remove valve cover and pour a gallon of oil over the valve mechanism.

Check valve lash and injector timing before cranking the engine.

A minimum water jacket of 160°F. should be maintained throughout the run.

The recommended oil pressures are 30 lbs. minimum at 2000 rpm (4 lbs. minimum at idle.)

Frictional losses in the engine will continue to decrease for 10 or 20 hours and consequently engine performance will improve. During this period it is desirable to avoid maximum power output except for short intervals.

SCHEDULE WITHOUT DYNAMOMETER

Where dynamometer is not available, engine RUN-IN schedule must be performed in the following manner.

1. Start engine and operate at fast idle until water temperature reaches 160° F. Observe and correct any existing oil or water leaks.
2. Run engine for 15 minutes at 1000 RPM—no load.
3. Run engine for 30 minutes at 1900 RPM—no load.
4. Tighten cylinder head nuts.
5. Lash valves, and adjust bridge on four-valve heads with engine hot. Refer to "Specifications" for dimensions.
6. Check injector rack for proper positioning, also check governor for proper operation.

7. Release vehicle to operator with instructions to continue with the following:

- a. Run engine on road for 30 minutes at governed speed with load and with transmission not higher than 3rd speed.
- b. Run engine on road for 30 minutes at governed speed with load and with transmission not higher than 4th speed.

8. Change lubricating oil and filter element, also clean strainer at or before 500 miles to remove any foreign material which may have accumulated during run-in period.

DYNAMOMETER SCHEDULE

Time (Hours)	Engine RPM	% Load
¼*	1000	0
½	1000	20
½	1300	30
½**	1500	50
½	1800	80
1	2000	100

TOTAL RUN-IN PERIOD—¾ HOURS

*Warm-up and inspection period. This is a minimum run-in schedule and if time permits, the engine should be run for longer time increments than specified before applying full load.

**Check valve lash with engine hot. Check injector timing. Refer to "Specifications" for dimensions.

Check injector balance and idle operation. (Refer to "Control Rack Positioning," in **INJECTOR** section of this manual and "Governor Adjustment," in respective **GOVERNOR** sections of this manual.

Inspect for oil and water leaks and tighten all external bolts.

Change lubricating oil and filter element, also clean oil strainer (where used) after completing the run-in to remove any metallic or foreign material accumulated during this period.

ENGINE TUNE-UP

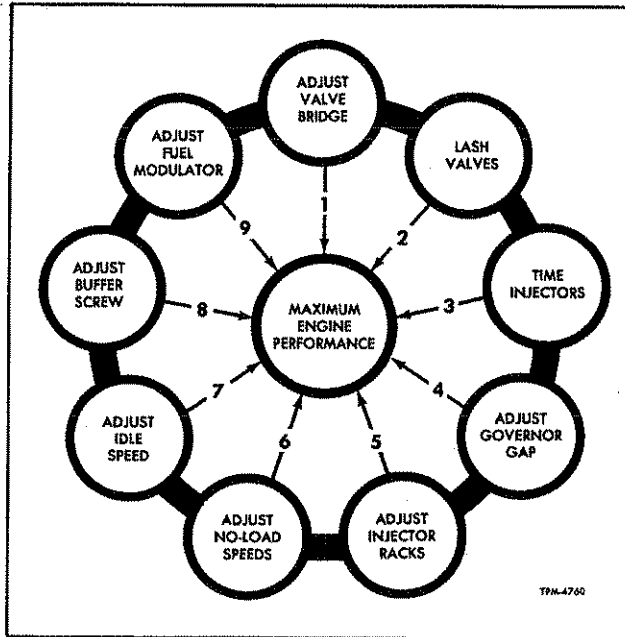


Figure 1—Engine Tune-up Chart

TUNE-UP CHART

Results obtained from an engine tune-up may be unsatisfactory if a "hit and miss" method is used instead of a systematic approach to the job; therefore the logical solution is a complete checkup following the cycle in figure 1 and carrying out each step as directed below.

NOTE: Before tune-up procedure is started it is important that air cleaners and fuel filters are serviced as described in applicable maintenance manuals. Crankcase breather tube and air box drains must be clean and unobstructed. Air box drains may be cleaned with compressed air.

CAUTION: Remove or at least loosen an air box hand hole cover, otherwise blower or end plate gaskets may be damaged by excessive air pressure.

Reference should be made to "TESTING AND DIAGNOSIS" also to "TROUBLE SHOOTING" for engine diagnosis, trouble symptoms, causes, and remedial measures.

The following tune-up adjustments are applicable to two and four-valve cylinder head engines.

TUNE-UP PROCEDURES

To completely tune-up an engine, all adjustments except bridge balancing adjustment and exhaust valve cold setting must be performed only after engine has reached its normal operating temperature.

Results obtained from an engine tune-up are usually unsatisfactory, unless a step-by-step, systematic, and orderly approach is used. Refer to figure 6 and proceed in the following sequence:

1. Bridge Balancing Adjustment (4 Valve Head)
2. Exhaust Valve Lash Adjustment
3. Time Fuel Injectors
4. Adjust Governor Gap
5. Adjust Injector Control Racks
6. Adjust Maximum No-Load Speeds
7. Adjust Idle Speed
8. Adjust Buffer Screw
9. Adjust Fuel Modulator (Turbo-Charged)

NOTE: Whenever a push rod has been disconnected from the clevis, the push rod must be screwed back into place until end of push rod appears through the clevis. If this is not done, the piston may hit the head of the valve when the engine is being turned, due to the small clearance, between the valves and piston head at the piston's upper position, or an injector plunger may "Bottom" before being properly adjusted.

Clearance between valve rocker arm and exhaust valve stem, or bridge with engine at operating temperature is important and should be maintained. Too little clearance causes a loss of compression, mis-firing of cylinders and eventual burning of valves and valve seats. Too much clearance results in noisy operation of the engine, especially in the low speed range.

BRIDGE BALANCING ADJUSTMENT

The exhaust valve bridge assembly is adjusted and the adjustment screw locked securely at the time the cylinder head is installed on the engine. Until wear occurs with the operation of the engine, no further adjustment is required on the exhaust valve bridge. When wear is evident, make complete bridge balancing adjustment as outlined in the following steps:

1. Refer to "Fuel Injector" in Fuel System Section and remove injector fuel jumper lines, then remove rocker arm shaft brackets. Lift rocker arms and swing back to provide accessibility to valve bridge.

2. Remove bridge and spring from guide.

3. Place bridge in a vise and loosen adjusting screw lock nut.

4. Install bridge on bridge guide without spring.

5. Press straight down on the pallet surface of bridge (fig. 2). Turn adjusting screw until it just touches the valve stem, then turn screw an additional $\frac{1}{8}$ to $\frac{1}{4}$ turn and tighten lock nut finger tight.

6. Remove bridge and place in a vise. With screwdriver, hold screw from turning and tighten lock nut on the adjusting screw. Complete the operation by tightening the lock nut to 25 ft. lbs. torque, being sure that screw does not turn.

IMPORTANT: Do not tighten while on engine as binding may damage bridge, guide, and valve.

7. Apply engine oil to bridge and bridge guide.

8. Reinstall the bridge in its original position without the bridge spring.

9. Place a .0015" feeler under each end of the bridge (fig. 3). **NOTE:** Feeler used at inner end of bridge must be narrow enough to fit in bridge locating groove. Pressing down on the pallet surface of the bridge, both feelers must be tight. If both feelers are not tight, readjust the screw as previously instructed.

10. Remove the bridge and reinstall in its original position with the bridge spring in place.

11. Adjust remaining bridges as instructed in previous paragraphs.

12. If cylinder head has been removed, reinstall on the engine. Tighten cylinder head stud nuts to their specified torque before assembling the rocker shaft brackets to the head. This precaution is necessary to prevent valve damage due to mislocated bridges.

13. Install the rocker arm assemblies, being sure valve bridges are properly positioned on the inner valve stems.

14. Tighten rocker shaft bracket bolts to their recommended torque.

15. Reconnect fuel jumper lines to injectors and connectors.

VALVE LASH ADJUSTMENT (4 Valve Type)

The clearance between the bridge adjusting screw and the valve stem should be set with the engine

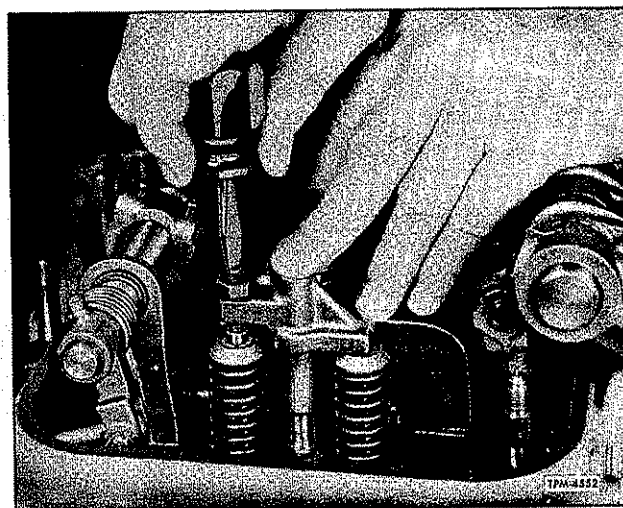


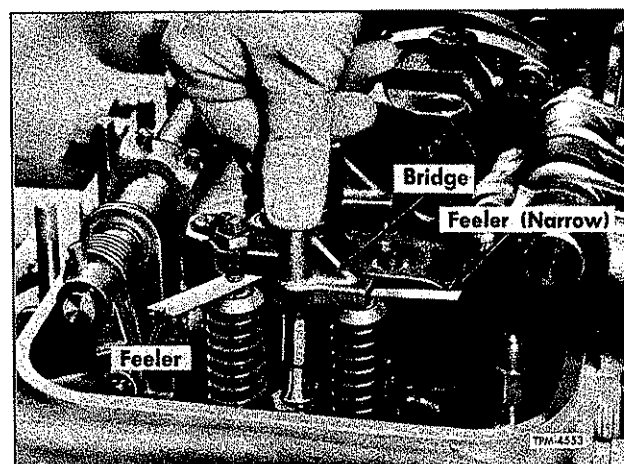
Figure 2—Adjusting Valve Bridge (4-Valve Head)

COLD. This setting should result in proper clearance at normal engine operating temperature. Refer to "Specifications" for COLD and HOT settings.

All valves may be lashed in firing order sequence during one full revolution of the crankshaft. **CAUTION:** Left hand rotation engines should not be barred in direction of rotation by use of wrench on crankshaft bolt. Refer to "General Information" in this manual for engine firing order.

VALVE LASH MUST ALWAYS BE ADJUSTED AT THE PUSH ROD. DO NOT DISTURB BRIDGE ADJUSTING SCREW.

1. Place governor throttle control lever in the **NO FUEL** position.



**Figure 3—Valve Bridge Adjustment Check
(4-Valve Head)**

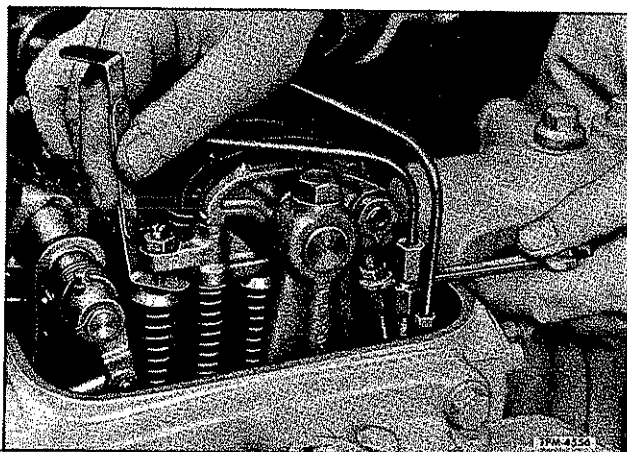


Figure 4—Valve Lash Adjustment (4-Valve Head)

2. Rotate crankshaft until the injector follower is fully depressed on the cylinder being adjusted.
3. Loosen push rod lock nut.
4. Place .017" feeler gauge between valve stem and valve bridge adjusting screw (fig. 4). Adjust push rod to obtain a smooth "pull" on the feeler gauge.
5. Remove feeler gauge. Hold push rod with wrench and tighten push rod lock nut.
6. Check and adjust remaining valves in manner described in previous paragraphs.
7. With engine at operating temperature (160°F. to 180°F.), recheck clearances. At this time, a .013" feeler gauge should pass between the end of the valve stem and the adjusting screw on the bridge and a .015" feeler gauge should not pass through. Readjust push rod if necessary.

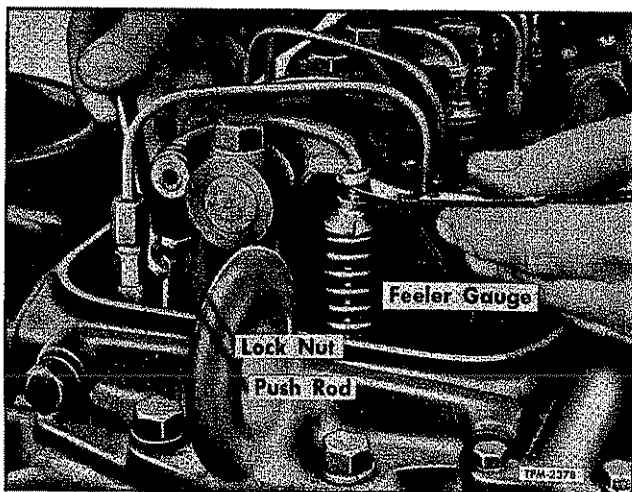


Figure 5—Valve Lash Adjustment (2-Valve Head)

VALVE LASH ADJUSTMENT (2 Valve Head)

1. Refer to figure 5 for reference to the following operation. To adjust valve clearance, use GO or NO GO feeler gauge set.
2. Remove valve rocker cover and set governor control lever in the no fuel position (off) to prevent accidental starting. As a further safety measure the emergency stop should be tripped at blower intake manifold as instructed in vehicle applicable maintenance manual.
3. Turn engine by use of a wrench placed on crankshaft cap retaining bolt or at barring hole in flywheel, also by starter to position valve rocker arms for adjustment.
4. The valve clearance should be measured only when the injector rocker arm has completely depressed the injector plunger for that particular cylinder.
5. Valve clearance adjustment may be made with a $\frac{5}{16}$ " open end wrench and a $\frac{1}{2}$ " open end wrench by loosening push rod locknut and turning the push rod with the wrench.
6. Place the thick end of feeler gauge between the end of the valve stem and the rocker arm, adjust push rod to obtain a smooth "pull" of feeler gauge.
7. Remove feeler gauge, hold push rod from turning and tighten push rod locknut.
8. Recheck clearance with feeler gauge. At this time the thin GO feeler should pass between end of valve stem and valve rocker arm. The thick NO GO feeler should not pass through. Readjust if necessary.

INJECTOR TIMING

To properly time the injector, the injector follower-guide must be adjusted to a definite height. Refer to figure 6 for reference to the following operation.

1. Set governor control lever in the no fuel (off) position.
2. Turn engine crankshaft manually or by means of the starter, until the exhaust valve rocker arms are fully depressed, for that particular cylinder.
3. The injector is identified by a colored tab stamped onto the injector body. Timing gauge of correct height must be used. Refer to "Injector Identification Chart" in **FUEL INJECTOR** section of this manual for injector identification and timing gauge height.

4. Place the injector timing gauge in the hole provided on top of the injector body with one of the "flats" toward the injector.

5. Adjust the injector rocker arm by loosening lock nut and turning the push rod with an end wrench, until the bottom of the timing gauge head will just pass over (drag lightly) the top of the injector follower guide.

6. Hold push rod from turning and tighten lock nut. Recheck adjustment with injector timing gauge and readjust if necessary.

GOVERNOR ADJUSTMENTS

Maximum efficiency, economy, and satisfactory performance of the engine cannot be obtained unless the governor is carefully and accurately adjusted. Adjustments must be performed in logical sequence. Reference should be made to respective **GOVERNOR** section of this manual for complete adjustment procedure, also to "Control Rack Positioning" in **FUEL INJECTOR** section of this manual.

THROTTLE DELAY ADJUSTMENT

The following instructions outline a procedure to follow when adjusting the throttle delay cylinder. Refer to figure 7.

1. Adjustment is made with the engine stopped.
2. Loosen two bolts attaching clamp to injector control tube.
3. Temporarily install a gauge between injector body and shoulder on injector rack (fig. 7). Gauge is .404" (approx. $1\frac{3}{32}$ ") thick and can be made locally.
4. Position gauge as shown and exert a light pressure on the control tube in the direction of full fuel.
5. Align the piston so it is flush with the cylinder edge.
6. Tighten the two clamp bolts, then remove gauge.
7. Rotate the injector control rack from "OFF" to "FULL" position to be sure it does not bind.

NOTE: Each time the injector racks are set the throttle delay must be first taken out of adjustment; injector racks are then set and the throttle delay re-adjusted.

FUEL MODULATOR ADJUSTMENT

The following adjustment should only be performed after other adjustments, such as, bridge balancing,

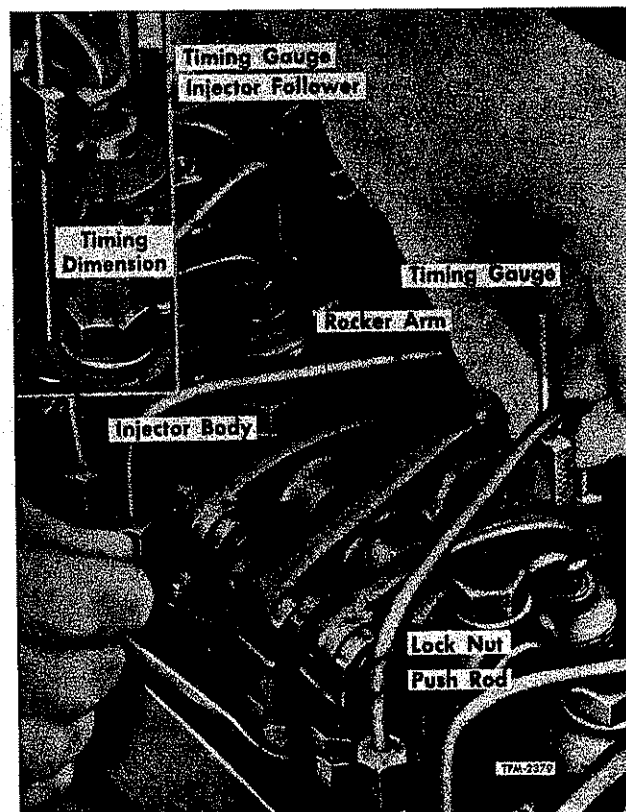


Figure 6—Timing Fuel Injector

valve lash, fuel injectors and governor adjustments have been completed.

1. Hold fuel modulator piston and cam in high speed position by applying not less than 20 psi air pressure to piston or by prying cam out with a screwdriver (fig. 8).

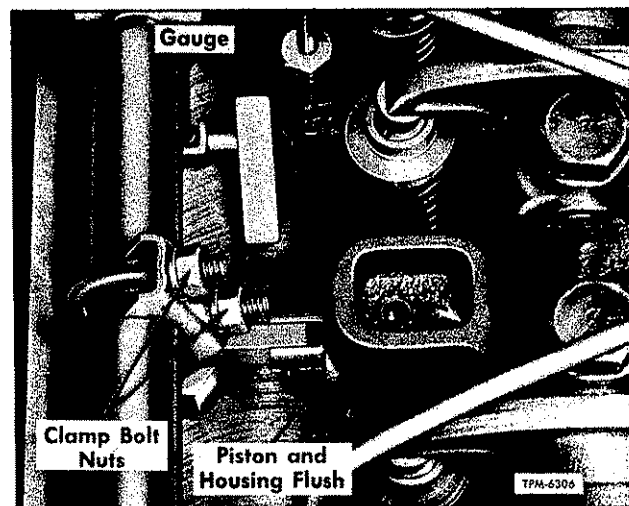


Figure 7—Throttle Delay Adjustment

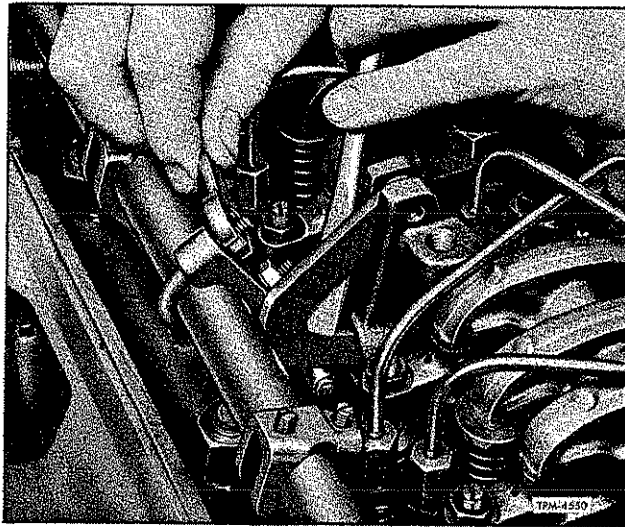


Figure 8—Fuel Modulator Adjustment

2. Hold injector rack in the full fuel position. While holding injector rack, move fuel modulating lever and roller assembly until roller contacts cam, then carefully tighten clamping nuts on "U" bolt. Avoid changing position of roller while tightening clamp bolt nuts.

3. Check adjustment several times as follows to be sure that it is correct.

a. Pry fuel modulating cam out with a screwdriver.

b. Move injector control tube to full fuel position.

c. Relax pressure on the screwdriver slightly and allow the cam to move slightly. If properly set the roller, of the fuel modulating lever and roller assembly, will rotate as soon as cam moves. (Repeat this check several times because it is rather easy to disturb a proper setting while tightening the "U" bolt clamping nuts.)

Diagnosis and Trouble Shooting

TESTING AND DIAGNOSIS

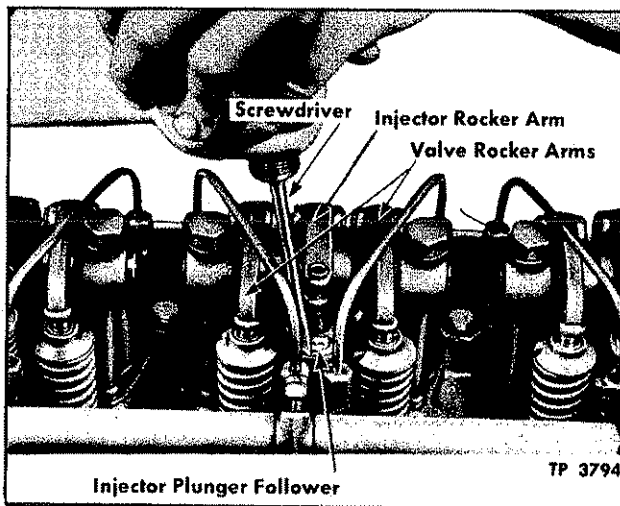
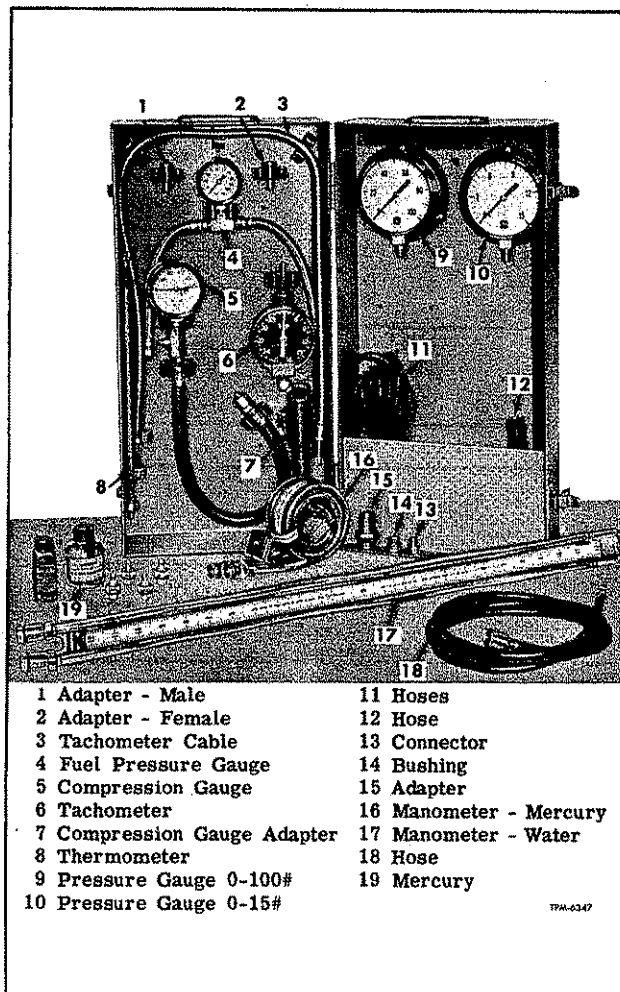
Various diesel engine pressures can be a definite aid in determining the condition of an engine or in diagnosing engine difficulties when abnormal operation is apparent. An engine which operates satisfactorily is characterized by normal air box pressure, crankcase pressure, exhaust back pressure, compression pressure, and low air intake restriction. Normal pressures are indicative of an efficient engine which, if properly tuned, is providing maximum power and torque for vehicle requirements while consuming as little fuel as possible consistent with the design of the engine.

Normal diesel engine pressures are presented herein and will prove useful as a means of measuring the operating condition of an engine. An attempt is made to list symptoms and causes of abnormal pressures however experience with the diesel engine and a basic knowledge of its operation are pre-requisites to the intelligent use of the pressures shown. The "TROUBLE-SHOOTING" section of this manual will also prove helpful in diagnosing the cause of abnormal pressures when encountered.

DIESEL ENGINE NORMAL PRESSURE CHART

	Manometer or Magnehelic Gauge	Pressure Gauge
Minimum Air Box Pressure		
Except "E" and "SE"—4-71	9.0" HG	4.4 PSI
Except "E" and "SE"—6-71	10.0" HG	4.9 PSI
"E" Series—2 Valve Head	6.5" HG	3.2 PSI
"ES" Series—4 Valve Head	6.0" HG	3.0 PSI
Maximum Crankcase Pressure		
4-71	2.7" H2O	
6-71	3.0" H2O	
Exhaust Back Pressure	5.0" HG	2.5 PSI
Maximum Blower Intake Restriction		
Clean Air Cleaner	20.0" H2O	
Dirty Air Cleaner	30.0" H2O	
Fuel Pressure at Inlet Manifold		
Normal		40-50 PSI
Minimum		20 PSI
Lubricating Oil Pressure		
Normal		40-60 PSI
Minimum for Safe Operation		30 PSI
Coolant Temperature—160°-185°		
Lubricating Oil Temperature—200°-225°		
Compression Pressure—600 RPM at Sea Level		
Average—New Engine—Except "E" and "SE"		450 PSI
Average—New Engine—"E" and "SE"		475 PSI
Minimum—"E" and "SE"		420 PSI
Minimum—Except "E" and "SE"		400 PSI

NOTE: Unless otherwise indicated, above specifications are taken at 2000 RPM,
 at 1500 feet above sea level, and at 90°F.
 H2O=Water—HG=Mercury—PSI=Lbs. Per Sq. In.

TESTING AND DIAGNOSIS**Figure 1—Cutting Out an Injector****Figure 2—Diagnosis Test Kit****LOCATING A MISFIRING CYLINDER**

1. Start engine and run at part load until it reaches normal operating temperatures.

2. Remove valve cover.

3. Run engine at IDLE speed and check valve clearance. The clearance should be .009" (two valve cylinder head) or .014" (four valve cylinder head).

4. Hold the No. 1 injector follower down with a screwdriver (fig. 1), thus preventing operation of the injector.

If the cylinder has been misfiring, there will be no noticeable difference in the sound and operation of the engine. If the cylinder has been firing properly, there will be a noticeable difference in the sound and operation when the plunger is held down. This is similar to short-circuiting a spark plug of a gasoline engine.

5. If cylinder No. 1 is firing properly, repeat the procedure on the other cylinders until the faulty one has been located.

6. Providing that the injector operating mechanism of the faulty cylinder is functioning satisfactorily, replace the fuel injector.

7. If the installation of the new injector does not eliminate the misfiring, the compression pressure of all cylinders should be checked.

COMPRESSION PRESSURE TEST

1. Start engine and run at approximately one-half rated load until normal operating temperature is reached.

2. With engine stopped, remove fuel pipes from the injector and fuel connectors.

3. Remove the injector from No. 1 cylinder, then install adapter and pressure gauge in its place as shown in figure 3.

4. Use one of the two fuel pipes as a jumper connection between the fuel inlet and return manifold to permit fuel to flow directly to the return manifold.

5. Start the engine and run at 600 rpm. Observe and record the compression pressure indicated on the gauge.

NOTE: Do not crank the engine with cranking (starting) motor to obtain the compression pressure.

6. Perform this operation on each cylinder. The compression pressure in any one cylinder should be not less than 400 psi at 600 rpm. In addition, the varia-

TESTING AND DIAGNOSIS

tion in compression pressures between cylinders of the engine must not exceed 25 psi at 600 rpm.

7. Low cylinder pressures may result from any one of several causes:

a. Piston rings may be stuck or broken. To determine the condition of the rings, inspect them through hand hole cover openings.

b. Compression may be leaking past the cylinder head gasket, the valve seats, the injector tubes, or a hole in the piston.

CRANKCASE PRESSURE TEST

A crankcase pressure of two to three inches of water at 2000 rpm is normal and indicates the amount of air passing between the oil control rings and the liner into the crankcase, most of which is clean air from the air box. A slight pressure in the crankcase is desirable to prevent the entrance of dust. A loss of engine lubricating oil through the governor breather tube, crankcase ventilator, or dipstick hole in the cylinder block is indicative of excessive crankcase pressure.

The causes of high crankcase pressure may be traced to excessive blow-by due to worn piston rings, a hole or crack in a piston crown, loose piston pin retainers, worn blower oil seals, defective blower, cylinder head or end plate gaskets, or excessive exhaust back pressure. Also, the breather tube or crankcase ventilator should be checked for obstructions.

The crankcase pressure may be checked by means of manometer in the engine diagnosis test kit. The manometer should be connected to the oil level dipstick opening in the cylinder block (fig. 4). Check the reading obtained with the pressure given in "Diesel Engine Normal Pressure Chart."

EXHAUST BACK PRESSURE TEST

A slight pressure in the exhaust system is normal. However, excessive exhaust back pressure seriously affects engine operation. It may cause an increase in the air box pressure with a resultant loss of efficiency of the blower. This means less air for scavenging which results in poor combustion and higher temperatures.

Causes of high exhaust pressure are usually a result of an inadequate or improper type of muffler, an exhaust pipe which is too long or too small in diameter, an excessive number of sharp bends in the exhaust system, or obstructions such as excessive carbon formation or foreign matter in the exhaust system.

The exhaust back pressure, measured in inches of

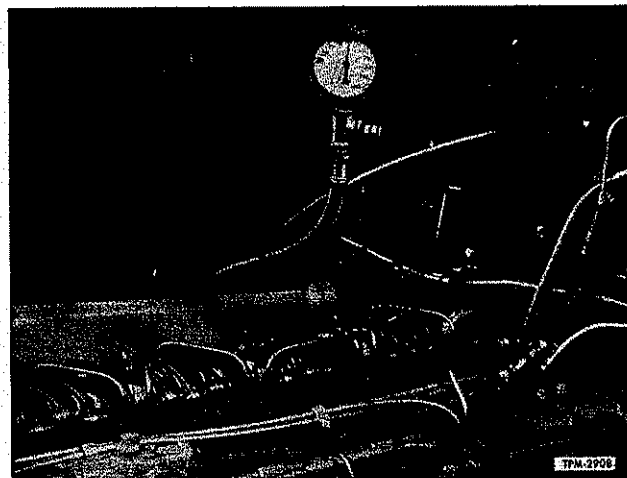


Figure 3—Checking Compression Pressure

mercury, may be checked with manometer in the engine diagnosis test kit. The manometer is connected for that purpose (fig. 5). If there is no opening provided, one can be made by drilling an $1\frac{1}{32}$ " hole in the exhaust manifold companion flange and tapping for $\frac{1}{8}$ " pipe thread.

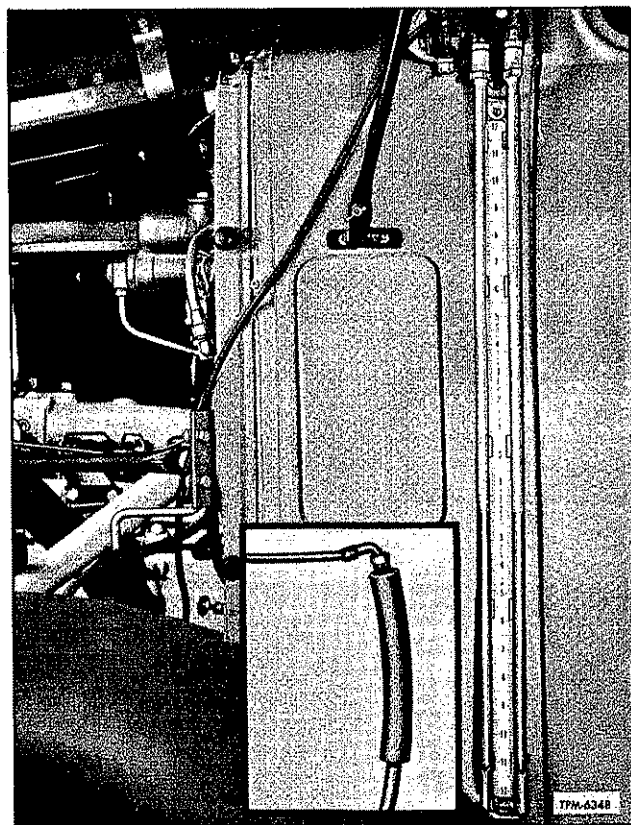


Figure 4—Checking Crankcase Pressure

TESTING AND DIAGNOSIS

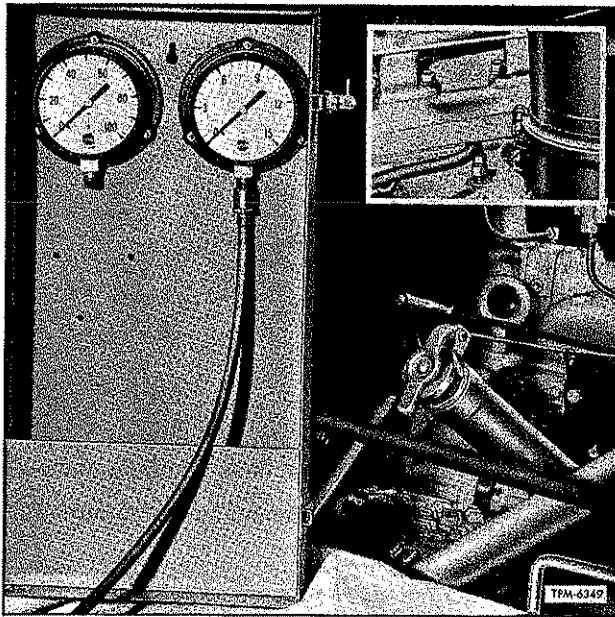


Figure 5—Checking Exhaust Pressure

Check the readings obtained at various speeds (at no load) with the specifications in the "Diesel Engine Normal Pressure Chart."

AIR BOX PRESSURE TEST

Proper air box pressure is required to maintain sufficient air for combustion and scavenging of the burned gases. Low air box pressure is caused by a high air intake restriction, damaged blower rotors, an air lead from the air box (such as leaking end plate gaskets), a clogged blower air inlet screen, or plugged cylinder liner ports. Lack of power, or black or grey exhaust smoke are indications of low air box pressure.

To check the air box pressure, connect manometer of engine diagnosis test kit to the air box of the cylinder block by removing one of the $\frac{1}{4}$ " pipe plugs located beneath the hand hole cover on the side of the engine opposite the blower, or to an air box drain (fig. 6).

Check the readings obtained at various speeds with the specifications in the "Diesel Engine Normal Pressure Chart."

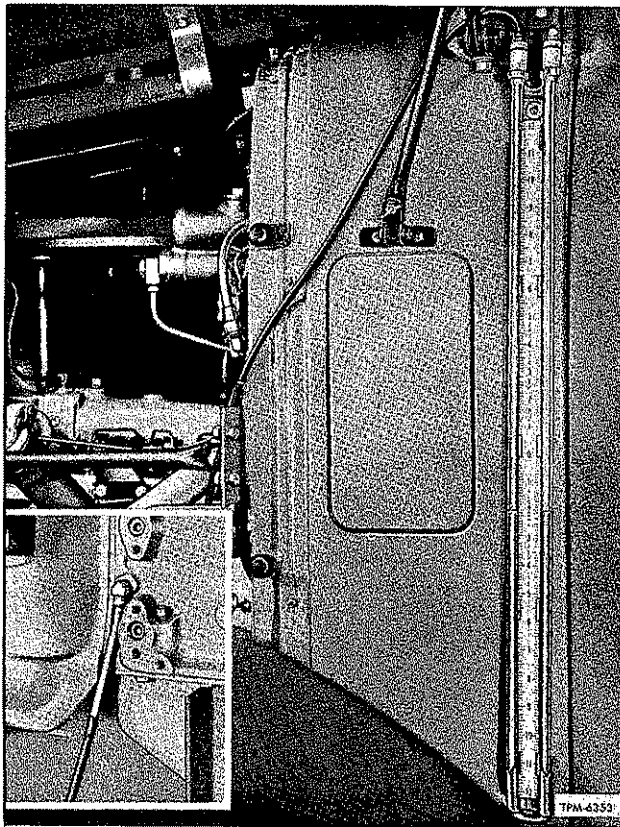


Figure 6—Checking Air Box Pressure

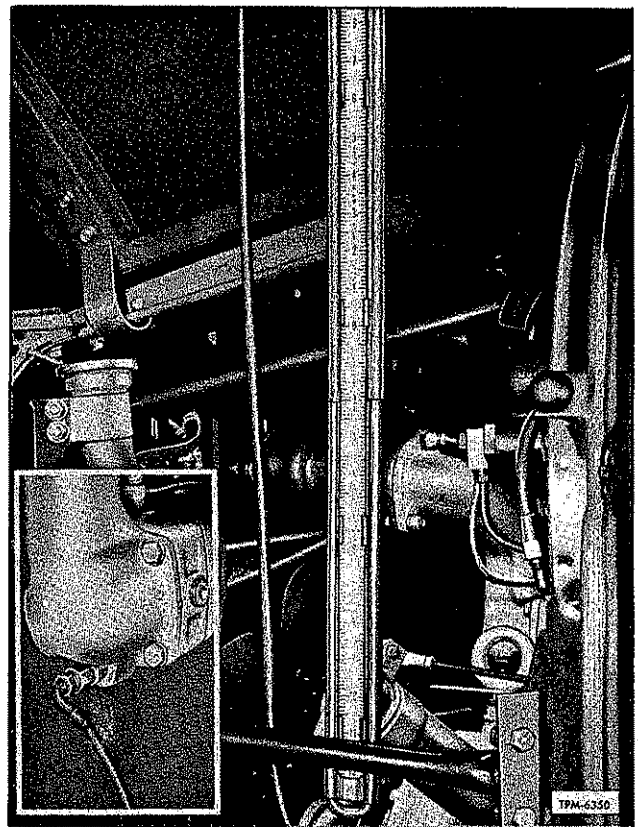


Figure 7—Checking Cooling System Pressure

TESTING AND DIAGNOSIS

AIR INTAKE RESTRICTION TEST

Excessive restriction of the air intake will affect the flow of air to the cylinders and result in poor combustion and lack of power. Consequently, the restriction must be kept as low as possible considering the size and capacity of the air cleaner. An obstruction in the air inlet system or dirty or damaged air cleaners will result in a high blower intake restriction.

The air intake restriction may be checked with manometer of engine diagnosis test kit. Connect the manometer to the blower air inlet assembly in the drilled and tapped hole provided for the cold weather starting aid connection.

Check the normal air intake vacuum at various speeds (at no load) and compare the results with specifications given in "Diesel Engine Normal Pressure Chart."

COOLING SYSTEM PRESSURE TEST

Remove the radiator test cock or convenient plug opening that will permit installation of 0-15 pressure gauge (fig. 7).

Start engine and observe pressure. With engine at normal operating temperature, from one to four and one-half (1 to 4½) pounds pressure should be indicated on the gauge.

ENGINE OIL PRESSURE TEST

To check operating oil pressure connect the 0-100 pressure gauge to the oil gallery or into oil line from gallery to oil filter (fig. 8).

Start engine. At 2,000 rpm normal engine operating oil pressure is between twenty-five (25) and fifty (50) pounds.

FUEL PRESSURE TEST

The Fuel Pressure Gauge is designed for use in checking fuel pressure at the injector with the engine in operation. Remove the jumper line from the injector to the return fuel manifold and connect the fuel gauge in place of the jumper line (fig. 9). At 2,000 rpm normal fuel pressure should be fifteen (15) pounds minimum.

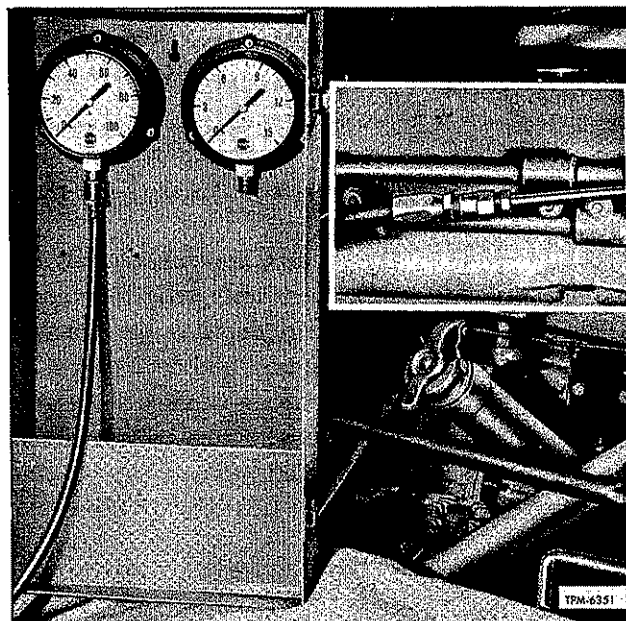


Figure 8—Checking Engine Oil Pressure

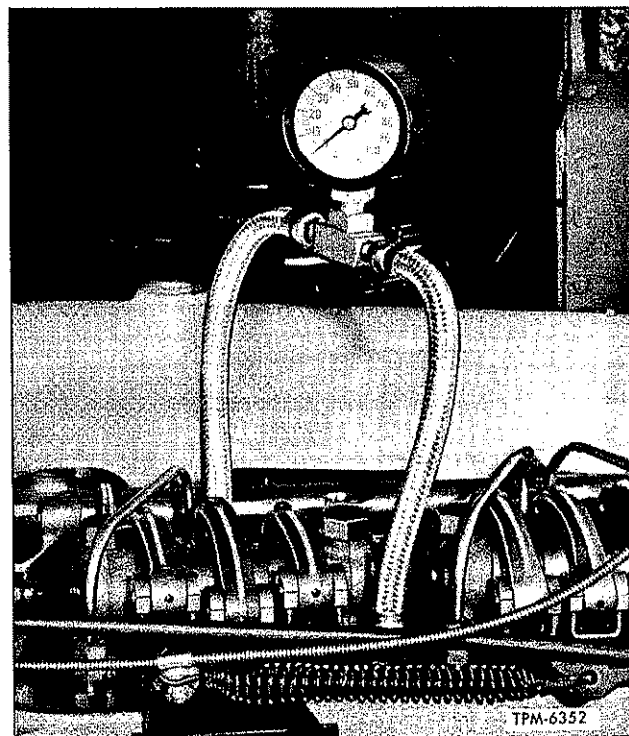


Figure 9—Checking Fuel Pressure at Injector

TROUBLE SHOOTING

The satisfactory performance of a Diesel engine depends on two items of foremost importance, (1) Sufficiently high compression pressure, and (2) The injection of the proper amount of fuel at the right time.

The first one of these items depends entirely on pistons, piston rings, valves, and valve operating mechanism; the second item depends on injectors and their operating mechanism, and fuel system.

Lack of engine power, uneven running, excessive vibration, and tendency to stall when idling may be caused by either a compression loss or faulty injector operation.

The causes of trouble symptoms may be varied; therefore a hit-and-miss search should be avoided. A proper diagnosis of symptoms is an orderly process of diagnosing the symptoms. An "orderly process" means to check the most probable common cause first; then proceed with the next probable cause.

The quick reference Trouble Shooting Charts on pages following lists symptoms, with probable causes, and remedies. References are made to other charts, also to various sections in this manual, which list correct remedies and procedures.

Hard Starting

Trouble—Cause—Remedy

LOW STARTING R.P.M.

IMPROPER LUBE OIL VISCOSITY—Refer to "Engine Oil Viscosity Chart."

INFREQUENT OIL CHANGES—Change oil at recommended intervals.

LOW BATTERY OUTPUT—Check for the following:

1. Poor or Shorted Connections—Properly connect or replace leads and terminals.
2. Undercharged or Defective—Recharge or replace battery.
3. Low Ambient Temperature—Use a starting aid.

FAULTY STARTER OR LOOSE STARTER CONNECTIONS—Replace starter or tighten connections.

LOW COMPRESSION

EXHAUST VALVES STICKING OR BURNED—Overhaul cylinder head.

COMPRESSION RINGS WORN OR BROKEN—Overhaul cylinder liner assemblies.

CYLINDER HEAD GASKET LEAKING—Replace cylinder head gasket.

IMPROPER VALVE CLEARANCE ADJUSTMENT—Adjust valve clearance.

BLOWER NOT FUNCTIONING—Check blower drive shaft and couplings.

EMERGENCY SHUT-OFF VALVE PARTIALLY OR COMPLETELY CLOSED—Reset.

TROUBLE SHOOTING

HARD STARTING (Cont.)

FUEL

AIR LEAKS, FLOW OBSTRUCTION, FUEL PUMP—Refer to “No Fuel or Insufficient Fuel” chart.

INJECTOR RACKS NOT IN FULL FUEL POSITION—Check control tube for binds and reset governor and control rack, if necessary.

FUEL TANK OR FUEL FILTER EMPTY—Fill fuel tank or prime filter.

IMPROPER GRADE AND TYPE FUEL—Refer to “Fuel Oil Specifications.”

DILUTED FUEL—Check storage and handling methods.

IMPROPERLY FILTERED OR RESTRICTED FUEL FLOW—Refer to “No Fuel or Insufficient Fuel” chart.

AIR IN FUEL SYSTEM—Bleed air from fuel system at secondary fuel filter.

Abnormal Engine Operation

Trouble—Cause—Remedy

UNEVEN RUNNING OR FREQUENT STALLING

CYLINDERS CUTTING OUT—Check for the following:

1. Valve Clearance Set Incorrectly—Readjust valve clearance as directed under “Valve Lash” in “Engine Tune-up.”
2. Insufficient Fuel—Refer to “No Fuel or Insufficient Fuel” chart.
3. Faulty Injector—Refer to “Injector Tests” under “Fuel Injectors.”

COOLING SYSTEM TEMPERATURE BELOW NORMAL—Refer to “Abnormal Engine Coolant Temperatures.”

NO FUEL OR INSUFFICIENT FUEL—Refer to “No Fuel or Insufficient Fuel” Chart.

FAULTY INJECTORS—

1. Improper Timing of Injectors—Retime injectors as directed under “Injector Timing.”
2. Incorrect Rack Setting—Readjust injector racks as outlined in the appropriate governor tune-up procedure.
3. Injector Spray Tip Leaks—Replace fuel injector.

CYLINDER PRESSURES LOW—Refer to “Hard Starting” chart.

TROUBLE SHOOTING**ABNORMAL ENGINE OPERATION (Cont.)****UNEVEN RUNNING OR FREQUENT STALLING—Cont.**

GOVERNOR INSTABILITY (HUNTING)—Check for the following:

1. Governor Instability—Perform engine tune-up.
2. Binding Injector Rack—Replace injector.
3. Faulty Adjustments—Perform appropriate tune-up procedure as outlined for the governor.

IMPROPER GRADE AND TYPE FUEL—Refer to "Fuel Oil Specifications."

DILUTED FUEL—check storage and handling methods.

IMPROPERLY FILTERED OR RESTRICTED FUEL FLOW—Refer to "No Fuel or Insufficient Fuel" chart.

DETONATION

OIL PICKED UP BY AIR STREAM—Check for the following:

1. Oil Pull Over From Air Cleaners—Remove, clean, and fill air cleaners with engine oil to proper oil level.
2. Accumulation in Air Box—Clean air box and air box drain tubes.
3. Defective Blower to Cylinder Block Gasket—Remove blower and gasket and install a new gasket and reinstall blower.
4. Leaking Blower Oil Seals—Remove and overhaul blower.

LOW COOLANT TEMPERATURE—Refer to "Abnormal Engine Coolant Temperatures" chart.

FAULTY INJECTORS—Check for the following:

1. Improper Timing—Retime injectors as directed under "Injectors Timing" in "Engine Tune-up."
2. Check Valve Leaking—Replace injector.
3. Spray Tip Holes Enlarged—Replace injector.
4. Broken Spray Tip—Replace injector.

LACK OF POWER

IMPROPER ENGINE ADJUSTMENTS—Check for the following:

1. Governor Gap Set Incorrect—Perform appropriate governor tune-up.
2. Rack Setting Incorrect—Perform appropriate governor tune-up.
3. Injector Timing Incorrect—Time fuel injectors as directed under "Injector Timing."
4. Valve Clearance Set Incorrectly—Readjust valve clearance as directed under "Valve Lash" in "Engine Tune-up."

ABNORMAL ENGINE OPERATION (Cont.)

LACK OF POWER—Cont.

INSUFFICIENT FUEL—Refer to “No Fuel or Insufficient Fuel” chart.

INSUFFICIENT AIR—Check for the following:

1. Air Cleaners Damaged or Clogged—Remove and clean, repair or replace damaged parts.
2. Cylinder Liner Air Inlet Ports Clogged—Clean cylinder liner ports.
3. Low Compression—Refer to “Low Compression” in “Hard Starting” chart.
4. Blower Air Intake Obstructed—Check and clean air cleaner and air inlet horn and screen.
5. Excessive Exhaust Back Pressure—Inspect exhaust pipe and muffler and replace if damaged.

Exhaust Smoke Analysis

(Checks to be made with water outlet temperature of 165°F. minimum)

Trouble—Cause—Remedy

BLACK OR GRAY SMOKE

INCOMPLETELY BURNT FUEL—Check for the following:

1. Insufficient Combustion Air—
 - a. High exhaust back pressure (measured with manometer)—Check exhaust piping and muffler for obstruction.
2. Restricted Air Inlet—
 - a. Cylinder liner ports clogged—Clean liner ports.
 - b. Air cleaner clogged or damaged—Remove and clean, repair or replace damaged parts.
 - c. Emergency stop not completely open—Check operation of emergency shutdown device and adjust if necessary.
 - d. Blower to air horn screen clogged—Remove screen and clean.

EXCESSIVE FUEL OR IRREGULAR FUEL DISTRIBUTION—Check for the following:

1. Improper Injector Rack Setting—Perform appropriate governor tune-up.
2. Improper Timing of Injectors—Time fuel injectors as directed under “Injector Timing.”
3. Faulty Injectors—Replace injectors.
4. Lugging Engine—Correct driving practices.

IMPROPER GRADE OF FUEL—Refer to “Fuel Oil Specifications.”

TROUBLE SHOOTING

EXHAUST SMOKE ANALYSIS (Cont.)

BLUE SMOKE

FUEL OR LUBRICATING OIL NOT BURNED IN CYLINDER (BLOWN THROUGH CYLINDER DURING SCAVENGING PERIOD)—Check for the following:

1. Internal Lubricating Oil Leaks—Refer to “High Lubricating Oil Consumption” chart.
2. Pullover of Air Cleaner Oil—Oil level to high or to light viscosity.

FAULTY INJECTOR—Refer to “Uneven Running or Frequent Stalling” in “Abnormal Engine Operation” chart.

COOLING SYSTEM TEMPERATURE BELOW NORMAL—Refer to “Abnormal Engine Coolant Temperatures” chart.

WHITE SMOKE

MIS-FIRING CYLINDERS—Check for the following:

1. Faulty Injectors—Replace injectors.
2. Low Compression—Refer to “Hard Starting” chart.
3. Low Cetane Fuel—Refer to “Fuel Oil Specifications.”

No Fuel or Insufficient Fuel

Trouble—Cause—Remedy

AIR LEAKS

LOW FUEL SUPPLY—Fill fuel tank.

LOOSE CONNECTIONS OR CRACKED LINES BETWEEN FUEL PUMP AND TANK OR SUCTION LINE IN TANK—Tighten connections and replace defective lines and fittings.

DAMAGED FUEL OIL STRAINER GASKET—Replace gasket.

FAULTY INJECTOR TIP ASSEMBLY—Make “Fuel Pressure Test” after ascertaining that all fuel lines and connections are assembled correctly. Replace faulty injectors.

FUEL FLOW

FUEL FILTER OR LINES RESTRICTED—Make “Fuel Pressure Test” and clean primary filter element or replace secondary and injector filter elements, also fuel lines if necessary.

NO FUEL OR INSUFFICIENT FUEL (Cont.)

FUEL FLOW—Cont.

TEMPERATURE LESS THAN 10°F. ABOVE THE POUR POINT OF FUEL—Refer to “Fuel Oil Specifications.”

RESTRICTED FITTING MISSING FROM RETURN MANIFOLD—Install new restricted fitting.

FAULTY FUEL PUMP

RELIEF VALVE NOT SEATING—Make “Fuel Pressure Test” and clean and inspect valve and seat assembly.

WORN GEARS OR PUMP HOUSING—Replace gear and shaft assembly and fuel pump if housing is damaged.

FUEL PUMP NOT ROTATING—Check condition of fuel pump drive and blower drive and replace if necessary.

High Lubricating Oil Consumption

Trouble—Cause—Remedy

EXTERNAL LEAKS

OIL LINES AND CONNECTIONS LEAKING—Tighten or replace defective parts.

GASKET OR OIL SEAL LEAKS—Replace defective gaskets or oil seals.

HIGH CRANKCASE PRESSURE—Refer to “High Crankcase Pressure” chart.

EXCESSIVE OIL IN AIR BOX—Refer to “Detonation” in “Abnormal Engine Operation” chart.

INTERNAL LEAKS

BLOWER OIL SEAL LEAKING—Remove and overhaul blower.

OIL COOLER CORE LEAKING—Replace oil cooler core and use a good cooling system cleaner to remove oil from water passages.

ENGINE BLOCK END PLATE GASKETS LEAKING—Replace block to end plate gaskets.

TROUBLE SHOOTING

HIGH LUBRICATING OIL CONSUMPTION (Cont.)

OIL CONTROL AT CYLINDER

OIL CONTROL RINGS WORN, BROKEN, OR IMPROPERLY INSTALLED—Replace rings on piston.

PISTON PIN RETAINER LOOSE—Replace piston retainer and defective parts.

SCORED LINERS, PISTONS, OR OIL RINGS—Remove and replace defective parts.

PISTON AND ROD ALIGNMENT (CAUSED BY WORN CRANKSHAFT THRUST WASHERS)—
Replace worn and defective parts.

EXCESSIVE INSTALLATION ANGLE—Decrease installation angle.

Low Oil Pressure

(Check to be made with engine water outlet temperature of 165°F. minimum)

Trouble—Cause—Remedy

LUBRICATING OIL

SUCTION LOSS—Check oil level and bring to “FULL” mark on dipstick or correct installation angle.

LUBRICATING OIL VISCOSITY—Check for the following:

1. Wrong Viscosity Lubricating Oil—Refer to “Engine Oil Viscosity” chart.
2. Plugged Oil Cooler—Clean oil cooler if oil temperature is abnormally high.
3. Fuel Oil Dilution—Check for fuel leaks at injector seal ring, fuel jumper line connections, and fuel manifolds.

PRESSURE GAUGE

FAULTY GAUGE—Replace gauge.

GAUGE LINE OBSTRUCTED—Remove and clean line, replace if necessary.

ORIFICE PLUGGED—Remove and clean orifice.

ELECTRICAL INSTRUMENT SENDING UNITS—Repair or replace defective equipment.

LOW OIL PRESSURE (Cont.)

CIRCULATION

STRAINER OR FILTER CLOGGED—Remove and clean or replace element.

COOLER CLOGGED—Remove oil cooler and clean.

COOLER BY-PASS VALVE NOT FUNCTIONING PROPERLY—Remove by-pass valve, clean valve and valve seat and inspect valve spring.

PRESSURE REGULATOR VALVE NOT FUNCTIONING PROPERLY—Remove pressure regulator valve and clean and inspect spring.

EXCESSIVE WEAR OF CRANKSHAFT BEARINGS—Change engine bearings, clean oil pan, refer to "Engine Oil Viscosity Chart" for proper grade, and change oil filter element.

GALLERY, CRANKSHAFT OR CAMSHAFT PLUGS MISSING—Replace plugs.

OIL PUMP

INTAKE SCREEN PARTIALLY CLOGGED—Remove oil pan and screen, clean oil pan and screen, refer to "Engine Oil Viscosity Chart" and refill crankcase and change oil filter element.

RELIEF VALVE NOT PROPERLY FUNCTIONING—Remove and inspect valve, valve bore, and spring.

AIR INTAKE IN PUMP INLET SYSTEM—Disassemble piping and install new gaskets.

PUMP WORN OR DAMAGED—Remove pump, clean and replace defective parts.

FLANGE LEAK PRESSURE SIDE—Remove flange and replace gasket.

Excessive Crankcase Pressure

Trouble—Cause—Remedy

CYLINDER BLOW-BY

CYLINDER HEAD GASKET LEAKING—Remove and replace head gaskets.

PISTON AND LINER DAMAGED—Remove and replace piston and liner.

PISTON RINGS WORN OR BROKEN—Remove and replace piston rings.

PISTON PIN RETAINER LOOSE—Remove.

TROUBLE SHOOTING

EXCESSIVE CRANKCASE PRESSURE (Cont.)

BREATHER RESTRICTION

OBSTRUCTION OR DAMAGE TO BREATHER—Clean, repair or replace breather.

AIR FROM BLOWER OR AIR BOX

DAMAGED BLOWER-TO-BLOCK GASKET—Remove blower and gasket, replace with new gasket.

ENGINE BLOCK END PLATE GASKETS LEAKING—Replace block to end plate gaskets.

BLOWER OIL SEAL LEAKING—Remove and overhaul blower.

EXCESSIVE EXHAUST BACK PRESSURE

EXCESSIVE MUFFLER RESISTANCE—Repair or replace muffler.

OBSTRUCTION IN MUFFLER—Repair or replace muffler.

EXHAUST PIPING—Check for the following:

1. Too Small—Replace with larger piping.
2. Too Long—Replace with larger piping.
3. Excessive Number of Bends—Reduce number of bends or replace with larger piping.
4. Use of Street Elbows—Replace with pipe elbows.

Abnormal Engine Coolant Temperatures

Trouble—Cause—Remedy

ABOVE NORMAL OPERATING TEMPERATURES

INSUFFICIENT HEAT TRANSFER—Check for the following:

1. Scale Deposits in Cooling System—Clean cooling system with a good cooling system cleaner and flush thoroughly.
2. Radiator Core Plugged Preventing Normal Air Flow—Clean outside of radiator core.
3. Fan Belt Loose—Tighten fan belt.
4. Improper Installation—Improper shrouding of fan.

TROUBLE SHOOTING

ABNORMAL ENGINE COOLANT TEMPERATURES (Cont.)

ABOVE NORMAL OPERATING TEMPERATURES

POOR CIRCULATION—Check for the following:

1. Coolant Level too Low—Fill radiator to filler neck.
2. Hoses Collapsed or Disintegrated—Replace hoses.
3. Thermostat Damaged—Replace thermostat.
4. Water Pump Impeller Loose on Shaft—Replace impeller and pin to shaft.
5. Inadequate Water Supply on Suction Side of Pump—Caused by:
 - a. Radiator Clogged—Clean radiator.
 - b. Combustion Gases in Cooling Water—Replace all head gaskets and inspect cylinder head for cracks on injector tube leaking.
 - c. Air in Cooling System—Caused by:
 - (1) Air Leak on Suction Side of Water Pump—Replace defective parts.
 - (2) Thermostat Housing Vent Not Open When Filling System—Open vent valve while filling system.

BELOW NORMAL

POOR CIRCULATION—Check for the following:

1. Thermostat Housing Vent Valve Open or Not Seating—Remove and clean up vent valve and seat in housing.
2. Thermostat Inoperative—Replace thermostat.
3. Thermostat Seat Damaged—Replace thermostat.

Special Tools

Reference is made to special tools and in many instances, are illustrated in this manual. These tools, or their equivalent, are necessary and are recommended to more readily and efficiently accomplish certain service operations. The tools, however, are not supplied by GMC Truck & Coach Division. Names and addresses of vendors or manufacturers are shown as a reference, and since such vendors are the sup-

pliers of these tools, information regarding availability, price etc. should be obtained directly from them. The tools are listed on following pages in order of reference in the text.

VENDORS

J=Kent Moore Organization, Warren, Michigan

KMO=Kent Moore Organization, Warren, Michigan

VENDOR TOOL NUMBER

TOOL NAME

SHOP EQUIPMENT

J1926-02	Engine Overhaul Stand and Adapter Plate
J-6837	Engine Overhaul Stand
J-8196	Adapter Plate
J-6387	Engine Parts Dolly

CYLINDER BLOCK AND LINERS

J-1927-01	Cylinder Block End Plate Aligning Stud Set
J-1918-02	Cylinder Liner Remover
J-5518	Cylinder Liner Clamp Retainer Set
	Cylinder Liner Clamping and Checking Set
J-5580	Cylinder Diameter Checking Gauge Set

CRANKSHAFT

J-3051	Crankshaft Gear Puller
J-4194	Crankshaft Oil Seal Sleeve Installer
J-872-5	Drive Handle for J-4194
J-1359	Crankshaft Oil Seal Expander
J-4195	Crankshaft Oil Seal Expander For Oversize Seal
J-5356	Fan Puller Hub Puller

FLYWHEEL AND CLUTCH PILOT

J-1904-01	Flywheel Puller Screws
J-6361-01	Flywheel Lifting Hook
J-4257	Flywheel Replacing Studs
J-1927-01	Flywheel Housing Aligning Studs
	Flywheel Bushing Installer (V-Transmission)
J-3187-A	Clutch Pilot Bearing Puller
J-3895	Clutch Pilot Tool Truck 4-71—Prior to 1955
J-6307	Clutch Pilot Tool 6-71 Truck, also 4-71 after 1955
	Clutch Pilot Tool Coach 4-71
J-1915	Clutch Pilot Tool Coach 6-71
J-1917-A	Tachometer Drive Remover
J-5901-3	Tachometer Drive Remover Adaptor

VENDOR TOOL NUMBER

TOOL NAME

PISTON AND CONNECTING ROD

J-3174-A	Piston Fitting Feeler Gauge Set
J-5438	Piston-to-Liner Feeler Gauge Set (Includes Next 3 Items)
HM-593-1	Tension Scale
J-593-14	Swivel Connection
J-3147-A	Feeler Gauges (9-14")
J-8128	Piston Ring Remover and Installer
J-3272-02	Piston Ring Compressor and Installer
J-3071-01	Piston Bushing Reamer Set
J-1513-02	Piston and Connecting Rod Bushing Installer and Remover (Includes Next 6 Items)
J-1513-1	Supporting Block
J-1513-2	Driver Handle
J-1513-3	Bushing Remover
J-1513-4	Spacer
J-1513-6	Bushing Installer
J-5118-A	Connecting Rod Holder
	Piston and Connecting Rod Bushing Remover and Installer Set
J-1686-01	Connecting Rod Bushing Reamer Set (Includes Next 4 Items)
J-1686-5	Rear Guide Bushing
J-1686-9	Fixture and Arbor
J-1686-10	Reamer
J-1686-11	Forward Guide Bushing
J-4895-01	Piston Pin Retainer Installer

CAMSHAFT AND GEAR TRAIN

J-1902-01	Camshaft Gear Puller W/Screws
J-1903	Camshaft and Oil Pump Gear Installer
J-1471	Blower Coupling Spring Spreader

CYLINDER HEAD AND VALVE MECHANISM

J-1928-01	Cylinder Head Nut Wrench
J-3087-01	Cylinder Head Holding Plate Set

SPECIAL TOOLS

SPECIAL TOOLS (Cont.)

VENDOR TOOL NUMBER	TOOL NAME	VENDOR TOOL NUMBER	TOOL NAME
CYLINDER HEAD AND VALVE MECHANISM—Cont.		BLOWER—Cont.	
J-8168	Valve Lash Feeler Gauge (.008"-.010")	J-6270—Cont.	
J-6653	Valve Lash Feeler Gauge (.013"-.015")	J-6270-4	Seal Ring Carrier, Collar, and Bearing Installer
J-6864	Valve Lash Feeler Gauge (.015"-.017")	J-6270-5	Blower Shaft Pilot
	Valve Guide Installer and Remover Set	J-6270-6	Gear and Bearing, and Seal Spacer Installer
J-267	Valve Guide Remover (2 Valve Head)	J-6270-7	Gear and Bearing Installer
J-6569	Valve Guide Remover (4 Valve Head)	J-6270-8	Gear Installing Screw, Nut, and Washer (Long)
J-4144	Valve Guide Replacer (2 Valve Head)	J-6270-9	Gear Installing Screw, Nut, and Washer (Short)
J-6570	Valve Guide Replacer (4 Valve Head)	J-1698-02	Blower Feeler Gauge Set
J-5437	Valve Guide Cleaner	J-4254	Blower Rotor Shaft Remover and Replacer Set (Includes Next 7 Items)
J-4824-01	Valve Seat Insert Remover (2 Valve Head)	J-4254-1	Screw
J-6567	Valve Seat Insert Remover (4 Valve Head)	J-4254-2	Body Sleeve
J-1736	Valve Seat Insert Installer (2 Valve Head)	J-4254-3	Cap
J-6568	Valve Seat Insert Installer (4 Valve Head)	J-4254-4	Forcing Nut
J-1227-01	Valve Spring Compressor (2 Valve Head)	J-4254-5	Tube
J-7455	Valve Spring Compressor (4 Valve Head)	J-4254-6	Collet
J-6846	Bridge Guide Replacer (4 Valve Head)	J-4254-8	Spacer
J-5840	Camshaft Follower Holding Fixture		
J-3092-01	Push Rod Remover Set		
	OIL PUMP		
J-2624	Oil Pump Bushing Reamer Set (Includes Next 4 Items)		FUEL INJECTORS
J-2624-1	Reamer (.622" Dia.)	J-1242	Injector Timing Gauge (1.484")
J-2624-2	Reamer (.645" Dia.)	J-1853	Injector Timing Gauge (1.460")
J-2624-3	Reamer Guide	J-1227-01	Injector Remover
J-2624-4	Canvas Bag	J-7509	Injector Testing Fixture
J-3051	Oil Pump Gear Puller	J-1261	Injector Body Vise (2 Valve Head)
J-1903	Oil Pump and Camshaft Gear Installer	J-3179	Lapping Block (Set of 3)
	WATER PUMP	J-3179-1	Lapping Block
J-4242	Water Pump Wrench	J-6259	Music Wire (.005" x 5')
J-1930	Water Pump Coupling Remover	J-6260	Music Wire (.006" x 5')
J-3277-01	Water Pump Impeller Installing Set (Includes Next 4 Items)	J-6261	Music Wire (.007" x 5')
J-3277-1	Installer—New Impeller—New Shaft	J-5119	Injector Tip Concentricity Gauge
J-3277-2	Installer—Old Impeller—New Shaft	J-6868	Injector Holding Fixture (2 or 4 Valve Head)
J-3277-3	Installer—New Impeller—Old Shaft	J-1241-03	Injector Service Set (Inc. Next 9 Items)
J-3277-5	Leatherette Kit	J-8152	Cleaning Brush (Rack and Bushing)
	BLOWER	J-8150	Cleaning Brush (Injector Nut)
J-6270	Blower Service Tool Set—Standard and Reduced Speed Types (Inc. Next 9 Items)	J-8170	Wire Sharpening Stone
J-6270-1	Gear, End Plate, and Seal Ring Carrier Puller	J-8169	Spray Tip Hole Cleaner
J-6270-2	Seal Ring Carrier Remover Adapter	J-1243	Spray Tip Reamer
J-6270-3	Bearings, and Seal or Collar Remover and Lip Seal Installer	J-4983-01	Injector Nut Wrench
		J-1291-01	Injector Spray Tip Driver and Bushing Cleaner
		J-4986-01	Injector Nut Tip Seat Reamer
		J-4987	Injector Valve Seat Deburring Stones (Pair)

SPECIAL TOOLS**SPECIAL TOOLS (Cont.)**

VENDOR TOOL NUMBER	TOOL NAME	VENDOR TOOL NUMBER	TOOL NAME
FUEL INJECTOR—Cont.		ENGINE TUNE-UP—Cont.	
J-5286	Injector Tube Reconditioning Set (Includes Next 10 Items)	J-7436—Cont.	
J-5286-1	Tube Holder	J-7436-1	Metal Box
J-5286-2	Tap	J-4209-7	0-15 Pound U.S. Pressure Gauge
J-5286-3	Tap Driving Rod	J-4209-8	0-100 Pound U.S. Pressure Gauge
J-5286-4	Installer Body	KMO-320-B	Fuel Pressure Gauge, 0-100 Pound (J-8151)
J-5286-5	Installer Pilot	J-6692	Compression Gauge, 0-1000 Pound
J-5286-6	Installer Flaring Die	J-6694	Compression Gauge Adapter
J-5286-7	First Reamer (Inc. Next 2 Items)	J-4209-9	300-3600 R.P.M. Tachometer
J-5286-13	First Reamer Body	J-4209-12	Tachometer—3 Ft. Flexible Extension 1/8 to 1/4 Pipe Bushing 3/16 Tube—1/8 Pipe—Inverter Flare— Male Connector
J-5286-14	Pilot Reamer	J-5907-3	Hoses (2 Required)
J-5286-8	Tube Tip Refinisher	J-5355	"Series 71" Tachometer Drive Adapter
J-5286-9	Second Reamer	J-4209-10	Male Friction Adapter
J-5286-10	Box and Filler	J-4209-11	Female Friction Adapter
FUEL OIL PUMP		J-5209-46	6" Section of 7/16" I.D. Hose
J-1508-02	Fuel Pump Service Kit (Inc. Next 4 Items)	J-7333-11	Manometer—Mercury
J-1508-7	Oil Seal Remover	J-7333-6	Manometer—Water
J-1508-8	Oil Seal Installer Handle	J-7333-5	Thermometer
J-1508-9	Oil Seal Installer	J-7436-7	Tachometer Cable Adapter
J-1508-10	Fuel Pump Holder	J-7333-13	Bottle of Mercury
J-4242	Fuel Pump Wrench	J-7333-12	Hoses for Manometer (2 Required)
ENGINE TUNE-UP		HM-593-1	Spring Scale
J-5345	Engine Tune-up Kit	J-1652-01	Governor Spring Retainer Wrench
J-7436	Diesel Engine Diagnosis Test Kit Test Kit Above Consists of Following 21 Items:	J-5956	Fuel System Primer

IMPORTANT—Tools are not available from GMC Truck & Coach Division. Order directly from vendor.

Specifications

BOLT, NUT AND STUD TORQUE SPECIFICATIONS

The latest recommended bolt, nut, and stud torque specifications for Series "71" General Motors Diesel Engines are presented in the following tables. It is important that special care be exercised to replace all bolts in their respective location during assembly of the engine and its sub-assemblies.

Table I lists the standard torque specifications for all bolts and nuts used on all Series "71" engine units, except those listed in Table II or Table III.

Table II lists the exceptions to the standard torques in Table I and identifies them as regards their application.

Table III lists stud torque specifications in either torque or driven height depending upon the application. Where a height is specified, the stud threads are cut so that the studs are tight by the time they have been driven to the given dimension.

TABLE I
STANDARD BOLT AND NUT TORQUE SPECIFICATIONS

Size Nut or Bolt	Torque (Ft.-Lbs.)	Size Nut or Bolt	Torque (Ft.-Lbs.)	Size Nut or Bolt	Torque (Ft.-Lbs.)
$\frac{1}{4}$ -20.....	7-9	$\frac{7}{16}$ -20.....	57-61	$\frac{3}{4}$ -10.....	240-250
$\frac{1}{4}$ -28.....	8-10	$\frac{1}{2}$ -13.....	71-75	$\frac{3}{4}$ -16.....	290-300
$\frac{5}{16}$ -18.....	13-17	$\frac{1}{2}$ -20.....	83-93	$\frac{7}{8}$ -9.....	410-420
$\frac{5}{16}$ -24.....	15-19	$\frac{9}{16}$ -12.....	90-100	$\frac{7}{8}$ -14.....	475-485
$\frac{3}{8}$ -16.....	30-35	$\frac{9}{16}$ -18.....	107-117	1 -8.....	580-590
$\frac{3}{8}$ -24.....	35-39	$\frac{5}{8}$ -11.....	137-147	1 -14.....	585-595
$\frac{7}{16}$ -14.....	46-50	$\frac{5}{8}$ -18.....	168-178		

TABLE II
EXCEPTIONS TO STANDARD TORQUE SPECIFICATIONS

APPLICATION	Size Nut or Bolt	Torque (Ft.-Lbs.)
Control Shaft Bracket Bolts	$\frac{1}{4}$ -20	10-12
Cam Follower Guide Bolts	$\frac{1}{4}$ -20	12-15
Blower Drive Coupling Bolts	$\frac{5}{16}$ -24	20-25
Blower Rotor Gear Hub Bolts	$\frac{5}{16}$ -24	25-30
Blower Rotor Gear Flexible Drive Bolts	$\frac{5}{16}$ -24	25-30
Water Pump Drive Coupling Attaching Bolt	$\frac{5}{16}$ -24	25
Hand Hole Cover Bolts	$\frac{3}{8}$ -16	10-15
Air Inlet Housing to Blower Bolts	$\frac{3}{8}$ -16	16-20
Water Pump Coupling Intermediate Shaft Expander Screws	$\frac{3}{8}$ -16	25-30
Cam and Balance Shaft End Bearing Bolts	$\frac{3}{8}$ -16	35-40
Flywheel Housing to Idler Gear and Dummy Hub Bolts	$\frac{3}{8}$ -16	25-40
Balance Weight Cover Bolts	$\frac{3}{8}$ -16-24	25-30
Flywheel Housing Bolts	$\frac{3}{8}$ -16-24	25-30
Crankshaft Front Cover Bolts	$\frac{3}{8}$ -24	25-30

BOLT, NUT AND STUD TORQUE SPECIFICATIONS (Cont.)**TABLE II (Cont.)**

APPLICATION	Size Nut or Bolt	Torque (Ft.-Lbs.)
Accessory Drive to Balance Gear Bolts (steel disc)	$\frac{3}{8}$ -24	45-50
Accessory Drive to Balance Gear Bolts (fiber disc)	$\frac{3}{8}$ -24	35-39
Exhaust Manifold Outlet Flange Nuts (brass)	$\frac{3}{8}$ -24	20-25
Injector Clamp Nuts	$\frac{3}{8}$ -24	20-25
Balance Weight Hub Bolts and Nuts	$\frac{3}{8}$ -24	25-30
Water Manifold Nuts	$\frac{3}{8}$ -24	25-30
Balance Weight to Timing Gear Bolts	$\frac{3}{8}$ -24	25-30
Blower Drive Ass'y Attaching Bolts and Nuts	$\frac{3}{8}$ -24	25-30
Blower to Block Bolts	$\frac{7}{16}$ -14	55-60
Lifter Bracket Bolts	$\frac{7}{16}$ -14	55-60
Fuel Manifold Connector Nuts	$\frac{7}{16}$ -20	30-35
Connecting Rod Bolts	$\frac{7}{16}$ -20	65-75
Crankshaft Front Cover Bolt	$\frac{1}{2}$ -13	80-90
Exhaust Manifold Nuts	$\frac{7}{16}$ -20	30-35
Idler Gear Hub and Dummy Hub Bolts	$\frac{1}{2}$ -13	80-90
Flywheel Housing Bolts	$\frac{1}{2}$ -13	90-100
Rocker Shaft Bolts	$\frac{1}{2}$ -13	90-100
Blower Rotor Gear Retaining Bolts	$\frac{1}{2}$ -20	55-65
Oil Pump Drive Idler Shaft Nuts	$\frac{1}{2}$ -20	60-70
Flywheel Bolts	$\frac{9}{16}$ -18	150-160
Main Bearing Bolts	$\frac{5}{8}$ -11	180-190
Main Bearing Nuts	$\frac{5}{8}$ -18	155-185
Cylinder Head Nuts	$\frac{5}{8}$ -18	165-175
Crankshaft End Bolts	1 -14	180-200
Cam and Balance Shaft Nuts	$1\frac{1}{8}$ -18	300-325
Blower Drive Gear Hub Nuts	$1\frac{1}{2}$ -16	50-60

TABLE III
STUD TORQUE SPECIFICATIONS

APPLICATION	TORQUE OR HEIGHT
Injector Clamp Studs	10-25 Ft.-Lbs.
Water Manifold Studs	10-25 Ft.-Lbs.
Exhaust Manifold Studs	25-40 Ft.-Lbs.
Cylinder Head Studs	Drive to height of $4\frac{3}{8}$ " $\pm \frac{1}{16}$ " 35-75 Ft.-Lbs.
Main Bearing Studs	Drive to height of 4" $\pm \frac{1}{32}$ " 35-75 Ft.-Lbs.

SPECIFICATIONS

FITS, TOLERANCES AND SERVICE SPECIFICATIONS

CYLINDER BLOCK

Block Bore	4.6265"-4.6275"
Bore Out-of-Round (Max.)	0.001"
Bore Taper (Max.)	0.001"
Cam and Balancer Shaft Bearing Bore	2.1875"-2.1885"
Main Bearing Line Bore	3.812"-3.813"
Cylinder Liner Counterbore	
Diameter	5.046"-5.0485"
Depth	.4785"-.4795"
Flatness At Head	
Transverse	0.003"
Longitudinal	(.471-0.007") (.671-0.009")
Refacing Limits (Max.)	0.008"

CYLINDER LINER

Type	Dry
Outside Diameter	4.6260"-4.6250"
Inside Diameter	4.2495"-4.2511"
Flange Diameter	4.776"-4.766"
Clearance-Liner to Bore	0.0005"-0.0025"
Out-of-Round	0.002"
Taper	0.001"
Oversizes Available—O.D.	0.005"-0.010" 0.020"-0.030"
Depth Below Block	.0465"-.050"
Shims Available	None
Liner Insert	
Thickness	.1795"-.1800"
Outside Dia.	5.044"-5.046"
Inside Dia.	4.640"-4.645"
Available Oversize & Undersize	
Oversize I.D.	Standard Thickness
Standard I.D.	0.004" Undersize
Standard I.D.	0.008" Undersize
Oversize I.D.	0.004" Undersize
Oversize I.D.	0.008" Undersize

CRANKSHAFT

Number of Bearings	
4-71	5
6-71	7
Journal Diameter—Main Bearing	3.499"-3.5000"
Journal Diameter—Conn. Rod	2.749"-2.750"
Journal Out-of-Round	0.00025"
Journal Taper	0.0005"
Runout—Total Indicator Reading	
4 Cylinder	
@ #2 and #4	0.002"
@ #3	0.004"
6 Cylinder	
@ #2 and #6	0.002"
@ #3 and #5	0.004"
@ #4	0.006"
Thrust Taken at	Rear Main Bearing
Thrust Washer Thickness	0.1220"-0.1205"
Available Oversize Thrust Washers	0.005"-0.010"
Normal Thrust Clearance	0.004"-0.011"
End Thrust (Max.)	0.018"

MAIN BEARINGS

Bearing Type	Heavy Duty Precision
Bearing Diameter (Vertical)	3.5014"-3.5034"
Bearing Clearance	0.0014"-0.0044"
Adjusting Shims Used	None
Bearing Thickness—90° from Parting Line	0.1553"-0.1548"
Available Undersizes	0.002"-0.010"-0.020"-0.030"

PISTONS

Fitting Pistons	See Instructions
Diameter	
At Top (Standard)	4.219"-4.222"
At Top (E Series)	4.2217"-4.2247"
At Ring Lands	4.235"-4.238"
Skirt (Below Compression Ring Groove to Bottom)	4.2433"-4.2455"
Clearance	
Top of Skirt	0.004"-0.0078"
Bottom of Skirt	0.004"-0.0078"
Out-of-Round—Max.	0.0005"
Taper—Max.	0.0005"
Diameter of Pin Bosses	1.6875"-1.6880"
Compression Ring Groove Width	
Upper (Standard)	0.134"-0.136"
Upper (Fire Ring—E Series)	0.088"-0.090"
2nd	0.132"-0.134"
3rd	0.130"-0.132"
4th (Standard)	0.130"-0.132"
Oil Ring Groove Width	0.1875"-0.1895"
Piston Pin Bushing Diameter	1.5025"-1.5030"
Oversize Pistons Available	0.010"-0.020"-0.030"

PISTON PINS

Diameter	1.4996"-1.5000"
Pin to Piston Bushing Clearance	0.0025"-0.0034"
Oversize Pins Available	0.010"
Pin to Rod Bushing Clearance	0.0015"-0.0024"
Length	3.605"-3.620"
Pin to Retainer Clearance	0.008"-0.0315"

PISTON RINGS

Compression Rings	
Number Used Each Piston	4
Width	
Fire Ring	0.077"-0.078"
Standard	0.1230"-0.1245"
Gap	0.018"-0.043"
Ring to Groove Clearance	
Fire Ring (E Series)	0.010"-0.012"
#1	0.010"-0.0125"
#2	0.008"-0.0105"
#3	0.006"-0.0085"
#4 (Standard)	0.006"-0.0085"
Oversize Available	0.010"-0.020"-0.030"
Oil Rings	
Type	3 Piece
Number Used Each Piston	2
Width	0.1840"-0.1860"
Gap	0.008"-0.023"
Ring to Groove Clearance	0.0015"-0.0055"
Oversize Available	0.010"-0.020"-0.030"

CONNECTING ROD

Length—Center to Center	10.124"-10.126"
Lower Bore-Dia.	3.062"-3.063"
Upper Bore-Dia.	1.7490"-1.7510"
Upper Bushing Diameter	1.5015"-1.5020"
Normal Rod End Thrust	0.006"-0.012"

CONNECTING ROD BEARING

Bearing Type	Heavy Duty Precision
Bearing Diameter	2.7514"-2.7534"
Bearing Clearance	0.0014"-0.0044"
Adjusting Shims Used	None
Bearing Thickness 90° from Parting Line	0.1548"-0.1553"
Available Undersizes	0.002"-0.010"-0.020"-0.030"

SPECIFICATIONS**FITS, TOLERANCES AND SERVICE SPECIFICATIONS (Cont.)****TIMING GEARS**

Blower Drive Gear	
No. of Teeth	39
Type	Helical
Backlash	0.003"-0.008"
Gear to Hub Fit	0.0005" Press-0.001" Free
Blower Drive Gear Support	
Support Bushing I.D.	1.6260"-1.6265"
Bushing to Hub Clearance	0.001"-0.0025"
Support to End Plate	0.0005" Pres-0.0025" Free
Blower Drive Gear Hub	
Diameter (At Bushing)	1.624"-1.6250"
Hub to Support Bushing Clearance	0.001"-0.0025"
Hub to Cam Clearance	0.002"-0.007"
End Thrust	0.005"-0.008"
Idler Gear	
No. of Teeth	68
Type	Helical
Backlash	0.003"-0.008"
Bearing Type	Opposed Tapered Roller
Camshaft and Balance Shaft Gears	
No. of Teeth	78
Type	Helical
Backlash	0.003"-0.008"
Gear to Shaft	0.0000"-0.0015" Press
Crankshaft Gear	
No. of Teeth	78
Type	Helical
Backlash	0.003"-0.008"
Gear to Shaft	0.001" Press-0.001" Loose

CAMSHAFT

No. of Bearings	
4-71	5
6-71	6
Shaft Diameter—At Bearings	
Front and Rear	1.4975"-1.4970"
Center and Intermediate	1.498"-1.4985"
Clearance—Shaft to Bearings	
Front and Rear	0.0025"-0.004"
Center and Intermediate	0.003"-0.0055"
Runout at Center Bearing (When Mounted on End Bearings)	
	0.002"
End Thrust	0.004"-0.012"
Thrust Washer Thickness	0.120"-0.122"
Oversize Washers Available	0.005"-0.010"

CAMSHAFT BEARINGS

Bearing Material	
Front and Rear	Steel Backed Copper Lead
Intermediate	Aluminum
Inside Diameter	
Front and Rear	1.500"-1.501"
Center and Intermediate	1.501"-1.503"
Undersize Bearing Available	0.010"-0.020"
Clearance—Bearings to Shaft	
Front and Rear	0.0025"-0.0040"
Center and Intermediate	0.0025"-0.0050"

BALANCER SHAFT

No. of Bearings	2
Shaft Diameter at Bearings	1.4970"-1.4975"
Clearance—Shaft to Bearings	0.0025"-0.004"
End Thrust	0.004"-0.012"
Thrust Washer Thickness	0.120"-0.122"
Oversize Thrust Washers Available	0.005"-0.010"

BALANCER SHAFT BEARINGS

Bearing Material	Steel Backed Copper Lead
Inside Diameter	1.500"-1.501"
Clearance—Shaft to Bearings	0.0025"-0.004"

BALANCE WEIGHTS (EARLY 6-71)

Balance Weight Bushing Diameter	1.8755"-1.8775"
Shim Pack Thickness	0.243"-0.259"
Individual Shim Thickness	0.015"-0.016"
Clearance—Weight to Hub	0.010"-0.023"

CYLINDER HEAD

Flatness (Max. Limits)	See Text
Refacing Limits (Max.)	0.020"
Cylinder Head Stud Height	4 $\frac{1}{16}$ "
Valve Guide Height Above Head	1 $\frac{1}{32}$ "
Cam Follower Bore	1.062"-1.063"
Exhaust Valve Seat Insert Counterbore	
Diameter (2 Valve)	1.626"-1.627"
Diameter (4 Valve)	1.260"-1.261"
Depth (2 Valve)	0.3705"-0.3845"
Diameter (4 Valve)	.388"-.352"

VALVE SEAT INSERT

Location	Cylinder Head
Exhaust Valve Seat Angle	30°
Exhaust Valve Seat Width	See Text
Oversize Available	0.010"
Diameter of Seat Counterbore in Head	
Standard (2 Valve)	1.6275"-1.6285"
Standard (4 Valve)	1.2615"-1.2625"
Valve Seat Runout	.002"

EXHAUST VALVE

Location	Cylinder Head
Diameter of Head (2 Valve)	1.579"-1.589"
Diameter of Head (4 Valve)	1.195"-1.205"
Stem Diameter (2 Valve)	0.3415"-0.3425"
Stem Diameter (4 Valve)	0.3095"-0.3105"
Clearance—Stem to Guide	0.002"-0.004"
Valve Lash (Hot) (2 Valve)	0.008" Go 0.010" No Go
Valve Lash (Cold) (2 Valve)	0.011" Go 0.013" No Go
Valve Lash (Hot) (4 Valve)	0.013" Go 0.015" No Go
Valve Lash (Cold) (4 Valve)	0.015" Go 0.017" No Go

VALVE GUIDE

Location	Cylinder Head
Height Above Cylinder Head (2 Valve)	1 $\frac{1}{32}$ "
Height Above Cylinder Head (4 Valve)	0.880"

SPECIFICATIONS**FITS, TOLERANCES AND SERVICE SPECIFICATIONS (Cont.)****VALVE GUIDE—Cont.**

Diameter—Inside (2 Valve)	0.3445"-0.3455"
Diameter—Inside (4 Valve)	0.3125"
Clearance—Stem to Guide	0.002"-0.004"
Oversize Available	0.016"

VALVE SPRING

Load—Valve Open @ 1 $\frac{5}{16}$ " (2 Valve) ...	142-150 lbs. Min.
Load—Valve Open @ 1.416" (4 Valve) ...	85-89 lbs. Min.

ROCKER ARM AND SHAFT

Rocker Shaft Diameter	0.8735"-0.8740"
Rocker Arm Large Bushing—I.D.	0.8750"-0.8760"
Clearance—Shaft to Bushing	0.001"-0.0025"
Rocker Arm Small Bushing—I.D.	0.564"-0.565"
Clevis Pin Bushing—O.D.	0.562"-0.5625"
Clearance—Pin to Arm Bushing	0.0015"-0.003"
Clevis Pin Bushing—I.D.	0.4375"-0.4385"
Push Rod Clevis Pin—O.D.	0.4380"-0.4385"
Clearance—Pin to Bushing ..0.001" Tight—	0.0005" Loose
Push Rod Clevis—I.D.	0.4370"-0.4385"
Clearance—Pin to Clevis ..0.0015" Tight—	0.0005" Loose
End Play—Clevis to Rocker Arm	0.008"-0.017"

CAM FOLLOWER

Diameter	1.060"-1.061"
Clearance—Follower to Head	0.001"-0.003"
Width of Roller Slot	0.5635"-0.5685"
Roller Pin Hole Diameter	0.4362"-0.437"

CAM FOLLOWER ROLLER AND PIN

Roller—O.D.	0.902"-0.907"
Roller Bushing—I.D.	0.4395"-0.4390"
Roller Pin—O.D.	0.4374"-0.4377"
Clearance—Pin to Bushing	0.0008"-0.0016"
End Play—Roller in Follower	0.015"-0.023"

CAM FOLLOWER SPRING

Free Length	2 $\frac{5}{8}$ "
Valve Open @ 2 $\frac{1}{4}$ "	176-192 lbs.

OIL PUMP

Drive Gear—On Crankshaft	
Type	Spur
No. of Teeth	40
Backlash to Idler Gear	0.010"-0.012"
Crankshaft Dia. at Gear	2.499"-2.500"
Gear Inside Diameter	2.501"-2.5005"
Clearance—Gear to Shaft	0.002"-0.006"
Idler Drive Gear	
Type	Spur
No. of Teeth	30
Backlash to Pump Gear	0.002"-0.010"
Support Diameter	0.9980"-0.9985"
Gear Bushing Diameter	1.0000"-0.9995"
Clearance—Gear to Support	0.001"-0.002"
Drive Driven Gear	
Type	Spur
No. of Teeth	24

OIL PUMP—Cont.

Backlash	0.002"-0.010"
Drive Gear	
Diameter—Outside	1.682"-1.683"
Diameter—Inside	0.6243"-0.6250"
Width (4 Cyl.)	1.269"-1.270"
Width (6 Cyl.)	1.7470"-1.7480"
Gear to Shaft Fit	Press
Radial Clearance—Gear to Housing ..	0.004"-0.008"
End Clearance—Gear to Housing	0.002"-0.005"
Backlash	0.018"-0.022"

Idler Gear

Diameter—Bushings I.D.	0.6245"-0.6255"
Diameter—Outside	1.682"-1.683"
Width (4 Cyl.)	1.269"-1.270"
Width (6 Cyl.)	1.7470"-1.7480"
Backlash	0.018"-0.022"
Clearance—Bushings to Shaft	0.001"-0.0025"

Oil Pump Body

Bushing—I.D.	0.6213"-0.6225"
Idler Shaft Bore in Body	0.6213"-0.6225"
Diameter of Gear Bore	1.687"-1.690"
Depth of Gear Bore	
4 Cyl.	1.270"-1.272"
6 Cyl.	1.750"-1.752"
Relief Valve Bore	0.7505"-0.7495"

Oil Pump Cover

Bushing—I.D.	0.6235"-0.6247"
Idler Shaft Bore	0.6235"-0.6247"

Oil Pump Drive Shaft

Diameter—at Bushings	0.6200"-0.6205"
Diameter—at Gear	0.6258"-0.6253"
Clearance—Shaft to Bushing	0.0008"-0.0025"

Oil Pump Idler Shaft

Diameter	0.6235"-0.623"
Projection Beyond Body	$\frac{3}{4}$ "
Shaft to Body Fit	Press

Pressure Relief Valve

Relief Valve Diameter	0.747"-0.7465"
Clearance—Valve to Body	0.004"-0.0025"

Relief Valve Spring

Free Length	2 $\frac{3}{4}$ "
Lbs. Pressure @ 1.596"	48-53

OIL PRESSURE REGULATOR VALVE

Valve Diameter	0.623"-0.622"
Housing Bore	0.624"-0.6255"
Clearance—Valve to Housing	0.001"-0.0035"

REGULATOR SPRING

Free Length	2 $\frac{3}{4}$ "
Lbs. Pressure at 1 $\frac{3}{32}$ "	14-15

OIL COOLER BY-PASS VALVE

Type RD and RB Engines	
Valve Diameter—O.D.	0.622"-0.623"
Adapter Ream	0.624"-0.6255"
Clearance—Valve to Adapter	0.001"-0.0035"
Relief Valve Spring	
Free Length	2 $\frac{1}{4}$ "

SPECIFICATIONS**FITS, TOLERANCES AND SERVICE SPECIFICATIONS (Cont.)****OIL COOLER BY-PASS VALVE—Cont.**

Lbs. Load @ 1.793"	13 $\frac{3}{8}$ "-14 $\frac{3}{8}$ "
Type LA and RA Engines	
Valve Diameter—O.D.	0.4970"-0.4985"
Adapter Ream	0.4995"-0.5005"
Clearance—Valve to Adapter	0.001"-0.0035"
Relief Valve Spring	
Free Length	1 $\frac{1}{16}$ "
Lbs. Load @ 1.520"	12-13 $\frac{1}{4}$ "

FLUID FAN DRIVE—BALANCE WEIGHT COVER

Torus Housing	
Bushing—Line Ream	2.376"-2.378"
Torus Driving Member Hub	
Bushing—Line Ream	1.126"-1.127"
Eccentricity Between Diameters	0.002"
Drive Shaft and Driven Torus	
Shaft & Torus Face	
Square Within .0.010" Total Indicator Reading	
Fan Drive Shaft	
Diameter	1.124"-1.125"
Thrust Washer	
Thickness	0.124"-0.126"
Sealing Ring	
Width	0.0930"-0.0935"
Diameter—Compressed	2.375"

FLUID FAN DRIVE—CRANKSHAFT TYPE

Sealing Ring Bushing—At Driven Torus Housing	
Diameter	2.375"-2.376"

FLUID FAN DRIVE—CRANKSHAFT TYPE—Cont.

Sealing Ring Bushing—At Driving Torus Housing	
Diameter	3.029"-3.031"
Sealing Ring at Fan Driving Torus	
Width	0.123"-0.1235"
Gap @ 3.030" Dia.	0.005"-0.014"
Sealing Ring at Fan Driven Torus	
Width	0.122"-0.124"
Gap @ 2.375" Diameter	0.005"-0.010"

FUEL PUMP

Capacity	
At 1500 Engine R.P.M.	90 Gal. Per Hr.
Relief Valve Opens (Max. Lbs. Pressure)	75
Pump Body	
Shaft Opening	0.5010"-0.5015"
Relief Valve Opening	0.3740"-0.3755"
Gear Opening—Diameter	1.1663"-1.1658"
Gear Opening—Depth	0.2500"-0.2510"
Pump Cover	
Shaft Opening	0.501"-0.5015"
Pump Gears	
Diameter	1.1628"-1.1633"
Width	0.2492"-0.2489"
Shaft Opening	0.4990"-0.4995"
Clearance—Gear to Body	0.0005"-0.0015"
Drive & Driven Shafts	
Diameter	0.4995"-0.5000"
Relief Valve	
Diameter	0.372"-0.373"
Relief Valve Spring	
Free Length	1 $\frac{3}{4}$ "
Lbs. Pressure @ 1 $\frac{3}{8}$ "	7.1-7.5

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