TM 9-2815-214-34

TECHNICAL MANUAL

DIRECT AND GENERAL SUPPORT MAINTENANCE MANUAL

GM MODEL 3-53 FOR ENGINE DIESEL

HEADQUARTERS, DEPARTMENT OF THE ARMY

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HEADQUARTERS
DEPARTMENT OF THE ARMY
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DIRECT AND GENERAL SUPPORT MAINTENANCE MANUAL

For

ENGINE DIESEL GM MODEL 3-53

INFORMATION REGARDING THE MANUAL AND ITS USE

This manual covers the 3-53 Diesel Engine built by the Detroit Diesel Engine Division of General Motors Corporation. Complete instructions on operation, adjustment (tune-up), preventive maintenance and lubrication, and repair (including complete overhaul) are covered. The manual was written primarily for persons servicing and overhauling the engine, and in addition contains all of the instructions essential to the operators and users.

This manual is divided into numbered sections. The first section covers the basic engine, and the following sections cover a complete system, such as the fuel system, lubrication system or air system. Each section is divided into sub-sections which contain complete maintenance and operating instructions for a specific subassembly on the engine. For example, section 1 which covers the basic engine contains sub-section 1.1 pertaining to the cylinder block, sub-section 1.2 covering the cylinder head, etc. The subjects and sections are listed in the Table of Contents on the preceding page. Pages are numbered consecutively, starting with a new page 1 at the beginning of each sub-section. The illustrations are numbered consecutively, beginning with a new figure 1 at the beginning of each sub-section.

In formation regarding a general subject, such as the lubricating system, can be located best by using the Table of Contents. Information on a specific subassembly or accessory can then be found by consulting the list of contents printed on the first page of each section. For example, the cylinder liner is part of the basic engine, therefore, it will be found in Section 1. Looking down the list of contents on the first page of Section 1, the cylinder liner is found to be in sub-section 1.6.3. An Alphabetical Index at the back of the manual has been provided as an additional aid for locating information.

SERVICE PARTS AVAILABILITY

Replacement parts are listed and illustrated in TM 9-2320-242-35P which is the authority for requisitioning repair parts.

CLEARANCES AND TORQUE SPECIFICATIONS

Clearances of new parts and wear limits on used parts are listed in tabulated form at the end of each section, or sub-section, throughout the manuaL It should be specifically noted that the "New Parts" clearances apply only when all new parts are used at the point where the specifications apply. This also applies to references within the text of the manual. The column entitled "Wear Limits" lists the amount of wear or increase in clearances that can be tolerated in used engine parts and still assure satisfactory performance. It should be emphasized that the figures given as "Wear Limits" must be qualified by the judgement of personnel responsible for installing new parts. These wear limits are, in general, listed only for the parts more frequently replaced in engine overhaul work. For additional information, refer to the paragraph entitled "Inspection" under General Procedures in this section.

Bolt, nut and stud torque specifications are also listed in tabular form throughout the manual.

PRINCIPLES OF OPERATION

The Diesel Principle

The diesel engine is an internal combustion power unit in which the heat of fuel is converted into work within the cylinder of the engine. In this type of *engine,* air alone is compressed in the cylinder. Then, after the air has been compressed, a charge of fuel is sprayed into the cylinder and ignition is accomplished by the beat of compression.

The Two-Cycle Principle

In the two-cycle engine, intake and exhaust take place during part of the compression and power strokes respectively, as shown in Figures 1 through 4. In contrast, a four-cycle engine requires four piston strokes to complete an operating cycle; thus during one half of its operation, the four-cycle engine functions merely as an air pump. A blower forces air into the cylinders for expelling exhaust gases and to supply the cylinders with fresh air for combustion. The cylinder wall contains a row of ports which are above the piston when it is at the bottom of its stroke. These ports admit the air from the blower into the cylinder as soon as the rim of the piston uncovers the ports, as shown in figure 1.

The unidirectional flow of air toward the exhaust valves produces a scavenging effect, leaving the cylinders full of clean air when the piston again covers the inlet ports. As the piston continues on the upward stroke, the exhaust valves close and the charge of fresh air is subjected to compression. as shown in figure 2. Shortly before the piston reaches its highest position, the required amount of fuel is sprayed into the combustion chamber by the unit fuel injector, as shown in Fig. 3. The intense Feat generated during the high compression of the air ignites the fine fuel spray immediately and combustion continues until the injected fuel has been burned. The resulting pressure forces the piston downward on its power stroke. The exhaust valves are again opened when the piston is about halfway down, allowing the burned gases to escape into the exhaust manifold as shown in figure 4. Shortly thereafter, the downward moving piston uncovers the inlet ports, and the cylinder is again swept with clean scavenging air, as shown in figure 1. This entire combustion cycle is completed in each cylinder for each revolution of the crankshaft or, in other words, in two strokes ; hence, it is a "two-stroke cycle".

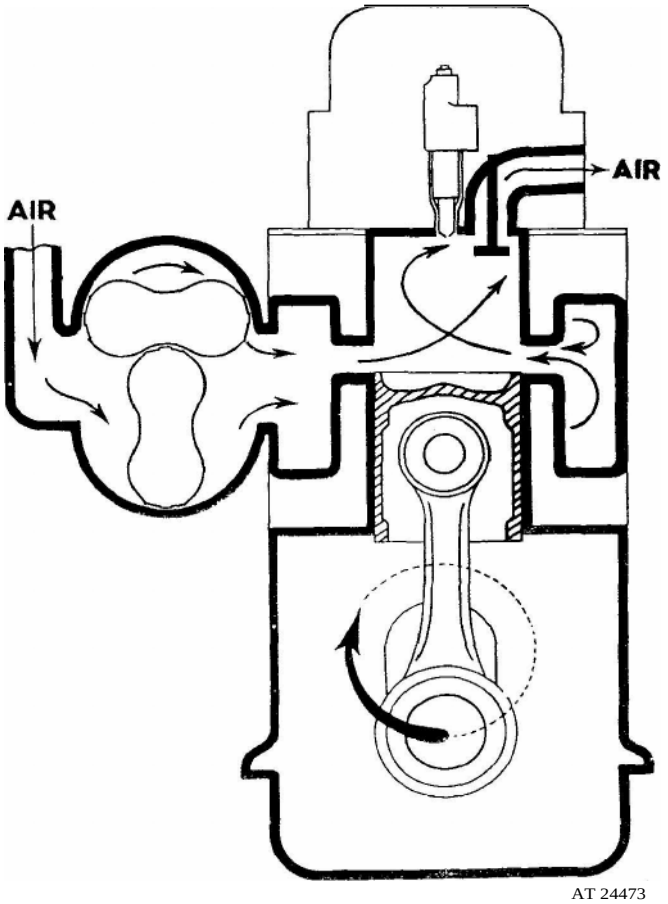


Figure !. Scavenging.

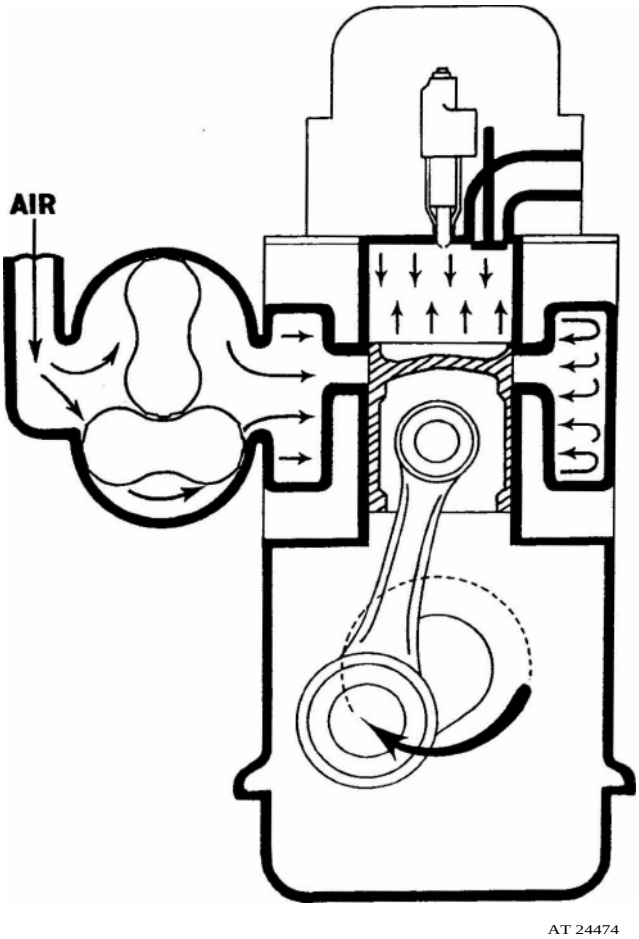


Figure 2. Compression.

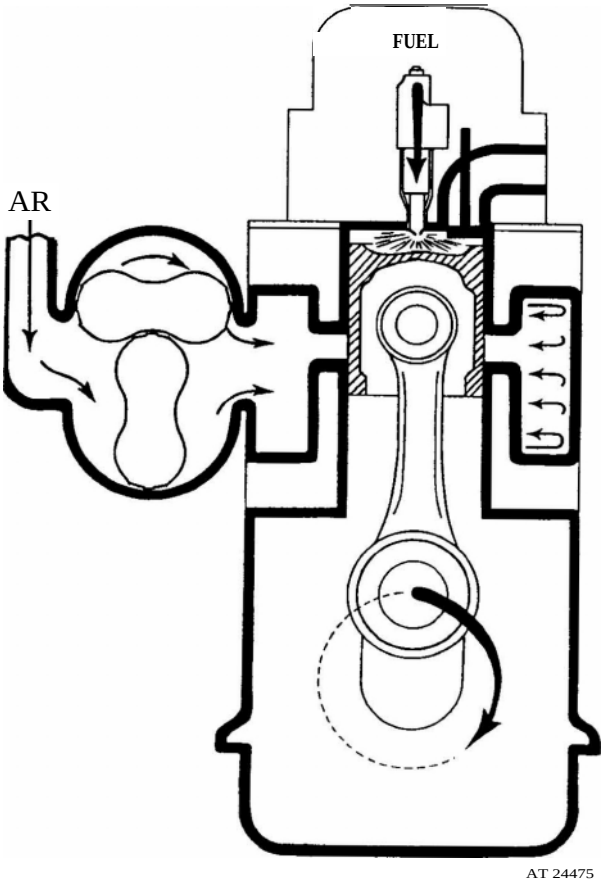


Figure 3. Power.

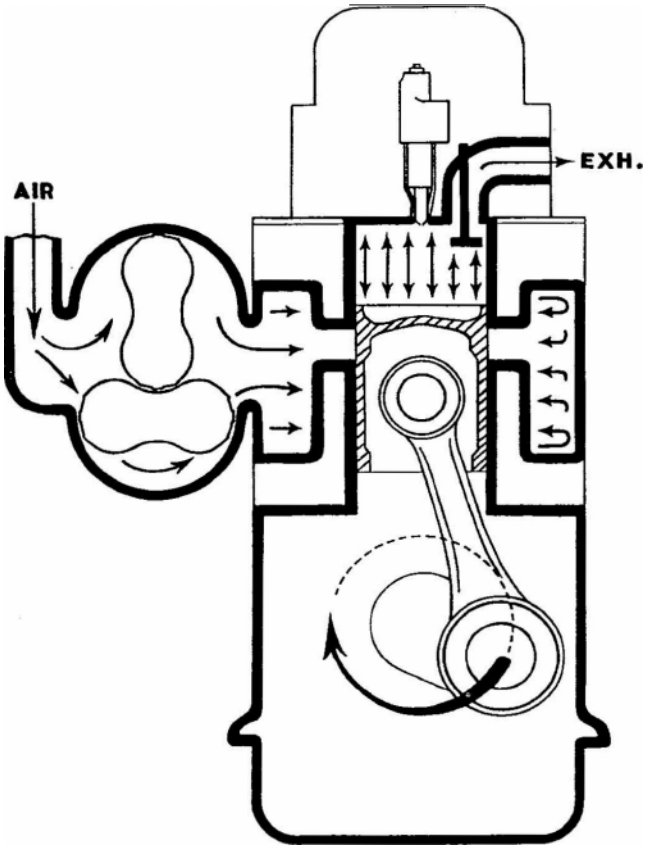


Figure 4. Exhaust.

GENERAL DESCRIPTION

The meaning of each digit in the model numbering system is shown in figure 5. The letter R indicates right-hand engine rotation as viewed from the front of the engine. The letter B, designates the blower and exhaust manifold location as viewed from the rear of the engine. The engines are equipped with an oil cooler replaceable element type lubricating oil filter, fuel oil strainer and filter, a governor, a fan, and a starting motor. Full pressure lubrication is supplied to all main connecting rod, and camshaft bearings, and to other moving parts. Oil is drawn by suction from the oil pan through the intake screen and pipe to the oil pump where it is pressurized and delivered to the oil filter and the oil cooler. From the oil cooler, the oil enters oil galleries in the cylinder block and cylinder head for distribution to the main bearings, connecting rod bearings, camshaft bearings, rocker arm mechanism and other functional parts. The cooling system has a centrifugal water pump which circulates the engine coolant through the oil cooler and water jackets. The engine temperature is regulated by a thermostat(s). Fuel is drawl from the supply tank through the fuel strainer and enters a gear type fuel pump at the inlet side. Upon leaving the pump under pressure, the fuel is forced through the fuel filter into the inlet manifold where it passes through fuel pipes into the inlet side of the fuel injectors. The fuel is filtered through elements in the injectors and then atomized through small spray tip orifices into the combustion chamber. Air for scavenging and combustion is supplied through an air cleaner by a blower. The engine is started by an electric starting system. The engine speed is regulated by an engine governor limiting speed.

5043 5101

SERIES 53	NUMBER OF CYLINDERS	APPLICATION DESIGNATION	BASIC ENGINE ARRANGEMENTS * (see below)	DESIGN VARIATION	SPECIFIC MODEL NUMBER AND STARTER—BLOWER ARRANGEMENT

APPLICATION DESIGNATION		DESIGN VARIATION	
5042-5100	MARINE	5043.5000	"N" ENGINE
5043-5100	FAN TO F/W—INDUSTRIAL	5043-5100	2 VALVE HEAD
5044-5100	POWER-BASE	5043.520b	4 VALVE HEAD
5045-5100	GENERATOR	5042·2 302	TURBOCHARGER
5047-5100	FAN TO F/W—VEHICLE		

STARTER—BLOWER ARRANGEMENT

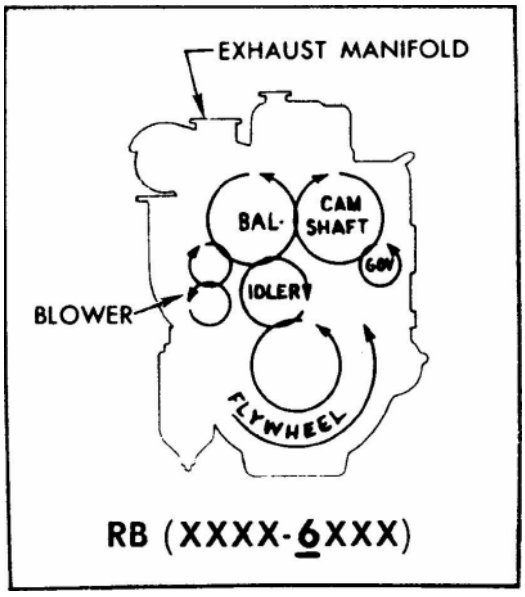
Odd number in last digit designates starter opposite blower.

Even number in last digit designates starter same side as blower.

*** 2, 3, 4-53 BASIC ENGINE ARRANGEMENTS**

Rotation: R-(right) designates rotation as viewed from the end of the engine opposite the flywheel.

Type: -B- designates location of exhaust manifold and blower as viewed from the flywheel end of the engine.



AT 24477

Figure 5. In-line engine model description, rotation and accessory arrangement.

Figure 6. Deleted.

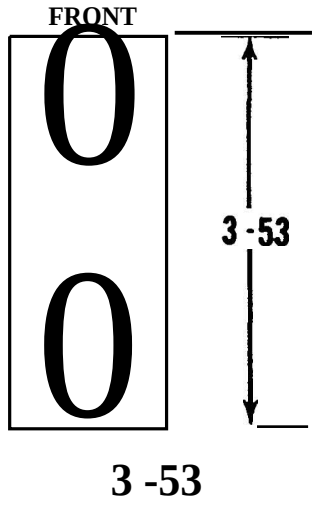


Figure 7. Series 53 cylinder arrangement.

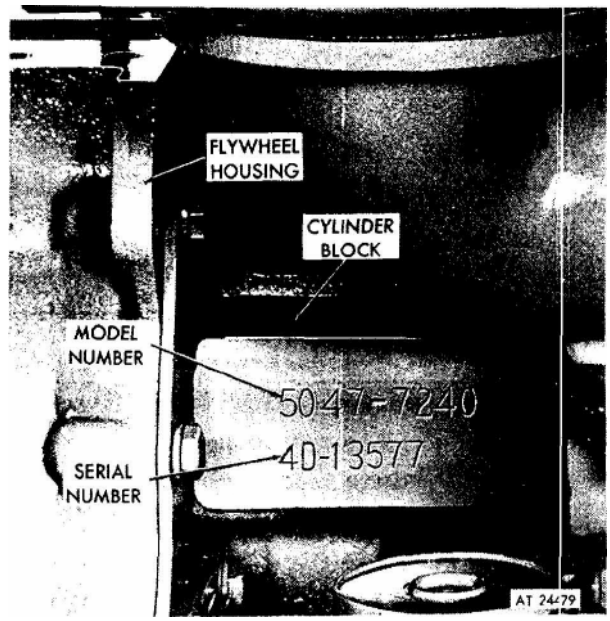


Figure 8. Typical model and serial numbers as stamped on cylinder block (in-line engine).

The model number and serial number are stamped on the right-hand side of the cylinder block on the upper rear corner (fig. 8).

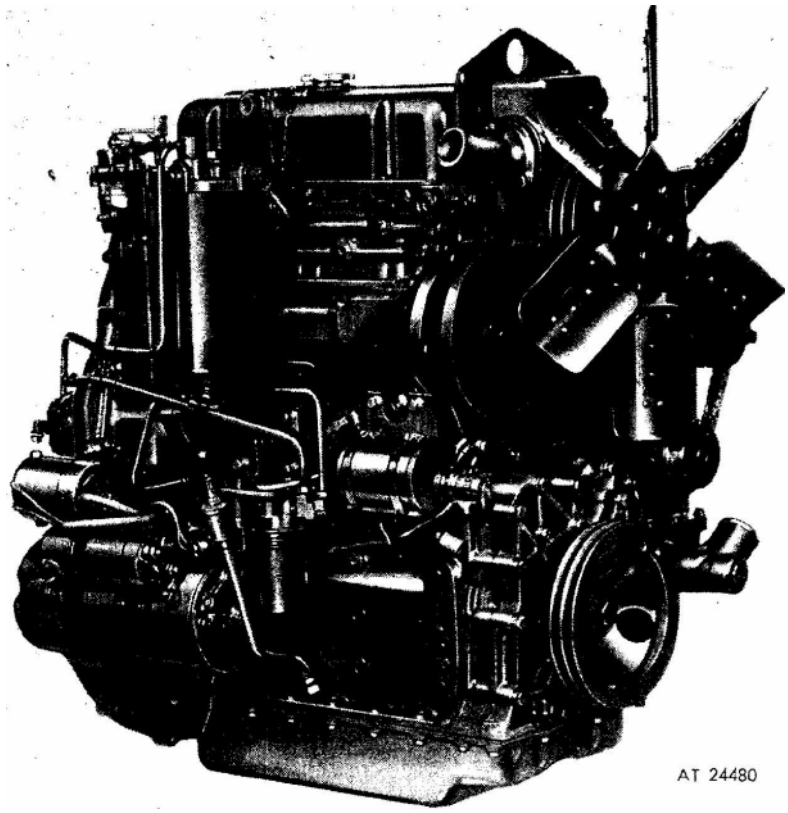


Figure 9. Engine — front view.

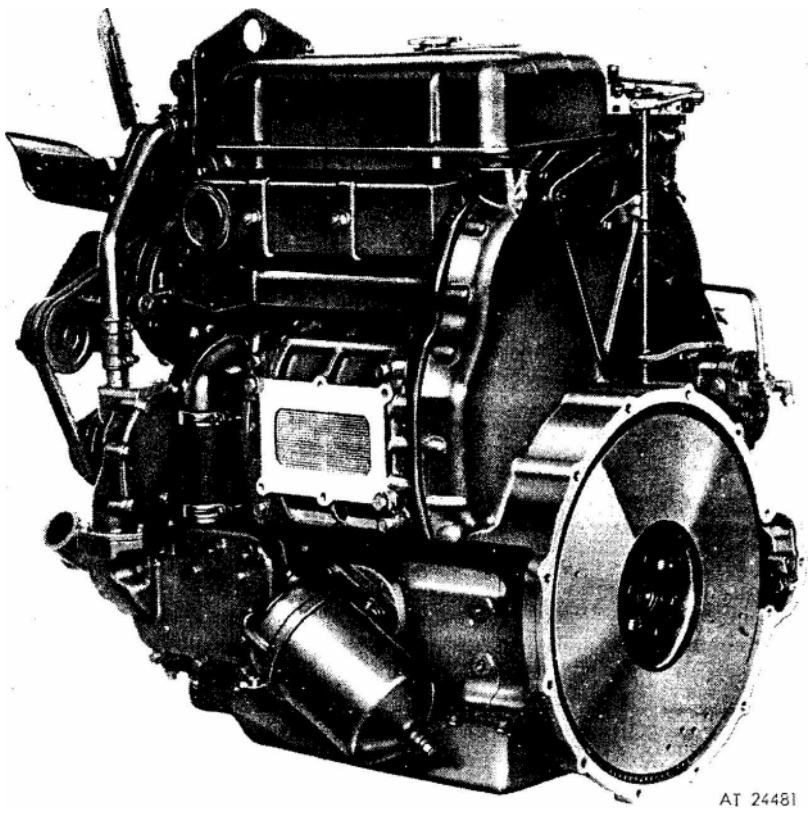


Figure 10. Engine—rear view.

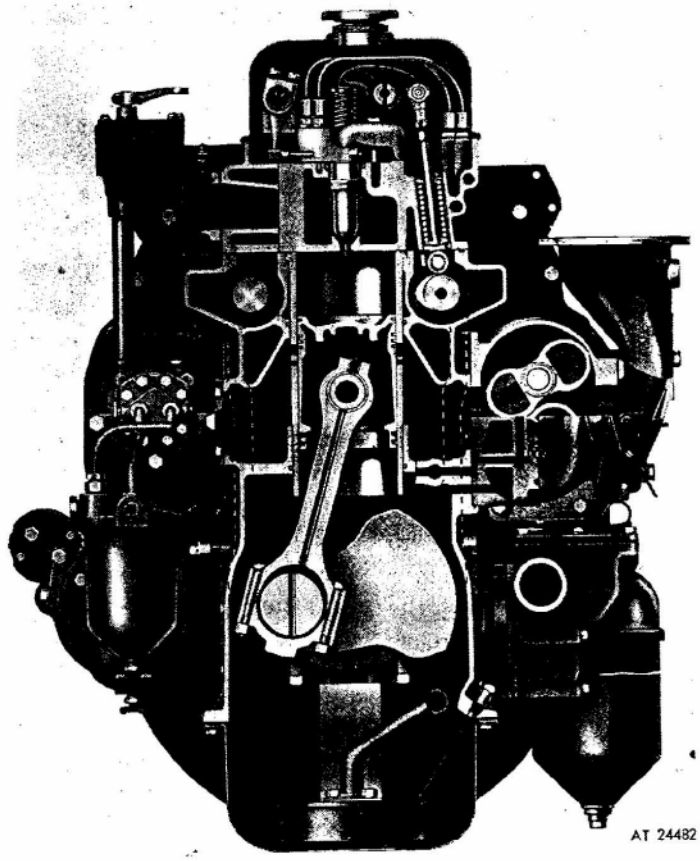


Figure 11. Cross section of engine.

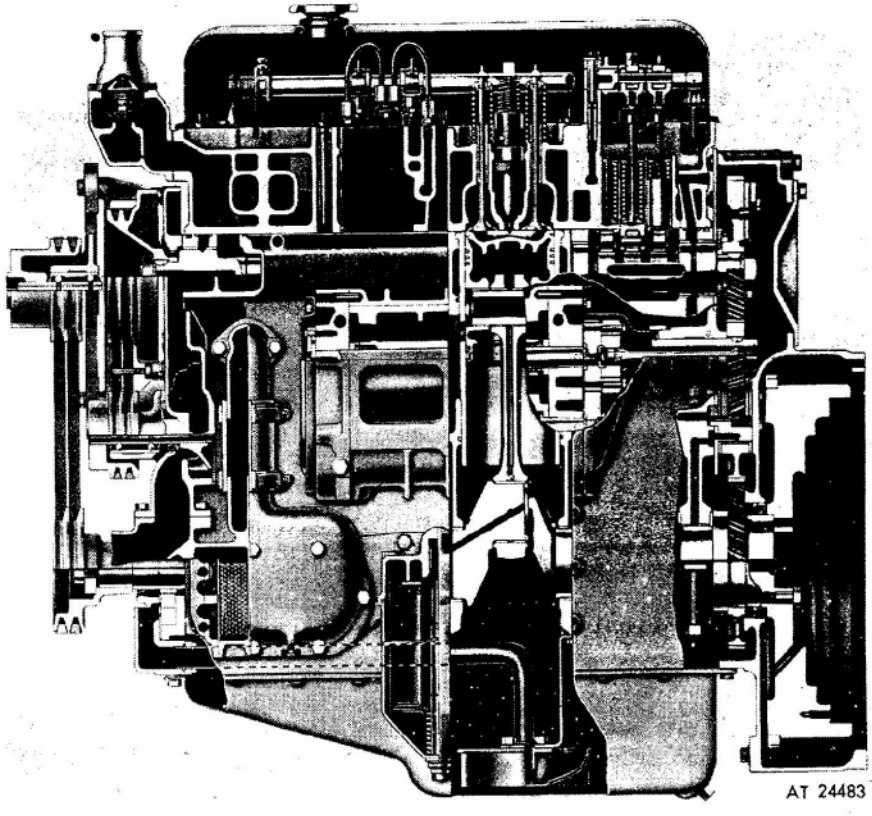


Figure 12. Cross section of engine.

GENERAL PROCEDURES

In many cases, a mechanic is justified in replacing parts with new material rather than attempting repair. However, there are times where a slight amount of reworking or reconditioning may save a customer considerable added expense. Crankshafts, cylinder liners and other parts are in this category. For example, if a cylinder liner is only slightly worn and within usable limits, a honing operation to remove the glaze may make it suitable for reuse with a standard size piston and new piston rings, thereby saving the expense of new parts. Various factors such as the type of operation of the unit, hours in service and next overhaul period must be considered when determining whether new parts are installed or used parts are reconditioned to provide trouble-free operation. For convenience and logical order in disassembly and assembly, the various subassemblies and other related parts mounted on the cylinder block will be treated as separate items in the various sections of the manual.

DISASSEMBLY

Before any major disassembly, the engine must be drained of lubricating oil, water and fuel. To perform a major overhaul or other extensive repairs, the complete engine assembly, after removal from the vehicle and drive mechanism, should be mounted on an engine overhaul stand; then the various subassemblies should be removed from the unit. When only a few items need replacement, it is not always necessary to mount the engine on an overhaul stand. Parts removed from an individual engine should be kept together so they will be available for inspection and assembly. Those items having machined faces, which might be easily damaged by steel or concrete, should be stored on suitable wooden racks or blocks or a parts dolly.

CLEANING

Before removal of subassemblies from the engine (but after removal of the electrical equipment) the exterior of the engine should be thoroughly cleaned. Then, after each subassembly is removed and disassembled, the individual parts should be cleaned. Thorough cleaning of each part is absolutely necessary before a part can be satisfactorily inspected. Below are listed various items of equipment needed for general cleaning. The cleaning procedure used for all ordinary cast iron parts is outlined under "Clean Cylinder Block" in Section 1.1, while any special cleaning procedures will be mentioned in the text wherever required.

Steam Cleaning

A steam cleaner is a necessary item in a large shop and is most useful for removing heavy accumulations of grease and dirt from the exterior of the engine and its subassemblies.

Solvent Tank Cleaning

A tank of sufficient size to contain the largest part which will require cleaning (usually the cylinder block) must be provided and provisions made for heating the cleaning solution to 180° F. This tank is filled with a commercial heavy-duty solvent which is heated to the above temperature. Large parts are lowered directly into the tank with a hoist; small parts are placed in a wire mesh basket and lowered into the tank. The parts are immersed in the cleaning tank long enough to loosen all grease and dirt.

Rinsing Bath

Another tank of similar size containing hot water should be provided for rinsing the parts.

Drying

Parts may be dried with compressed air. The heat from the hot tanks will quite frequently complete the drying of parts without the use of air.

Rust Inhibiting

If parts are not to be used immediately after cleaning, they should be dipped in suitable rust inhibiting compound. Remove the rust proofing compound before installing the parts in an engine.

INSPECTION

The purpose of parts inspection is to determine which parts can be used and which must be replaced. Although the engine overhaul specifications given throughout the text will aid in determining which parts should be replaced, considerable judgment must be exercised by the inspector. The guiding factors in determining the usability of worn parts, which are otherwise in good condition is the clearance between the mating parts and the rate of wear on each of the parts. If it is determined that the rate of wear will maintain the clearances within the specified maximum allowable until the next overhaul period, the reinstallation of the used parts may be justified. Rate of wear of a part is determined by dividing the amount the part has worn by the hours it has operated.

Many service replacement parts are available in various undersize and oversize as well as standard

sizes. Also, service kits for reconditioning certain parts and service sets which include all of the parts necessary to complete a particular repair job are available. A complete discussion of the proper methods of precision measuring and inspection are outside the scope of this manual. However, every shop should he equipped with standard gages, such as dial bore gages, dial indicators, and inside and outside micrometers. In addition to measuring the used parts after cleaning, the parts should be carefully inspected for cracks, scoring, chipping, and other defects.

ASSEMBLY

Following cleaning and inspection, the engine should he assembled using new parts as determined by the inspection. Use of the proper equipment and tools makes the job progress faster and produces better results. Likewise, a suitable working space with proper lighting must be provided. The time and money invested in providing the proper tools, equipment, and space will be repaid many times. Keep the working space, the equipment, tools, and engine assemblies and parts clean at all times. The area where assembly operations take place should if possible, be located away from the disassembly and cleaning operation. Also, any machining operations should he removed as far as possible from the assembly area. Particular attention should be paid to storing parts and subassemblies, after removal and cleaning, and prior to assembly, in such a place or manner as to keep them clean. In case there is any doubt as to the cleanliness of such parts, they should he recleaned. When assembling an engine or any part thereof, refer to the table of torque specifications at the end of each section for proper bolt, nut and stud torques.

SAFETY

Safety, based on knowledge, technical skill, and years of experience, has been carefully built into the engine. Time, money, and effort have been invested in making the diesel engine a safe product. The dividend that is realized from this investment is your personal safety.

It should be remembered, however, that power-driven equipment is only as safe as the man who is at the controls. You are urged to keep your fingers and clothing awa y from revolving "V" belts, gears, blower. fan, drive shafts etc. An accident can be prevented with your help.

SECTION 1

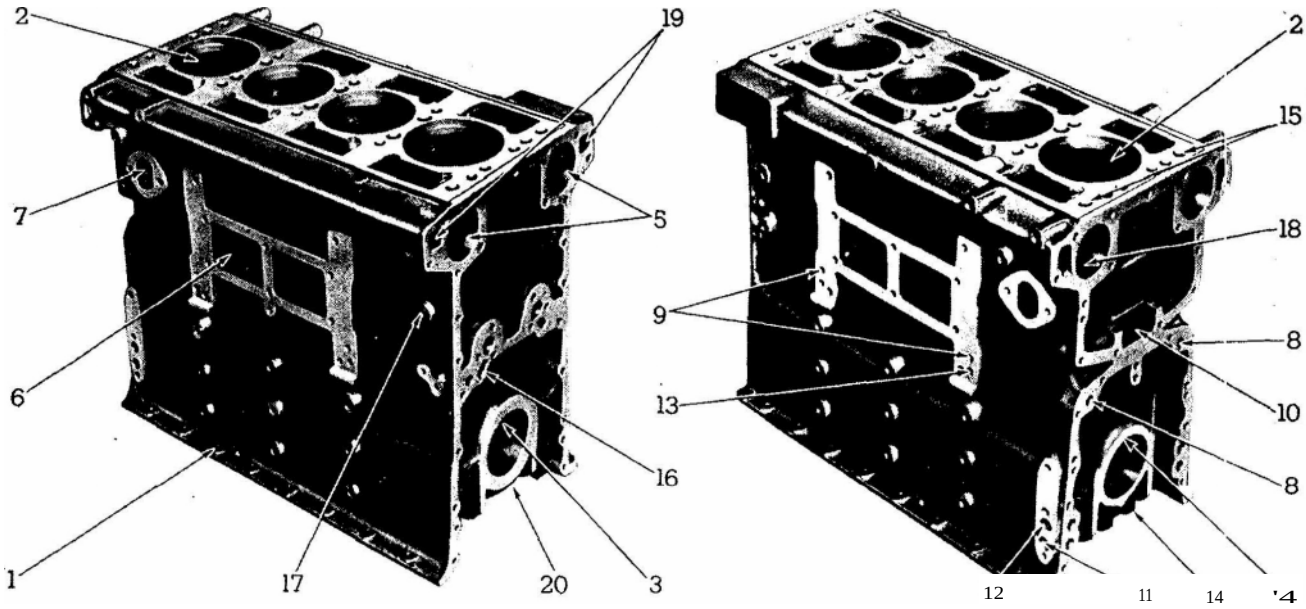
BASIC ENGINE

CONTENTS

CYLINDER BLOCK

The cylinder block (fig. 1) is a one-piece casting which forms the main structural part of the engine. Transverse webs provide rigidity and strength and ensure alignment of the block bores and bearings under load. The block is bored to receive replaceable wet-type cylinder liners. A water jacket surrounds the upper half of each cylinder liner. The vat er jacket and air box are sealed off by a seal ring compressed between the liner and a groove in the block (fig. 2). The camshaft and balance shaft bores are located, on opposite sides, near the top of the in-line engine block. The upper halves of the main bearing supports are cast integral with the block. The main bearing bores are line-bored with the hearing caps in place to ensure longitudinal alignment. Drilled passages in the block carry the lubricating oil to all moving parts of the engine and thus eliminate external piping. The opening in the side of the block opposite the blower permit access to the air box and inspection of the pistons and rings through the air inlet ports. The top surface of the in-line block is grooved to accommodate a block-to- head seal ring. Also, each water or oil hole is counterbored to provide for individual seal rings (fig. 3). Each cylinder liner is retained in the block by a flange at its upper end, which seats in the counterbore in the clock bore. An individual compression gasket is used at each cylinder. When the cylinder head is installed, the individual gaskets and seal rings compress sufficiently to form a tight seal between the head and the block. The in-line-cylinder blocks have been revised to improve the breathing characteristics and increase the flow of the lubricating oil returning from the cylinder head to the engine oil sump, by the addition of two vertical oil passages directly under the camshaft and balance shaft at the front end of the cylinder block (fig. 6). Cylinder blocks with the vertical oil passages were used in engines beginning with serial numbers 2D-4010, 3D-117 and 4D-348. Since the cylinder block is the main structural part of the-engine, the various subassemblies must be removed when an engine is overhauled. The hydraulically operated overhaul stand, illustrated in figure 6, provides a convenient support when stripping a cylinder block. The engine is mounted in an upright position. It may then be tipped on its side, rotated in either direction 90 ° or 180' where it is locked in place, and then, if desired, tipped back with either and or the oil pan side up.

1.1 CYLINDER BLOCK



1 Cylinder block
2 Bore for cylinder liner
3 Support—upper main bearing-rear
4 Support—upper main bearing-front
5 Bore—cam or balance shaft
6 Air box
7 Water passage from oil 1 cooler to block
8 Oil gallery—main
9 Oil gallery—to blower
10 Oil drain from front cover
11 Oil passage to oil cooler
12 Oil passage from oil cooler
13 Oil drain *from* blower
14 Cap—main bearing (front)
15 Oil passage to cylinder head (from camshaft)
16 Oil Passage (idler gear bearing)
17 Water drain
18 Oil gallery to camshaft or balance shaft
19 Oil drain from cylinder head
20 Cap—main bearing (rear)

Figure 1. Cylinder block (in. line cylinder block shown).

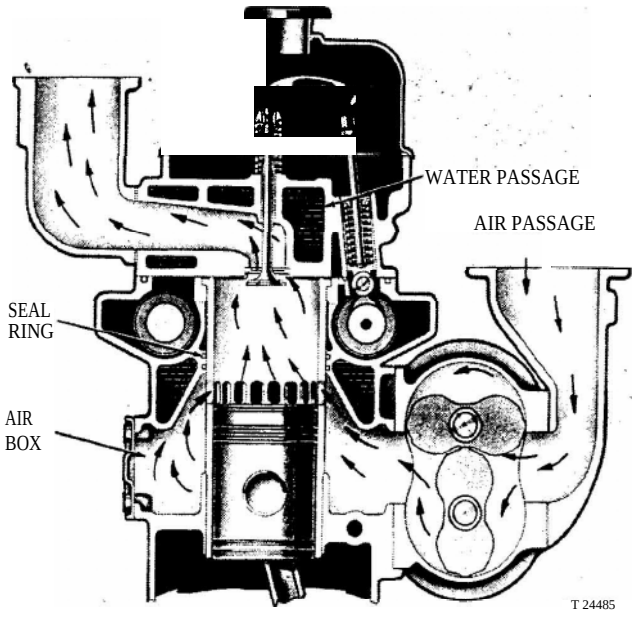


Figure 2. Air and water passages in in-line cylinder block.

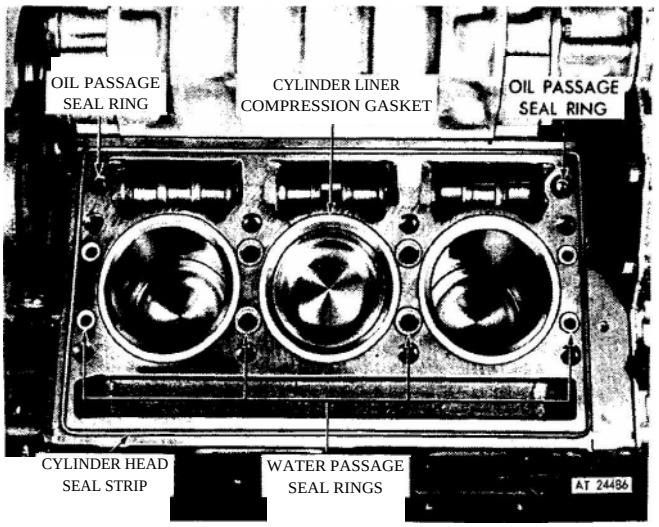


Figure 3. Cylinder head gaskets and seals in place on cylinder block.

Remove and Disassemble Engine

Before mounting an engine on an overhaul stand, it must be removed from its base and disconnected from the transmission or other driven mechanism. Details of this procedure will vary from one application to another. However, the following steps will be necessary:

1. Drain the cooling system.
2. Drain the lubricating oil.
3. Disconnect the fuel lines.
4. Remove the air silencer or air cleaner and mounting bracket.
5. Remove the blower.
6. Disconnect the exhaust piping and remove the exhaust manifold.
7. Disconnect and remove the starting motor, batter-charging generator and other electrical equipment.
8. Remove the air compressor or vacuum pump, if used.
9. Remove the air box drain tubes and fittings.
10. Remove the air box heater cover assembly.
11. Disconnect any other lubricating oil lines, fuel lines, or electrical connections.
12. Remove the radiator and fan guard and other related cooling system parts.
13. Separate the engine from the transmission or other driven mechanism.
14. Remove the engine mounting bolts.
15. Use a sling and chain hoist to lift the engine from its base.
16. Place the cylinder block on the overhaul stand (fig. 61.
17. Align the bolt holes in the adaptor plate with the holes in the cylinder block, then, install the 3/8"-16 and 5 / 16"-18 bolts, with a flat washer under the head of each bolt, and tighten them securely.

CAUTION

Be sure the engine is securely mounted to the overhaul stand before releasing the lifting sling. Severe injury to personnel and destruction of engine parts will result if the engine breaks away from the overhaul stand.

18. With the engine mounted on the overhaul stand, remove all of the subassemblies and parts from the cylinder block. The procedure for removing each subassembly from the cylinder block, together with disassembly, inspection, repair and reassembly of each, will be found in the various sections of this manual. After stripping the cylinder block, it should be cleaned and thoroughly inspected.

1.1 CYLINDER BLOCK

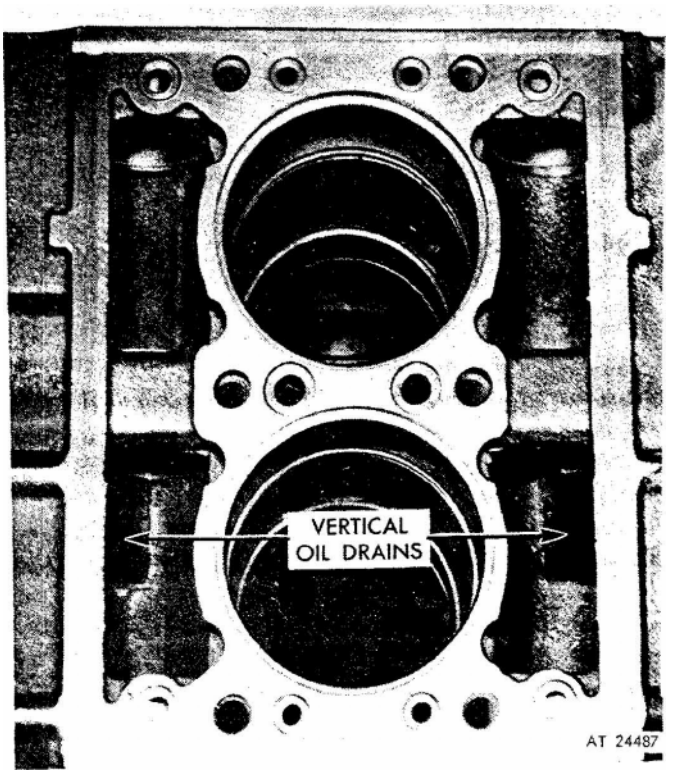


Figure 4. Vertical oil passages in top of cylinder block.

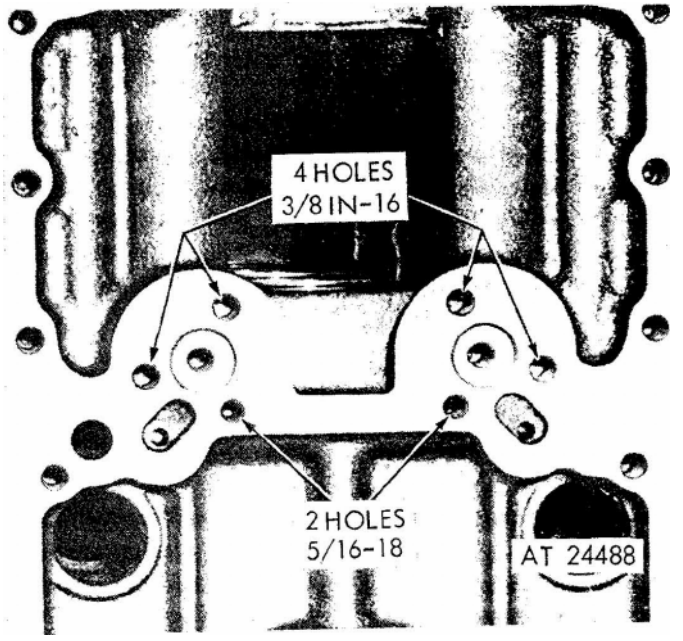
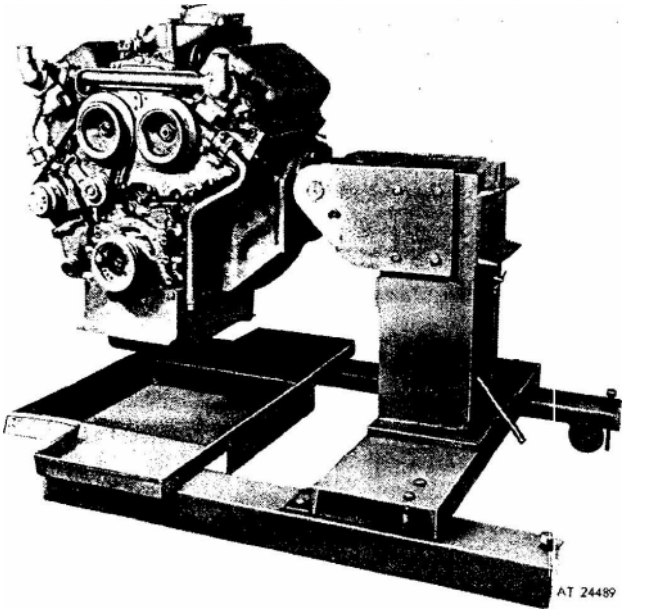


Figure 5. Location of the four ⅜"-16 bolt holes in rear of cylinder block.



igure 0. Engine mounted on overhaul stand.

Clean Cylinder Block

1. Remove all of the plugs (except cup plugs) and scrape all old gasket material from the block. Use care to avoid damaging seal surface.

2. Clean the block with live steam. Make sure the oil galleries, air box floor, and air box drain openings are thoroughly cleaned. Oil is directed to the cam followers through small slots incorporated in the camshaft and balance shaft bearings.

3. Dry the block with compressed air.

Pressure Test Cylinder Block

After the cylinder block has been cleaned and descaled, it must be pressure tested for cracks or leaks by either one of two methods. In either method, it will be necessary to make a steel plate d ½" stock to cover each cylinder bank of the block (fig. 9). The plate(s) will adequately seal the top surface of the block when used with cylinder liner compression gaskets and water hole seal rings. It will also be necessary to use water hole cover plates d gaskets to seal the water inlet openings in the sides of the block. One cover plate should be drilled and tapped to provide a connection for an air line so the water jacket can be pressurized.

METHOD "A"

This method may be used when a large enough water tank is available and the cylinder block is completely stripped of all parts.

I. Make sure the seal ring grooves in the cylinder bores of the block are clean. Then, install new seal rings in the grooves (above the air inlet ports).

NOTE

The blocks have two seal ring grooves above the air inlet ports of each cylinder bore. Only one seal ring is required, however. Install the seal ring in the upper groove, if it is in good condition; if the upper groove is pitted or eroded, install the seal ring in the lower groove.

2. Apply a light coating of hydrogenated vegetable type shortening or permanent type anti-freeze solution to the seal rings.

3. Slide the cylinder liners into the block, being careful not to roll or damage the seal rings. Install new compression gaskets and water hole seal rings in the counterbores in the top surface of the block.

4. Place the plate(s) on the top of the block and tighten it securely with ten 5/8"-11 bolts and flat washers.

5. Install the water hole cover plates and gaskets on the sides of the block.

6. Immerse the block for twenty minutes in a tank of water which is heated to 180° -200" F.

7. Attach an air line to the water hole cover plate and apply 80-100 p.s.i. air pressure to the water jackets and observe the water in the tank. for bubbles which will indicate cracks or leaks

8. Remove the block from the water tank. Then, remove the plates, seals, gaskets, and liners and blow out all of the passages in the block with compressed air.

9. Dry the cylinder liners with compressed air and coat them with oil to prevent rust.

METHOD "B"

This method may be used when a large tank for water testing is unavailable.

Prepare the block as outlined in Method "A". However, before installing the large sealing plate, fill the water jacket with a mixture of water and one gallon of permanent type antifreeze. The antifreeze will penetrate small cracks, and its color will aid in detecting their presence.

2. Install the sealing plate(s) and water hole covers as outlined in Method "A".

3. Apply 80-100 psi air pressure to the water jacket and maintain this pressure for at least two hours to give the water and antifreeze mixture ample time to work its way through any cracks wich may exist.

4. At the end of the test period, examine the cylinder bores, air box, oil passages, crankcase and exterior of the block for water and antifreeze mixture, which will indicate the presence of cracks.

5. After the pressure test is completed, remove the sealing plates and drain the water jacket. Then, remove the liners and seal rings and blow out all of the passages in the block with compressed air.

6. Dry the cylinder liners with compressed air and coat them with oil to prevent rust.

Inspect Cylinder Block

After cleaning and pressure testing, inspect the cylinder block as follows:

1. Check the top of the block for flatness with an accurate straight edge and a feeler gage. The top surface must not vary more than .003" transversely and not over .006" (3-53 engine) longitudinally.

2. Check the block bores as follows:

a. Make sure the seal ring grooves (fig. 8) are thoroughly clean. Then, inspect the grooves and lands for evidence of pitting and erosion. Two grooves are provided above the air inlet ports of each cylinder bore in the block. However, a cylinder liner seal ring is required in the upper groove only. The lower groove is provided for the seal ring if inspection reveals extensive pitting or erosion along the upper land or inner surface of the upper groove. If both grooves are eroded to the extent that sealing is affected, then the block must be replaced.

b. Measure each block bore, at the positions indicated in figure 9, on axes 90 apart. Use cylinder bore gage J 5347, which has a dial indicator calibrated in .0001" increments, and set the gage to zero with dial bore gage setting fixture J 23059. If the diameter does not exceed 4.5235" at position "A", 4.4900" at position "B" (and a sealing problem hasn't occurred), or 4.3595" at positions "C" and "D", then the block may be reused. Also, the taper and out-of-roundness must not exceed .0015".

3. Check the main bearing bores as follows:

a. Lubricate the bolt threads and the bolt head contact areas with a small quantity of International Compound No. 2 or equivalent. Install the bearing caps and tighten the bolts to the specified torque (sec. 1.1.0).

NOTE

It is imperative that the main bearing caps are reinstalled in their original positions to maintain the main bearing bore alignment. The bearing caps are numbered to correspond with their respective positions in the block. The number of the front hearing cap is also stamped on the face of

the oil pan mounting flange of the block, adjacent to its permanent location in the engine as established at the time of manufacture. The No. 1 cylinder and main bearing cap is always located at the end opposite the flywheel end of the block (*fig.* 101.

NOTE 2

Main bearing cap bolts are especially designed for this purpose and must not be replaced by ordinary bolts.

b. Measure the bearing bores. The bearing bores must be 3.251" to 3.252" (in-line block). If the bores do not fall within these limits, discard the block.

c. Check the main bearing bores for alignment. The hearing bores may be considered properly aligned with one another if a crankshaft with standard size journals can be rotated freely by hand, after new standard size main bearing shells have *been* installed *and* lubricated, and the bearing caps have been secured as in Step "a".

d. Service replacement main bearing caps are available, if a new bearing cap is required. However, it may be necessary to try several replacement caps before one is found to provide the correct bore alignment in a particular block. If a replacement bearing cap is installed, be sure to stamp the correct bearing number on the cap.

4. Make sure the cylinder liner counterbores in the block are clean and free of dirt. Then, check the depth. The depth must be from .300" to .302" and must not vary more than .0015" throughout the entire circumference. The counterbored surfaces must be smooth and square with the cylinder bore within .001" total indicator reading. There must not he over .001" difference in depth between any two adjacent cylinder counterbores when measured along the longitudinal center line of the cylinder block.

5. Check all of the machined surfaces and threaded holes in the block. Remove nicks and burrs from the machined surfaces with a file. Clean-up damaged threads in the tapped holes with a tap or install helical thread inserts.

6. Replace loose or damaged dowel pins.

7. Install all required plugs. Use a good grade sealing compound on the threads of the plugs. If a new service block is used, make sure the tor surface is plugged correctly to prevent low oil pressure or the accumulation of abnormal quantities of del in the cylinder head.

8. If a new service replacement block is used, stam p the unit serial number and model number on the upper rear corner of the In-line block. Also, make sure the hearing caps are properly numbered 10).

9. After inspection, if the cylinder block is not to he used immediately, spray the machined surfaces with engine oil. If the block is to be stored for an extended period of time, spray or dip the block in a polar rust preventive such as Valvoline Oil Company's "Tectyl 502-C", or its equivalent. Castings free of grease or oil will rust when exposed to the at mosphere.

Assemble and Install Engine

After the cylinder block has been cleaned and inspected, assemble the engine as follows:

1. Clean all oil or rust preventive from the block.
2. Mount the block on an overhaul stand, if rem oved.
3. Clean and inspect all engine parts and subassemblies and. using new parts as required, install them on the cylinder block by reversing the sequence of disassembly.
4. Remove the engine from the overhaul stand.
5. Install the air box heater cover and fasten with special screws.
6. install the accessories that were removed from the engine before it was mounted on the overhaul stand (prior to disassembly).
7. Operate the engine on a dynamometer following the run-in procedure outlined in section 13.2.1.
8. Reinstall the engine in the unit.
9. Fill the crankcase to the proper level with lubricating oil recommended in section 13.3.
10. Close all drains and fill the cooling system.

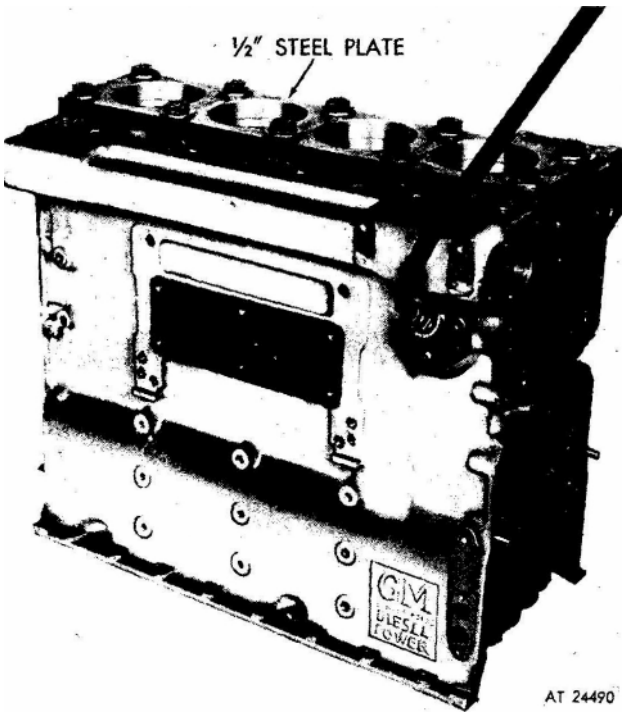


Figure 7. Cylinder block prepared for pressure test.

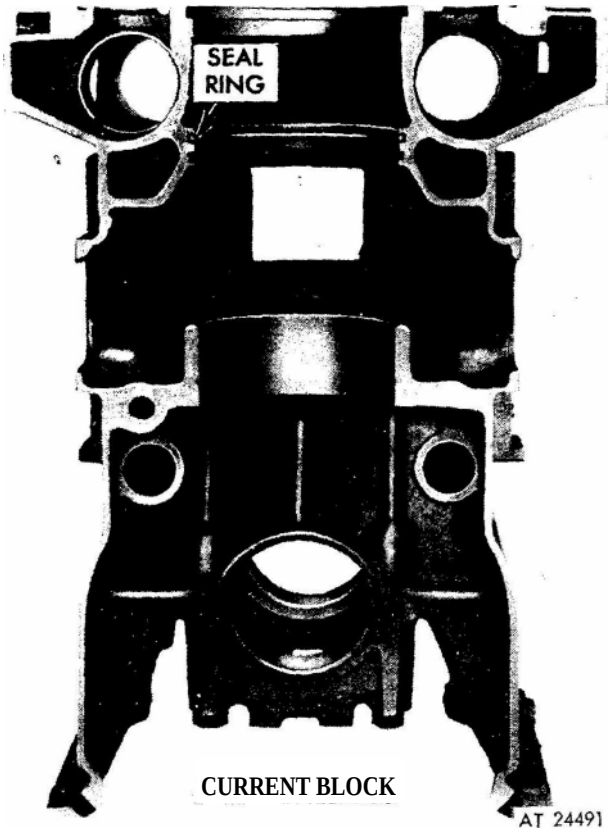


Figure 8. Location of block bore seal ring grooves.

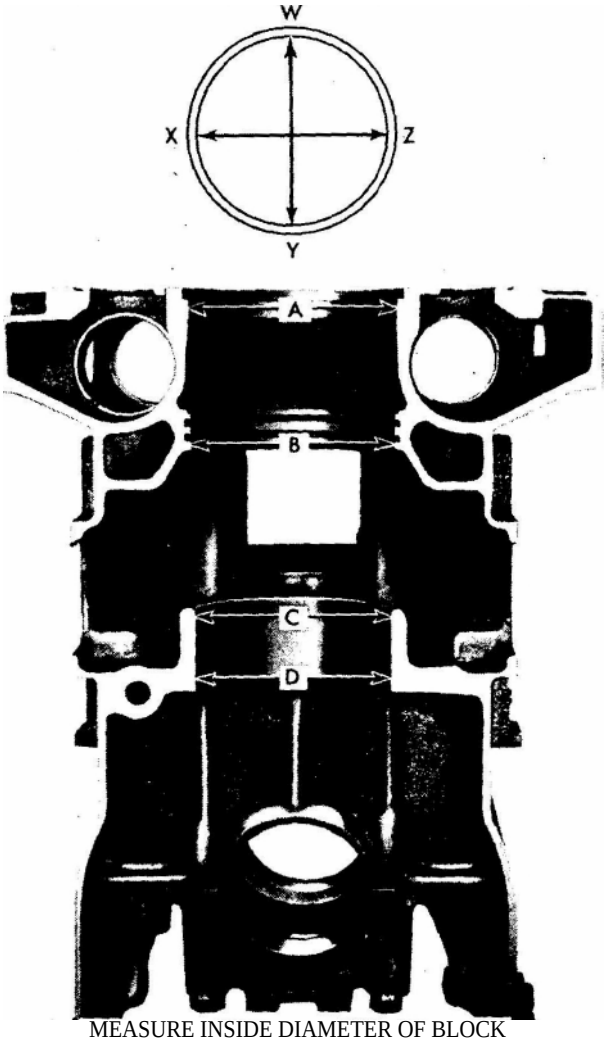


Figure 9. Block bore measurement diagram.

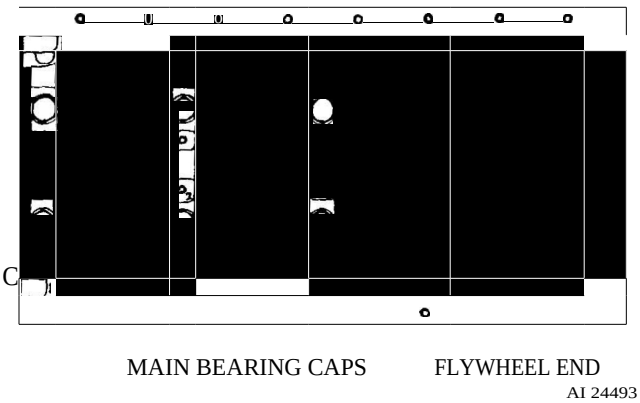


Figure 10. Typical cylinder block markings.

CYLINDER BLOCK END PLATE

A flat steel plate is bolted to the rear end of the cylinder block to provide a means of attaching the flywheel housing. At the time of a complete engine overhaul or of a cylinder block change, the cylinder block rear end plate will be removed and reinstalled on the block.

Inspection

When the end plate is removed, it is essential that all of the old gasket material be removed form both surfaces of the end plate and cleaned as outlined under "Clean Cylinder Block" in section 1.1. Check the surfaces of the end plate for nicks, dents, scratches or score marks; also check the end plate for flatness. Plug nuts in the end plate should also he checked for cracks and damaged threads. If nicks or scratches on the sealing surfaces of the end plate are too deep to be cleaned up, or the plug nuts are damaged, the end plate or plug nuts must be replaced. When installing a plug nut, support the end plate on a solid flat surface to avoid distorting the plate. Then, press the nut in the end plate until the head on the nut seats on the end plate.

Install Cylinder Block Rear End Plate

1. Affix a new gasket to the end of the cylinder block (flywheel end), using a non-hardening gasket cement; also apply an even coating of gasket cement to the outer surface of the gasket next to the end plate.

2. Align the dowel pin holes in the end plate with the dowel pins in the cylinder block. Then, start the end plate over the dowel pins and push it up against the cylinder block.

NOTE

When installing the end plate, the heads *af* the plug nuts at the top of the end plate should always face the forward end of the cylinder block, as shown in figure 1.

3. Refer to figure 1 for the location and install the ⅛"-16 x 7 / 8" bolts with lockwashers. Tighten the bolts to 30-35 lb-ft torque.

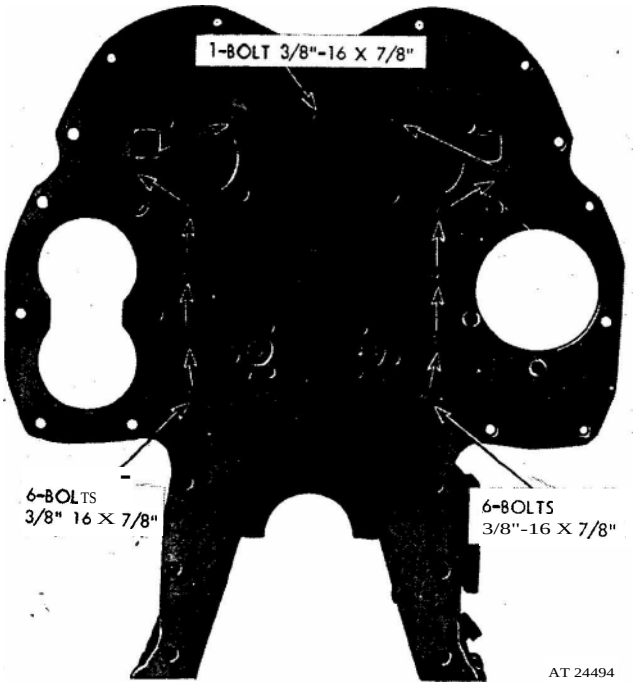


Figure 1. Cylinder block rear end plate mounting—in-line engines.

AIR BOX DRAINS

During normal engine operation, water vapor from the air charge, as well as a slight amount of fuel and lubricating oil fumes, condense and settle on the bottom of the air box. This condensation is removed by the air box pressure through the air box drain tube mounted on the side of the cylinder block (fig. I). One drain tube is used on an In-line engine, (fig. 1 I. The air box drain should be open at all times. With the engine running-. a periodic check is recommended for air flow from the air box drain tube. Liquid accumulation on the bottom of the air box, indicates a drain tube may be plugged. Such accumulations can be seen by removing the cylinder block air box heater cover and should be wiped out with rags or blown out with compressed air. Then remove the drain tube and connector from the cylinder block and clean them thoroughly.

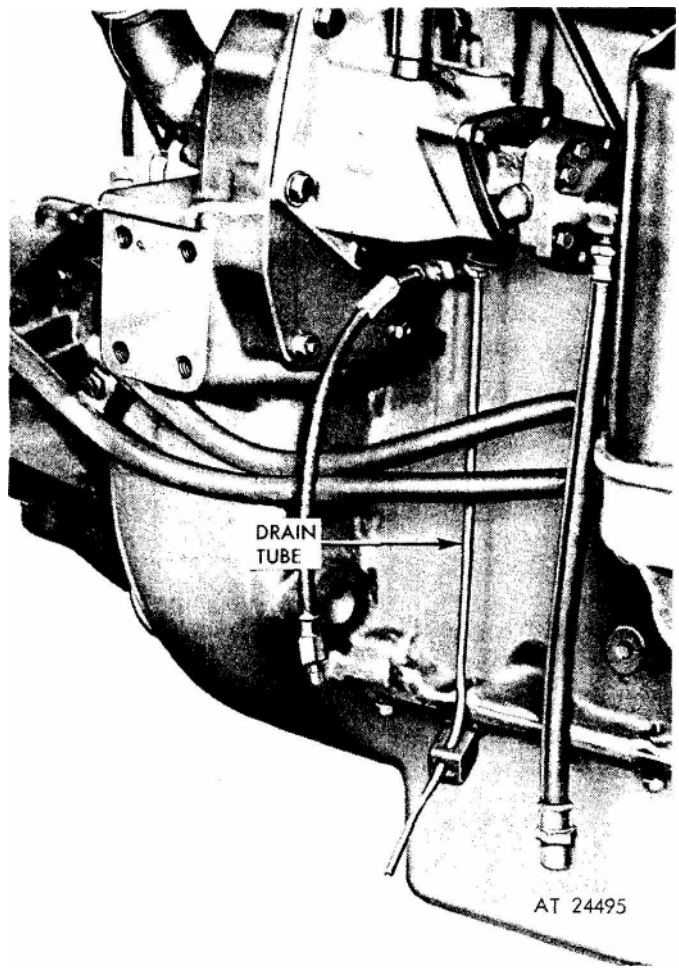


Figure 1. Air box drain tube mounting (in-line engines).

SHOP NOTES-SPECIFICATIONS-SERVICE TOOLS

SHOP NOTES

Teflon Wrapped Pipe Plugs

Pipe plugs can be hand wrapped satisfactorily with teflon tape to provide a better seal and facilitate plug removal. When a teflon wrapped plug is installed, it is extremely important that the specified torque not he exceeded. Hand wrap a pipe plug with teflon tape as follows:

I. Be sure the pipe plug is clean.

2. Wrap the tape on the plug in the same direction as you would turn a nut.

3. Start the tape a half to one thread back from the base of the plug and wrap it tightly one and a half times around the plug. Be sure the tape is at least half way down in the thread grooves.

4. Hand tighten and hand torque the pipe plug and do not exceed the specified torque. Do not use power tools.

SPECIFICATIONS

Table of Specifications, New Clearances, and Wear Limits

Engine part (standard size)	New parts Minimum	New parts Maximum	Wear Limits
CYLINDER BLOCK			
Block Bores			
Diameter (Top)	4.5195"	4.5215"	4.5235"
Diameter (Center)	4.4865"	4.4880"	4.4900"
Diameter (Bottom)	4.3565"	4.3575"	4.3595"
Out-of-Round		.0015"	
Taper		.0015"	
Top Surface			
Flatness—Transverse (All)			.0030"
Flatness—Longitudinal (3)			.0060"
Depth of Counterbores (Top Surface)			
Cylinder Head Seal Strip Groove	.0970"	.1070"	
Oil Holes	.0920"	.0980"	
Water Holes	.1090"	.1150"	
Main Bearing Bore			
Inside Diameter (Vertical Axis) In-Line Engine	3.2510"	3.2520"	
Cylinder Liner Counterbore			
Diameter	4.8200"	4.8350"	
Depth	.3000"	.3020"	

Standard Bolt and Nut Torque Specifications

Size nut or bolt	Torque (lb ft)	Size nut or bolt	Torque (lb-ft)	Size nut or bolt	Torque (lb-ft
1/4 20	7-9	7/16 - 20	57-61	3/4 - 10	240-250
1/4 - 28	8-10	1/2 - 13	71-75	3/4 - 16	290-300
5/16 - 18	13-17	1/2 - 20	83-93	7/8 - 9	410-420
5/16 - 24	15-19	9/16 - 12	90-100	7/8 - 14	475-485
3/8 - 16	30-35	9/16 - 18	107-117	1 - 8	580-590
3/8 - 24	35-39	5/8 - 11	137-147	1 - 14	685-695
7/16 - 14	46-50	5/8 - 18	168-178		

Exceptions to Standard Bolt and Nat Torque Specifications-

Application	Size nut or bolt	Torque (ib-ft)
Air Box Cover Bolts (In-Line Engine)	3/8 - 16	12-16
Stabilizer to Cylinder Block Bolt	7/16 - 14	70-75
*Main Bearing Cap Bolt	9/16 - 12	120-130

*Lubricate at assembly with a small quantity of International Compound No. 2 or equivalent.

SERVICE TOOLS

Tool No.	Tool name
J 5437	Bore Gage
J 6837-01	Engine Overhaul Stand
J 7622	Adaptor Plate (In-Line)
J 23059	Dial Bore Gage Master Setting Fixture

CYLINDER HEAD

The cylinder head (fig. 1) is a one-piece casting. It may be removed from the engine as an assembly containing cam followers, cam follower guides, rocker arms, exhaust valves and injectors. The head is securely held to the top of the cylinder block with bolts.

Located in the cylinder head are the exhaust valves, a fuel injector and three rocker arms for each cylinder. One rocker arm operates the injector plunger; the other two operate the exhaust valves. The rocker arms are operated by the camshaft through cam followers and push rods.

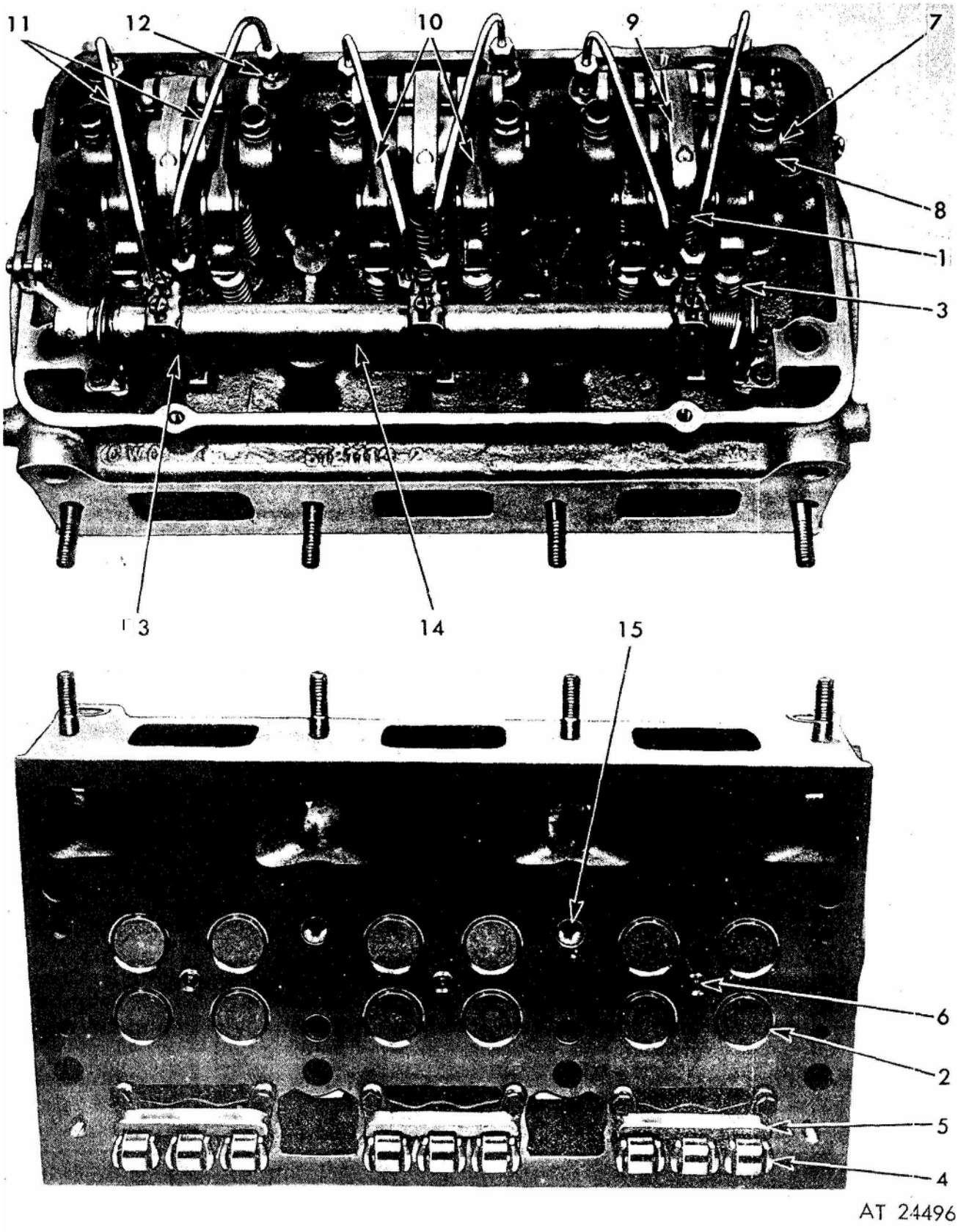


Figure 1. Typical four valve cylinder head assembly.

Exhaust valve inserts (valve seats), pressed into the cylinder head, permit accurate seating of the valves under varying conditions of temperature and materially prolong the life of the cylinder head. The inserts are ground to a very close limits and their freedom from warpage, under ordinary conditions, reduces valve reconditioning to a minimum. The exhaust valves and valve seat inserts are ground to a seating angle of 30 To ensure efficient cooling, each fuel injector is inserted into a thin-walled tube which passes through the water space in the cylinder head. The lower end of the injector tube is pressed into the cylinder head and flared over; the upper end is flanged and sealed with a neoprene seal. The flared lower end and sealed upper end prevent water leaks around the copper tube. The exhaust passages from the exhaust valves of each cylinder lead through a single port to the exhaust manifold. The exhaust passages, exhaust valve inserts and injector tubes are completely surrounded by cooling system water. In addition to being surrounded by water, cooling of these areas is further assured by the use of double jet spray nozzles installed between each pair of cylinders in the water inlet ports of four valve cylinder heads. Nozzle holes are so positioned in the cylinder head that the comparatively cool water which enters the head is directed at high velocity against the sections of the head which are subjected to the greatest heat. To seal compression between the cylinder head and the cylinder block, separate laminated metal gaskets are provided at each cylinder. Water and oil passages between the block and head are sealed with synthetic rubber seal rings which fit into counterbored holes in the block. A synthetic rubber seal fits into a milled groove in the block near the outer edge of the area covered by the cylinder head. When the cylinder head is pulled down, a positive leakproof metal-to-metal contact is assured between the head and block. Certain service operations on the engine require the removal of the cylinder head. These operations are

1. Removing and installing the pistons.
2. Removing and installing the cylinder liners.
3. Removing and installing the exhaust valves.
4. Removing and installing the valve guides.
5. Recondition the exhaust valves and valve seats.
6. Replacing the injector tubes.
7. Installing new cylinder head gaskets.
8. Removing and installing the camshaft.

1 Injector
2 Exhaust valve
3 Spring—valve
4 Cam follower
5 Guide—cam follower
6 Spray tip—injector
7 Shaft—rocker arm
8 Bracket—rocker arm shaft
9 Rocker arm—injector
10 Rocker arms—exhaust valve
11 Fuel lines
12 Connector—fuel line
13 Lever—injector control tube
14 Tube—injector control
15 Water nozzle

CYLINDER HEAD MAINTENANCE

The development of cracks in the cylinder head may he caused by abnormal operating conditions or

through neglect of certain maintenance items. If this type of failure should occur, a careful inspection should he made to find the cause so that a recurrence of the failure will be prevented. Engine temperatures should be maintained between 160 —185° F. and the cooling system should be inspected daily and kept full at all times. Adding cold water to a hot engine may result in head cracks. Water must he added slowly to a hot engine to avoid rapid cooling which will result in distortion and (Tacking of the cylinder head (and cylinder block Unsuitable water in the cooling system may result in lime and *scale* formation and prevent proper cooling. A cracked cylinder head should be inspected around the exhaust valve water jackets. This *can* be done by removing an injector tube. Where inspection discloses such deposits are prevalent, a reliable, non-corrosive scale remover should be used to remove deposits from the cooling system of the engine since a similar condition will exist in the cylinder block and other components of the engine. if a soft or non-scale forming water cannot be obtained, use a scale inhibiting compound with the cooling water. See section 5 for further cooling, system maintenance procedures. Loose or improperly seated injector tubes may result in compression leaks into the cooling system and cause a loss of engine coolant. The tubes should be tight and properly seated. See section 2.1.4. Overtightening the injector clamp bolts may also result in head cracks. Always use a torque wrench to tighten the bolts to the specified torque. Other conditions which may eventually result in bead cracks are-

1. Excess fuel in the cylinder. Check for leaking injectors as outlined in section 2.1.

2. Neglected cylinder block air box drains which allow liquid accumulations and permit oil to be drawn into the cylinders. The drains should be inspected and blown out with compressed air periodically, see section 1.1.2.

Remove Cylinder Head

Due to various optional and accessory equipment used on the different models of the Series 53 engines, only the general steps for removal of the cylinder head are covered. If the unit is equipped with special accessories other than those mentioned below, the mechanic should carefully disconnect or remove those affecting cylinder head removal, making sure to note their position to assure correct reassembly.

1. Disconnect the exhaust piping at the exhaust manifold.
2. Drain the cooling system.
3. Disconnect the air connection.
4. Disconnect the fuel lines at the cylinder head.
5. Remove the thermostat housing and the thermostat as an assembly.
6. Remove the valve rocker cover.
7. Disconnect and remove the fuel rod between the governor and the injector control tube lever. Remove the fuel rod cover, if used.
8. Remove the exhaust manifold:
9. Remove the injector control tube and brackets as an assembly.
10. If the cylinder head is to be stripped for reconditioning of valves and valve seats or for a complete cylinder head overhaul. the fuel lines and injectors should be removed at this time. Refer to section 2.1.1 for removal of the injectors.
11. Remove the cylinder head bolts. Then, lift. the cylinder head off the cylinder block, using tool J 2206 -01 (fig. 21.

CAUTION

When resting the cylinder head assembly on a bench, protect the cam follower rollers and the injector spray tips by resting the valve side of the head on wooden blocks at least 2" thick.

12. Remove the cylinder head compression gaskets, oil seals, and water seals.

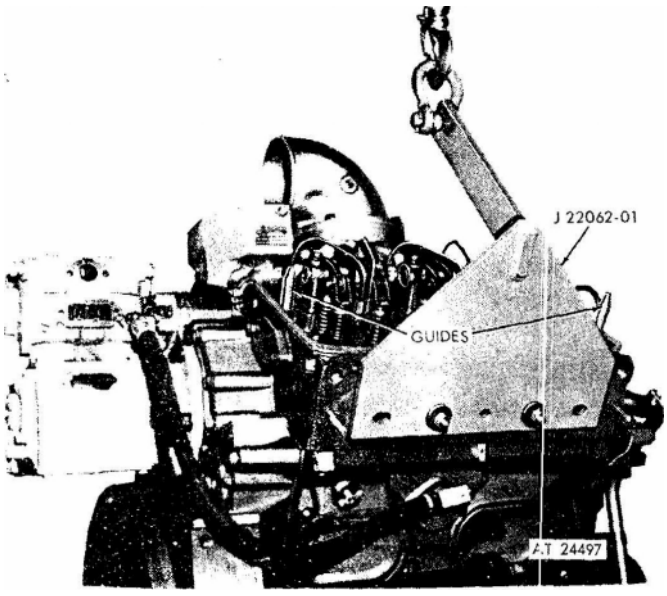


Figure 2. Lifting cylinder head assembly off cylinder block.

Disassemble Cylinder Head

If a cylinder head was removed for inspection and possible repair or replacement, remove the following parts:

1. Fuel injectors, if not previously removed.
2. Fuel connectors.
3. Cam follower guides and cam followers.
4. Rocker arms, rocker arm shafts, brackets, push rods, push rod springs, spring seats and spring seat retainers.
5. Exhaust valves and valve springs.

The removal procedures to be followed, when removing the parts mentioned above, are covered in their respective sections of this manual.

Inspect Parts Removed from Cylinder Head

The parts removed from the cylinder head should he inspected before they are reinstalled in the old head or transferred to a new cylinder head. The inspection procedures to be followed are covered in their respective sections of this manual. New factory-engineered cylinder heads for replacement purposes are equipped with exhaust valve seat inserts, exhaust valve guides, and the necessary plugs.

Clean Cylinder Head

After the cylinder head has been stripped of all its component parts and all of the plugs (except cup plugs) have been removed, steam clean the head thoroughly. Thoroughly clean a service cylinder head to remove all of the rust preventive compound, particularly from the integral fuel manifolds, before the plugs are installed in the fuel manifolds and the head is mounted on an engine. A simple method of removing the rust preventive compound is to immerse the head in solvent, oleum or fuel oil; then, go over the head and through all of the openings with a soft bristle brush. A suitable brush for cleaning the fuel manifolds can be made by attaching a IA" brass rod to brush J 8152. After cleaning the head, it should be blown dry with compressed air to remove all of the solvent.

inspect Cylinder Head

1. Check the cylinder head for leaks using the following procedure:

a. Seal off the water holes in the head, using steel plates and suitable rubber gaskets held in place by bolts.

b. Install dummy or scrap injectors to ensure seating of the injector tubes. Dummy injectors may be made up with old injector nuts and bodies — the injector spray tip is not necessary. Tighten the injector clamp bolt to 20-25 lb-ft torque.

c. Drill and tap into one of the water hole cover plates for an air hose connection and apply 80-100 psi air pressure to the water jacket. Then, immerse the head in a tank of water previously heated to 180 °-200°F. for twenty minutes to thoroughly heat the cylinder head. Observe the water in the tank for bubbles indicating cracks or leaks.

d. Dry the head with compressed air.

e. Replace any leaking injector tubes as outlined in section 2.1.4. If inspection revealed cracks in the cylinder head, it should be replaced. Over a prolonged period of operation, the cylinder head may assume a contour to match that of the cylinder block, which is normal. However, if the cylinder head is allowed to become overheated because of coolant loss, the resultant high temperatures cause stresses to occur in the casting which will affect the flatness of the head. Therefore, the bottom (fire deck) of the cylinder head should be checked for flatness as follows:

2. Use an accurate straight-edge and feeler gage J 3172 to check for transverse warpage at each end and between all cylinders. Also, check for longitudinal warpage in six places, as shown in figure 3. Maximum allowable warpage is given in the following table:

Engine	Maximum longitudinal warpage	Maximum transverse warpage
3-53	.005"	.004"

The maximum allowable warpage limits should be used as a guide in determining the advisability of reinstalling the head on the engine or of refacing it. The number of times a cylinder head may be refaced will of course, depend upon the amount of stock removed from the head during previous reworking operations. When refacing a cylinder head, the amount of stock removed should be stamped on the face of the fire deck near the outer edge of the head, in an area not used as a sealing surface. Not over .020" of metal should be removed from the fire deck of any cylinder head. The distance from the top to the bottom (fire deck) of tile cylinder head must not be less than 4.376", as shown in figure 4. If the cylinder head is to be refaced, the injector tubes should be removed prior to refacing the head. After a cylinder head has been refaced, and new injector tubes have been installed as outlined in section 2.1.4, the cylinder head should be pressure checked. The top surface of the cylinder block will not warp to the extent that

machining will become necessary, therefore no warpage limits or machining limits are required.

3. Inspect the cam follower bores in the cylinder head for scoring or wear. Light score marks may be cleaned up with crocus cloth wet with fuel oil. If the bores are excessively scored or worn so that cam follower-to-head clearance exceeds .006", replace the cylinder head.

4. Check the valve seat inserts for cracks or burning. Also, check the valve guides for scoring.

5. Check the water nozzles to be sure they are not loose. Water nozzles are used only in the passages between the cylinders. To install or replace the cylinder head water nozzles:

a. Be sure the water inlet ports in the bottom of the head are clean and free of scale. The water holes may be cleaned up with a $\frac{5}{8}$" diameter drill. Break the edges of the holes slightly.

b. Check to be sure the nozzles will fit tight in the cylinder head. If the water holes in the head have been enlarged by corrosion, use a wooden plug or other suitable tool to expand the nozzles, so that they will remain tight after installation.

c. Press the nozzles into place with the outlet holes positioned as shown in figure 5. The angle between the outlet holes in the nozzles is 90 ° . The nozzles should he from flush to 1 / 32" below the bottom surface of the cylinder head, otherwise interference with proper seating of the head on the cylinder block may be *encountered.*

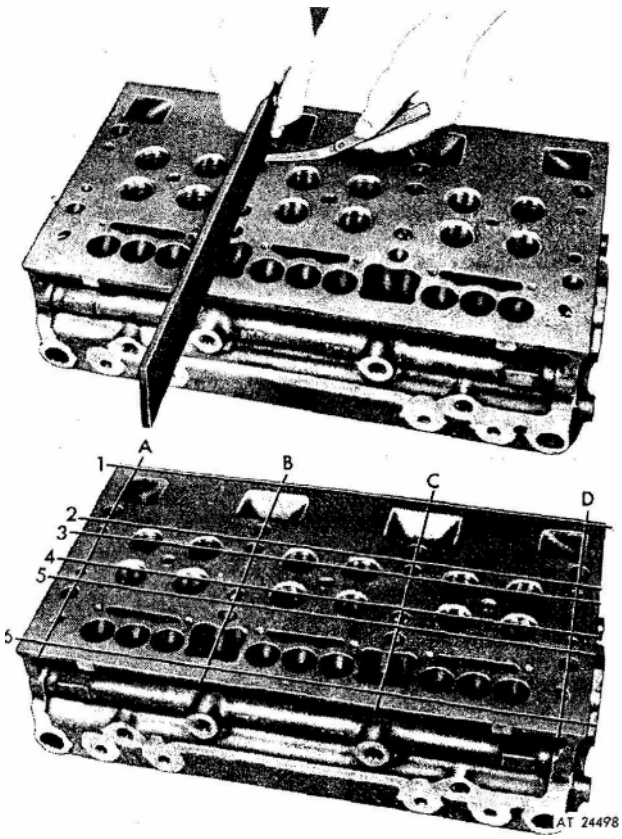


Figure 3. Checking bottom face of cylinder head for warpage.

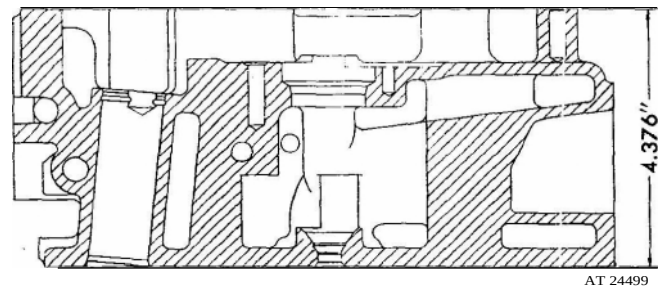


Figure 4. Minimum distance between top and bottom faces of cylinder head.

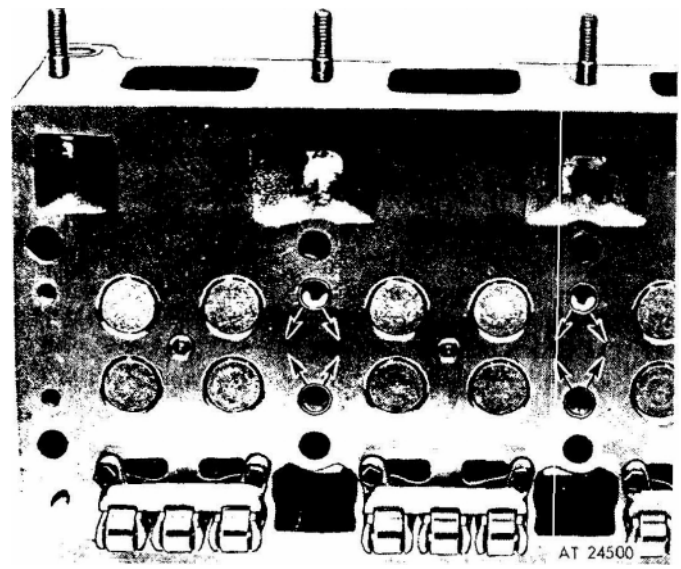


Figure 5. Correct installation of water nozzles in four valve cylinder head.

Assemble Cylinder Head

A service replacement cylinder head includes valve guides, valve seat inserts, water nozzles, injector tubes, a governor control link adaptor and the necessary plugs.

CAUTION

When installing the plugs in the fuel manifolds, apply a small amount of sealant merchandized as a "dual purpose sealer" to the threads of the plugs only. Work the sealant into the threads and wipe off excess with a clean, lint-free cloth so that *the* sealant will not be washed into the fuel system and result in serious damage to the injectors.

Arm the following parts are cleaned and inspected, reinstall them in -the old cylinder head or transfer them to the new head. Refer to section 1.2.0 for torque specifications on bolts and nuts.

1. Exhaust manifold studs (sec. 6.1).
2. Exhaust valves and springs (sec. 1.2.2).
3. Install the fuel injectors at this time or after installing the cylinder head (sec. 2.1 or 2.1.1).
4. Cam followers, cam follower guides, push rod assemblies, rocker arm shaft and rocker arms; but do not tighten the rocker arm bracket bolts now (sec. 1.2.1).
5. Place new washers on the fuel connectors; then install the fuel connectors and tighten them to 20-28 lb-ft torque.

Pre-Installation Inspection

The following inspections should be made just prior to installing the cylinder head on the engine. These inspections should be made whether the head was removed from the engine for servicing only the head assembly, or to facilitate other repairs to the engine.

1. Check the cylinder liner flange height with relationship to the cylinder block, as outlined in section 1.6.3.
2. Check to be sure the tops of the pistons are clean and free of foreign material.
3. Check to see that each push rod is threaded its clevis until the end of the push rod projects through the clevis. This is important since serious engine damage will be prevented when the crankshaft is rotated during tune-up.
4. To avoid damage to the water and oil seals, check to be sure that the groove and the counterbores in the top of the cylinder block are clean and smooth.

Install Cylinder Head

1. Install *new* cylinder head compression gaskets, and seals as outlined below:

a. Install a new compression gasket on each cylinder liner.

h. Place new seal rings in the counterbores of the water and oil holes in the cylinder block.

c. Install a new oil seal in the milled groove near the outer edge of the area covered by the cylinder head.

NOTE

Water seals, oil seals, and compression gaskets should NEVER be reused.

2. To install the cylinder head on the engine without disturbing the gaskets and seals, special guides J 9665 should be used. Install the cylinder head guide studs, in the end cylinder block bolt holes (fig. 2).

Make a final visual check of all the cylinder head gaskets and seals to ensure that they are in place just before the cylinder head is lowered onto the cylinder block. This is a very important check. Compression gaskets and seals which are jarred out of their proper position will lead to leaks and "blow-by" with resultant poor engine performance and damage to the engine. Wipe the bottom of the cylinder head clean ; then, lower the head on the block.

3. Lubricate the threads and the under side of each cylinder head bolt with a small quantity of International Compound No. 2 or equivalent. Then, install the bolts and tighten them to the specified torque.

NOTE

Cylinder head bolts are especially designed for this purpose and must not be replaced by ordinary bolts.

4. The cylinder head must be gradually and uniformly drawn down on the gaskets and seals to ensure a good seal between the cylinder head and block. Therefore, it is vitally important that the cylinder head be installed with the utmost care.
5. Then, begin on the camshaft side of the head to take up the tension in the cam follower springs by tightening the bolts lightly. Finally tighten the bolts to 170-180 lb-ft torque with a torque wrench, about one-half turn at a time, in the sequence shown in figure 6. Under no circumstances should the torque exceed the specified limits, otherwise the bolts may become stretched beyond their elastic limits.

6. Cover the oil drain holes in the cylinder head to prevent foreign objects from falling into the holes.

7. If the injectors were not previously installed, refer to section 2.1.1 and install them at this time.

8. Set injector control tube assembly in place on cylinder head and tighten hold-down bolts, finger tight only. When positioning injector control tube he sure that ball end of injector control rack levers engage the slots in the injector control racks. With one end of the control tube return spring hooked around one injector rack control lever and the other end hooked around the control tube bracket, tighten bracket bolts with a 7 / 16" universal socket wrench to 10-12 lb-ft torque. After tightening bolts, revolve tube and see if the return spring pulls the injector racks OUT (NO FUEL POSITION) after they have been moved all the way IN (FULL FUEL POSITION). Since the injector control tube is mounted in self-aligning bearings, tapping the tube lightly with a soft hammer will remove any bind that exists. The injector racks MUST return to the no fuel position freely by aid of the return spring only. DO NOT bend the return spring to bring about this condition.

9. Install rod, also fuel rod cover if used.

10. Remove the oil drain hole covers in the cylinder head.

11. Install exhaust manifold.

12. Install thermostat housing and thermostat.

13. Install water hose and hose clamps.

14. Connect fuel lines.

15. Fill cooling system and check for leaks.

16. With throttle in OFF position, hand crank engine to be assured that all parts function freely.

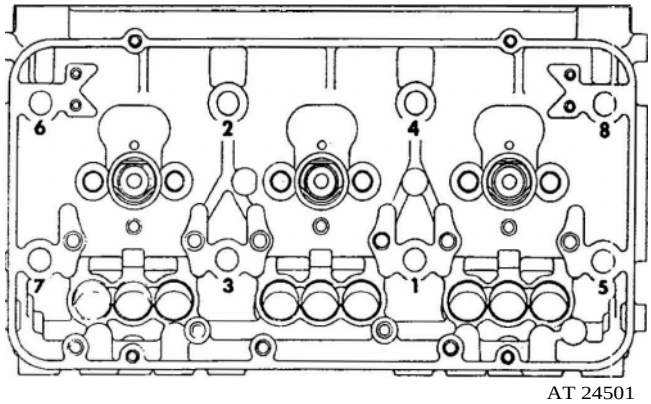
17. Before starting engine, perform engine tune-up as outlined in section 14.

18. Refer to section 13.1 and start engine. After starting engine, see that all fuel line connections are tight to ensure that no fuel oil leaks into the cylinder head compartment to dilute the lubricating Oil.

19. After engine has been warmed up (to at least 160°F.) check torque of cylinder head bolts.

20. Recheck exhaust valve clearance adjustment with engine at normal operating temperature as outlined in section 14.1.

21. Examine all fuel oil, lubricating oil, and water connections for possible leaks, and correct any that are discovered.



AT 24501

3V-53 CYLINDER HEAD

Figure 6. Sequence for tightening cylinder head bolts.'

VALVE AND INJECTOR OPERATING MECHANISM

Three rocker arms are provided for each cylinder; the two outer arms operate the exhaust valves and the center arm operates the fuel injector. Each set of three rocker arm assemblies pivots on a separate shaft supported by two brackets. A single bolt secures each bracket to the top of the cylinder head. Consequently, the removal of two bracket bolts permits the rocker arm assembly for one cylinder to be raised providing easy access to the fuel injector and valve springs. The rocker arms are operated by the camshaft through cam followers and short push rods extending through the cylinder head (fig. 1). Contact between each cam follower and the camshaft is effected by a hardened roller incorporating a pressed-in bushing, which runs directly on a pin in the lower end of the cam follower. Each follower operates in a bore in the cylinder bead. A guide for each set of three cam followers is attached to the bottom -of the cylinder head to keep the follower rollers in line with the cams and serves as a retainer during assembly and disassembly. A separate coil spring, located inside each cam follower, is held in place in the cylinder head by a spring seat and spring seat retainer. Several operations may be performed on the valve mechanism without removing the cylinder head from the cylinder block, while the head must be removed for certain other operations. The operations NOT requiring the removal of the head are-

1. Adjusting valve clearance.
2. Removing and installing a valve spring.
3. Removing and installing a rocker arm.
4. Removing and installing a rocker arm shaft or shaft bracket.
5. Removing and installing an injector.

It is also possible, if occasion requires, to remove or replace a push rod, push rod spring, spring seats or cam follower without removing the cylinder head. These parts, however, are more easily changed from the lower side of the cylinder head when the head is off the engine. Both methods are covered in this section.

To remove and install valves, valve guides. valve seat inserts and to recondition valves and valve seats, the cylinder head must be removed. Exhaust valves. guides and inserts are covered in section 1.2.2.

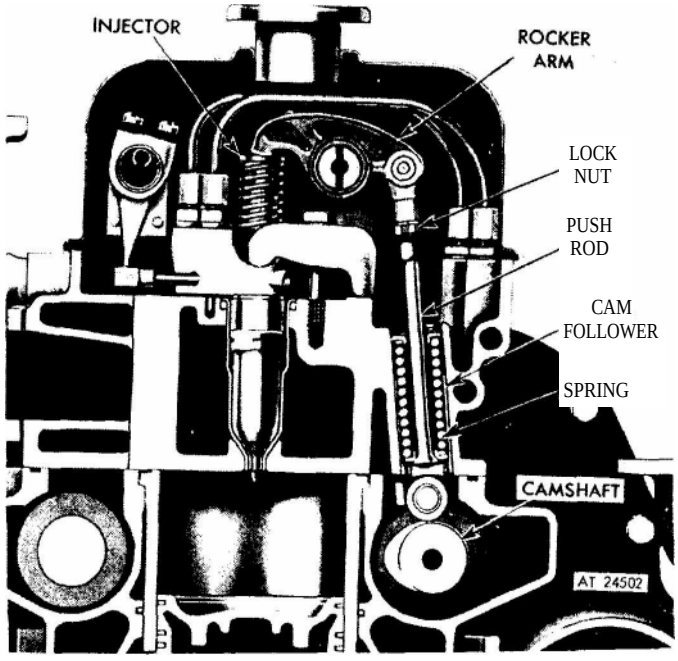


Figure I. Injector operating mechanism (in line engine shown).

Lubrication

The valve and injector operating mechanism is lubricated by oil from a longitudinal oil passage, on the camshaft side of the cylinder head, which connects with oil passages in the cylinder block. Oil from this longitudinal passage enters the drilled rocker arm shafts through the lower end of the drilled rocker shaft bracket bolts, and lubricates the rocker arms. Excess oil from the rocker arms lubricates the exhaust valves and cam followers. Additional cam follower lubrication is provided by oil from grooves in the camshaft bushing bores which is jetted against the cam follower rollers.

Remove Rocker Arms and Rocker Arm Shaft

emove the valve rocker cov

2. Remove the fuel lines from the injector and fuel connectors.

3. liar *engine* over in direction of *engine* rotation or crank engine with starting motor. if necessary, to bring push rod ends—outer ends—of injector and valve rocker arms in line horizontally.

Remove the two bolts which hold the rocker arm shaft brackets to the cylinder head. Remove brackets and shaft.

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

Inspection

Wash the rocker arms, rocker arm shaft and brackets thoroughly in clean fuel oil and dry them with compressed air. Make certain that the oil passages in the rocker arms, rocker arm shaft, and bracket bolts are open and clean. Inspect all parts for excessive wear. The maximum clearance between the rocker arm shaft and the injector rocker arm bushing or an exhaust valve rocker arm (which has no bushing) is .004" with used parts. Examine each rocker arm pallet (contact face) for wear or galling. Also check the contact surfaces of the exhaust valve bridge.

Remove Cam Follower and Push Rod Assembly (Cylinder Head Removed from Engine)

Cant followers may be removed from either the top or bottom of the cylinder head: When the followers are removed from the bottom, removal of the cylinder head will be necessary; when they are removed from the top, cylinder head removal is unnecessary. If the cylinder head is off the engine for any reason, the cam followers can best be removed front the bottom of the head, as shown in figure 2. To remove the cam followers:

1. Remove the cylinder head as outlined in section 1.2.
2. Rest the cylinder head on its side and remove the two bolts and lock washers securing the cam follower guide to the bottom of the cylinder head (fig. 2). Remove the guide.
3. Pull the cam followers from the bottom of the cylinder head.
4. Remove the fuel lines from the injector and fuel connectors.
5. Loosen the lock nuts at the upper *end* of the push rods, and unscrew push rods from the rocker ant clevises.
6. Pull the push rod and spring assemblies from the bottom of the cylinder head.
7. Remove the push rod lock nut, upper spring seat, spring, and lower spring seat from each push rod for cleaning and inspection. The push rod spring seat retainers remain in the cylinder head. If the head is to be changed, these retainers must be removed and installed in the new head.

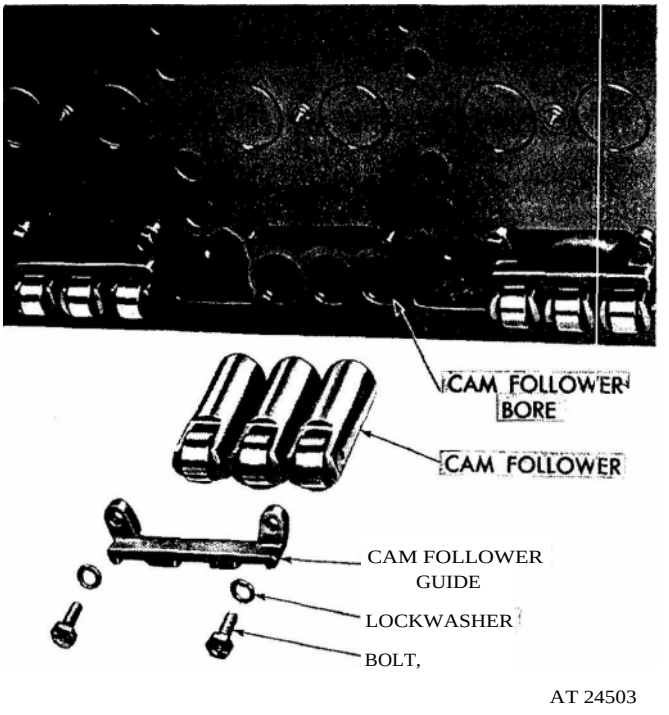


Figure 2. Cam *followers and guide location.*

Remove Cam Follower and Push Rod Assembly (Cylinder Head Not Removed from Engine)

A push rod, push rod spring, spring seats and cam follower may be removed from the top of the cylinder head by using tool J 3092-01, as shown in figure 3.

1. Remove the valve rocker cover.
2. Remove the fuel lines from the injector and the fuel connectors.
3. Remove the rocker arm brackets and rocker arm shaft as outlined in Steps 3 and 4 under "Remove Rocker Arms and Rocker Arm Shaft."
4. Loosen the lock nut at the upper end of the push rod, next to the clevis, and unscrew the rocker arm from the push rod to be removed. Remove the lock nut from the push rod.
5. Install the remover J 3092-01, flat washer, and nut on the push rod (fig. 3). Screw the nut down on the end of the push rod, to compress the push rod spring.
6. Remove the retainer from the cylinder head with *a screw driver or* similar tool, as shown *in* figure 3.

7. Unscrew the nut at the outer end of the push rod, thus releasing the spring.

8. Pull the push rod, spring, spring seats and cam follower out through the top of the cylinder head.

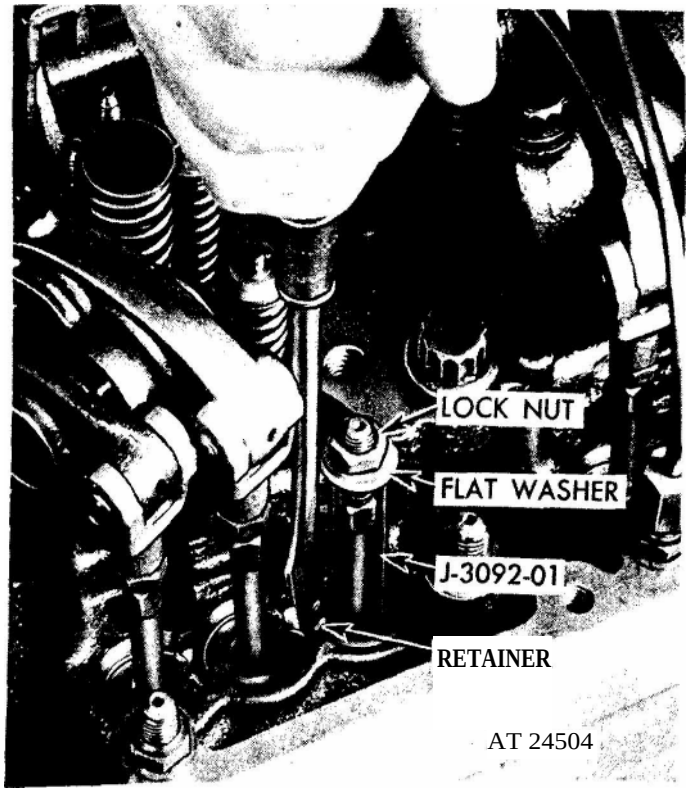
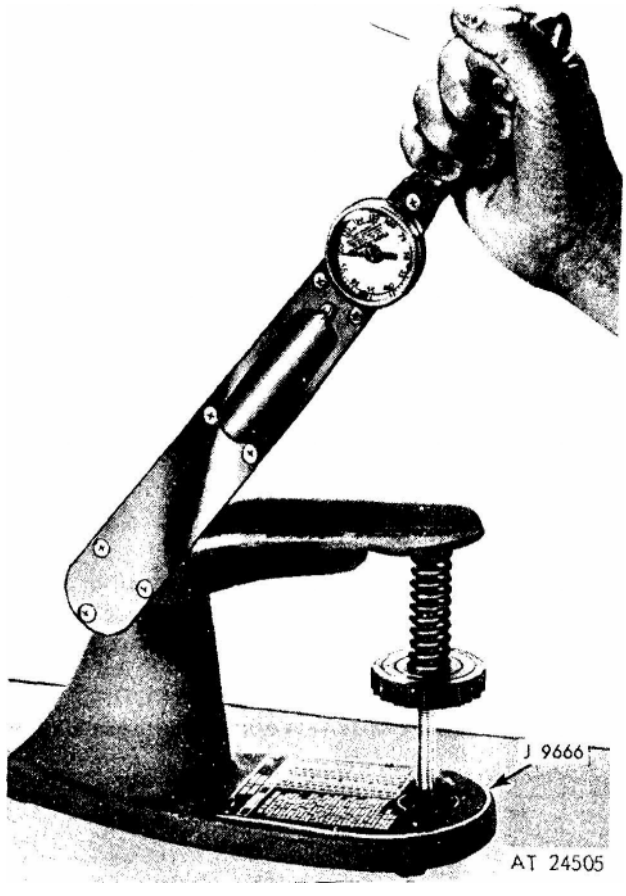


Figure 3. Removing push rod from upper side of cylinder head with tool J 3092-01.

Inspection

Proper cam follower inspection and service are necessary in obtaining continued efficient engine performance. When any appreciable change in injector timing or exhaust valve clearance occurs during engine operation, the cam followers, and their related parts, should be removed and inpected for excessive wear. This change in injector timing or exhaust valve clearance during engine operation can usually be detected by excessive noise at idle speed. After the cam followers and associated parts are removed, clean the parts thoroughly with fuel oil and dry them with compressed air. Inspect the rounded end of the push rods for wear. Replace any push rod which is worn or bent. The purpose of a push rod spring is to maintain a predetermined load on the cam follower to insure contact of the cam rollller on the camshaft lobe at all times. Check the push rod spring load whenever the cam followers and related parts are removed for inspection. Use spring tester J 9666 and an accurate torque wrench to check the push rod spring load (fig. 4). Replace the spring when a load of less than 250 pounds will compress it to a length of 2-9 / 64". Examine the cam follower holes in the cylinder head to make sure they are clean, smooth and free of score marks to permit proper functioning of the cam followers. Any existing score marks must be cleaned up. Check the cam follower-to-cylinder head clearance. The clearance must not exceed .006" with used parts. The cam follower roller must turn smoothly and freely on its pin, and the roller must be free from flat spots or scuff marks. If the roller does not turn freely or has been scored or worn flat, then examine the cam on which it operates. If the cam is excessively worn or damaged, replace the canshaft. Check the total side clearance between the roller and follower; this clearance must not be less than .015" or more than .023". Also, measure the total clearance between the roller bushing and pin, crosswise of the pin, as shown in figure 5. If the diametric clearance exeeds .010", replace the cam follower assembly or install a new cam roller and pin.



1.2.1 VALVE AND INJECTOR OPERATING MECHANISM

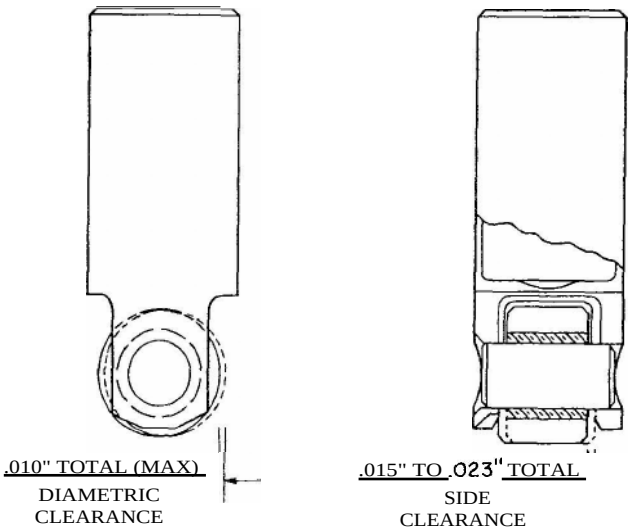


Figure 5. Cam roller wear and clearance diagram.

Figure 6. Fortner and current cam followers.

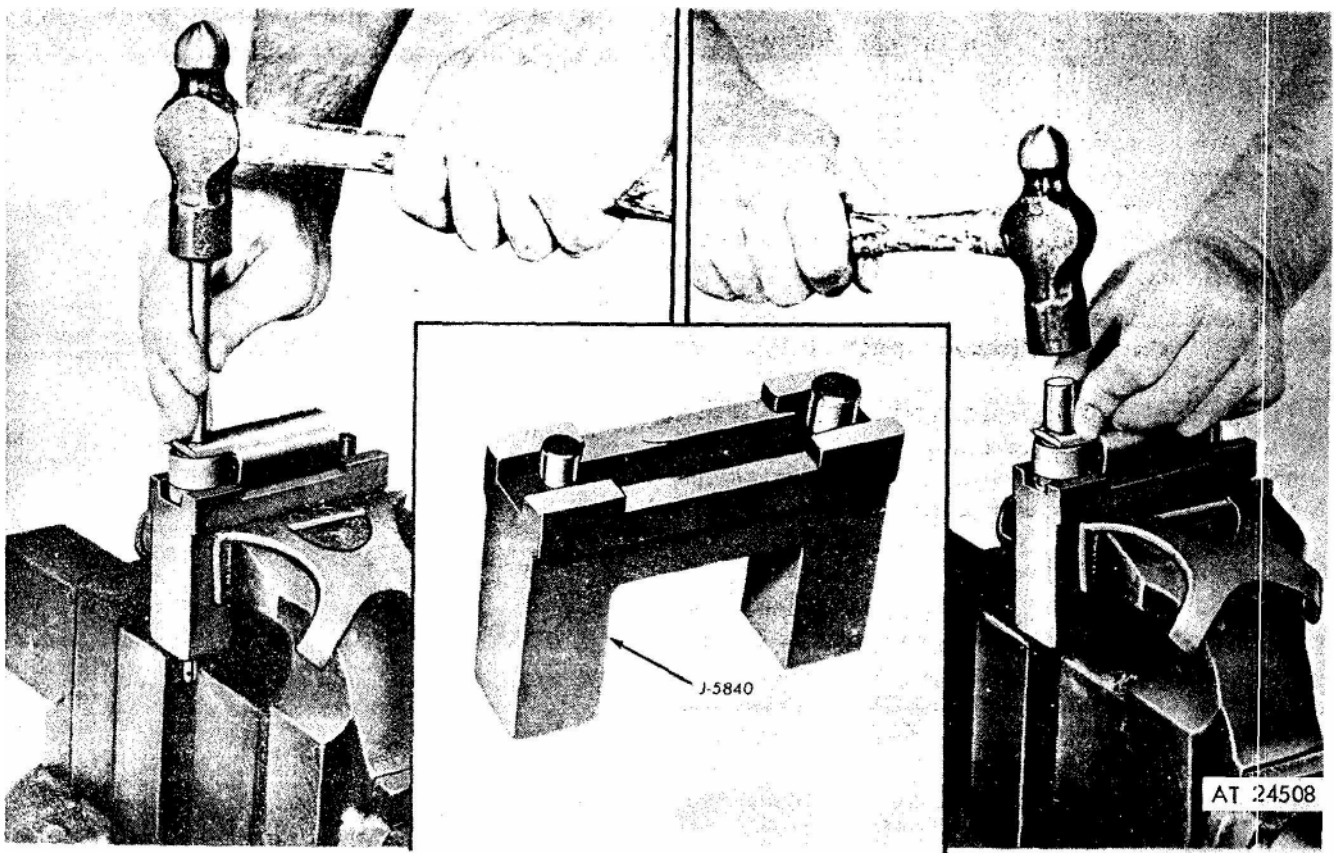


Figure 7. Removing or installing cam follower roller and pin with cam follower holding fixture tool J .5840.

Remove and Install Cam Follower Roller and Pin

I. Clamp fixture J 5840 securely in a vise as shown in figure 7 and place the cam follower in the groove in the top of the fixture with the follower pin resting on top of the corresponding plunger in the fixture.

2. With a suitable drift, drive the pin from the roller. Exercise caution in removing the cam follower body and roller from the fixture as the follower pin is seated on top of a spring-loaded plunger in the fixture body.

3. Prior to installing a new roller and pin, remove, any burrs on the surfaces of the cam follower at the pin holes.

4. Position the follower body in the groove of the fixture with the proper size fixture plunger extending through the roller pin hole in one of the legs of the follower body.

5. Coat the new roller bushing and pin with engine oil.

6. Position the roller in the cam follower body (fig. 7). The small plunger in the tool will align the roller with the pin holes in the follower body.

7. Align the pin with the hole in the follower body and carefully drive the pin into the body until the ends of the pin are centered in the legs of the body.

8. Check the side clearance between the roller and the follower body. This clearance must be .015" to .023".

Install Cam Follower and Push Rod Assembly (Cylinder Head Removed from Engine)

1. Install a serrated lower spring seat on each push rod.

2. Place the push rod springs on the push rods.

3. Install the proper upper spring seat on each push rod.

4. Install the spring seat retainer in the cylinder head; then, slide the push rod, lower spring seat, spring and upper spring seat as an assembly into the proper cam follower bore (injector or exhaust valve).

5. Screw the push rod lock nut down on the upper end of the push rod as far as possible; then, screw the push rod into the clevis until the end of the rod is flush with or above the inner side of the clevis.

6. Immerse the cam follower assemblies in Cindol 1705 (heated to 100°-125°F.) for at least one hour before placing them in the cylinder head, to ensure initial lubrication between the cam follower roller pins and roller bushings. Rotate the cam follower rollers during the soaking period to aid in purging any air from the bushing-roller area. The heated Cindol 1705 results in even better penetration as it is less viscous and flows more easily between the pin and the roller bushing surfaces. After the cam follower is removed from the lubricant, the cooling action of any trapped air in the pin and bushing area tends to pull the lubricant into the cavity. Heat the Cindol 1705 in a small pail, with a screen insert. The screen insert will prevent the follower assemblies from touching the bottom of the pail during soaking, thus avoiding the possibility of contamination. Also, when installing a roller and pin kit, first remove the preservative from the roller and pin by washing in diesel fuel oil or a similar petroleum base solvent. Then, pre-lubricate the parts with Cindol 1705 before assembly and again as described above during engine assembly.

7. Note the oil hole in the bottom of the cam follower. With this oil hole pointing away from the valves, slide the cam follower into position from the bottom of the head.

8. Attach the cam follower guide (fig. 8) to the bottom of the cylinder head to hold the group of cam followers in place. Tighten the cam follower guide bolts to 12-15 lb-ft torque. Now, check to be sure there is at least .005" clearance between the cam follower legs and the cam follower guide (fig. 9). If there is insufficient clearance, loosen the guide bolts slightly and tap each corner of the guide with a brass rod (fig. 10); then, retighten the bolts to 12-15 lb-ft torque and recheck the clearance.

1.2.1 VALVE AND INJECTOR OPERATING MECHANISM

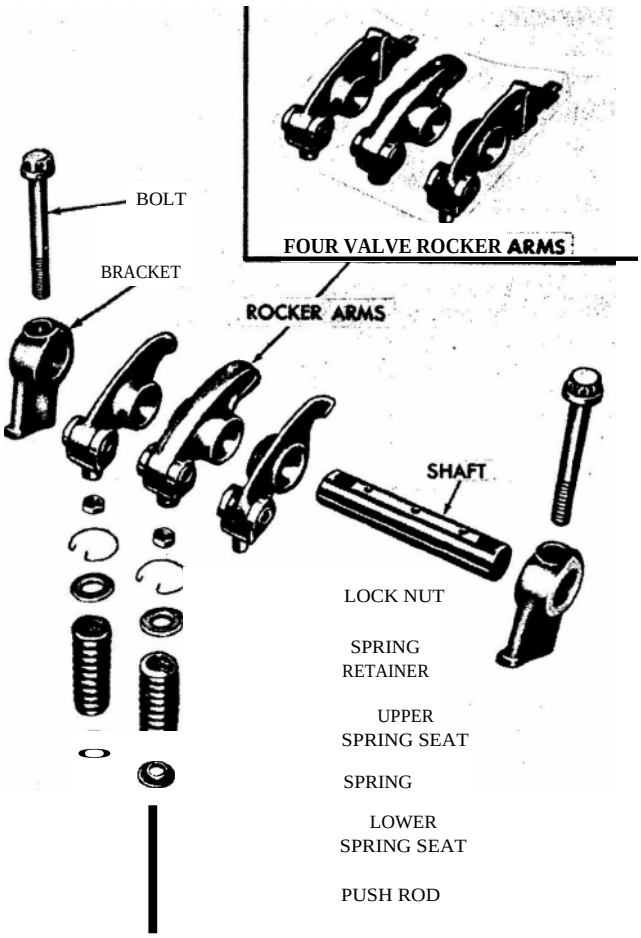


Figure 8. Valve and injector operating mechanism details and relative location of parts.

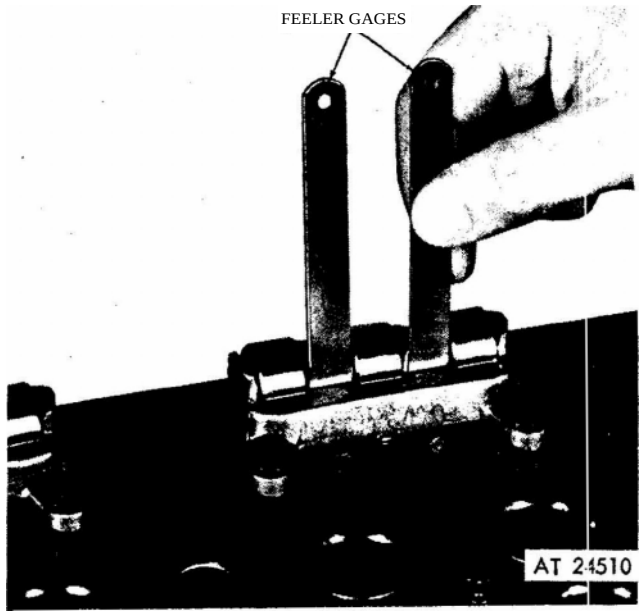


Figure 9. Checking the clearance between the cam follower guide and cam follower legs.

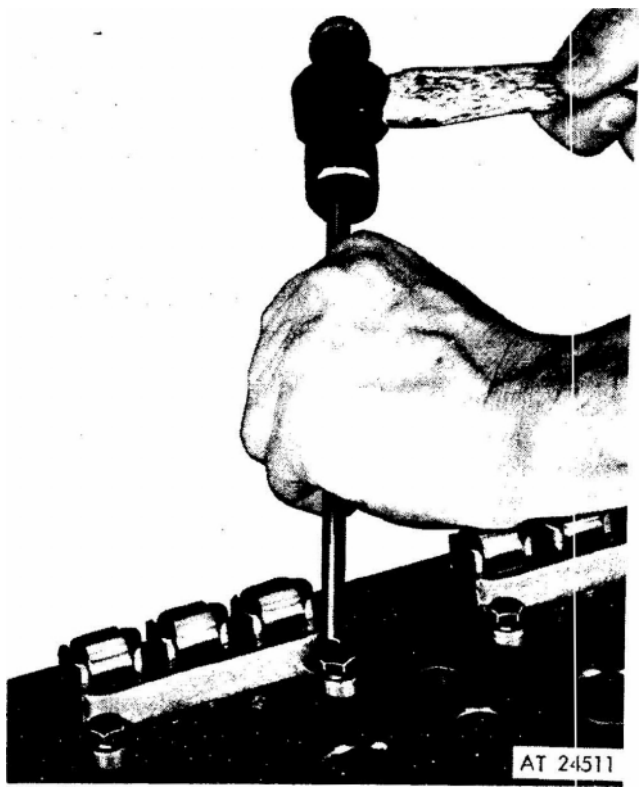


Figure 10. Tapping the corner of the guide.

Install Cam Follower and Push Rod Assembly (Cylinder Head Not Removed from Engine)

1. Refer to step 6 under "Install Cam Follower and Push Rod Assembly (Cylinder Head Removed from Engine)" and lubricate the cam followers.
2. Note the oil hole in the bottom of the cam follower. With this hole pointing away from the exhaust valves, slide the cam follower into position.
3. Install a serrated lower spring seat on each push rod.
4. Place the push rod springs on the push rods.
5. Install the upper spring seat on each push rod.
6. Set the push rod, lower spring seat, spring, and upper spring seat down into the proper cam follower (injector or exhaust valve). 7. Install a flat washer and nut on the push rod, Then-, place tool J 3092-01 on the push rod, between the flat washer and upper spring seat. Screw the nut down on the push rod until the spring is compressed sufficiently to permit the retainer to be installed. Partically collapse the retainer and install it in the cylinder head groove.
8. Remove the nut, flat washer, and tool J 3092-01 from the push rod.
9. Reinstall the nut on the push rod. Screw the nut down as far as possible on the push rod; then, screw the rocker arm clevis down on the push rod until the end of the push rod is flush with or above the inner side of the clevis. Note that the injector rocker arm (the center arm of the group) is slightly different from the exhaust valve rocker arms; the boss for the shaft on the valve rocker arms is longer on one side of the arm than on the other. The extended boss of the valve rocker arms must face the injector rocker arm.

Install Rocker Arms and Rocker Arm Shaft

1. Install the cylinder head, if removed, as outlined in Section 1.2.
2. Apply clean engine oil to the surface of the rocker arm shaft.
3. Install the rocker arms and rocker arm shaft by reversing the sequence of operations for removal. Tighten the rocker arm shaft bracket bolts to 50-55 lb-ft torque. After tightening the bolts, check for some side clearance to prevent bind between the rocker arms.

CAUTION

On four-valve cylinder heads, there is a possibility of damaging the exhaust valves if the exhaust valve bridges are not resting on the ends of the exhaust valves when tightening the rocker arm shaft bracket bolts (fig. 12). Therefore, note the position of the exhaust valve bridges before, during and after tightening the rocker arm shaft bracket bolts.

4. Align the fuel pipes and connect them to the injectors and the fuel connectors. Tighten the fuel pipe nuts to 12-15 lb-ft torque with socket J 8932-01 and an accurate torque wrench.

CAUTION

Do not bend the fuel pipes and do not exceed the specified torque. Excessive tightning will twist or fracture the flared ends of the fuel pipes and result in leaks. Lubricating oil diluted by fuel oil can cause serious damage to the engine bearings.

5. Fill the cooling system.
6. Adjust the exhaust valve clearance and time the fuel injector as outlined in sections 14.1 and 14.2 before starting the engine.
7. Start the engine and check for leaks in the fuel, water, and lubrication systems.
8. Tune-up the engine, as outlined in Section 14, after the engine reaches normal operating temperature.

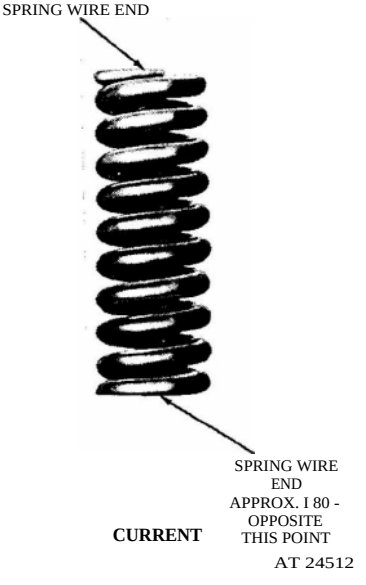


Figure 11. Push rod spring identification.

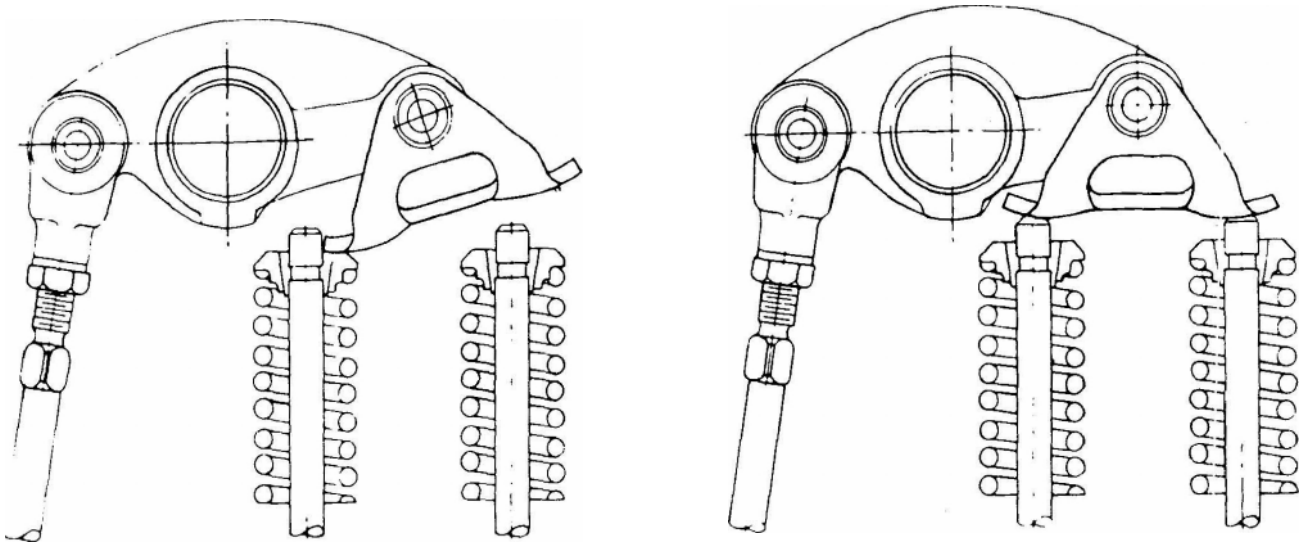


Figure 12. Relationship between exhaust valve bridge and valve sterns.

EXHAUST VALVES

Four exhaust valves are provided for each cylinder. They are actuated by the valve operating mechanism or in transverse pairs. Pre-finished replaceable guides are pressed into the cylinder head. Exhaust valve inserts (valve seats) are pressed into the cylinder head. The exhaust valves and valve insert are ground to a 30°seating angle. The exhaust valve springs are held in place by the valve spring caps and tapered two-piece valve locks. Excess oil from the rocker arms lubricates the exhaust valve stems.

Exhaust Valve Clearance Adjustment

Correct valve clearance adjustment is important for proper operation of the engine. Too little clearance between the exhaust valve stem and the rocker arm causes a loss of compression, misfiring cylinder, and eventual burning of the valves and valve inserts. Too much clearance results in noisy operation of the engine, especially at idle speed. Refer to section 14.1 for the procedure to be followed when adjusting the valve clearance.

Exhaust Valve Maintenance

Efficient combustion in the engine requires that the exhaust valves be maintained in good operating condition. Valve seats must be true and unpitted to assure leak-proof seating, valve stems must work freely and smoothly within the valve guides, and correct valve clearance must be provided. Proper maintenance and operation of the engine is important to long valve life. Engine operating temperature should be maintained between 160°F., and 1851'. Low operating temperatures, usually due to extended periods of idling or light engine loads, result in incomplete combustion, formation of excessive carbon deposits and fuel lacquers on valves and related parts, and a greater tendency for lubricating oil to smudge. Unsuitable fuels may also cause formation of deposits on the valves, especially when operating at low temperatures. When carbon deposits, due to partially burned fuel, build up around the valve stems and extend to that portion of the stem which operates in the valve guide,

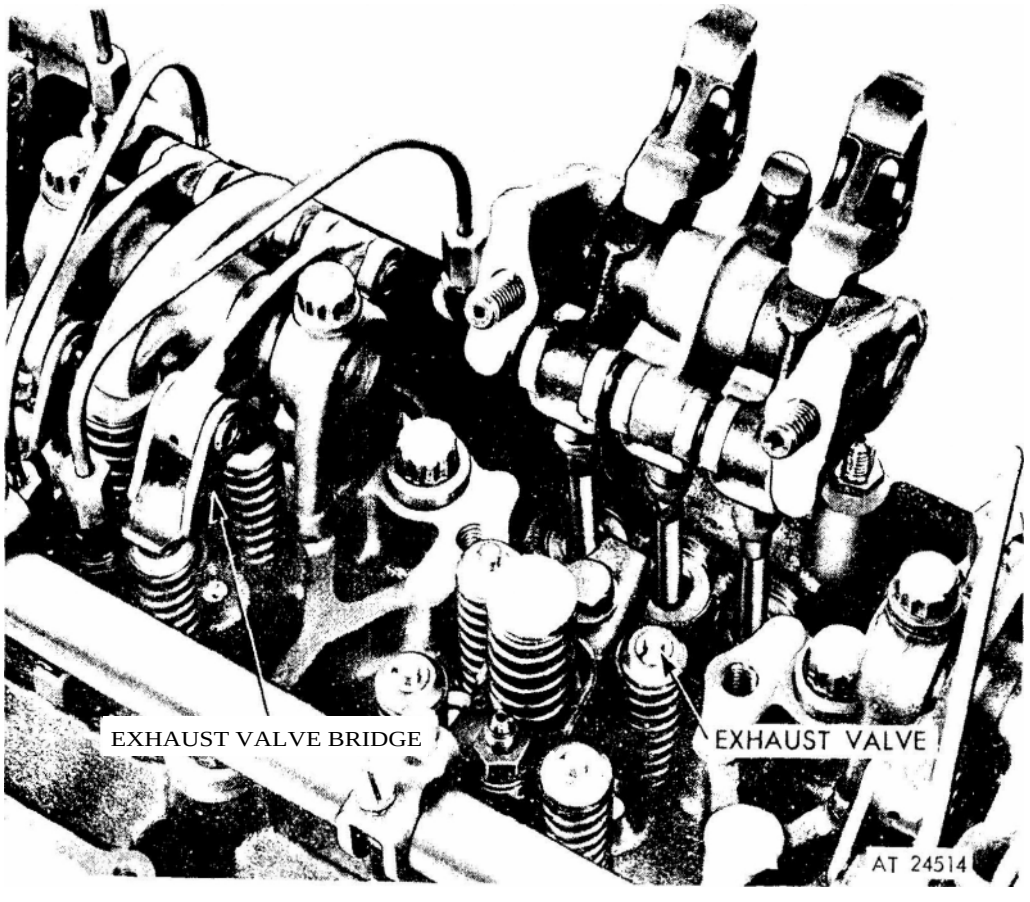


Figure 1. Location of exhaust calves.

1.2.2 EXHAUST VALVES

sticking valves will result. Thus, the valves cannot seat properly and pitted and burned valves and valve seats and loss of compression will result. Lubricating oil and oil filters shoud be changed periodically to aviod the accumulation of sludge. Valve sticking may also result from valve stems which have been scored due to foreign matter in the lubricating oil, leakage of anti-freeze (glycol) into the lubricating oil which forms a soft sticky carbon and gums the valve stems, and bent or worn valve *guides.* Sticking valves may eventually result in valves being held in the open position, being struck by the piston and becoming bent or broken. It is highly important that injector timing and valve clearance he accurately adjusted and inspected periodically. Improperly timed injectors will have adverse effects upon combustion. Tightly adjusted valves will cause rapid pitting of the valve seats and a hotter running condition on the valve stems. The - cylinder head must first be removed before guides can be removed for replacement or reconditioning. However, the valve springs may be removed without removing the cylinder head, if necessary.

Remove Exhaust Valve Spring

It is possible, if occasion requires, to remove or replace the exhaust valve springs without removing cylinder head. The springs, however, are normally removed when the head is off the engine. Both methods are covered in this section. An exhaust valve spring may be removed, without removing the cylinder head from the engine, as follows:

1. Remove the valve rocker cover.
2. Crank the engine over to bring the valve and injector rocker arms in line horizontally.
3. Disconnect and remove the fuel lines from the injector and fuel connectors.
4. Remove the two bolts holding the rocker arm shaft brackets to the cylinder bead and remove the brackets and shaft.
5. Remove the cylinder block air box cover so that the piston travel may be observed, then turn the crankshaft until the piston is at top of its stroke.
6. Thread the spring compressor J 7455 into one of the cylinder head bolt holes (fig. 2). Then, compress the spring and remove the two-piece valve lock.
7. Release the tool and remove the valve spring cap, valve spring and spring seat.

To remove an exhaust valve spring with the cylinder head removed from the engine, use the following procedure:

1. Support the cylinder head on wood blocks 2" above the bench to keep the cam followers clear of the bench.
2. Remove the fuel lines from the injector and fuel connectors.
3. Remove the two bolts holding the rocker arm shaft brackets to the cylinder head and remove the brackets and the shaft.
4. Remove the fuel injector.
5. Place a block of wood under the cylinder head to support the exhaust valve. Next, remove the valve as outlined in Step 6 above.
6. Remove cam follower and push rod assembly (Cylinder Head Removed from Engine)".

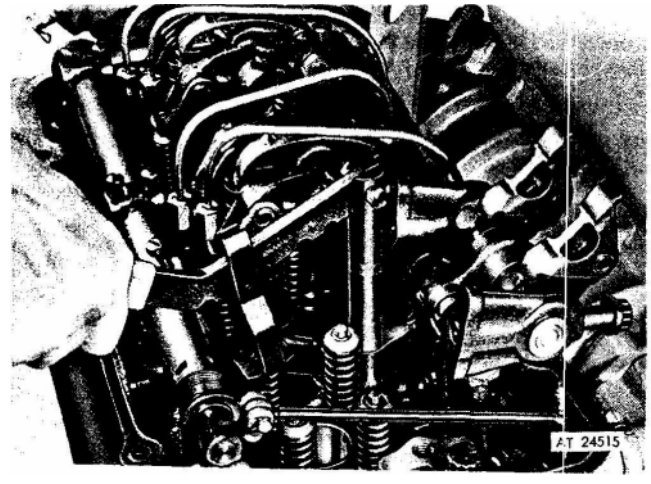


Figure 2. Removing exhaust valve spring.

Inspect Exhaust Valve Spring

Clean the spring with fuel oil and dry it with compressed air. Then, check the spring for pitted or fractured coils. Check the spring with spring tester J 9666 and an accurate torque wrench (fig. 3). Replace the spring if a load of less than 25 pounds will compress a spring to 1.93 inches. The difference in the load between the two springs must not exceed 6 pounds or the exhaust valve bridge will be unbalanced. When it is necessary to replace one or more valve springs it is recommended that all of the exhaust valve springs be replaced with the current spring (yellow stripe).

Figure 3. Testing exhaust valve spring

Remove Exhaust Valve

1. Remove the exhaust valve springs as outlined above.
2. Turn the cylinder head over, using care to keep the valves from falling out of the head.
3. Number the valves so they can be reinstalled in the same location ; then, withdraw the valves.

Inspect Exhaust Valve

Clean the exhaust valve with fuel oil.
Check the valve stem for scratches or scuff marks. The valve face should be smooth, unpitted and free from ridges or cracks. Carbon on the face of the valve indicates a faulty seat and a resultant leak (or blow-by). The valve head should be square with the valve stem and should not be warped. If necessary, reface the valve or install a new valve.

Inspect Exhaust Valve Guides

Clean the inside diameter of the valve guides with brush J 7793 as shown in figure 4. This brush will remove gum and carbon deposits from the valve guides, including the threads. Inspect the valve guides for fractures, scoring or excessive wear. Check the valve-to-guide clearance, since worn valve guides may eventually result in improper valve seat contact. If the clearance exceeds .005" replace the valve guides.

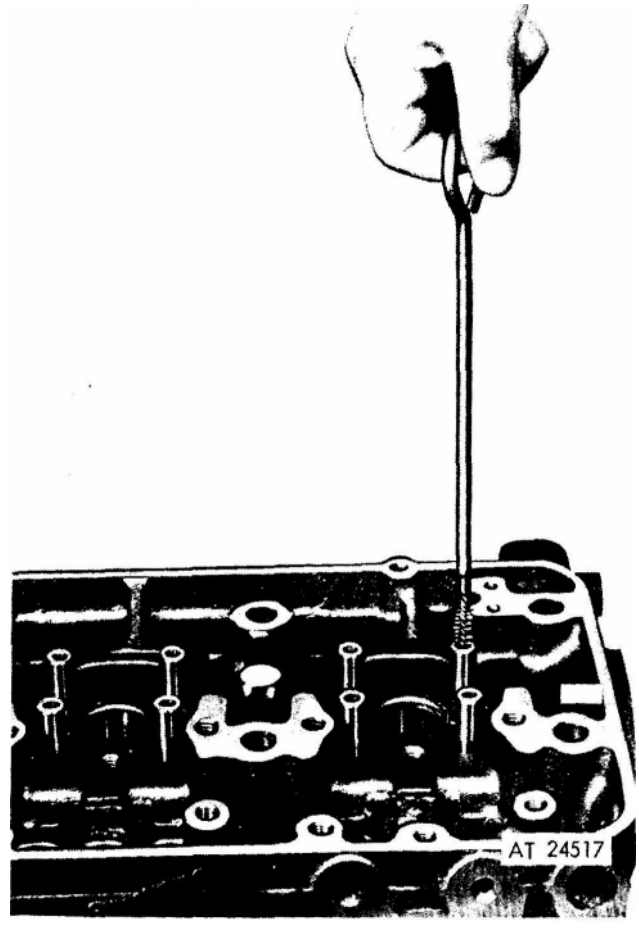


Figure 4. Cleaning exhaust valve guide.

Remove Exhaust Valve Guide

1. Support the cylinder head, bottom side up, on wooden blocks which are at least 3" thick.
2. Drive the valve guide out of the cylinder head with valve guide remover J 7775 as shown in figure 5.

1.2.2 EXHAUST VALVES

Figure 5. Removing exhaust valve guide.

Install Exhaust Valve Guide

Turn the cylinder head right side up and install the alve guide as follows:

Insert the threaded end of the valve guide in the proper valve guide installing tool (refer to - chart). Be sure to use the correct tool to avoid damage to the valve guide, and to locate the valve guide to the proper dimension.

2. Position the valve guide squarely in the bore in the cylinder head and tap the installing tool gently to start the guide in place (fig. 6). Then, drive the guide in until the tool contacts the cylinder head.

CAUTION

Do not use the valve guides as a means of turning the cylinder head over or in handling the cylinder head.

Valve Guide Installing Tool Chart

Tool No.	Cyl. Head	Valve Guide	Distance of guide bellow top of head
J 9729	4 Valve	45 Chamfer	.01"-.040"

Figure 6. Installing exhaust valve guide.

Inspect Exhaust Valve Seat Inserts

Inspect the valve seat inserts for excessive wear, pitting, cracking or improper seat angle. The proper angle for the seating face of both the valve and the insert is 30°.

Remove Exhaust Valve Seat Insert

The valve seat inserts are pressed into the cylinder head and, therefore. must be removed as outlined in the following procedure to aviod damage to the cylinder head:

1. Place the cylinder head on its side on the bench as shown in figure 7.

2. Place collet of tool (four valve head) inside the valve seat insert so the bottom of the collet is flush with the bottom of the insert.

3. Hold the collet handle and turn the T handle to expand the collet cone until the insert is held securely by the tool.

4. Insert the drive bar of the tool through the valve guide.

5. Tap the drive bar once or twice to move the insert about 1 / 16" away from its seat in the cylinder head.
6. Loosen the collet cone and move the tool into the insert slightly so the narrow flange at the bottom of the collet is below the valve seat insert.
7. Tighten the collet cone and continue to drive the insert out of the cylinder head.

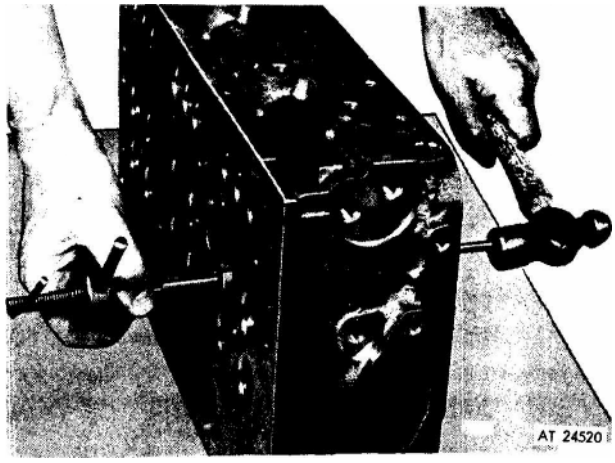


Figure 7. ***Removing exhaust valve seat insert.***

Install Exhaust Valve Seat Insert

1. Clean the valve seat insert counterbores in the head with trichlorethylene or other good solvent. Also, wash the valve seat inserts with the same solvent. Dry the counterbores and the inserts with compressed air.
2. Inspect the counterbores for cleanliness, concentricity, flatness and cracks. The counterbores have a diameter of 1.159" to 1.160" and a depth of .300" to .312".
3. Immerse the cylinder head for at least 30 minutes in water heated to 180°F. to 200°F.
4. Rest the cylinder head, bottom side up, on the work bench and locate the insert squarely in the counterbore, seating face up. Install the insert in the cylinder head while the head is still hot and the insert is at room temperature, otherwise installation will be difficult and the parts may be damaged.
5. Drive the insert in place with installer J 7790 as shown in figure 8 until it seats solidly in the cylinder head.
6. Grind the valve seat insert and check it for concentricity in relation to the valve guide as outlined below.

Figure 8. Installing exhaust valve seat insert.

Recondition Exhaust Valve and Valve Seat Insert

Reface an exhaust valve which is to be reused as shown in figure 9. The edge of the valve at the valve head must not be less than 1 / 32" in thickness and still be within the specifications shown in figure 12 after refacing. Before either a new or used valve is installed, examine the valve seat 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 to provide proper seating of the valve. When a new valve seat insert is installed, or an old insert is reconditioned, the work must be done with a grinding wheel as illustrated in figure 10. The eccentric grinding method for reconditioning a valve seat insert is recommended. This method produces a finer, more accurate finish since only one point of the grinding wheel is in contact with the valve seat at any time. A micrometer feed permits feeding the grinding wheel into the work .001" at a time. To grind the valve inserts in a four valve cylinder head use the following tools:

1.2.2 EXHAUST VALVES

1. Grinder J 8165-1
2. Dial Gage J8165-2
3. Pilot J 7792-1
4. Grinding Wheel (15°) J 7792-2
5. Grinding Wheel (30°) J 7792-3
6. Grinding Wheel (601 J 7792-4

Grind the valve seat inserts as follows:

1. First apply the 30 ° grinding wheel on the valve seat insert.
2. Use the 60°grinding wheel to open the throat of the insert.
3. Then, grind the top surface of the insert with the 15° wheel to narrow the width of the seat to the specified 3 / 64" to 5 / 64" (fig. 11). The 30°face the insert may be adjusted, relative to the center the *valve* face, with the 15° and 60 ° *grinding* wheels.

CAUTION

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

When occasion requires, the grinding wheel may be dressed to maintain the desired seat angle (fig. 12). The position of the exhaust valve (when the valve is in the closed position), to maintain the proper piston-to-valve clearance, is shown in figure 11. Grinding will reduce the thickness of the valve seat insert and cause the valve to recede *into* the cylinder head. If, after several grinding operations, the valve recedes beyond the limits shown in figure 11, replace the valve seat insert. After the grinding has been completed, clean the valve seat insert thoroughly with fuel oil and dry it with compressed air. Set the dial indicator J 8165-2 in position as shown in figure 13 and rotate it to determine the concentricity of each valve seat insert relative to the valve guide. Total runout must not exceed .002". If a runout of more than .002" is indicated, check for a bent valve guide before regrinding the insert. When a valve seat insert runout within the desired limits is obtained, determine the position of the contact area between the valve and the *valve* seat insert. First, apply a light coat of Prussian blue, or a similar paste, to the valve seat insert. Next, lower the stem of the valve in the valve guide and bounce, but do not rotate, the valve on the insert, This procedure will indicate the area of contact on the valve face. The most desirable area of contact is at the center of the valve face. After the valve seat inserts have been ground and checked, thoroughly clean the cylinder head before installing the valves.

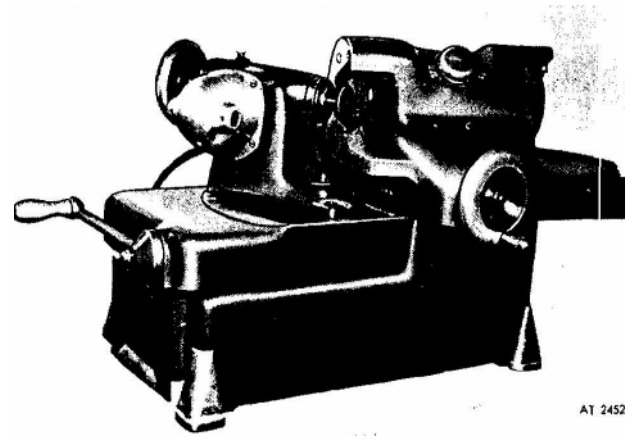


Figure 9. Refacing exhaust valve.

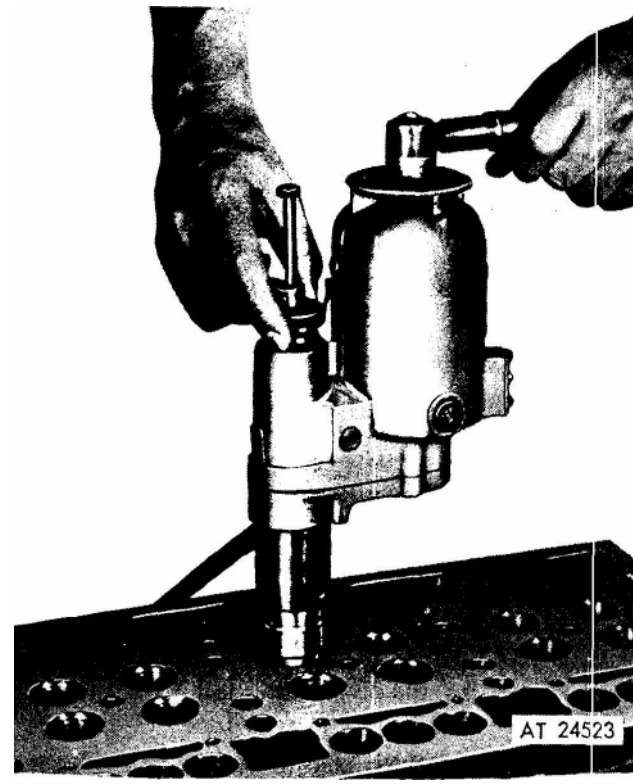


Figure 10. Grinding exhaust valve seat insert.

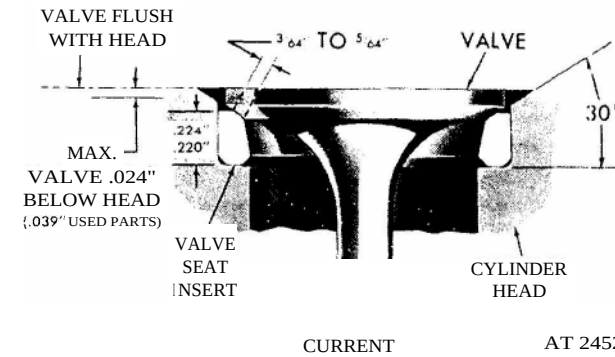


Figure 11. Relationship between exhaust valve, insert and cylinder head (four valve head).

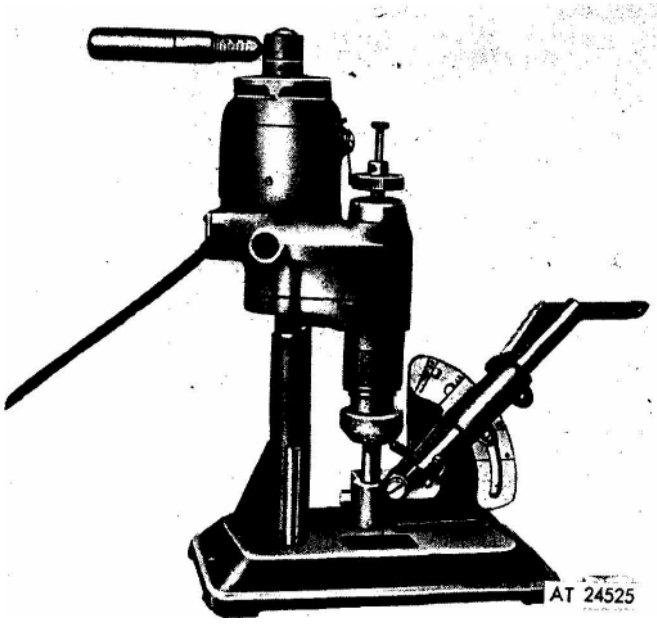


Figure 12. Grinding wheel dressing tool of set J 8165.

Install Exhaust Valves and Springs

When installing exhaust valves, check to see that the valves are within the specifications shown in figure 11.

1. Apply a light coat of engine oil on the valve stems and install the valves in the cyliner head. If reconditioned valves are used, install them in the same relative location from which they were removed.

NOTE

The distance from the top of the four valve cylinder head to the bottom of the valve spring seat counterbore is 1-11 / 64".

The valve spring lock groove in the exhaust valves is .310" from the end of the valve. Cylinder heads are equipped with the thin valve spring seats (.060") and current design exhaust valves (fig. 14).

2. Hold the valves in place with a strip of masking tape and turn the cylinder head right side up on the work bench. Place a board under the head to support the valves and to provide clearance between the cam followers and the bench.

3. Install the valve springs and valve spring caps.

4. 'Thread the valve spring compressor J 7455 into one of the rocker shaft bolt holes in the cylinder head (fig. 2).

5. Apply pressure to the free end of the tool to compress the valve spring and install the two-piece tapered valve lock. Exercise care to avoid scoring the valve stem with the valve cap when compressing the spring.

6. Release the tool and install the valve locks on the remaining exhaust valves in the same manner.

7. Check the position of the exhaust valve (fig. 11).

8. With the exhaust valves installed in the cylinder heads, and using spring checking gage WRE 500-60, note the gage reading the moment the exhaust valve starts to open (fig. 15). The minimum pressure required to start to open the exhaust valve must not be less than 25 pounds for a four valve cylinder head.

9. Install the injectors, rocker arms, shafts, brackets, and any other parts that were previously removed from the cylinder head.

10. Install the cylinder head (see "Pre-I nstallation Inspection" and "Install Cylinder Head" in section 1.2).

12. Perform a complete engine tune-up.

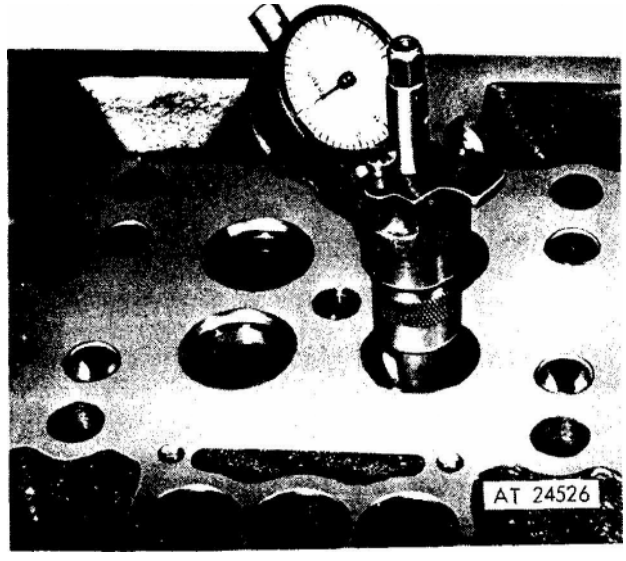


Figure 13. Checking relative concentricity of exhaust valve seat insert with relation to valve guide.

1.2.2 EXHAUST VALVES

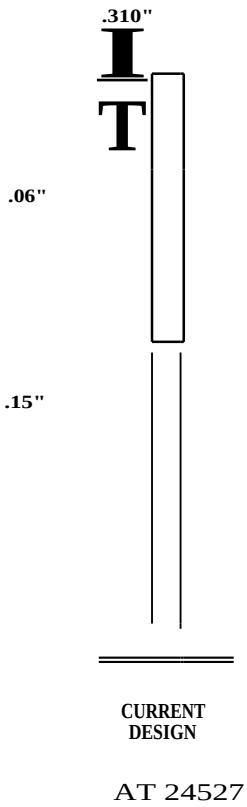


Figure 14. Current design exhaust valves and spring seats (four valve head).

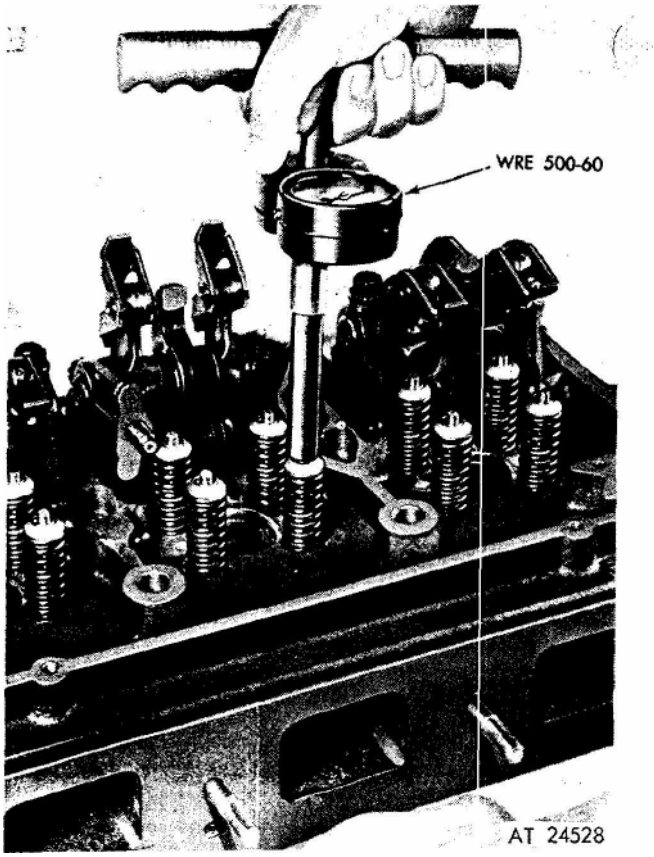


*Figure 15. Checking exhaust valve opening with spring checking gage **WRE-500-60**.*

VALVE ROCKER COVER

The valve rocker cover assembly (fig. 1) completely *encloses the valve* and injector rocker arm compartment at the top of the cylinder head(s). The top of the cylinder head is sealed against oil leakage by a gasket located in the flanged edge of the cover(s).

Remove and Install Valve Rocker Cover

Clean the cover before removing it from the engine to avoid dust or dirt from entering the valve mechanism. Then remove the valve cover screws and lift the cover straight up from the cylinder head. Use a new gasket when installing the valve cover.

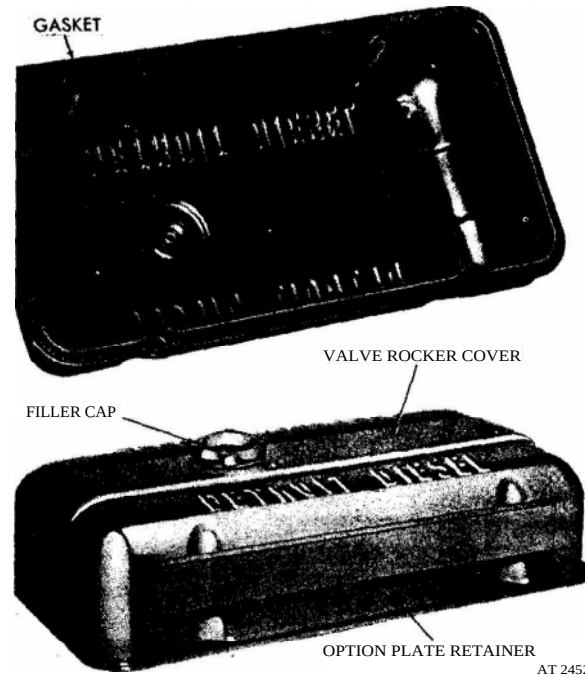


Figure 1. Typical valve rocker cover assembly.

TROUBLE SHOOTING-SPECIFICATIONS--SERVICE TOOLS

TROUBLE SHOOTING

EXHAUST VALVE

Probable Causes

1. STICKING VALVE
2. IMPROPER VALVE SEATING
3. VALVE SEAT PITTED OR OVER HEATED
4. BENT VALVE
5. BROKEN VALVE
6. EXCESSIVE VALVE-TO-GUIDE CLEARANCE
7. CARBON DEPOSITS ON VALVE HEAD
8. VARNISH DEPOSITS ON VALVE STEM
9. SCORED OR SCUFFED VALVE STEM
10. ALL VALVES BENT

SUGGESTED REMEDY

1. Check for carbon deposits, bent guide, defective spring, or anti-freeze (glycol) in the lubricating oil. Replace a bent guide. Cean-up and reface valve. Replace the valve if necessary.

2. Check for excessive valve-to-guide clearance, bent guide, or carbon deposits. Replace a bent or worn guide. Clean the carbon from the valve. Reface or replace the valve, if necessary.

3. Check the operating conditions such as engine overload, inadequate cooling or improper timing. Reface the valve and insert. Replace the valve if warped or too badly pitted. Use a harder-face valve if operating conditions warrant.

4. Check for contact between valve head and piston as a result of incorrect valve lash, exhaust valve bridge improperly positioned, or a defective spring. Check valve guide, insert, cylinder head and piston for damage. Replace damaged parts.

5. Check for excessive valve-to-guide clearance, defective spring or etching of the valve stem at the weld. Improper valve lash is also a cause of this type failure. Check guide, insert, cylinder head and piston for damage. Replace damaged parts.

6. Replace worn valve guide. Check and replace the valve, if necessary.

7. Black carbon deposits extending from the valve seat to the guide indicate cold operation due to light loads or the use of low volatility fuel. Rusty brown valve head with carbon deposits forming narrow collars near guide indicate hot operation due to overloads, inadequate cooling or improper timing which results in carbonization of lubricating oil. Clean-up valves, guides and inserts. Reface valves and inserts; replace if warped, pitted or scored.

8. Check for worn guides or excessive exhaust back pressure. Replace worn guides. Check valve seat for improper seating. Reface the valve and insert or, if necessary, replace.

9. Check for bent valve stem or guide, metal chips or dirt or for lack of lubrication. Clean up valve stem with crocus cloth wet with fuel oil, or replace the valve. Replace the guide. When installing the valve, use care in depressing the spring so spring cap DOES NOT scrape the valve stem.

10. Check the gear train timing or for gear train failure.

SPECIFICATIONS

Table of Specifications, New Clearances, and New Wear Limits

Engine part (standard size)	New parts		Wear Limits
	Minimum	Maximum	
CYLINDER HEAD			
Cam Follower Bore	1.0626"	1.0636"	See Cam Follower Clearance
Exhaust Valve Seat Insert Counterbore Diameter (4-Valve Cylinder Head)	1.1590"	1.1600"	
ROCKER ARMS AND SHAFTS			
Rocker Arm Shaft Diameter	.8735"	8740"	
Injector Rocker Arm Bushing inside Diameter	.8750"	.8760"	
Diameter of Bore in Exhaust Valve Rocker Arm for Rocker Arm Shaft	.8753"	.8763"	
Clearance-Shaft-to-Injector Rocker Arm Bushing	.0010"	.0025"	.0040"
Clearance-Shaft-to-Exhaust Valve Rocker Arm Bore	.0013"	.0028"	.0040"
CAM FOLLOWERS			
Diameter	1.0600"	1.0610"	
Clearance—Follower-to-Head - Former	.0010"	.0030"	.0060"
Clearance-Follower-to-Head - Current	.0016"	.0036"	.0060"
Width of Roller Slot	.5635"	.5685"	
Roller Pin Hole Diameter	.4362"	.4370"	
CAM FOLLOWER ROLLERS AND PINS			
Roller Outside Diameter	.9020"	.9070"	
Roller Bushing Inside Diameter	.4390"	.4395"	
Roller Pin Outside Diameter	.4374"	.4377"	
Clearance-Pin-to-Bushing	.0013"	.0021"	.01" Horiz.
Side Clearance-Roller-in-Follower	.0150"	.0230"	.0230"
EXHAUST VALVES			
Stem Diameter	.2480"	.2488"	See Guide Clearance
4-Valve Cylinder Head	Valve Flush with Head	.024" Max. below	.039" Max. below

✻ These clearances also apply to oversize or undersize parts.

Table of Specifications, New Clearances, and Wear Limits

Engine part (standard size)	New parts		Wear Limits
	Minimum	Maximum	
VALVE GUIDES			
Distance Below Top of Head (Plain Guide)	.0100"	.0400"	
Diameter—Inside (4-Valve Cyl. Head)	.2505"	.2515"	
Clearanc Stem-to-Guide (4-Valve Cyl. Head)	.0017"	.0035"	.0050"
VALVE SEAT INSERTS			
Outside Diameter (4-Valve Cyl. Head)	1.1605"	1.1615"	
Seat Width	3/64"	5/64"	5/64"
Valve Seat Runout		.0020"	.0020"

Standard Bolt and Nut Torque Specifications

Size nut or bolt	Torque (lb-ft)	Size nut or bolt	Torque (lb-ft	Size nut or bolt	Torque (lb-ft)
1/4 - 20	7-9	7/16 - 20	57-61	3/4 - 10	240-250
1/4 - 28	8-10	1/2 - 13	71-75	3/4 - 16	290-300
5/16 - 18	13-17	1/2 - 20	83-93	7/8 - 9	410-420
5/16 - 24	15-19	9/16 - 12	90-100	7/8 - 14	475-485
3/8 - 16	30-35	9/16 - 18	107-117	1 - 8	580-590
3/8 - 24	35-39	5/8 - 11	137-147	1 - 14	685-695
/16 - 14	46-50	5/8 - 18	168-178		

Exceptions to Standard Bolt and Nut Torque Specification

Application	Size nut or bolt	Torque (lb-ft)
injector Control Shaft Bracket Bolts	1/4 - 20	10-12
Cam Follower Guide Bolts	1/4 - 20	12-15
Injector Clamp Bolt	3/8 - 16	20-25
Fuel Line Nuts	3/8 - 24	12-15
Fuel Connector	3/8 - 24	20-28
Rocker Arm Bracket Bolts	7/16 - 14	50-55
*Cylinder Head Bolts	5/8 - 11	170-180

* Lubricate at assembly with a small quantity of International Compound No. 2 or equivalent.

SERVICE TOOLS

Tool No.	Tool name
J 3092-01	Push Rod Remover (Set of 3)
J 5840	Cam Follower Holding Fixture
J 7455	Valve Spring Compressor (2 or 4-Valve Head)
J 7774	Valve Seat Insert Remover (4-Valve Head)
J 7775	Valve Guide Remover (4-Valve Head)
J 7790	Valve Seat Insert Installer (4-Valve Head)
J 7792-1	Pilot (4-Valve Head)
J 7792-2	Grinding Wheel (15°) (4-Valve Head)
J 7792-3	Grinding Wheel (30°) (4-Valve Head)
J 7792-4	Grinding Wheel (60°1 (4-Valve Head)
J 7793	Valve Guide Cleaner (4-Valve Head)
J 7832	Valve Guide Installer (15°) (4-Valve Head)
J 8152	Brush
J 8165-1	Grinder (2 and 4-Valve Head)
J 8165-2	Dial Gage (2 and 4-Valve Head)
J 8932-01	Socket
J 9665	Cylinder Head Guides (Set of two)
J 9666	Spring Tester
J 9729	Valve Guide Installer (45 9) (4-Valve Head)
J 22062-01	Cylinder Head Lifter
WRE 500-60	Valve Spring Checking Gage

CRANKSHAFT

The crankshaft (fig. 1) is a one-piece steel forging, heat-treated to ensure strength and durability. All main and connecting rod bearing journal surfaces and oil seal surfaces are induction hardened. Complete static and dynamic balance of the crankshaft has been achieved by counterweights incorporated in the crankshaft. Crankshaft thrust is taken through two-piece washers on each side of the rear main bearing. Ful pressure lubrication to all connecting rod and main bearings is provided by drilled passages within the crankshaft and cylinder block. Six tapped holes are provided in the rear end of the crankshaft for attaching the flywheel. In-line engine main bearing journals are 3" in diameter and the connecting rod journals are 2 ½" in diameter. Crankshaft wear is usually associated with hearing troubles. Therefore, whenever main or connecting rod bearings are inspected (see Sections 1.3.4 and 1.6.1), the crankshaft should also be inspected. Remove the main bearing caps (one at a time) and connecting rod caps and examine the crankshaft for scoring, ridging, overheating, cracks or abnormal wear. If the crankshaft appears to be in good condition, it may be unnecessary to remove it to change the bearing shells. However, should the crankshaft journals show signs of distress or abnormal wear, the crankshaft must be reground or replaced.

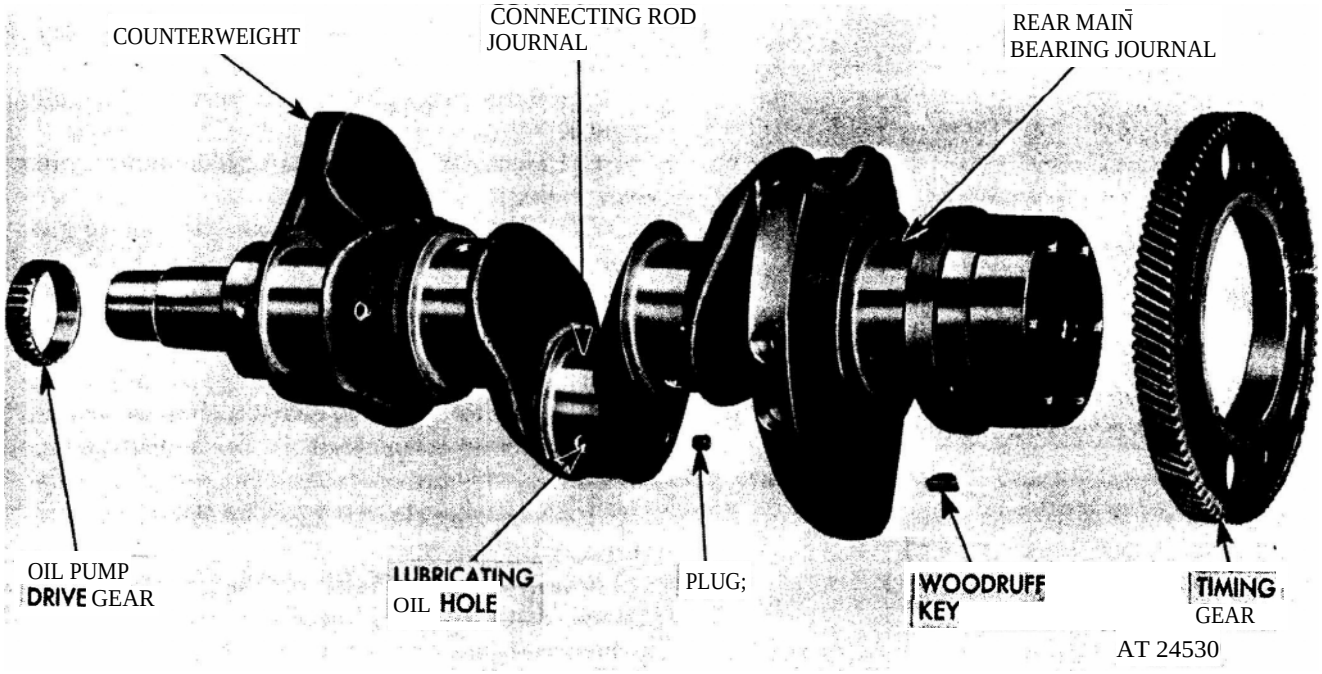


Figure I. Crankshaft details and relative location of parts—three cylinder in-line engine crankshaft shown.

Remove Crankshaft

When crankshaft removal becomes necessary, first remove or disconnect the power transmission, if engine is so equipped, then proceed as follows:

1. Clean the exterior of the engine thoroughly.
2. Drain the cooling system.
3. Drain the engine crankcase.
4. Remove all engine to base attaching bolts; then with chain hoist and sling attached to lifter brackets at each end of engine, remove engine from its base, if used.
5. Remove all accessories and assemblies with their attaching parts as necessary to permit the engine to be mounted on an overhaul stand.
6. Mount the engine on an overhaul stand, and fasten it securely to the mounting plate.

1.3 CRANKSHAFT

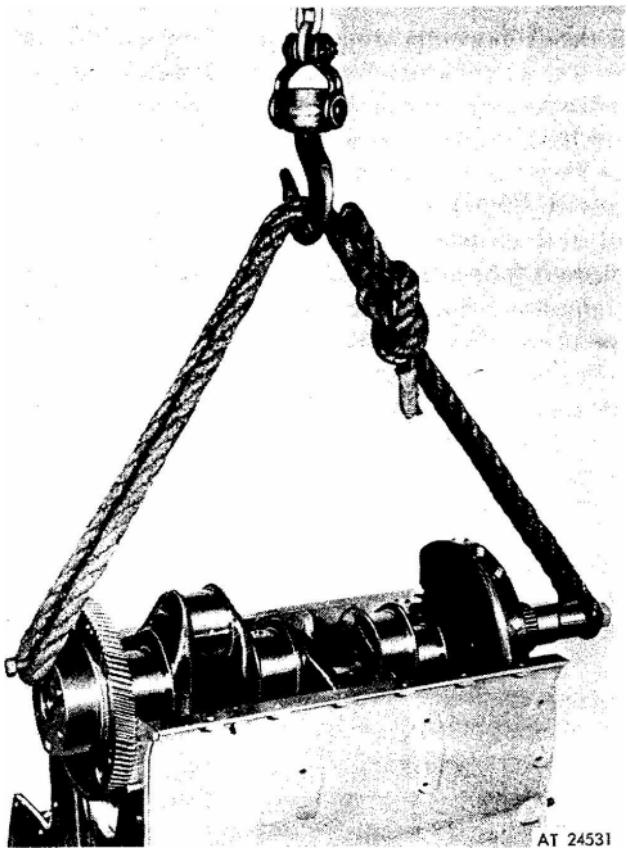
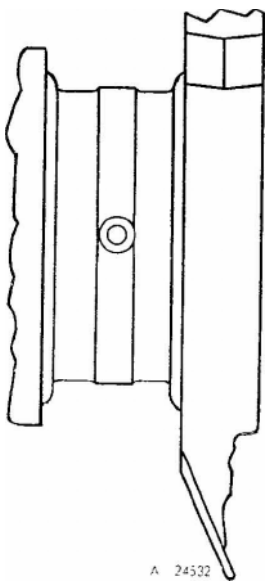


Figure 2. Lifting or lowering crankshaft from into cylinder block.



Fugire 3. Typical ridging of crankshaft.

CAUTION

Be absolutely sure the engine is securely mounted to the stand before releasing the lifting sling. Severe injury to personnel and destruction of engine parts will result if the engine breaks away from the stand.

7. Remove the oil pan.
8. Remove the oil pump inlet pipe and screen.
9. Remove the flywheel and flywheel housing.
10. Remove the crankshaft pulley.
11. Remove the front engine support, if the unit is so equipped.
12. Remove the engine lower front cover and oil pump assembly.
13. Remove the cylinder head(s).
14. Remove the main bearing cap stabilizers.
13. Remove the connecting rod bearing caps.
16. Remove the main bearing caps.
17. Remove the thrust washers from each side of the rear main bearing.
18. Remove the pistons, connecting rods and liners.
19. Remove the crankshaft, including timing gear (fig. 2).
20. See section 1.7.5 for crankshaft timing gear removal, and section 4.1 for the procedure covering removal of the oil pump drive gear.

Crankshaft Inspection

When a crankshaft has been removed for reconditioning, a thorough inspection should be carried out before the crankshaft is reinstalled in the engine.

1. Remove crankshaft plugs and clean out all oil passages thoroughly.
2. Support crankshaft on its front and rear journals in a V-block or in a lathe and check runout on intermediate main bearing journals, using a dial indicator. On 3-53, carnkshafts the maximum runout on the intermediate journal(s) must not exceed .002" total indicator reading.
3. Measure all main and connecting rod bearing journals. The journals should be measured at several places on the circumference in order to determine the smallest diameter, in case the journals have worn out-of-round. Taper on the journals of a used shaft should not exceed .003", and out-of-round should not exceed .003". The maximum taper on a new shaft is .0005" and maximum out-of-round is .00025".
4. Used crankshafts will sometimes show a certain amount of ridging caused by the groove in the upper main bearing shell. See figure 4. If this

ridge is not removed before new bearing shells are installed, localized high unit pressures on the bearings will result during engine operation. A ridge exceeding .0002" or more must be removed. The ridges may be removed by working crocus cloth, wet with fuel oil, around the circumference of the crankshaft journal. Rotate the crankshaft frequently to eliminate an out-of-round condition. If the ridges are greater than .0005", first use 120 grit emery cloth to clean up the ridge, followed by the use of 240 grit emery cloth for finishing. Then, wet crocus cloth should be used for the polishing operation. If ridges are greater than .001", crankshaft may have to be reground.

5. Check surfaces of crankshaft for evidence of cracks. Several methods of determining the presence of minute cracks not visible to the eye are outlined below.

a. Magnetic Particle Method-Part is magnetized and then covered with a fine magnetic powder or solution. Flaw, such as cracks, form a small local magnet which caused the magnetic particles in the powder or solution to gather there, effectively marking the crack. The crankshaft must be demagnetized after the test.

b. Fluorescent Magnetic Particle Method— This method is similar to the magnetic particle method, but is more sensitive since it employs magnetic particles which are fluorescent and glow under "black light". Very fine cracks that may be missed under the first method, especially on discolored or dark surfaces will be disclosed under the "black light".

c. Flourescent Penetrant Method-This is a method which may be used on non-magnetic materials such as stainless steel, aluminum and plastics. A highly fluorescent liquid penetrant is applied to the part. Then, the excess penetrant is wiped off and the part dried. A developing powder is then applied which helps to draw the penetrant out of flaws by capillary action. Inspection is carried out under "black light". A majority of indications revealed by the above inspection *methods* are normal and harmless and only in a small percentage of cases is reliability of the part impaired when indications are found. Since inspection reveals the harmless indications with the same intensity as the harmful ones, detection of indications is but a first step in the procedure. INTERPRETATION of the indications is the most important step. All Detroit Diesel crankshafts are magnetic particle inspected after manufacture to ensure against any shafts with harmful indications getting into the original equipment or factory parts stock. Crankshaft failures are rare, and when one cracks or breaks completely, it is very important to make a thorough inspection for contributory factors. Unless abnormal conditions are, discovered and corrected, there will be a repetition of the failure. There are two types of loads imposed on a crankshaft in service—a bending force and a twisting force. The design of the shaft is such that these forces produce practically no stress over most of the surface. Certain small areas, designated as critical areas, however. sustain most of the load (fig. 4).

a. Bending fatigue failures result from bending of the crankshaft which takes place once per revolution. The crankshaft is supported between each of the cylinders by a main bearing, and the load imposed by the gas pressure on top of piston is divided between adjacent bearings. An abnormal bending stress in the crankshaft, particularly in the crank fillet, may be a result of misalignment of main bearing bores, bearings improperly fitted, bearing failures, a loose or broken bearing cap, or unbalanced pulleys. Also, drive belts which are too tight may impose a bending load upon the crankshaft. Failures resulting from bending start at the pin fillet and progress throughout the crank *cheek,* sometimes extending into the journal fillet. If main bearings are replaced due to one or more badly damaged hearings, a careful inspection must be made to determine if any cracks have started in the crankshaft. These cracks are most likely to occur on either side of the damaged bearing.

b. Torsional fatigue failures result from torsional vibration which takes place at high frequency. A combination of abnormal speed and load conditions may cause the twisting forces to set up a vibration, referred to as torsional vibration, which imposes high stresses at the locations shown in figure 5. Torsional stresses may produce a fracture in either the crankpin or the crank cheek. Crankpin failures are usually at the fillet at 45 to the axis of the shaft. The introduction of improper or additional pulleys or couplings, are usual causes of this type of failure. Also, overspeeding of the engine, or resetting the governor at a different speed than intended for the engine application may be contributory factors.

As previously mentioned most indications found in service inspection of the crankshaft are harmless. The two types of indications to look for are circumferential fillet cracks at the critical areas, and 45° cracks (45 with axis of shaft) starting from either the critical fillet locations or the crank pin

holes as shown in figure 5. Cracks of this nature should result in replacement of the crankshaft.

6. 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 end thrust clearance within the specified limits of .004" to .011" for new parts or a maximum of .018" with a used crankshaft. Otherwise, it may be necessary to use .005" oversize rear thrust washers, or regrind thrust surfaces to maintain end thrust with .010" oversize thrust washers.

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

. 8. Carefully inspect crankshaft in area of front and rear oil seal contact surface for evidence of rough or grooved condition. Any imperfections of oil seal contact surface will result in oil leakage at this point. Slight ridges of approximately .0002" in variation may be removed with crocus cloth, wet with fuel oil. The crankshaft should be rotated at intervals to remove ridges from the complete circumference of the shaft without disturbing the concentricity. Ridges which approach .0005" or greater, should first be cleaned up with 120 grit emery cloth, followed by use of 240 grit emery cloth for finishing. Crocus cloth, wet with fuel oil, should then be used for final polishing.

9. If the crankshaft cannot be cleaned up satisfactorily, the oil seals may be repositioned in the flywheel housing and front cover as outlined in Section 1.3.2.

10. Eccessive war or grooving on the front or rear crankshaft oil seal area may require the use of an oil seal sleeve which may be pressed on the crankshaft (fig. 61. The oil seal sleeve provides a replaceable wear surface for the lip-type oil seal. However, an oversize oil seal must be used with the sleeve. Install the rear oil seal sleeve as follows:

a. Stone the high spots from the oil seal contact surface of the crankshaft.

b. Coat the area of the shaft, where the sleeve will be positioned, with shellac or an equivalent sealant.

c. Drive the sleeve squarely on the shaft with crankshaft rear oil seal sleeve installer 7 21277.

d. Wipe off any excess sealant. Install the front oil seal sleeve on In-line engines as follows:

a. Stone the high spots from the oil seal contact surface of the crankshaft.

b. Coat the area of the shaft, where the sleeve will be positioned, with shellac or an equivalent sealant.

c. Position the sleeve on the crankshaft with the radius on the sleeve facing away from the engine.

d. Press the front oil seal sleeve squarely on the crankshaft with front oil seal sleeve installer J 22524 and the crankshaft pulley retainer bolt.

e. Wipe off any excess sealant.

11. Check the oil pump drive gear and crankshaft timing gear for worn or chipped teeth and replace if necessary.

12. If the crankshaft is worn so that the maximum journal-to-bearing shell clearan (with new shells) exceeds .0045" In-line engine (connecting rod bearings) and .0040" In-line engines (main bearings), or if the maximum journal taper or out-of-round is greater than .003", the crankshaft must be reground to .010", .020" or .030" under size. Measurements of the crankshaft should be accurate to the nearest .002".

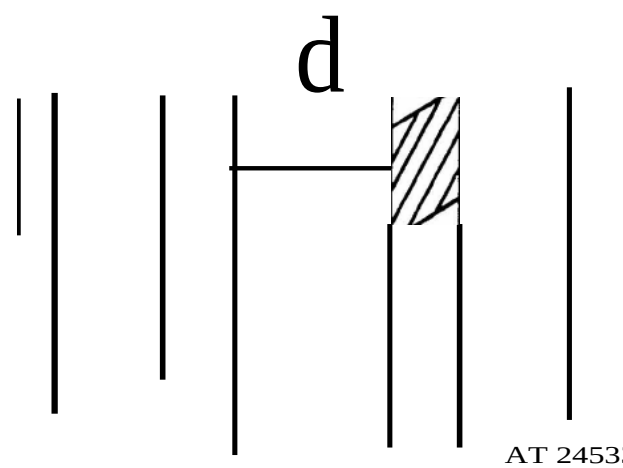


Figure 4. Critical crankshaft loading zones.

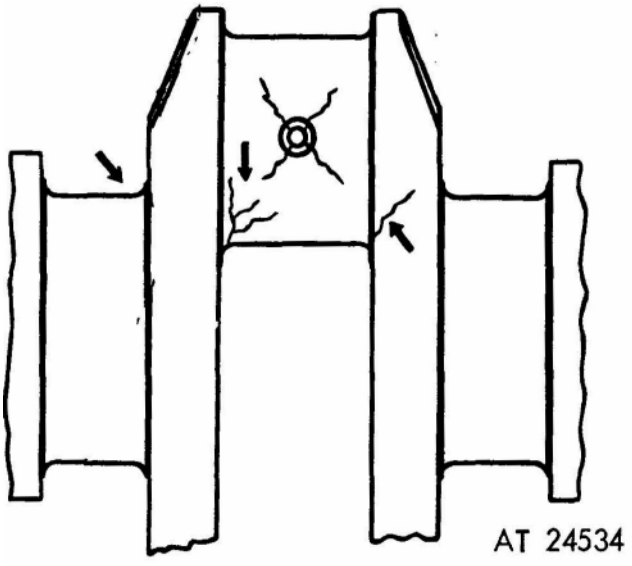


Figure 5. Crankshaft fatigue cracks.

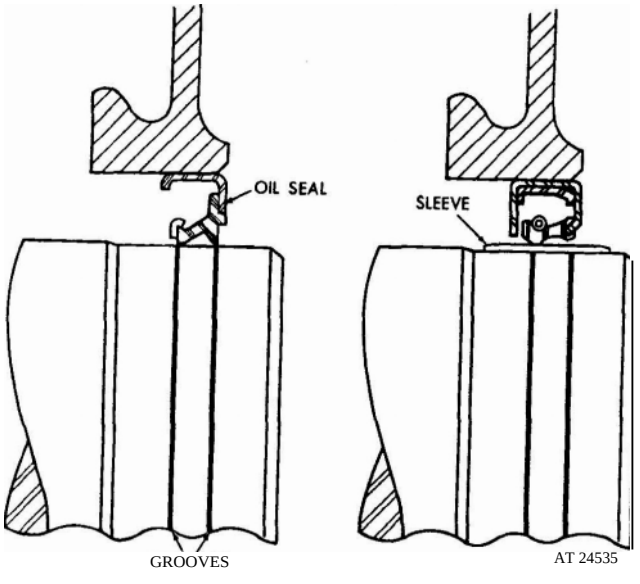


Figure 6. Use of rear oil seal sleeve on on crankshaft

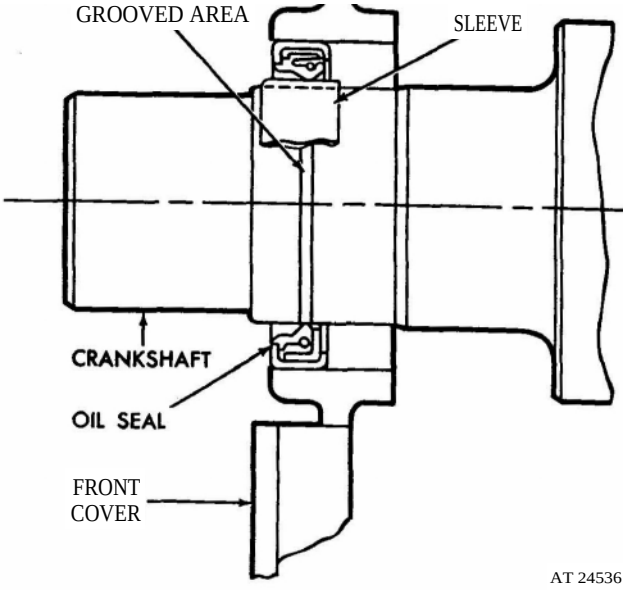


Figure 7. Use of front oil seal sleeve on grooved crankshaft (in-line and V engines)

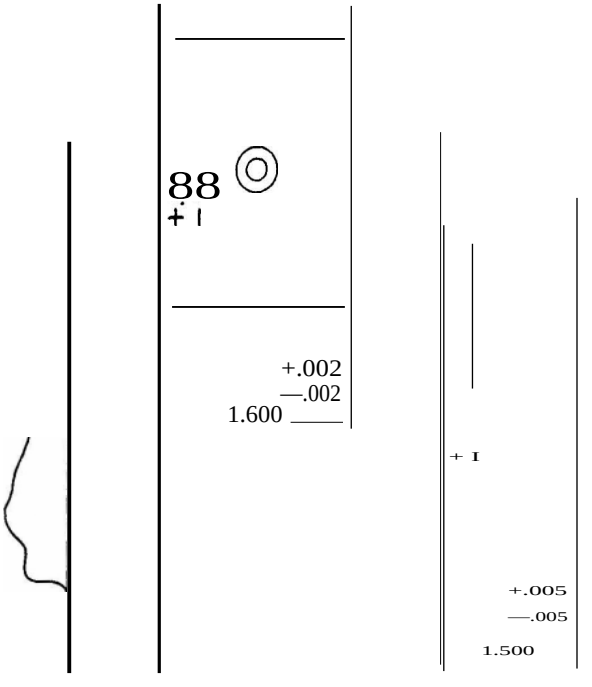


Figure 8. Dimensions of crankshaft journals and crankpins — In-line engines.

1.3 CRANKSHAFT

Crankshaft Grinding

1. Prior to grinding a crankshaft, a careful check should be made for cracks which start at an oil hole and follow the journal surface at an angle of 45° to the axis. Any crankshaft with such cracks must be rejected, as these cracks indicate torsional fatigue, and grinding of the shaft will increase the stress at the cracks causing eventual failure (see item 5 under "Inspect Crankshaft"). Also, when a shaft is inspected by the magnetic particle method, there may be indications of minute cracks beneath the surface. However, such cracks are not detrimental provided the regrinding operation does not bring them out onto the surface.

Bearing Size	Conn. rod journal dia	Main bearing journal dia.
	In-line engines	
Standard	2.500"	3.000"
.002" Undersize	2.500"	3.000"
.010" Undersize	2.490"	2.990"
.020" Undersize	2.480"	2.980"
.030" Undersize	2.470"	2.970"

NOTE

If the crankshaft has been subjected to excessive overheating, the heat treatment will be destroyed and a new crankshaft should be installed.

2. Measurement of the crankshaft journals, and comparison of these measurements to the diameters required for various undersize bearings shown in figure 8 and the table below ; will determine the size m which the crankshaft journals must be reground.

3. In addition to the standard main and connecting rod bearings, .002", .010", .020", and .030" undersize bearings are available.

NOTE

The .002" undersize bearings are used only to compensate for slight crankshaft wear in those cases where regrinding is unnecessary.

4. If one or more main or connecting rod journals require grinding, then all main or all connecting rod journals should be ground to the same required size.

5. When reginding crankshafts, all journal fillets on the In-line crankshafts must have a .130" to .160" radius between the crank cheek and the crank journal, see figure 9. The fillets must not have any sharp grind marks, and must blend smoothly into the journal and cheek, and be free of scratches.

6. 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.

7. Reground crankshaft journals will be subject to excessive wear unless the ground surfaces are polished absolutely smooth (8-12 R.M.S. finish).

8. If thrust surfaces of the crankshaft are worn or ridged excessively, they also must be ground undersize. See Section 1.3.4 for the installation of oversize thrust washers. When the thrust surfaces of the crankshaft are ground undersize, special care must he taken to leave a .130" to .160" radius on the In-line engine crankshaft, between the thrust surfaces and the bearing journal (fig. 9). This radius may be checked with a fillet gage.

9. The amount of grinding necessary on the crankshaft thrust surfaces depends upon how badly the surface is scored or worn. In many cases only slight grinding or "dressing up" of the thrust surface is necessary. In such cases, use of new standard thrust washers will probably Fuld the thrust clearances within the specified .004" to .011" limit. If the thrust clearance exceed .011", use .005" oversize thrust washers in place of the standard washers on the crankshaft rear thrust surface face (against thrust surface "A" fig. 10). The dimensions which indicate that standard thrust washers should be used are illustrated in figure 10. If one of the thrust surfaces is worn more than the other, it may be necessary, after regrinding, to install thrust washers of different thickn esses on either side of the bearing to properly center the crankshaft main journal on the bearing. However, if the crankshaft thrust surfaces are not worn enough to require regrinding, or if the sur faces are worn and ground evenly, thrust washers of equal thickness should be installed. Thrust washers are available in .005" and .010" oversize thickness, as shown in the table.

Nominal size	Thrust washer thic ness	
	Min.	Ma>.
Standard	.1190"	.1220"
.005" Oversize	.1255"	.1270"
.010" Oversize	.1300"	.132)"

A comparison of the dimensions in figure 10 with corresponding dimensions on the crankshaft with reground thrust surfaces will indicate the size of thrust washer required to provide the correct clearance. The clearance must not exceed .011" on a new crankshaft or .018" on a used crankshaft.

10. Polish the thrust surfaces of the crankshaft, after grinding.

11. The edges of the oil holes in the journal surfaces should be stoned smooth to a radius of approximately 3 / 32". Remove the plugs and clean the oil holes with a stiff wire brush.

12. The crankshaft should be magnetic particle inspected again to determine whether cracks are present due to insufficient cooling or crowding of the grinding wheel. Then, the crankshaft must be demagnetized.

13. Clean the crankshaft with fuel oil, and dry with compressed air. Blow out the oil passages, and reinstall the plugs.

14. Measure the thickness of the main bearing and connecting rod bearing shells as described in section 1.3.4. Install new bearing shells if the used ones are beyond wear limits.

NOTE

New main and connecting rod upper and lower bearing shells must be used when a new or reground crankshaft is installed.

Install Crankshaft

The crankshaft main bearing upper shells are grooved for lubrication and the lower shells are not. When installing the shells preparatory to setting the crankshaft in place, make sure the grooved shells are placed in the cylinder block as shown in figure 1 in section 1.3.4. If the shells previously used are to be used again, install them in the same locations from which they were removed. When a new crankshaft is installed, all new main and connecting rod (upper and lower) bearing shells should also be installed. Refer to sections 1.7.5 and install the crankshaft timing gear, if it was removed. Refer to section 4.1 and install the lubricating oil pump drive gear on In-line engine, if it was removed. After the crankshaft timing gear and oil pump drive gear are assembled on the rear and front ends of the crankshaft. the crankshaft may be installed as fol lows :

1. Install the upper grooved bearing shells in the cylinder block.

2. Appl[y] clean engine oil to the crankshaft journals and set the crankshaft in place so that timing marks on the crankshaft timing gear and the gear train idler gear match. Refer to section 1.7.2 for the correct method of timing the gear train.

3. Install the upper halves of the rear main bearing thrust washers on each side of the bearing, and the doweled lower halves on each side of the rear main bearing cap.

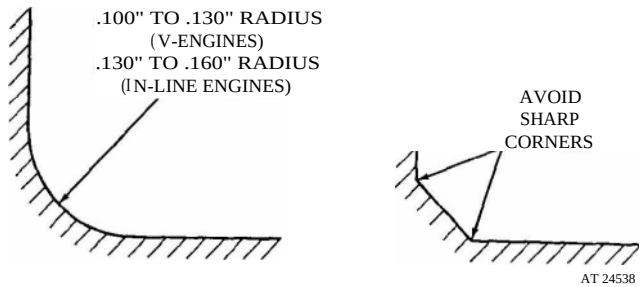


Figure 9. Crankshaft journal fillets.

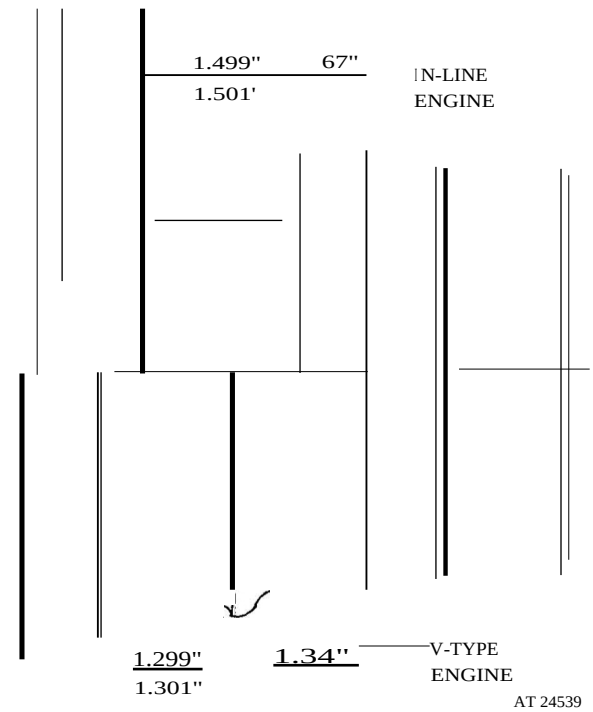


Figure 10. Standard dimensions at rear main bearing thrust washers — In-line and V engines.

4. With the lower main bearing shells installed in the hearing caps, install the caps and stabilizers in their original position. Lubricate the bolt threads and the bolt head contact areas with a small quantity of International Compound No. 2. or equivalent, and install them in the bearing caps. Draw the bolts up snug. Then, tap the caps lightly with a soft hammer to seat them properly, and draw the hearing cap bolts uniformly tight, starting with center cap and working alternately towards both ends of the block, to 120-130 lb-ft torque. Tighten the stabilizer to cylinder block bolts to 70-75 lb-ft torque. Rotate the crankshaft to see that it rotates freely.

NOTE

If the bearings have been installed properly, the crankshaft will turn freely with all of the main bearing cap bolts drawn to the specified torque.

5. Check the crankshaft end play by moving the crankshaft toward the gage as shown in figure 11. Keep a constant pressure on the tool and set the dial indicator to zero. Then, remove and insert the screw driver On the other side of the bearing cap. Force the screw driver in the opposite direction and note the amount of end play on the dial. The clearance should be .004" to .011" with new parts or a maximum of .018" with used parts. Insufficient clearance can be the result of a misaligned rear main bearing or a burr or dirt on the inner face of one or more of the thrust washers. If the rear bearing is misaligned it m ay be loosened and retightened as described in Item 4.

6. Install cylinder liner, piston and connecting rod assembly (sec. 1.6.3).

7. Install the cylinder head, section 1.2.

8. Install the flywheel housing (sec. 1.5), then install the flywheel.

9. Install the crankshaft lower engine front cover and the lubricating oil pump assembly, (sec. 1.3.5).

10. Install the engine front support, if so equipped.

11. Install the crankshaft pulley (sec. 1.3.7).

12. Install the oil pump inlet pipe and screen on In-line engines; (sec. 4.1).

13. Affix a new gasket to the oil pan flange and install the oil pan.

14. Use a chain hoist and sling attached to the lifting bracket at each end of the engine and remove the engine from the overhaul stand. Mount the *engine* as required.

15. Install all of the accessories that were removed.

16. After the engine has been completely reassembled, refer to the "Lubricating Oil Specifications" in section 13.3 and refill the crankcase to the proper level on the dipstick.

17. Close all the drains and fill the cooling system.

18. After replacing the main or connecting rod hearings or installing a new crankshaft, operate the engine as outlined in the run-in schedule, section 13.2.1. While the engine is operating, check for fuel, lubricating oil and cooling system leaks.

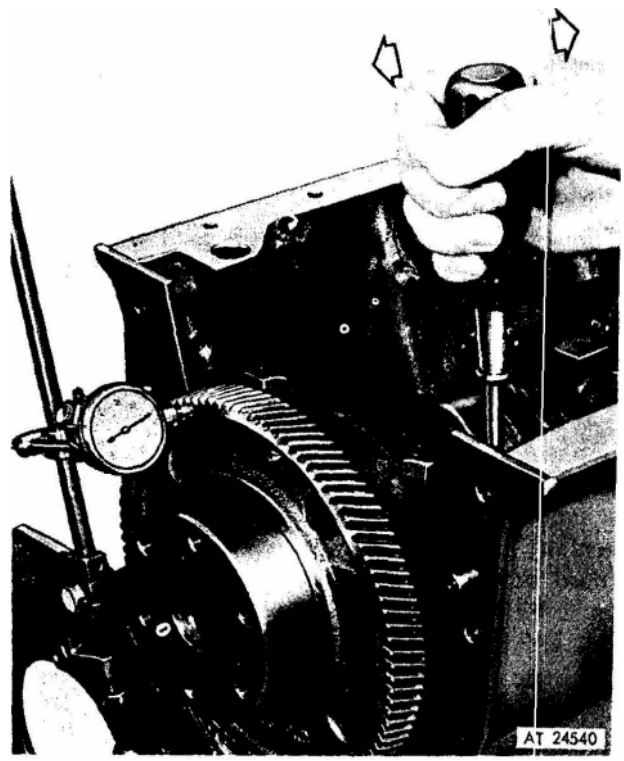


Figure 11. Checking crankshaft end play.

CRANKSHAFT OIL SEALS

An oil seal is used at each end of the crankshaft to retain the lubricating oil in the crankcase. The rear oil seal is pressed into the flywheel housing. The front oil seal is pressed into the lower front cover. Oil seals may become worn or damaged due to improper installation, excessive main bearing clearances, or grooved sealing durfaces. To avoid repetition of oil seal troubles, the above possible conditions should be checked.

Remove Crankshaft Oil Seals

1. Remove the engine front cover as outlined in section 1.3.5 and remove the flywheel housing as outlined in section 1.5.
2. Support the forward face of the front cover on two wood blocks next to the oil seal bore. Then press or drive the oil seal out of the front cover.
3. Support the forward face of the flywheel housing on two wood blocks next to the oil seal bore. Then press or drive the oil seal out of the housing.
4. Clean the oil seal bore in the front cover, or flywheel housing thoroughly before installing a new oil seal. When necessary, the crankshaft oil seals may be removed without removing the front cover or flywheel housing. This may be done by drilling diametrically opposite holes in the seal casing and threading metal screws, backed by flat washers, into the casing. Then the seal may be removed by prying against the washers with pry bars.

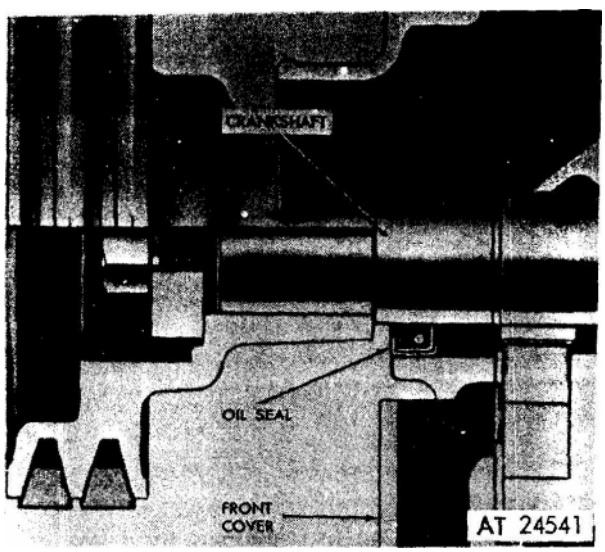


Figure 1. Crankshaft front oil seal.

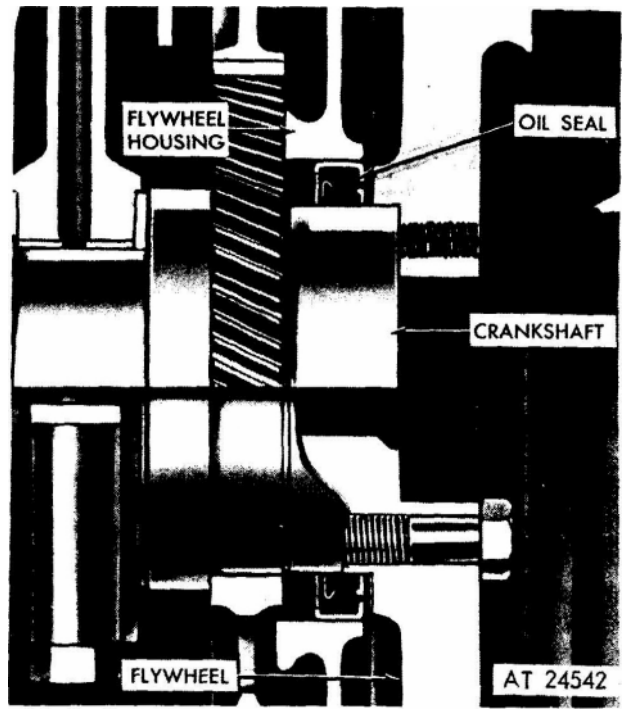


Figure 2. Crankshaft rear oil seal.

Inspection

The seals should be checked for scoring, cracking or charring. Seals may become hard and brittle from excessive heat. Oil leaks are indications of worn or damaged oil seals. Inspect the rear end of the crankshaft for wear due to the rubbing action of the oil seal, dirt build-up, or fretting caused by the action of the flywheel. The crankshaft must be clean and smooth, otherwise the oil seal lip will be damaged when the new oil seal is installed. If necessary, the crankshaft may be smoothed up with emery cloth, and polished with crocus cloth wet with fuel oil. Rotate the crankshaft at intervals to clean up the circumference of the shaft without disturbing the concentricity. On In-line engines, if the crankshaft cannot be cleaned up satisfactorily, the oil seal may be pressed into the flywheel housing or the front cover 1/4" from its original position. Excessive wear or grooving in the front or rear crankshaft oil seal area, may require the use of an oil seal sleeve which may be pressed on the crankshaft (sec. 1.3).

Install Crankshaft Front Oil Seal

1. If the outside diameter of the seal isn't precoated with sealant, coat the bore in the engine front cover with non-hardening sealant.
2. Apply grease to the lip of the oil seal; then, position the seal in the cover with the lip of the seal pointing toward the inner face of the cover.

CAUTION

Keep the lip of the oil seal clean and free from scratches.

3. Place the cover in an arbor press (inner face down).
4. On In-line engines press the oil seal into the cover until the seal is flush with the outside face of the cover.
5. Remove all excess sealant.
6. Install the engine front cover as outlined in section 1.3.5.

Install Crankshaft Rear Oil Seal

1. Support the inner face of the flywheel housing in an arbor press.
2. If the oil seal casing is not pre-coated with a plastic coating or a sealant, coat the outside diameter of the casing with non-hardening sealant.
3. If not previously lubricated, apply grease to the lip of the oil seal; then, position the seal in the flywheel housing bore with the lip of the oil seal pointing toward the inner face of the housing.

CAUTION

Keep the lip of the oil seal clean and free from scratches.

4. On I n-line engines use installer J 9479 to press the oil seal into the flywheel housing until the seal is flush with the outside face of the housing (fig. 3). If the flywheel housing was not removed from the engine, place oil seal expander J 9769 (standard size seal) or J 21278 (oversize seal) up against the rear end of the crankshaft; then, with the lip of the oil seal pointed toward the flywheel housing, slide the seal over the expander and on the crankshaft. Next thread the guide studs J 9472-2 into the crankshaft. Now drive the seal into the flywheel housing with installer J 9479-1 until the seal is flush with the face of the housing.
5. Remove all excess sealant from the housing and the *seal.*
6. Install the flywheel housing as outlined in section 1.5.

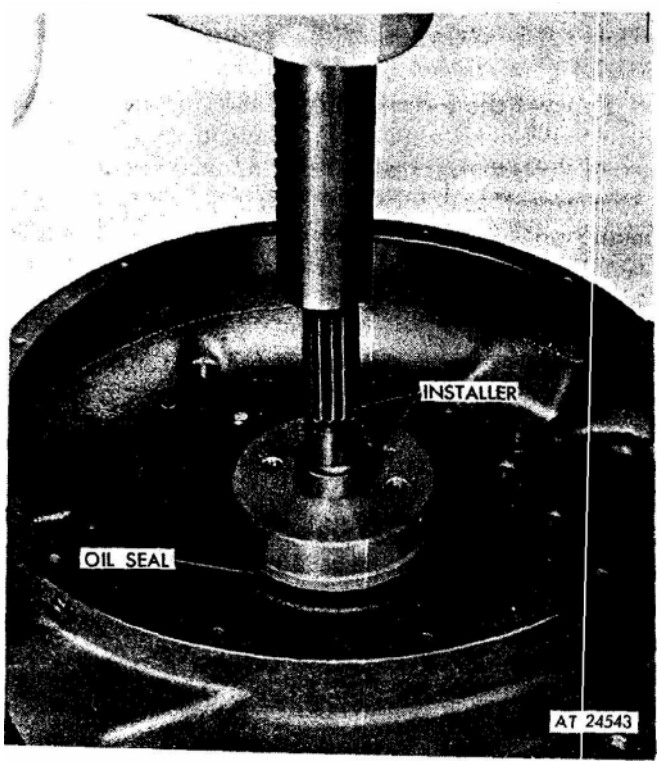


Figure 3. Installing oil seal in flywheel housing.

CRANKSHAFT MAIN BEARINGS

The main bearing shells are of the precision type and are readily replaceable without machining. They are used at each journal and consist of an upper shell seated in the cylinder block main bearing support and a lower shell seated in the main bearing cap. The bearing shells are prevented from endwise or radial movement by a tang at the parting line at one end of each shell. The bearing caps are numbered 1, 2, 3, etc., indicating their respective positions and, when removed, must always be reinstalled in their original position. A / 16" oil hole in the groove of each upper shell, midway between the parting lines, registers with a vertical oil passage in the cylinder block. Lubricating oil, under pressure, passes from the cylinder block by way of the bearing shells to the drilled passages in the crankshaft, then to the connecting rods. Lower main bearing shells have no grooves; therefore, the upper and lower bearing shells must not be interchanged. Rear main bearing thrust washers absorb the crankshaft thrust at each side of **the rear** main bearing, *see* figure 1. Each washer is made of two halves; the lower halves are doweled to the bearing cap, the upper halves are not doweled. Oil seals prevent oil from seeping out along the journals at either end of the crankshaft (sec. 1.3.2) The copper-lead or aluminum coplated bearings have an inner surface, called the matrix of copper-lead or aluminum. A thin deposit of babbitt is then plated onto the matrix. This babbitt overlay has excellent resistance to friction, corrosion, and scoring tendencies which, combined with the material of the matrix, provides improved lead carrying characteristics. These bearings have a satin silver sheen due to the babbitt when new and a dull gray after being in service.

Main bearing trouble is ordinarily indicated by low or no oil pressure and, in extreme cases, may cause the flywheel to wobble. All the main bearing load is carried on the lower bearing; therefore, wear will occur on the lower shells first. Flaking pitting, dirt grooving, scoring and wear of the lower main bearing shells may be observed by removing the main hearings. If main bearing trouble is suspected, remove the oil pan, then remove the main bearing caps — one at a time — as outlined below and examine the bearing shells. One main bearing shell alone should not be replaced. If a bearing shell requires replacement, all new shells, both upper and lower, should be installed.

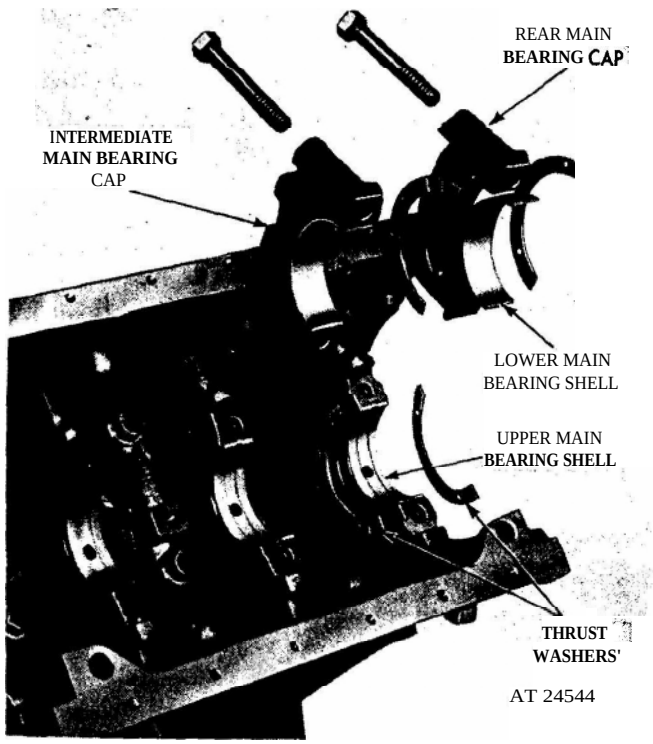


Figure 1. Upper and lower main bearing shells, bearing caps and rear main bearing thrust washers — in-line engines.

Remove Main Bearing Shells (Crankshaft in Place)

When removal of main bearing shells becomes necessary, but removal of the crankshaft is not required, refer to figures 2 and 3 and proceed in the manner outlined below. All crankshaft main bearing journals except the rear are drilled for an oil passage. The procedure, therefore, for removing the shells with crankshaft in place is somewhat different on the drilled journals than on the one at the rear which is not drilled. The method for removal of both types is given below.

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

2. Remove the oil pump intake pipe and screen assembly.

3. To remove all except rear main bearing shell, insert a ¼" x ¾ bolt with a ½" diameter, and, a 1 / 16" thick head (made from a standard bolt), into the crankshaft journal oil hole, then revolve the shaft to tile right (clockwise) and roll the bearing

shell out of position. The head of the bolt should not extend beyond the outside diameter of the shell, see figure 2. Remove one main bearing cap at a time, inspect as outlined under "INSPECTION" in this section, and complete replacement of shell and reinstallation of cap before another cap is removed. 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 pushing on end of washer with a small rod, thus forcing washer around and out on opposite side of bearing.

4. Remove rear main bearing upper shell by driving on the edge of the bearing shell with a small curved rod, (fig. 3), at the same time revolving the crankshaft, thus rolling the shell from its position.

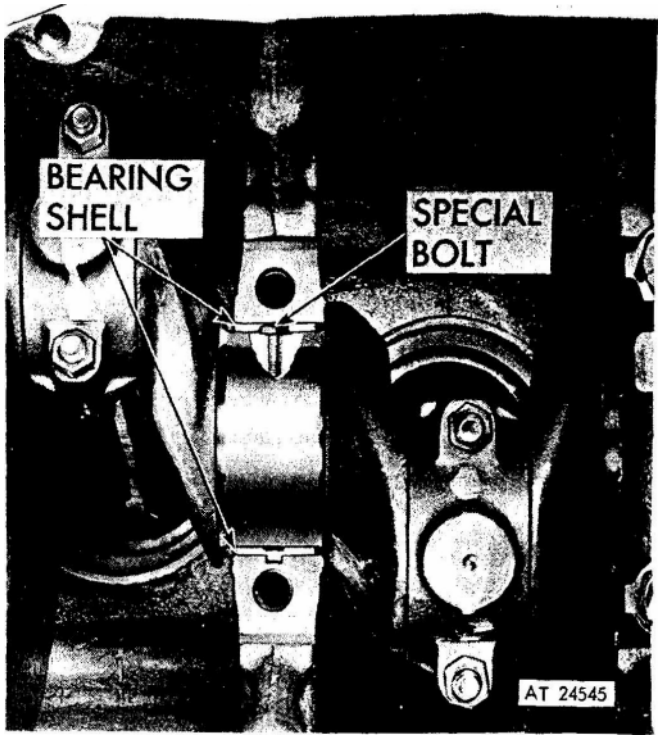


Figure 2. Removing main hearing upper shell (except rear main) — Crankshaft in place.

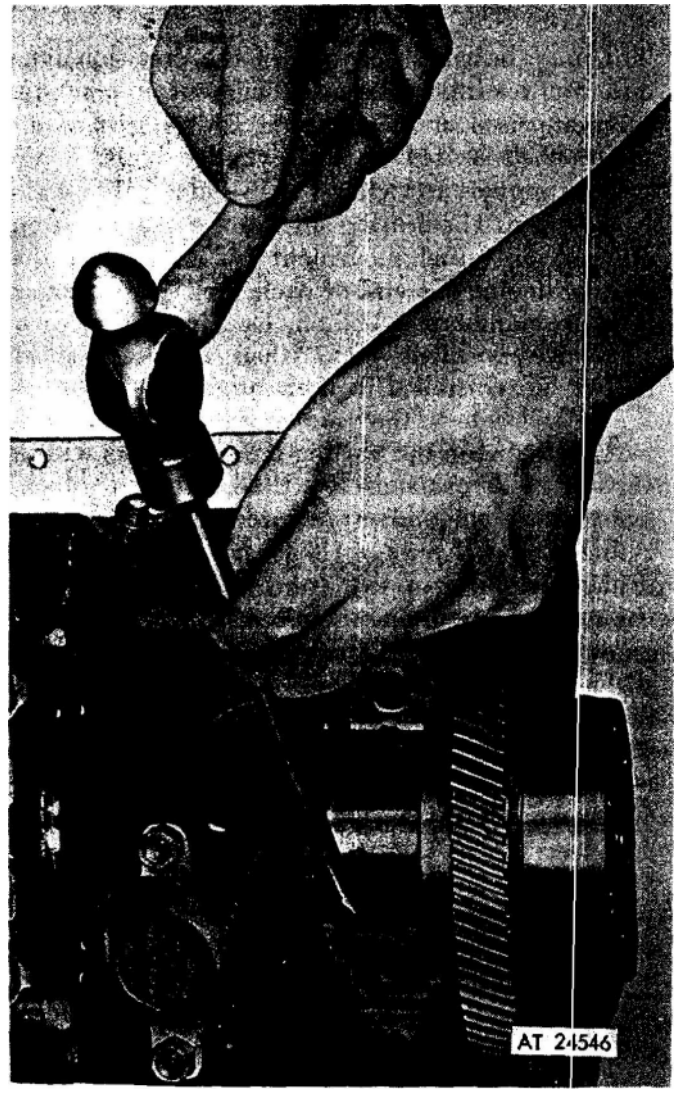


Figure 3. Removing rear main bearing upper shell— crankshaft in place

Inspection

Visual inspection, as well as dimensional measurements, should be made to determine

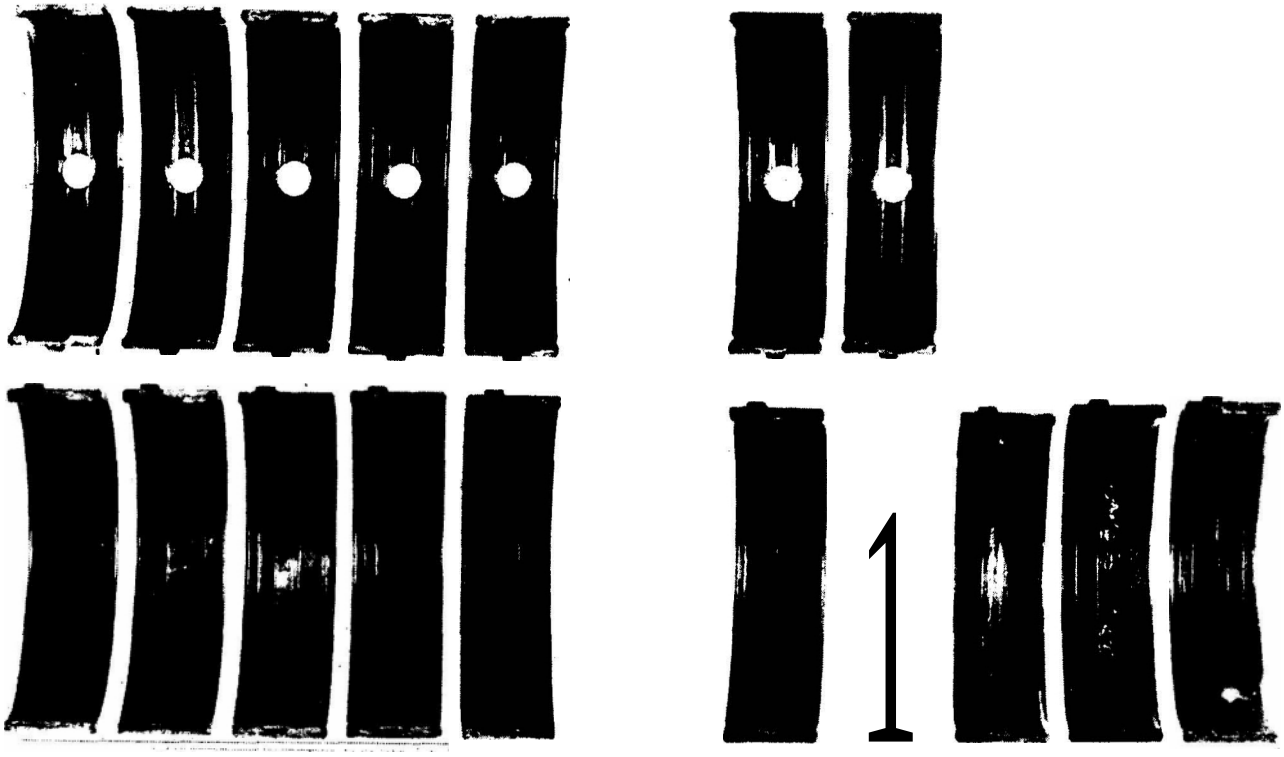


Figure 4. Comparison of main bearing ***shells.***

whether the used bearings are satisfactory- for further service or must be replaced. Bearing failures may result from deterioration (acid formation) or contamination of oil or loss of oil which results in scratching, etching, scoring or excessive wear. An analysis of the lubricating oil may be required to determine if corrosive acid and sulphur are present which cause acid etching, flaking and pitting. Bearing seizure may be due to low oil or no oil. The oil filter elements should be checked and replaced. if necessary. Also, the oil by-pass valve should be checked to determine if it is operating freely. After removal, clean the bearing shells and inspect them for scoring, pitting, flaking, chipping, cracking, loss of babbitt, or signs of overheating. If any of these defects are present, the bearings must be **discarded**. However, babbitt plated bearings may develop minute cracks or small isolated cavities on the bearing surface during engine operation. These are characteristics of and are not detrimental to this type of hearing. The bearings should not be replaced for these minor surface imperfections since functioning of the bearings is on no way impaired and they will give many additional hours of trouble-free operation. The lower bearing shells, which carry the load, will normally show signs of distress before the upper shells do. Inspect the back of the bearing shells for bright spots which indicate they have been moving in the caps or cylinder block. If such spots are present, discard the bearing shells. The thickness of the bearing shells should be measured at point "C", 90° from parting line, as shown in figure 5.

1.3.4 MAIN BEARINGS

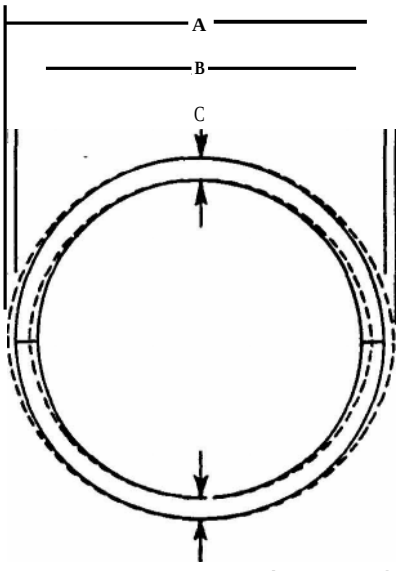


Figure S. ***Inside diameter*** *of* ***main bearing shell at parting line and 90? to parting line.***

Tool J-4757, placed between the shell and a micrometer, as illustrated in figure 6, will give an accurate measurement. The bearing shell thickness will be the total thickness of steel ball in tool and shell, less the diameter of ball. The above is the only practical method for measuring shell thickness unless a special micrometer is available for this purpose. Minimum thickness of a worn standard main bearing shell is .123" and, if any of the shells are thinner than this dimension, all shells must be discarded and replaced with new shells. A new bearing shell has a thickness of .1245" to .1250" on In-line engines. In addition to this thickness measurement, the clearance between main bearings and crankshaft journals should be checked. This clearance may be determined with the crankshaft in place by means of a soft plastic measuring strip which is squeezed between journal and hearing, or with the crankshaft removed, by measuring the outside diameter of the crankshaft main bearing journals, and the inside diameter of the main bearing shells when installed in place with the proper torque of 120-130 lb-ft on the main bearing cap bolts. If the clearance between any crankshaft main bearing journal and its bearing shells exceed .006", all bearing shells must be discarded and replaced with new shells. For clearances with new bearing shells refer to section 1.3.0. Bearing shells when in place have a larger diameter at the parting line than 90° from the parting line as shown in figure 5. The two shells do not form a true circle when not installed and when measured for inside diameter should be installed in the cylinder block with caps bolted in place (crankshaft removed). The two halves of the shells have a squeeze fit in the cylinder block and cap, and must be tight when the cap is drawn down. This "crush" assures a tight, uniform contact between the bearing shell and seat. Bearing shells that do not have sufficient **crush will** not have uniform seat contact, as shown by shiny spots on the bearing shell backs, and should be replaced.

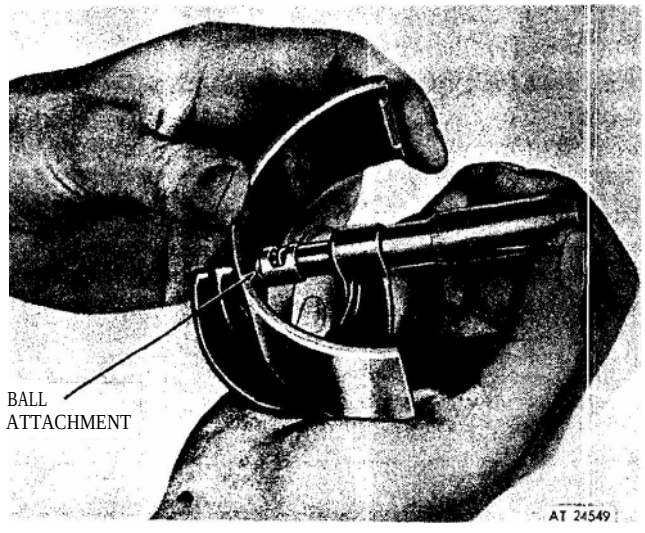


Figure 6. Measuring thickness of main bearing shell

When main bearing replacement is **necessary**, it is very important that the crankshaft journals be thoroughly inspected before new replacement bearings are installed. Very often, after prolonged engine operation, a ridge is formed on the **circumference** of the crankshaft journals in line with the journal oil holes. This ridge must not exceed .0002" and, if it is not removed before new bearings are installed, then, during engine operation, localized high unit pressures in the center area of the hearing shell will cause pitting of the bearing surface. Also, damaged bearings may cause bending fatigue and resultant cracks in the crankshaft. See section 1.3 under "Crankshaft Inspection" for removal of the ridge and inspection of the crankshaft. The crankshaft journals may he inpected for scoring, over-heating or wear without removing the crankshaft. To measure journal diameter, however, removal of the crankshaft is necessary. See "Crankshaft Inspection" in section 1.3. One main bearing shell alone should not be

replaced. If one bearing shell requires replacement, all new shells, both upper and lower shell; should be installed. Bearing shells which are. .002" undersize are available to compensate for slight crankshaft journal wear in those cases where it is unnecessary to regrind the crankshaft. Bearing shells in .010", .020" and .030" undersize are available for service with crankshafts which have *been gr*ound to a smaller journal diameter.

NOTE

Bearing shells are NOT reworkable from one undersize- to another under any circumstances.

The table below gives the minimum bearing shell thickness for new standard and various undersize bearings, and gives the crankshaft main bearing journal diameters corresponding to each bearing size. As will be seen from figures 1 and 7 the crankshaft thrust washers located at the rear main bearing consists of two pieces on each side of the hearing. The lower portion is doweled to the bearing cap in two places on each side of the cap.

Nominal size of bearing	Minimum new bearing shell thickness	Crankshaft main bearing journal dia.
In-line engines		
Standard	,1245"	2.999"-3.000"
.002" Undersize	.1255"	2.997"-2.998"
.010" Undersize	.1295"	***2.989"-2.990"**
.020" Undersize	.1345"	***2.979"-2.980"**
.030" Undersize	.1395"	***2.969"-2.970"**

* Dimension of reground crankshafts

Excessive end thrust from use of an improper flywheel or improper cluth adjustment can be contributory factors to scoring of the thrust washers. If these washers have been scored, or otherwise damaged, or if the crankshaft end thrust is excessive, they should be replaced. Crankshaft end thrust, as measured between the crankshaft flange and NEW thrust washers, (fig. 8) should be within limits of .004" to .011". The maximum allowable end thrust with used washers is .018". The crankshaft thrust surfaces should be inspected and, if scored, may require grinding (sec. 1.3 under crankshaft grinding). If after "dressing up" or grinding the crankshaft, new standard size thrust washers do not hold the end thrust within the

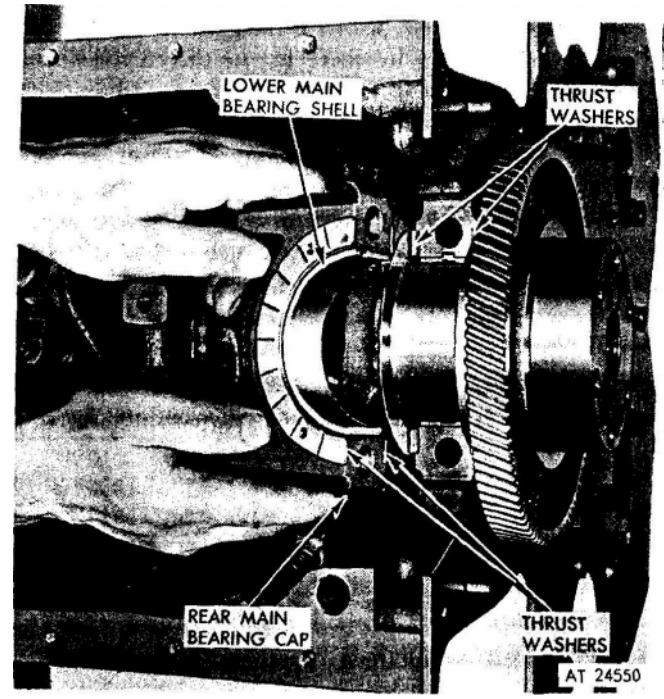


Figure 7. ***Rear main*** *bearing thrust washer and mounting.*

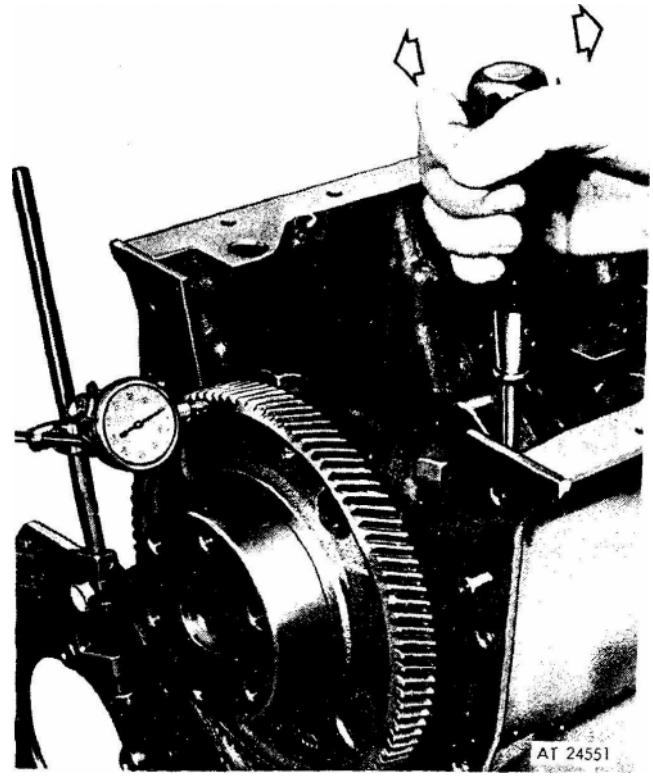


Figure 8. Checking crankshaft end play.

specified .004" to .011" limits, then oversize thrust washers must be used, If *one* of the thrust surfaces of the crankshaft is worn or ground considerable more than the other, it may be necessary to install thrust washers of different thicknesses on either side of the main bearing to properly center the crankshaft main journal on the bearing. However, if the .thrust surfaces are worn or reground evenly, thrust washers of equal thickness should be installed on either side of the bearing. The oversize thrust washers are listed in he following table:

Nominal size	Washer thickness
Standard	.1205" / .1220"
.005" Oversize	.1255" / .1270"
.010" Oversize	.1300"/ .1320"

Install Main Bearing Shells (Crankshaft in Place)

Make sure all parts are clean. Apply clean engine oil to all crankshaft journals and install main bearing shells by reversing the sequence of operations given for removal. Main bearing shells should not be replaced separately. If a bearing shell requires replacement, a new upper and lower shell should be installed. If a new or reground crankshaft is used, all new bearing shells should be installed. II new main bearing shells are being installed, the crankshaft journals should be examined for excessive wear and the crankshaft replaced if necessary. See section 1.3. Upper and lower main bearing shells are not alike; the upper shell is grooved and drilled for lubrication—the lower shell in not. Be sure to install the grooved and drilled shells in the cylinder block and plain shells in the bearing caps, otherwise the oil feed to the upper end of the connecting rods will be blocked off. If used bearing shells are reinstalled they must be assembled to the same journal from which they were removed.

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

2. Assemble crankshaft thrust washer before installing rear main bearing cap. Clean both halves of thrust washer carefully, removing any burrs from the seats — the slightest particle of dirt may decrease clearance between washers and crankshaft beyond limits. Slide upper halves of thrust washers into place in their grooves, as shown in figure 7; then assemblye lower halves *over* dowel pins *in* hearing cap.

NOTE

Main bearing caps are bored in position and marked 1, 2, 3, etc. They must be replaced in their original positions with marked side of caps facing the same side of cylinder block that carries the engine serial number.

3. With the lower main bearing shells installed in the bearing caps, install the caps and stabilizers in their original position. Lubricate the bolt threads and the bolt head contact areas with a small quantity of International Compound No. 2, or equivalent, and install them in the bearing caps. Draw the bolts up snug. Then, tap the caps lightly with a soft hammer to seat them properly, and draw the bearing cap bolts uniformly tight, starting with center cap and working alternately towards both ends of the block, to 120-130 lb-ft torque. Do not exceed the torque limit. Tighten the stabilizer to cylinder block bolts to 70-75 lb-ft torque.

NOTE

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

4. Check the crankshaft end play by moving the crankshaft toward the gage as shown in figure 8. Keep a constant pressure on the tool and set the dial indicator to zero. Then, remove and insert the screw driver on the other side of the bearing cap. Force the screw driver in the opposite direction and note the amount of end play on the dial. The clearance should be .004" to .011" with new parts or a maximum of .018 ' with used parts. Insufficient clearance can be the result of a misaligned rear main bearing or a burr or dirt on the inner face of one or more of the thrust washers. If the rear bearing is misaligned it may be loosened and retightened as described in Step 3.

5. Install the lubricating oil pump intake pipe assembly.

6. Install the oil pan with a new gasket.

7. Refer to Lubricating Oil Specifications in section 13.3 and refill the crankcase to the proper level on the dipstick.

8. After installing new bearing shells, operate the engine on a run-in schedule as outlined in section 13.2.1.

ENGINE FRONT COVER LOWER

The engine lower front cover is mounted against the cylinder block at the lower front end of the engine (fig. 1). It serves as a housing for the crankshaft front oil seal, the lubricating oil pump, the oil pressure regulator valve and the oil cooler by-pass valve. It will be necessary to remove the engine lower front cover to remove and install the crankshaft or lubricating oil pump, or when the engine is overhauled.

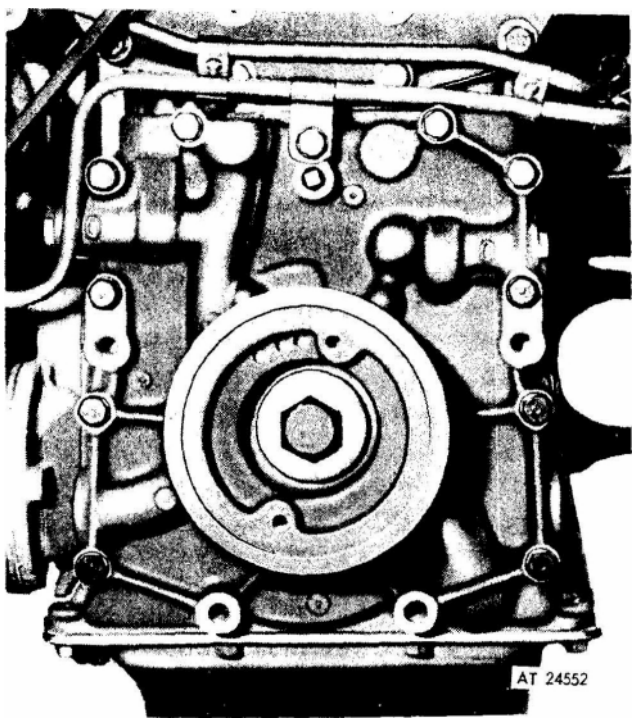


Figure 1. Engine front cover mounting (lower).

Remove Engine Front Cover

1. Remove the crankshaft pulley, as outlined in section 1.3.7.
2. Remove the oil pan drain plug and drain the lubricating oil. Install and tighten the drain plug.
3. Remove the oil pan and gasket.
4. Remove the two bolts and lock washers that secure the lubricating oil pump inlet tube flange or elbow to the engine front cover.
5. Remove the bolts and lock washers that secure the engine front cover to the cylinder block.
6. Strike the cover with a soft hammer to free the cover from the dowels. Pull the cover straight off the end of the crankshaft.
7. Remove the cover gasket.
8. Inspect the oil seal and lubricating oil pump as outlined in sections 1.3.2 and 4.1. Also, check the oil pressure regulator valve and oil cooler by-pass valve as outlined in sections 4.1.1 and 4.4.

Install Engine Front Cover

1. Affix a new cover gasket to the cylinder block.
2. Install oil seal expander J 7454 over the front end of the crankshaft.
3. Thread two ⅜"-16 pilot studs approximately 8" long into two diametrically opposite bolt holes in the cylinder block to guide the cover in place (fig.

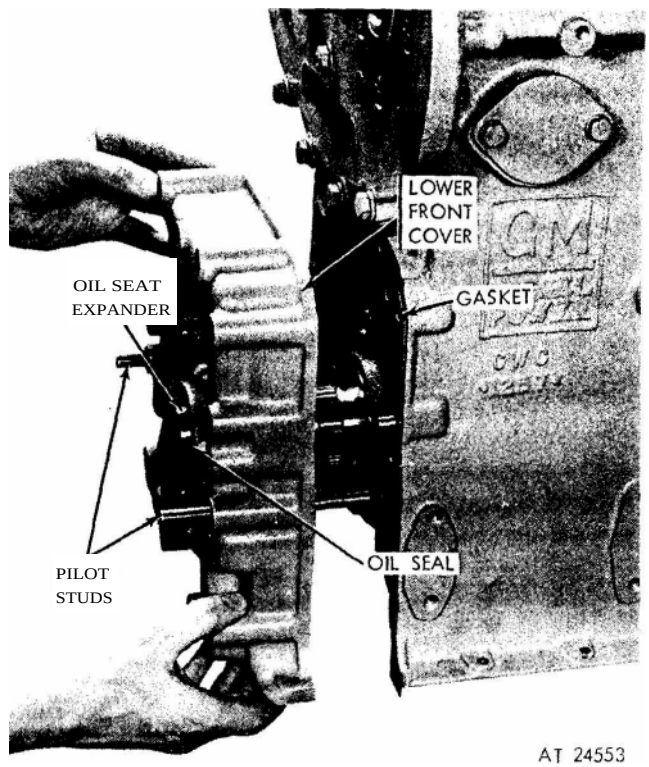


Figure 2. Installing crankshaft front cover—in-line engine.

4. Apply a light coat of cup grease to the lip of the oil seal. Slide the engine front cover over the oil seal expander and pilot studs as shown in figure 2. Push the cover forward until the inner rotor of the oil pump contacts the pump drive gear on the crankshaft. Rotate the crankshaft slightly to align the teeth, then push the cover up against the gasket and block. Do not force the cover.
5. Remove the oil seal expander and pilot studs.
6. Refer to figure 1 and install the ⅜"-16 bolts

and lock washers. Tighten the bolts to 30-35 lb-ft torque.

7. Affix a new gasket to the elbow. Attach the flange or elbow to the front cover with bolts and lock washers. Tighten the bolts to 13-17 lb-ft torque.

8. Affix a new oil pan gasket to the bottom of the cylinder block ; then secure the oil pan to the block with .bolts and lock washers. Tighten the bolts to 13-17 lb-ft torque.

9. Install the crankshaft pulley as outlined in section 1.3.7.

10. Refer to Lubricating Oil Specifications in section 13.3 and refill the crankcase to the proper level on the dipstick.

CRANKSHAFT PULLEY

The crankshaft pulley is secured to the front end of the crankshaft by a special washer and a bolt.

Remove Crankshaft Pulley

1.. Remove the belts from the crankshaft pulley.

2. Remove the crankshaft pulley retaining bolt and special washer.

3. If a rigid type pulley is being removed, install the pulley retaining bolt and puller J 4794-01 as shown in figure 1. Then force the pulley off the crankshaft by turning the puller center screw in.

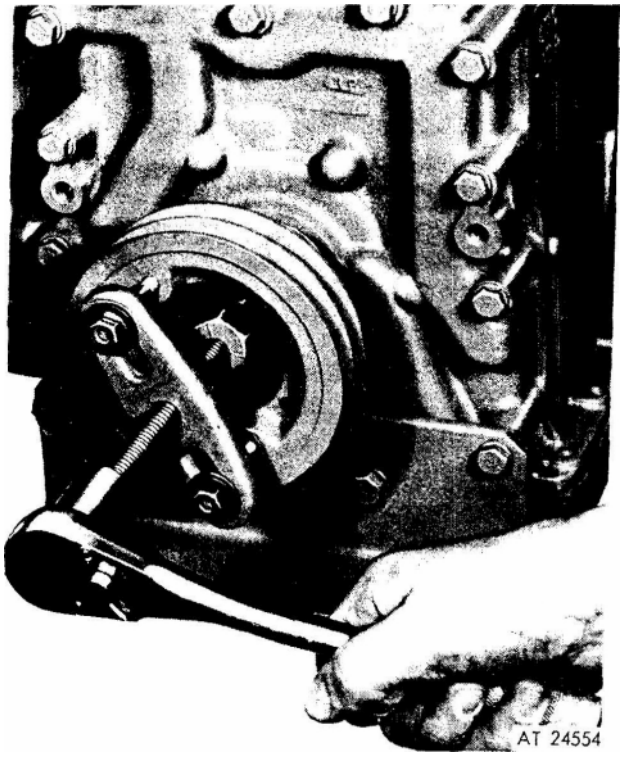


Figure 1. Removing crankshaft pulley using puller J 4794-01.

Install Crankshaft Pulley

1. Lubricate the end of the crankshaft to facilitate pulley installation.

2. Start the pulley straight on the end of the crankshaft.

3. Install a rigid type pulley with installer J 7773 as shown in figure 2. Then remove the installer.

4. Place the washer on the crankshaft bolt and thread the bolt into the front end of the crankshaft.

5. On all In-line engines, including In-line engines with cone mounted pulleys stamped with the letter "A", tighten the ¾"-16 crankshaft bolt to 200-220 lb-ft torque. On In-line engines with cone mounted pulleys not stamped with the letter "A" tighten the ¾"-16 bolt to 290-310 lb-ft torque.

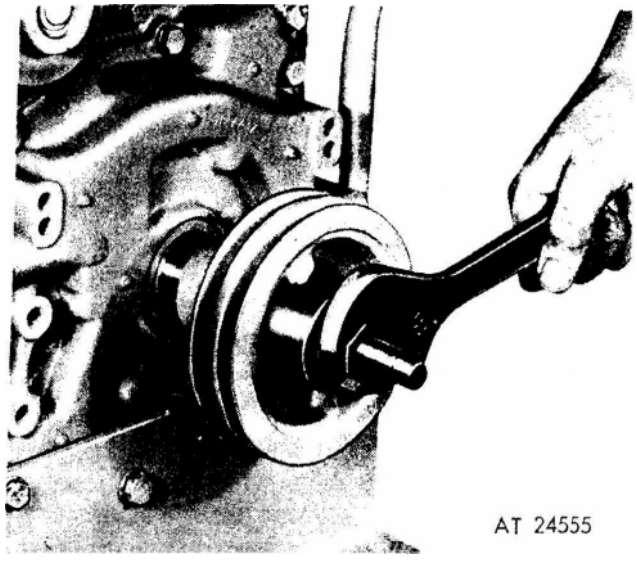


Figure 2. Installing crankshaft pulley using installer J 7773.

SHOP NOTES-SPECIFICATIONS-SERVICE TOOLS

SHOP NOTES

Checking Bearing Clearances

A strip of soft plastic squeezed between the crankshaft journal and connecting rod bearing or main bearing may be used to measure the bearing clearances. The strip is a specially moded plastic "wire" manufactured commerically, and is availble in three sizes and colors. Type PG-1 (green) has a clearance range of .001" to .003", type PR-1 (red) has a range of .002" to .006" and, type PB-1 (blue) has a range of .004" to .009". The plastic strip may be used for checking bearing clearances as follows:

1. Remove the bearing cap and wipe the oil from the bearing shell and crankshaft journal.

NOTE

When checking main bearing clearances with the engine in a position where the main bearing caps are supporting the weight of the crankshaft and the flywheel, an erroneous reading, due to the weight of the crankshaft and flywheel, can be eliminated by supporting the weight of the crankshaft by means of a jack under the counterweight adjoining the bearing being checked.

2. Place a piece of the plastic strip the full width of the bearing shell about ¼" off center, see figure 1.

3. Rotate the crank about 30° from bottom dead center and reinstall the bearing cap. Tighten the bolts to specified torque.

4. Remove the bearing cap. The flattened plastic strip will be found adhering to either the bearing shell or the crankshaft.

5. Compare the width of the flattened plastic strip at its widest point with the graduations of the envelope, see figure 1. The number within the graduation on the envelope indicates the bearing clearance in thousandths of an inch. Taper may be indicated when one end of the flattened plastic strip is wider than the other. Measure each end of the plastic; the difference between the readings is the approximate amount of taper.

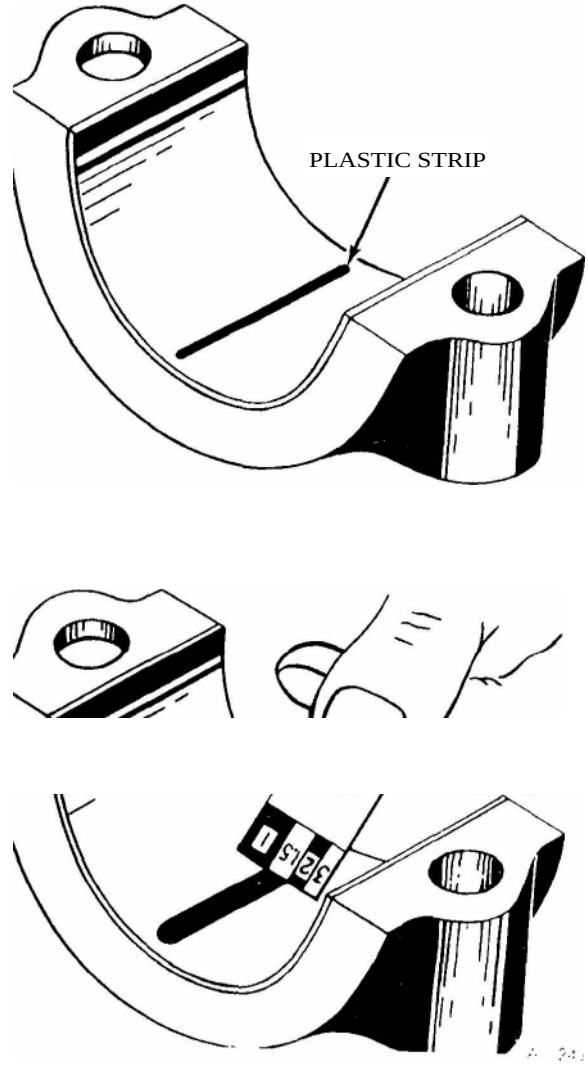


Figure 1. Using plastic strip to measure bearing-to-crankshaft clearance.

SPECIFICATIONS

Table of Specifications, New Clearances, and Wear Limits

Engine part (standard size)	New parts		Wear Limits
	Minimum	Maximum	
CYLINDER BLOCK			
Main Bearing Bore			
Inside Diameter (Vertical Axis) In-Line Engines	3.2510"	3.2520"	
CRANKSHAFT			
Journal Diameter—Main Bearing-In-Line Engine	2.9990"	3.0000"	
Journal Diameter—Connecting Rod-In-Line Engine	2.4990"	2.5000"	
Journal Out-of-Round		.00025"	
Journal Taper		.0005"	.0030"
Runout at Journal-Total Indicator Reading, 3-53		.0020"*	
Thrust Washer Thickness	.1205"	.1220"	
End Thrust Clearance	.0040"	.0110"	.0180"
MAIN BEARINGS			
Bearing Inside Diameter (Vertical Axis) In-Line Engine	3.0020"	3.0030"	
Bearing Thickness—90° from Parting Line-In-Line Engine	.1245"	.1250"	.1230"
Clearance-Bearing-to-Journal-In-Line Engine	.0010"	.0040"	.0060"
CONNECTING RODS			
Length Center-to-Center	8.7990"	8.8010"	
Lower Bore-Diameter	2.7515"	2.7525"	
Upper Bore-Diameter	1.6000"	1.6010"	
Bushing Inside Diameter	1.3760"	1.3765"	
CONNECTING ROD BEARINGS			
Bearing Inside Diameter (Vertical Axis)	2.5015"	2.5035"	
Bearing Thickness-90° from Parting Line	.1245"	.1250"	.1230"
Clearance-Bearing-to-Crankshaft Journal	.0015"	.0045"	.0060"

* This runout tolerance given for guidance when regrinding crankshafts:
Crankshaft for 3-53 supported on No. 1 and No. 4 journals; runout measured at No. 2 and No. 3 journals. When runout on adjacent journals is in the opposite direction, the sum must not exceed .003" total indicator reading ; when in the same direction, the difference must not exceed :003" total indicator reading. When high spots of runout on adjacent journals are at right angles to each other, the sum must not exceed .004" total indicator reading, or .002" on each journal.

·.These clearances also apply to oversize or undersize parts.

Standard Bolt and Nut Torque Specification

Size nut or bolt	Torque (lb-ft)	Size nut or bolt	Torque lb-ft)	Size nut or bolt	Torque (lb-ft)
1/4 - 20	7-9	7/16 - 20	57-61	3/4 - 10	240-250
1/4 - 28	8-10	1/2 - 13	71-75	3/4 - 16	290-300
5/16 - 18	13-17	1/2 - 20	83-93	7/8 - 9	410-420
5/16 - 24	15-19	9/16 - 12	90-100	7/8 - 14	475-485
3/8 - 16	30-35	9/16 - 18	107-117	1 - 8	580-590
3/8 - 24	35-39	5/8 - 11	137-147	1 - 14	685-695
7/16 - 14	46-50	5/8 - 18	168-178		

Exceptions to Standard Bolt and Nut Torque Specifications

Application	Size nut or bolt	Torque (lb-ft
Connecting Rod Nuts	3/8" - 24	40-45
*Main Bearing Cap Bolts	9/16" - 12	120-130
Stabilizer to Cylinder Block Bolts	7/16" - 14	70-75
Crankshaft End Bolt	3/ 4" - 16	200-220

* Lubricate at assembly with International Compound **No. 2** or equivalent.

Service Tools

Tool No.	name
J 4757	Micrometer Ball Attachment
J 4794-01	Puller
J 7454	Oil Seal Expander (In-Line and 6V)
J 7773	Crankshaft Pulley Installer
J 9479	Oil Seal Installer
J 9479-1	Installer (Part of J 9479)
J 9479-2	Stud (2) (Part of J 9479)
J 9769	Oil Seal Expander
J 21277	Crankshaft Rear Oil Seal Sleeve Installer
J 21278	Crankshaft Rear Oil Seal (Oversize) Expander
J 21899	Camshaft Oil Seal Installer
J 22153	Crankshaft Front Oil Seal Installer
J 22524	Crankshaft Front Oil Seal Sleeve Installer

FLYWHEEL

The flywheel is attached securely to the rear end of the crankshaft with six bolts in any one of six positions. The flywheel is machined to permit *a* true alignment of a clutch with the flywheel, and the center bore of the flywheel provides for installation of a pilot bearing. A starter ring gear is shrunk onto the rim of the flywheel. The rugged construction of the flywheel makes necessity for service on this part very remote. However, the flywheel must be removed for other service operations such as removing and replacing the ring gear.

Remove Flywheel (Transmission Removed)

1. Remove the flywheel attaching bolts and scuff plate while holding the flywheel in position by hand, then reinstall one bolt.

CAUTION

When removing or installing the attaching bolts, hold the flywheel firmly against the crankshaft by hand to prevent it from slipping off the end of the crankshaft. The flywheel is NOT dowelled to the crankshaft.

2. Attach the flywheel lifting tool J 6361-01 to the flywheel with two ⅜"-16 bolts of suitable length as shown in figure 1

3. Attach a chain hoist to the lifting tool to support the flywheel as shown in figure 1.

4. Remove the remaining flywheel attaching bolt.

5. Mo've the upper end of the tool back and forth to loosen the flywheel, then withdraw the flywheel from the crankshaft and the flywheel housing.

6. If equipped with a clutch pilot bearing, remove the bearing from the flywheel.

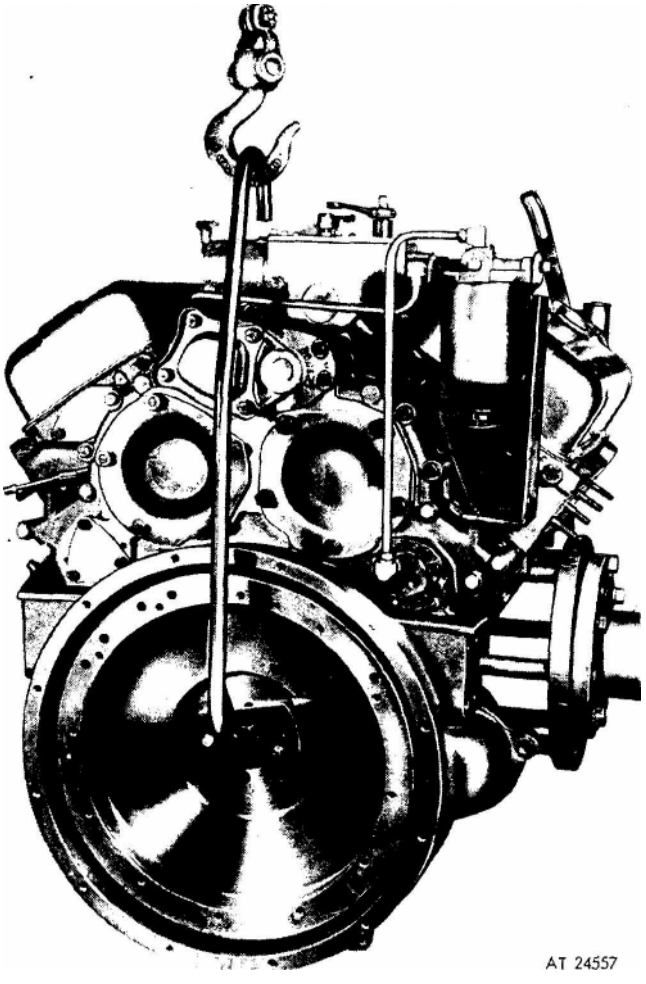


Figure 1. Removing flywheel with toolJ 636-01.

1.4 FLYWHEEL

Inspection

After removal, check flywheel for cracks, scoring or overheating of the clutch contact face. If the flywheel clutch surface is scored, it may be refaced. However, not more than .020" of metal should be removed from the flywheel and all radii should be maintained. If the contact face of the clutch wear plate shows signs of overheating or excessive scoring, replace the wear plate. Although the flywheel seldom wears to the point of requiring replacement, the flywheel ring gear may become worn due to normal usage or damaged by improper use of the starting motor to the extent that it must be replaced. Examine the teeth on the ring gear. If replacement of the ring gear is necessary, remove the ring gear as outlined below.

Remove Ring Gear from Flywheel

Before removing the ring gear from the flywheel, note the teeth chamfer. The replacement gear must be installed so the chamfer on the teeth faces the same direction with relationship to the flywheel as on the gear that was removed. Then, remove the ring gear as follows:

1. Support the flywheel, crankshaft side down, on a solid flat surface or a hardwood block, which is slightly smaller than the inside diameter of the ring gear.
2. With a suitable drift and hammer, drive the ring gear off of the flywheel. Work around the circumference of the ring gear to avoid binding the gear on the flywheel.

Install Ring Gear on Flywheel

1. Support the flywheel, ring gear side up, on a solid flat surface.
2. Rest the ring gear on a flat metal surface and heat the ring gear uniformly with an acetylene torch, keeping the torch moving around the gear to avoid hot spots.

CAUTION

Do not, under any circumstances, heat the gear over 400°F.; excessive heating may destroy the original heat treatment.

NOTE

Heat indicating "crayons", which are placed on the ring gear and melt at a predetermined temperature, may be obtained from most tool vendors. Use of one of these "crayons" will insure against overheating the gear.

3. Use a pair of tongs to place the gear on the flywheel with the chamfer, if any, facing the same direction as on the gear just removed.
4. Tap the gear into place against the shoulder on the flywheel. If the gear cannot be tapped into place readily, remove it and apply additional heat, heeding the above caution about overheating.

Install Flywheel

1. Mount the flywheel, using lifting tool J 6361-01 and chain hoist, into position against the rear end of the crankshaft.
2. While holding the flywheel in place by hand, remove the flywheel lifting tool and install the flywheel attaching bolts and scuff plate. Tighten the bolts to 1 10- 120 lb-ft torque.
3. Mount a dial indicator on the flywheel housing and check the runout of the flywheel at the clutch contact face. Maximum allowable runout is .001" total indicator reading per inch of radius (the radius is measured from the center of the flywheel to the outer edge of the clutch contact face of flywheel).

SPECIFICATIONS-SERVICE TOOLS

SPECIFICATIONS

Standard Bolt and Nut Torque Specifications

Size nut or bolt	Torque (lb-ft)	Size nut or bolt	Torque (lb-ft)	Size nu or bolt	Torque (lb-ft)
1 / 4 - 20	7-9	t / 16 - 20	57-61	3 / 4 - 10	240-250
1 / 4 - 28	8-10	1 / 2 - 13	71-75	3 / 4 - 16	290-300
5 / 16 - 18	13-17	1 / 2 - 20	83-93	7 / 8 - 9	410-420
5 / 16 - 24	15-19	9/ 16 - 12	90-100	7 / 8 - 14	475-485
3 / 8 - 16	30-35	9 / 16 - 18	107-117	1 - 8	580-590
3 / 8 - 24	35-39	5 / 8 - 11	137-147	1 - 14	685-695
7/16 - 14	46-50	5 / 8 - 18	168-178		

Exceptions to Standard Bolt and Nut Torque Specifications

Application	Size nut or bolt	Torque (lb-ft
Flywheel Bolts	1 /2 - 20	110-120

Service Tools

Tool No.	Tool name
J 6361-01	Flywheel Lifting Tool

FLYWHEEL HOUSING

The flywheel housing is a one-piece casting mounted on the rear end of the engine. The crankshaft rear oil seal which is pressed into the housing may be removed or installed without removing the housing (sec 1.3.2).

Remove Flywheel Housing

1. Remove the engine from the unit as outlined in section 1.1.
2. Remove the starter from the flywheel housing.
3. Remove the flywheel as outlined in section 1.4.
4. Remove the oil pan
5. Remove the fuel pump.
6. Remove all of the bolts from the flywheel housing. Don't forget the blower-to-flywheel housing bolts.

NOTE

When removing the flywheel housing bolts, note the location of the various size bolts, lockwashers, flat washers, and copper washers so they .may be reinstalled in their proper location.

7. To guide the flywheel housing until the oil seal clears the end of the crankshaft, thread two pilot studs, J 7540, into the cylinder block (fig. 1).
8. Thread eyebolts into the tapped holes in the pads (if provided) on the top or sides of the flywheel housing, and attach a chain hoist with a suitable sling to the eyebolts (fig. 1). Then strike the front face of the housing alternately on each side of the engine with a soft hammer to loosen and work it off the dowel pins.
9. Remove all traces of the old gasket(s I from the cylinder block rear end plate and the flywheel housing.

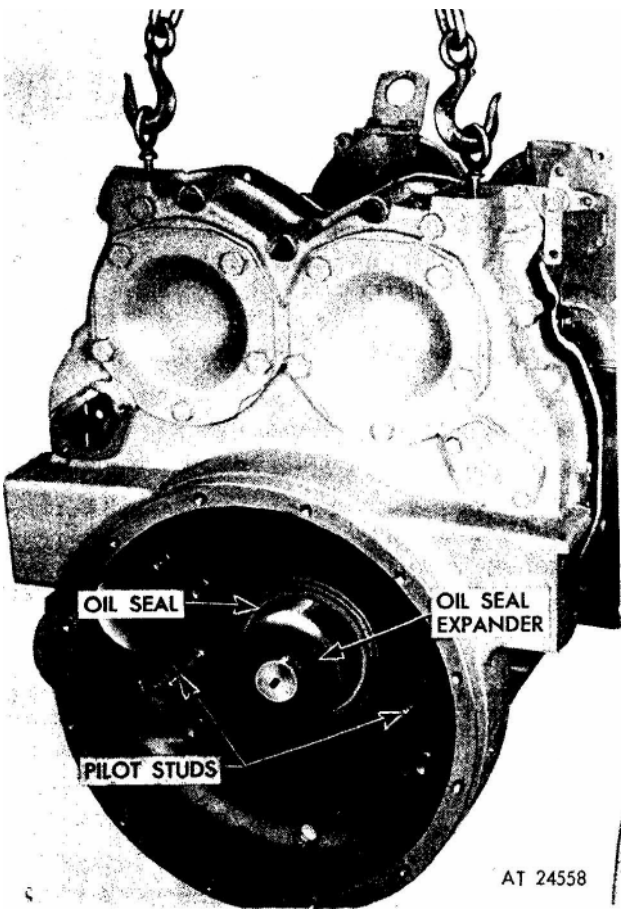


Figure 1. Installing flywheel housing.

1.5 FLYWHEEL HOUSING

Inspection

Clean and inspect the flywheel housing for cracks or any other damage. Replace the housing if it is damaged. The crankshaft rear oil seal should be carefully inspected and, if necessary, replaced as outlined in section 1.3.2.

Install Flywheel Housing

1. Lubricate the gear train teeth with clean *engine* oil.
2. Affix a new flywheel housing gasket to the rear face of the cylinder block rear end plate.
3. The flywheel housing has an integral cast hub. Install a flywheel housing-to-end plate shim (.015" thick). Use grease to affix the shim to the cylinder block rear end plate (fig. 2).
4. Apply a light coat of high temperature cup grease to the lip of the crankshaft rear oil seal. Do not use hypoid gear lubricants.
5. To pilot the oil seal on the crankshaft successfully, use oil seal expander J9769)standard size seal) of J 21278 (oversize seal) on the end of the crankshaft. Also thread two pilot studs, J 7540, into the cylinder block to guide the housing in place (fig. 1).
6. With the flywheel housing suitably supported, position it over the crankshaft and up against the cylinder block rear end plate and gasket(s).

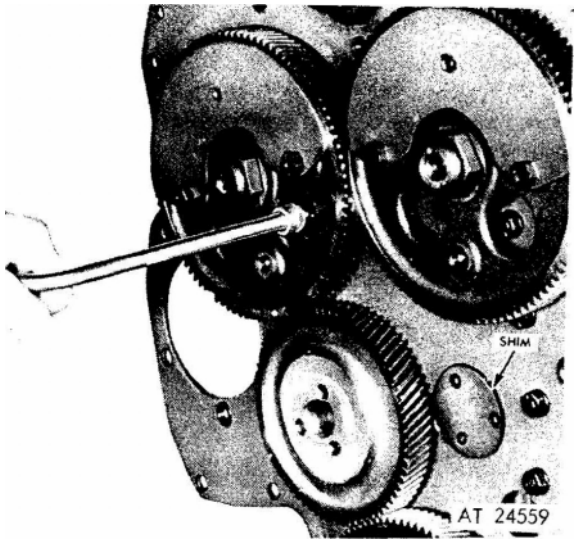


Figure 2. Location of shim.

NOTE

While sliding the housing into position, manually hold the oil seal expander tool up against the rear end of the crankshaft.

7. Install all of the flywheel housing bolts, lock washers, flat washers, and copper washers in their proper location — finger tight only

8. Start at No. 1 and draw the flywheel housing bolts up snug in the sequence shown in Figure 3.

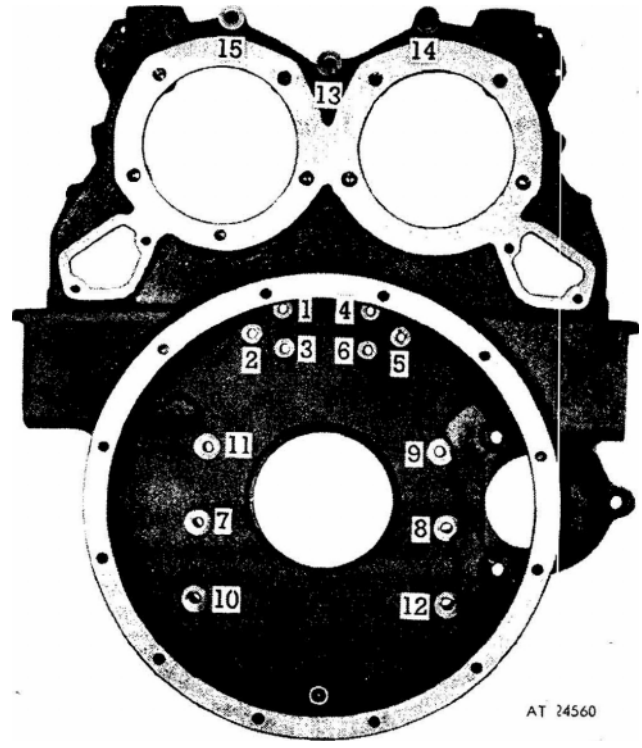


Figure 3. Flywheel housing bolt tightening sequence (operation 1).

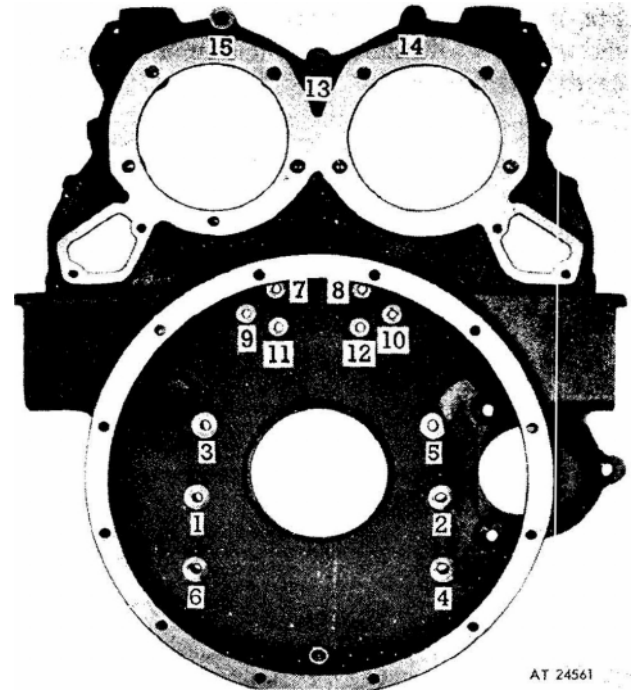


Figure 4. Flywheel housing bolt tightening sequence (operation 2)—in-line engines.

9. Refer to figure 4 for the final bolt tightening sequence on an in-line engine; then, start at No. 1 and tighten the bolts to the specified torque Tighten the 5 16"-18 bolts (numbers 11 and 12) to 19-23 lb-ft torque and the ⅜"-16 bolts (numbers 7 through 10) to 40-45 lb-ft torque. Tighten the remaining ⅜"-16 and %"-24 bolts to 25-30 lb-ft torque. Tighten the two 5 16"-18 bolts that secure the top of the governor to the flywheel housing to 10-12 lb-ft torque.

10. Check the flywheel housing concentricity and bolting flange face with tool J9737 as follows:

a. Refer to figure 5 and thread the base post J 9737-3 tightly into one of the tapped holes in the flywheel. Then, assemble the dial indicators on the base post with the attaching parts provided in the tool set.

b. Position the dial indicators straight and square with the flywheel housing and make sure each indicator has adequate travel in each direction.

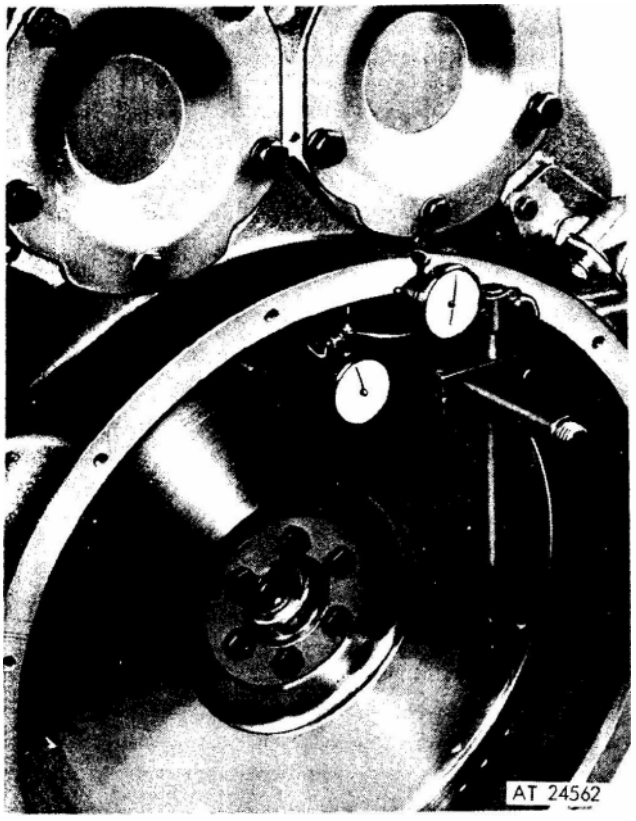


Figure 5. Checking flywheel housing concentricity with tool J 9737.

NOTE

If the flywheel extends beyond the flywheel housing bell, the housing bore and face must be checked separately. Use the special adaptor in tool set J 9737 to check the housing bore.

c. Pry and hold the crankshaft in one direction to ensure end play is in one direction only.

d. Adjust each dial indicator to read zero at the twelve o'clock position. Then, rotate the crankshaft one full revolution, taking readings at 45° intervals (8 readings each on the flywheel housing bore and bolting flange face). Stop and remove the wrench or cranking bar before recording each reading to ensure accuracy. The maximum total indicator reading must not exceed .013" for either the bore or face.

e. If the run-out exceeds the maximum limits remove the flywheel housing; and check for dirt or foreign material (such as old gasket material) between the flywheel housing and the end plate, and between the end plate and the cylinder block. Reinstall the flywheel housing and tighten the attaching bolts in the proper sequence, to the specified torque. Then, recheck the run-out. If necessary, replace the flywheel housing.

11. Install the fuel pump as outlined in Section 2.2.

12. Install the flywheel as outlined in section 1.4.

13. Affix a new gasket to the oil pan, and install the oil pan.

14. Remove the engine from the overhaul stand and install all accessories previously removed.

15. Install the transmission.

16. Fill the crankcase with lubricating oil.

17. Refill the cooling system.

SPECIFICATIONS—SERVICE TOOLS

SPECIFICATIONS

Standard Bolt and Nut Torque Specifications

Size nut or bolt	Torque (lb-ft)	Size nut or bolt	Torque (lb-ft)	Size nut or bolt	Torque (lb-ft
1 / 4 - 20	7-9	7 / 16 - 20	57-61	3/ 4 - 10	z40-250
1 / 4 - 28	8-10	1 / 2 - 13	71-75	3 / 4 - 10	290-300
5 / 16 - 18	13-17	1 / 2 - 20	83-93	7 / 8 - 9	410-420
5 / 16 24	15-19	9 / 16 - 12	90-100	7 / 8 - 14	475-485
3 / 8 - 16	30-35	9 / 16 - 18	107-117	1 - 8	580-590
3 / 8 - 24	35-39	5 / 8 - 11	137-147	1 - 14	685-695
7 / 16 - 14	46-50	5 / 8 - 18	168-178		

Exceptions to Standard Bolt and Nut Torque Specifications

Application	Size nut or bolt	Torque (lb-ft)
Governor to Flywheel Housing Bolts	5/ i6 - 18	10-12
Idler Gear Hub and Spacer Bolts	5 / 16 - 18	19-23
Idler Gear Hub and Spacer Bolts	3/8 - 16	40-45
Flywheel Housing Bolts	3/8 - 16	25-30
Flywheel Housing Bolts	3/ 8 - 24	25-30

Service Toots

Tool No.	Tool name
J 7540	Flywheel Housing Aligning Studs (Set of 2)
J 8001-3	Dial Indicator
J 9737	Flywheel Housing Concentricity Gage
J 9748	Dial Indicator Post
J 9769	Crankshaft Rear Oil Seal Expander (Standard Size Seal)
J 21278	Crankshaft Rear Oil Seal Expander (Oversize Seal)

PISTON AND PISTON RINGS

The trunk type malleable iron piston, figure 1, is plated with a protective coating of tin which permits close fitting, reduces scuffing and prolongs piston life. The top of the piston forms the combustion chamber bowl and is designed to compress the air into close proximity to the fuel spray.

The piston is cooled by a spray of lubricating oil directed at the underside of the piston head from a nozzle in the top of the connecting rod, by fresh air from the blower to the top of the piston and indirectly by the water jacket around the cylinder. Each piston is balanced to close limits by machining a balancing rib, provided on the inside at the bottom of the piston skirt. Two bushings with helical grooved oil passages, are pressed into the piston to provide bearing for the hardened, floating piston pin. After the piston pin has been installed, the hole in the piston at each end of the pin is sealed with a tight retainer. Thus, lubricating oil returning from the underside of the piston head and working through the grooves in the piston bushings is prevented from reaching the cylinder walls.

The piston pin is subject to downward loading only since the piston is at all times under pressures of compression or expansion in the two-stroke cycle. Consequently, free movement of the piston pin is desirable to secure perfect alignment and uniform wear. The piston pin is therefore assembled with a full floating fit in both the connecting rod and piston bushings. Rotation of the pin and positive lubrication through the helical bushing grooves reduce wear to a minimum! Moreover, worn clearances can be comparatively large and still be sat isfactory.

Each piston is fitted with six piston rings. Four compression rings are placed above the piston pin and two oil-control rings are placed below the pin to scrape off the excess lubricating oil thrown onto the cylinder liner by the crankshaft and the lower end of the connecting rod. Two piece oil control rings are used in both the upper and lower positions on ıe piston. Eight equally spaced holes are drilled just below each oil control ring land to permit the excess oil that is scraped off the cylinder walls to return to the crankcase.

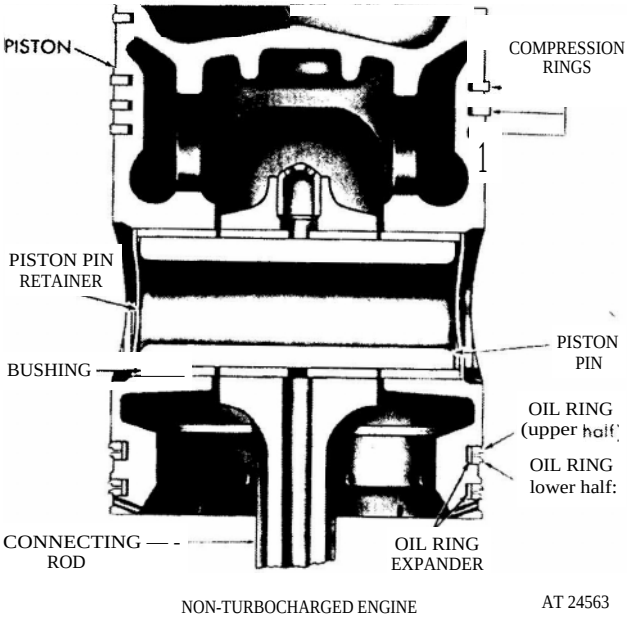


Figure I. Typical piston assembly.

Inspect Piston Rings

When an engine becomes hard to start, runs uneven or lacks power, the cause may be worn, or sticking compression rings which must be replaced to maintain uniform compression pressures in all cylinders. The compression rings may be inspected through the ports of the cylinder liners after removing the heater air box cover. If the rings are free and are not worn to the extent that the plating or grooves have disappeared the compression should be within operating specifications. Refer to section 15.2 for compression pressure checking procedure. However, if excessive wear on any part of the piston assembly is indicated by inspection through the cylinder liner ports, the piston and connecting rod must be removed from the top of the cylinder block in the following manner:

Remove Piston and Connecting Rod

1. Drain the lubricating system and remove the oil pan.
2. Remove the cylinder head as outlined in section 1.2.

3. Remove the carbon from the upper inner surface of the cylinder liner.

4. If there is a ridge in the cylinder liner at the top of the piston ring travel, remove the ridge with a ridge cutter.

NOTE

Move the piston to the bottom of its travel and place a cloth on top of the piston to collect the cuttings.

5. After the ridge is removed, turn the crankshaft until the piston is at the top of its stroke and carefully remove the cloth with the cuttings.

6. Refer to figures 1 and 2 in section 1.6.1 and remove the bearing cap and the lower bearing shell from the lower end of the connecting rod; then push the piston and rod assembly out through the top of the cylinder block. The piston and rod cannot he removed from the bottom of the block.

7. Reassemble the bearing cap and the bearing shell to the connecting rod.

Figure 2. Removing or replacing piston rings.

Disassemble Piston and Connecting Rod

1. Secure connecting rod in bench vise equipped with soft jaws and remove piston rings with tool J 8128, as shown in figure 2.

2. Punch a hole through the center of one of the piston pin retainers with a narrow chisel or punch and pry retainer from piston, being careful not to damage piston or bushings.

3. Withdraw piston pin from piston, thus freeing connecting rod.

4. The other piston pin retainer may be driven out from the inside, using a brass rod or other suitable tool.

Clean Piston

Clean the piston with fuel oil; dry it with compressed air. If fuel oil will not remove the carbon deposits, use a chemical solvent that will not attack the piston pill bushings or the tin coating on the piston (fig. 3). The upper part of the piston, including the ring lands and grooves, is not coated with tin and may he wire-brushed to remove any hard carbon. However, use care to avoid damage to the tin coating on the piston skirt. Clean the ring grooves with a suitable tool or a piece of an old piston ring that has been ground to a bevel edge. Clean the cooling surfaces on the inside of the piston and the oil return holes in the lower half of the piston skirt. Exercise care to avoid enlarging the holes while cleaning them.

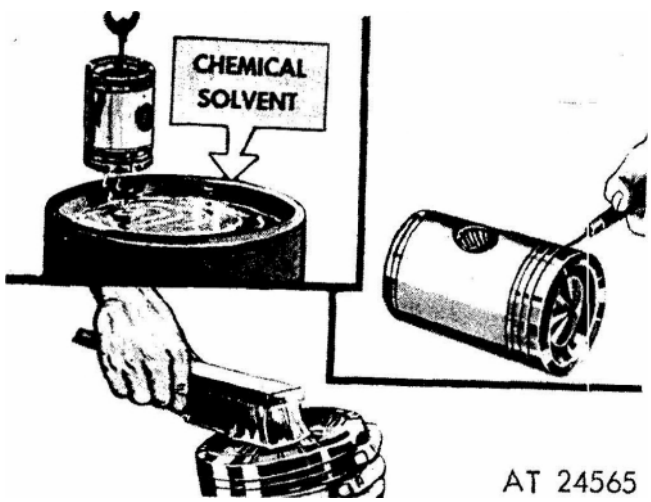


Figure 3. Cleaning piston.

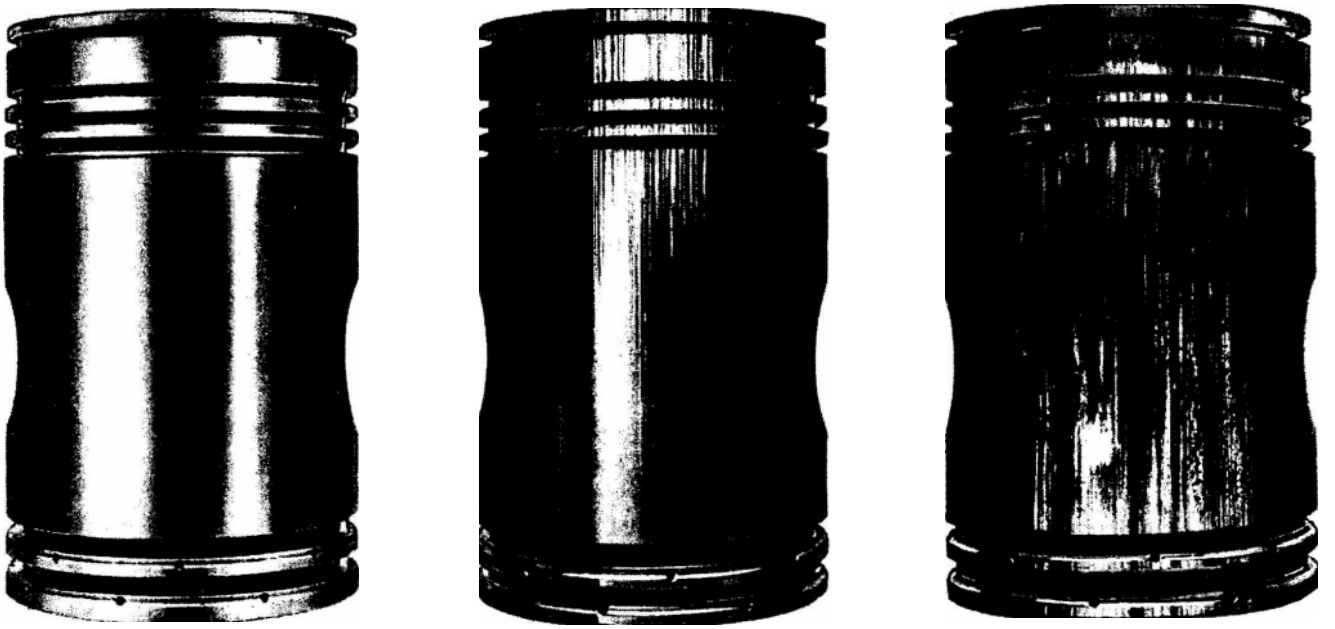


Figure 4. Comparison of pistons.

Inspection

The presence of the tin coating on the piston and the original grooves in the piston rings indicates very little wear. An excessively worn or scored piston, rings, or cylinder liner may be the result of abnormal maintenance or operating conditions which should be corrected to avoid recurrence of the failure. Proper maintenance of the lubricating oil filters and air cleaners will reduce to a minimum] the amount of abrasive dust and foreign material introduced into the cylinders and will, in turn, reduce the rate of wear. Extended periods of operation at idle speed or the use of improper lubricating oil or fuel should be avoided, otherwise heavy carbon formation and sticking rings will be the result. Always maintain the lubricating oil and engine coolant at the specified levels to avoid overheating the engine. Examine the piston for scoring, overheating, cracks, and damaged ring grooves. Replace the piston, if necessary. A piston with light score marks may be cleaned up and reused. Refer to figure 4 for a comparison of pistons. Check for cracks across the struts in the piston, as outlined in section 1.3 under "Crankshaft Inspection". Other factors that contribute to piston failure are oil leaks into the air box, dribbling injectors, combustion blow-by, and dilution of the lubricating oil. Inspect and measure the piston pin and piston pin bushings. The inside diameter of a new hushing in the piston is 1.3775" to 1.3780", and the outside diameter of a new piston pin is 1.3746" to 1.3750". The piston pin-to-bushing clearance with new parts is .0025" to .0034". A maximum clearance of .010" is alowable with worn parts. The piston pin bushings in the connecting rod are covered in section 1.6.1.

Remove Bushings From Piston

1. Place the piston in the holding fixture J 1531-1 so that the bushing bores are in alignment with the hole in the fixture base.
2. Drive each bushing from the piston with bushing remover J 1513-3 and handle J 1513-2 in the manner illustrated in figure 5.

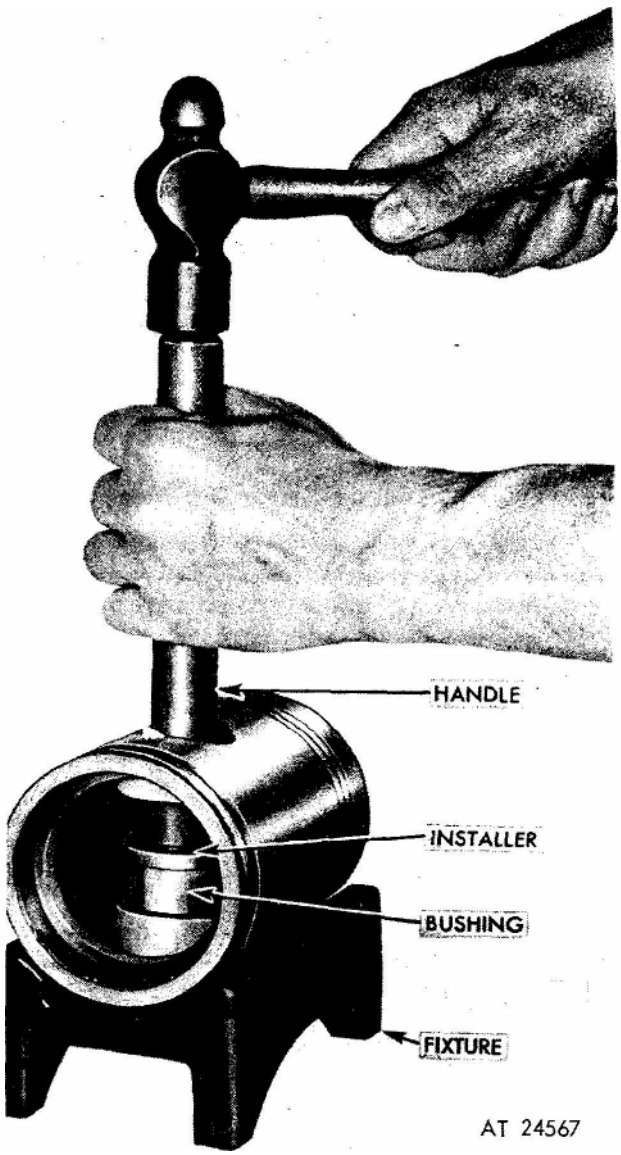


Figure 5. Removing or installing piston pin bushings in piston.

Install Bushings in Piston

1. Place spacer J 7587-1 in counterbore of holding fixture J 1513-1 (small end up).
2. Place the piston on the holding fixture so that the spacer protrudes into the piston pin bushing bore.
3. Insert the installer J 4972-2 in a bushing; then, position the bushing and installer over the lower bushing bore.

NOTE

Locate the joint in the bushing toward the bottom of the piston (fig. 6).

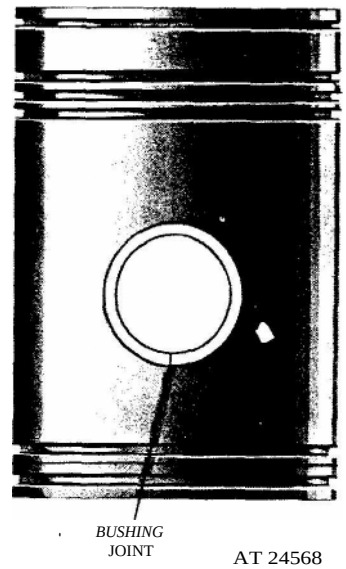


Figure 6. Location of joint in piston pin bushings.

4. Insert the handle J 1513-2 in the bushing installer and drive the bushing in until it bottoms on the spacer.
5. Install the second piston pin bushing in the same manner.

Ream Bushings in Piston

1. Clamp the piston bushing reaming fixture .J 5273 in a bench vise (fig. 71; then, insert guide bushing J 4970-5 in the fixture and secure it with the set screw.
2. Place the piston assembly in the fixture and insert the pilot end of reamer J 4970-4 through the clamping bar, piston pin bushings, and into the guide bushing.
3. With the piston fixture and reamer in alignment, tighten the wing nuts securely.
4. Ream the piston pin bushings by turning the reamer in a clockwise direction only, when reaming and withdrawing the reamer. For best results use only moderate pressure on the reamer.
5. Withdraw the reamer and remove the piston from the fixture. Blow out the chips and check the inside diameter of the bushings, which must be 1.3775" to 1.3780".

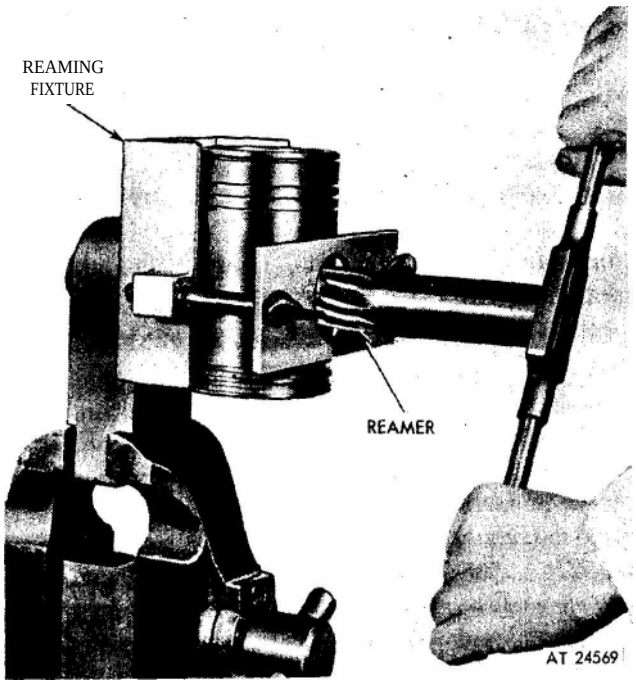


Figure 7. ***Reaming piston pin bushings.***

Fitting Pistons

Measurements of the pistons and cylinder liner bores should be taken at room temperature (70 F.). Measure the piston skirt diameter. The diameter of a new piston from a point 1.750" from the top of the piston to the bottom of the piston is 3.8693" to 3.8715", except near the piston pin bore. The inside diameter of a new cylinder liner is 3.8752" to 3.8767". Therefore, with new parts, the piston-to-liner clearance is .0037" to .0074", and should not exceed .010", with used parts. After inspecting and installing the cylinder liner (new or used) as outlined in section 1.6.3, check the piston-to-liner clearance. This clearance should be checked in four places 90° apart, while holding the piston upside down in the cylinder liner (fig. 8).

Feeler gage set J 5438 may be used for checking the piston-to-liner clearance. The set consists of a feeler gage pack J 3174-01, a spring scale J 8129, and a swivel connection J 593-14. The spring scale, attached to the appropriate feeler gage, is used to measure the force in pounds required to withdraw the feeler gage from between the piston and liner. The clearance will be .001" greater than the thickness of the feeler gage used, i.e. a .004" thick feeler gage will indicate a clearance of -.005" when it is withdrawn at **a pull of six** pounds. The feeler gage must be perfectly flat and free of nicks and bends. If any bind between the piston and liner is detected, remove the piston and inspect the piston and liner for burrs. Remove the burrs with a fine hone (a flat one is preferable) before proceeding with the clearance check.

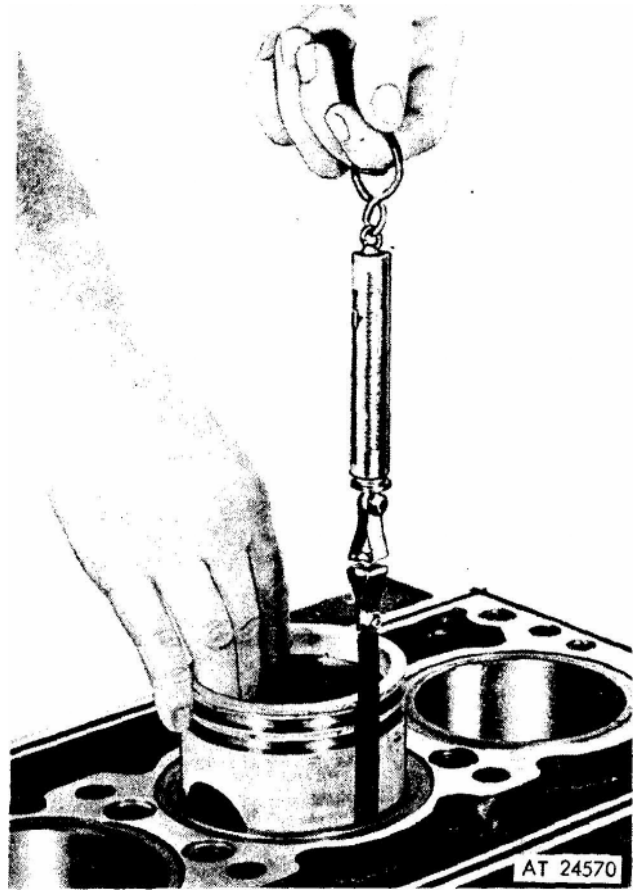


Figure ***8. Measuring piston-to-liner*** **clearance.**

Fitting Piston Rings

Use new piston rings whenever a piston is removed for inspection or replacement. When fitting piston rings, the gap between the ends of the rings should be measured before installing the rings on the piston. This is done by inserting one ring at a time inside the liner, and far enough down in the bore to be on the normal wiping area of the rings when the piston is installed. To assure that the ring is parallel with the top of the liner, use a piston to push the ring into the liner bore, then measure the gap with a feeler as illustrated in figure 9. For the specified ring gap see section 1.6.0. If the piston ring gap is below the specified limits, it may be increased by filing or stoning the piston ring in such a direction that the file or stone will cut from the outside (chrome plated) surface of ring toward the inside surface. This will prevent any chipping or peeling of the chrome plate. The ends of the ring must

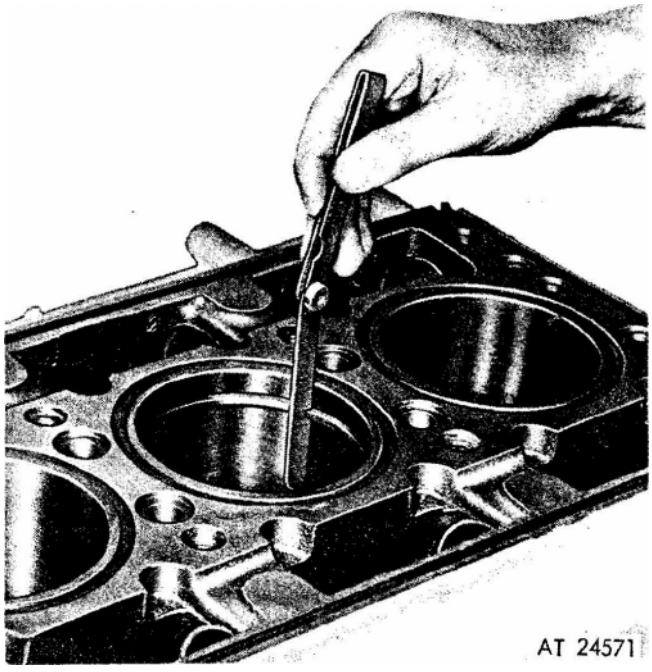


Figure 9. Measuring piston ring gap with feeler gage.

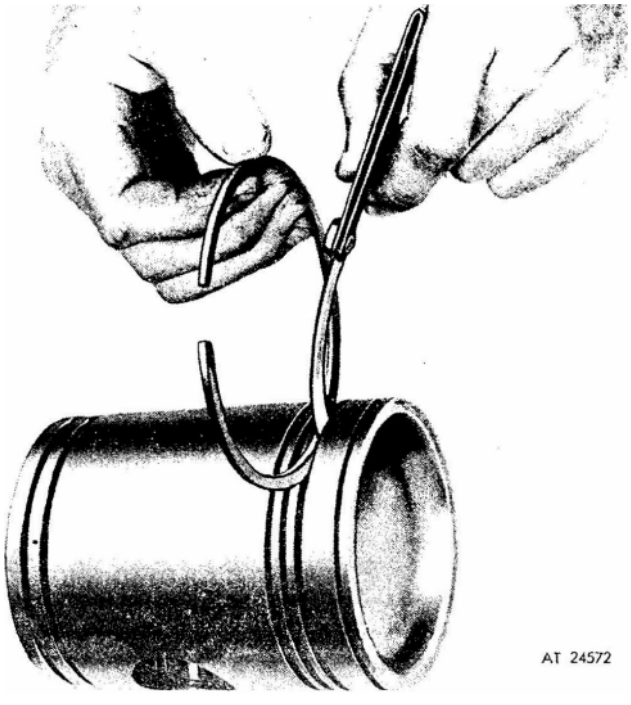


Figure 10. Measuring piston ring side clearance.

remain square and the chamfer must be approximately 015" on the outer edge. Check the ring clearances in the piston grooves as illustrated in figure 10. The ring clearances should be as follows:

Upper compression (Fire) ring	.003"-.006"
Second compression ring	.007"-.010"
Third compression ring	005"-.008"
Lower compression ring	005"-.008"
Upper oil control ring	0015"-.0055"
Lower oil control ring	0015"-.0055"

For allowable wear limits, refer to the chart in section 1.6.0.

Install Compression Rings on Piston

With the connecting rod assembly inspected and assembled to the piston as outlined in section 1.6.1, refer to figure 1 for the proper location of the piston rings on the piston. Assemble the compression rings on the piston with tool J 8128, as shown in figure 2. and stagger the ring gaps around the piston. When installing the compression or oil control rings, do not spread the rings more than is necessary to slip them on the piston to avoid overstressing the rings.

NOTE

When installing the top compression (fire) ring with the tapered face, be sure and install the ring with the mark "TOP" toward the top of the piston.

Install Oil Control Rings on Piston

Install the oil control rings by hand, with the scraper edge of each ring down, as follows:

1. Install a peripheral abutment expander in the upper oil ring groove (fig. 1), being careful not to overlap the ends.

NOTE

The oil control ring expander must be completely seated in the oil ring groove. The ends of the expander can very easily be overlapped. If this occurs, the oil control rings will protrude slightly and be broken when the piston ring compressor is installed over the piston and rod assembly, or when the piston and rod assembly is installed in the cylinder liner.

2. Install the top oil ring, with the gap 180 °from the ends of the expander, in the piston upper oil ring groove.

3. Check the ends of the expander, to be sure they are not overlapped.

4. Install the bottom oil ring, with the gap 45° from the gap of the top oil ring in the piston upper oil ring groove. Recheck to be sure the ends of the expander are not overlapped.

NOTE

Do not, at any time, cut off or grind the ends of the oil ring expander to prevent the ends from overlapping. Cutting off or grinding the ends of the expander will decrease the tension on the oil control rings and result in high lubricating oil consumption.

5. Install the second set of oil control rings and expander in the piston lower oil ring groove in the same manner as described above.

CONNECTING ROD

Each connecting rod (figs. 1 and 2) is made of steel and forged to an "I" section with a closed hub at the tipper end and a cap at the lower end. The rod is drilled to provide lubrication to the piston pin at the upper end and is equipped with an oil spray nozzle for cooling the underside of the piston head. The connecting rod bearing shells are of the precision type without shim adjustments. The upper and lower connecting rod bearing shells are different and, therefore, are not interchangeable. A helically-grooved bushing is pressed into each side of the connecting rod at the upper end. A cavity of approximately ⅛" between the inner ends of these bushings, registering with the drilled oil passage in the connecting rod, forms a duct around the piston pin. A portion of the oil from this duct lubricates the piston pin and bushings, the remainder of the oil is forced out of the spray nozzle for piston cooling. The piston pin floats in both the piston and connecting rod bushings. Service connecting rod assemblies include the lower bearing cap, bolts,, nuts, spray nozzle and the upper piston pin bushings pressed in place and bored to size. The bearing shells (upper and lower) are replaceable-without machining ; new piston pin bushings must be reamed after being pressed into the connecting rod. Bushing installation and reaming precedures are outlined on the following pages.

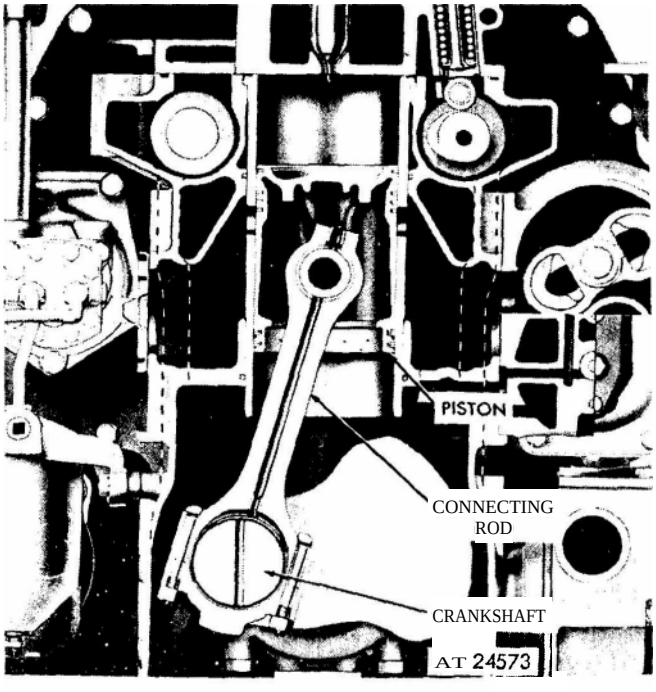


Figure 1. Connecting rod mounting.

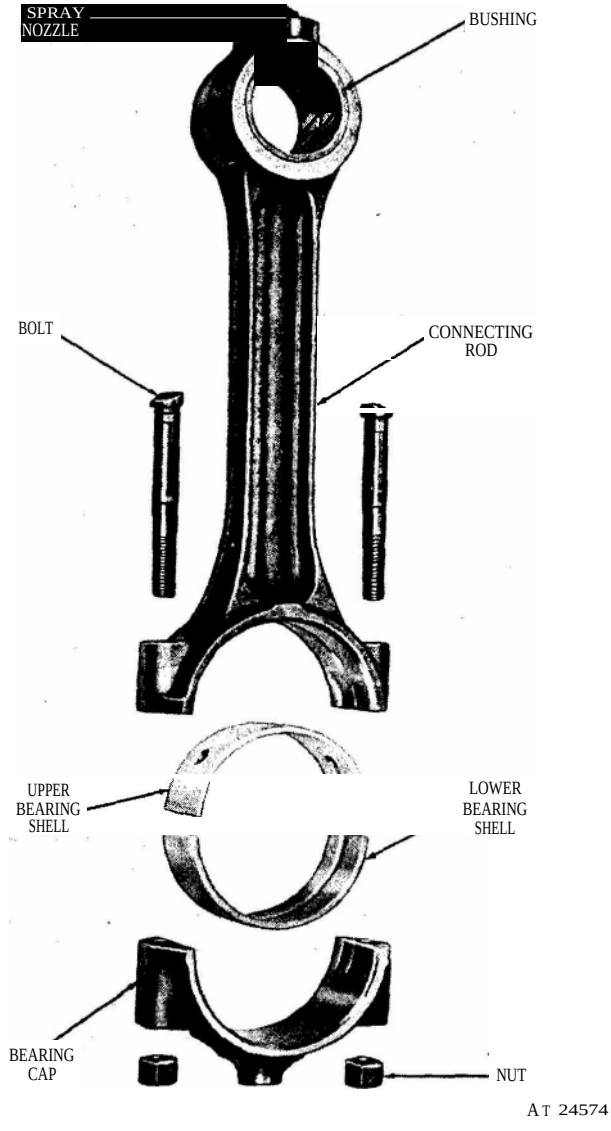


Figure 2. Typical connecting rod details and relative location of parts.

Disassemble Connecting Rod from Piston (Rod and Piston Assembly Removed from Engine)

Disassemble the piston and connecting rod as outlined in section 1.6.

Inspect Connecting Rod and Piston Pin

Clean the connecting rod and piston pin with fuel oil and dry them with compressed air. Inspect and open the holes in the spray nozzle. Blow dry compressed air through the drilled oil passage in the rod and nozzle to be sure all passages are open. Connecting rods may be checked for cracks as

1.6.1 CONNECTING ROD

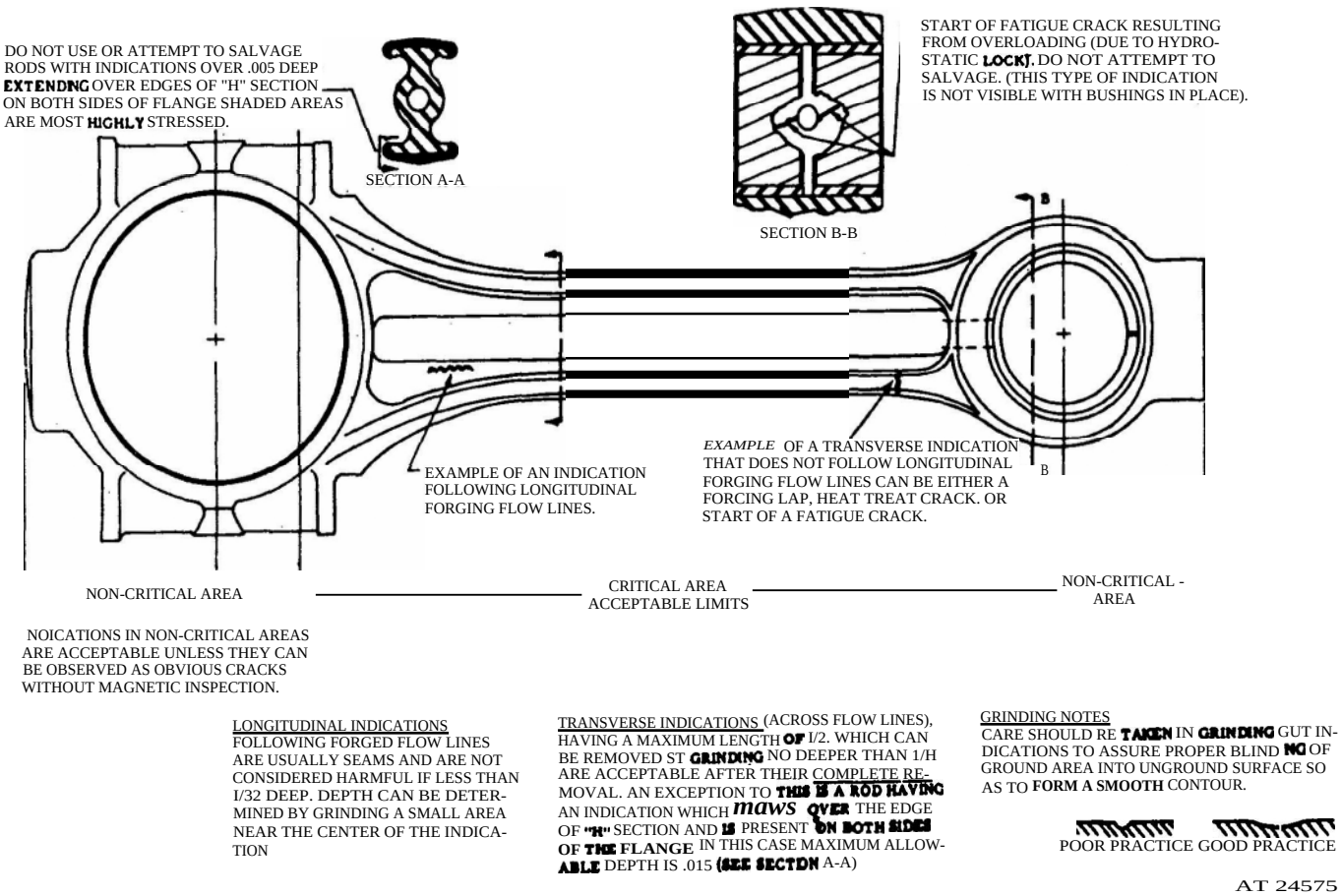


Figure 3. Magnetic particle inspection limits for connecting rod.

outlined in section 1.3 under "Crankshaft Inspection". Refer to figure 3, in this section for the inspection limits. Check the connecting rod bushings for scoring, overheating, or other damage. Bushings that have overheated may become loose and creep together thus blocking off the lubricating oil to the piston pin, bushings, and spray nozzle. The outside diameter of a new piston pin is 1.3746" to 1.3750" ; the inside diameter of a new bushing in a connecting rod is 1.3760" to 1.3765". Check the clearance between the piston pin and the connecting rod bushings. If the clearance exceeds .010" with used parts, replace the piston pin and or the bushings.

Remove Bushings from Connecting Rod

If it is necessary to replace the connecting rod bushings, remove them as follows:

1. Clamp the upper end of the connecting rod in holder J 7632 as shown in figure 4, so that the bore in the bushings is aligned with the hole in the base of the holder.

2. Set the bushing remover 4972-4 in the connecting rod bushing; insert handle J 1513-2 in the remover and drive the bushings from the rod.

Replace Spray Nozzle

If it is necessary to replace the spray nozzle, remove the old nozzle as follows:

1. Remove the piston pin bushings front the connnecting rod as outlined above.

2. Place the connecting rod, spray nozzle remover J 8995, and a short sleeve in an arbor press as shown in figure 5.

NOTE

The orifice in the lower end of the drilled passage in the connecting rod is not serviced separately, and it is not necessary to remove it when replacing the spray nozzle.

3. Press the spray nozzle out of the connecting rod.

Install a new spray nozzle in the connecting rod as follows:

1. Start the spray nozzle, with the holes positioned *as* shown in *figure 6, straight* into the counterbore in the top of the connecting rod.

2. Support the connecting rod in an arbor press. Then, place *a* short ⅜" I.D. sleeve on top of the

;pray nozzle and under the ram of the press.

3. Press the spray nozzle into the connecting rod until it bottoms in the counterbore.

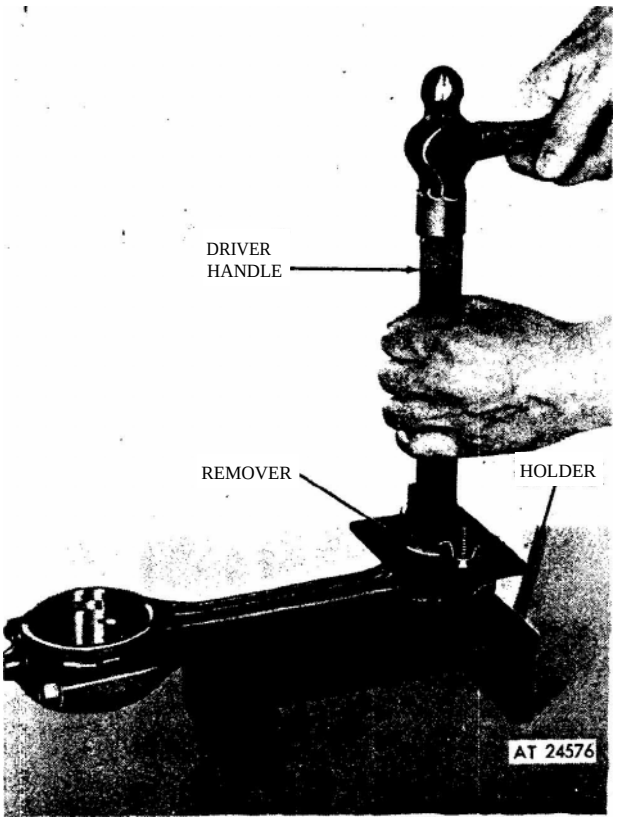


Figure 4. Removing or installing bushings.

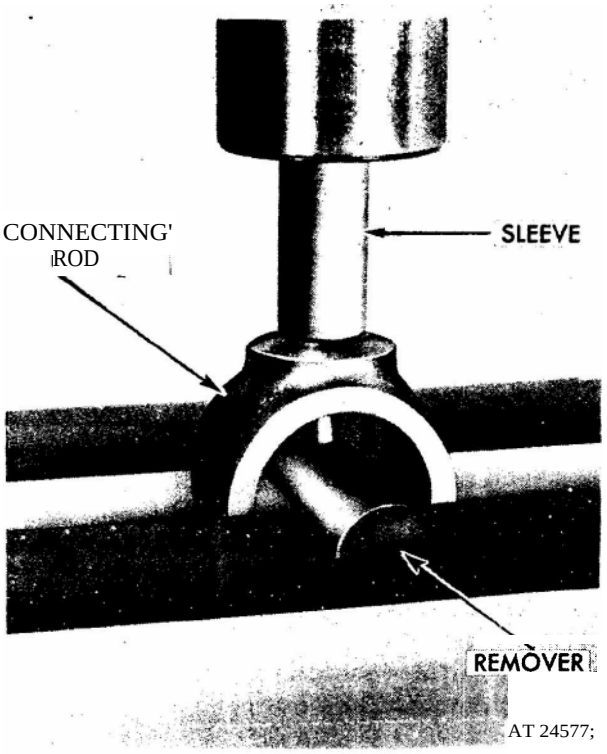


Figure 5. Removing spray nozzle from connecting rod.

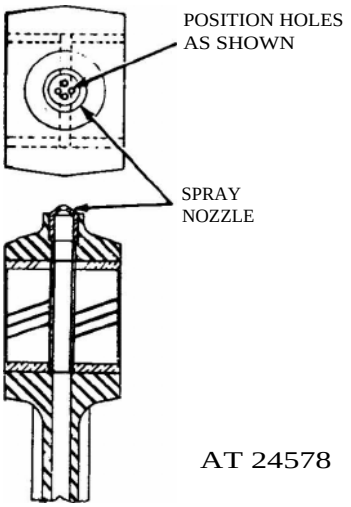


Figure 6. Location of spray nozzle in connecting rod.

Install Bushings in Connecting Rod

Clamp the upper end of the connecting rod assembly in holder J 7632 so that the bore for the bushings is aligned with the hole in the base of the tool.

2. Start a new bushing straight into the bore of the connecting rod.

NOTE

When installing a bushing in the connecting rod, locate the joint at the top of the connecting rod. as shown in figure 7.

3. Insert installer J 4972-2 in the bushing; then, insert handleJ 1513-2 in the installer and drive the bushing into the connecting rod until the flange of the installer bottoms on the connecting rod, as shown in figure 4.

4. Turn the connecting rod over in the holder and install the second bushing in the same manner.

Ream Bushings in Connecting Rod

The inside diameter of replacement bushings is smaller than the final finished diameter; therefore, the bushings must be finished reamed after being installed in the connecting rod. Refer to figure 8 and ream the bushings in the following foamier:

1. Clamp reaming fixture J 7608-4 in a vise.

2. Place the crankshaft end of the connecting rod on the arbor of the fixture. Tighten the nuts on the %"-24 bolts (In-line and V-type engines) to 40-45 lb-ft torque.

3. Install the front guide bushing J 4971-6 in the fixture (pin end out).

4. Install spacer J7608-3 in the fixture

5. Align the upper end of the connecting rod with the hole in the reaming fixture.

1.6.1 CONNECTING ROD

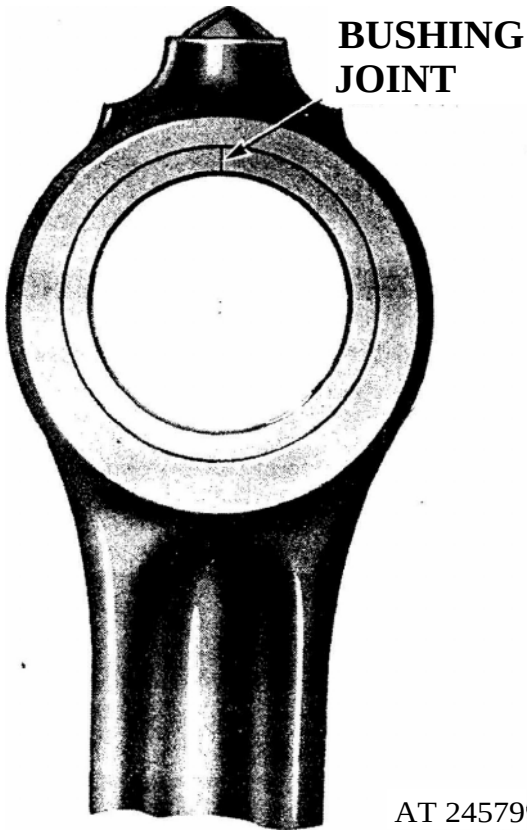


Figure 7. Location of bushing joint in connecting rod.

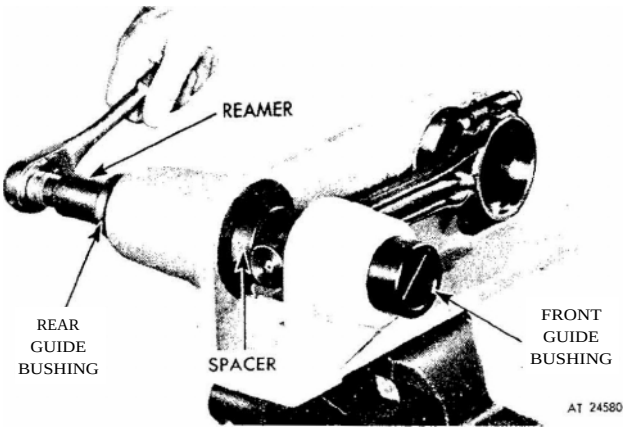


Figure 8. Reaming piston pin bushings in connecting rod.

6. Install the rear guide bushing J 1686-5 on the reamer J 4971-4; then, slide the reamer and bushing into the fixture.

7. Turn the reamer in a clockwise direction only, when reaming and withdrawing the reamer. For best results, use only moderate pressure on the reamer.

8. Remove the reamer and the connecting rod from the fixture, blow out the chips, and measure the inside diameter of the bushings. The inside diameter of the bushings should be 1.3760" to 1.3765".

Assemble Connecting Rod to Piston

1. Apply clean engine oil to the piston pin and bushings.

2. Rest the piston in the holding fixture, as shown in figure 9.

3. Place a new piston pin retainer in the piston; then place the crowned end of installer J 4895-01 the retainer and strike the tool just hard enough to deflect the retainer and seat it evenly.

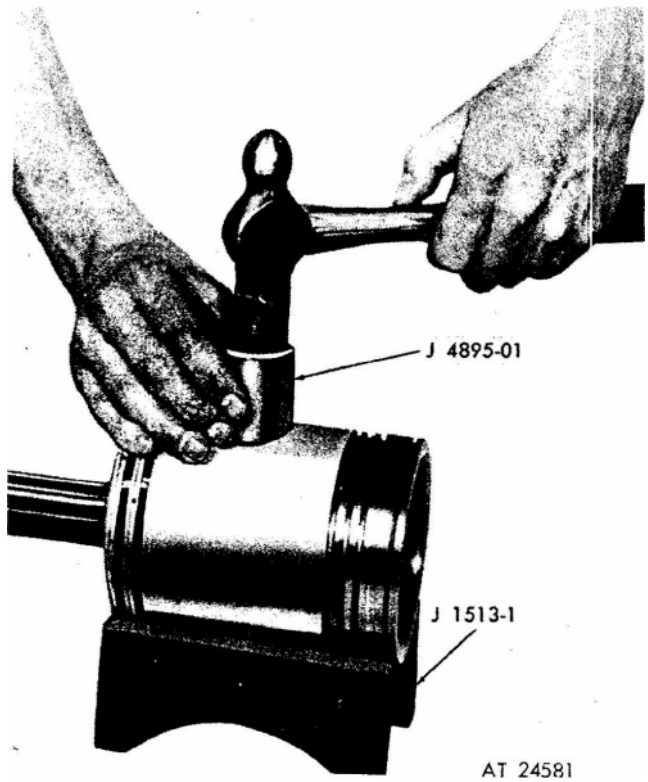


Figure 9. Installing piston pin retainer.

CAUTION

Do not drive too hard on the retainer or the bushing may be moved inward and result in reduced piston pin end clearance

4. Slide the piston pin into the piston and the upper end of the connecting rod. The piston pin will slip readily into position without forcing it i the clearances are correct.

5. Install the second piston pin retainer as outlined above.

6. After the piston pin retainers have been intailed, check for piston pin end clearance by "cocking" the connecting rod on the pin and shifting the pin in its bushings.

7. One important function of the piston pin retainer is to prevent the oil, which cools the underside of the piston and lubricates the piston pin bushings, from reaching the cylinder walls. Check the retainers for proper sealing as follows:

a. Place the piston and connecting rod assembly upside down on a bench.

b. Pour clean fuel oil in the piston to a level above the piston pin bosses.

c. Dry the external surfaces of the piston in the area around the retainers, and allow the fuel oil to set for about fifteen minutes.

d. Check for seepage of fuel oil around the retainers. If the fuel oil leaks around the retainers, install new retainers. In extreme cases, it may be necessary to replace the piston.

e. After the leakage test is completed, empty the fuel oil from the piston, dry the parts with compressed air, and lubricate the piston pin with clean engine oil.

8. Install the piston rings on the piston as outlined in section 1.6.

9. Install the piston and connecting rod assembly in the engine as outlined in section 1.6.3.

CONNECTING ROD BEARINGS

The connecting rod bearing shells are of the replaceable precision type without shim adjustments, and consist of an upper shell carried in the connecting rod and a lower shell seated in the connecting rod cap (fig. 2, sec. 1.6.1). The bearing shells are located by and prevented from end wise *or* radial movement by a tang at the parting line at one end of each shell. The connecting rod bearing caps are numbered 1, 2, 3, etc., with matching numbers stamped on the connecting rod. Each bearing cap (and bearing shell) must be installed on its original connecting rod. Since the upper and lower connecting rod bearing shells are different, they must not be interchanged. The upper bearing shell has two short oil grooves and two oil holes; each groove begins at the end of the shell and terminates at an oil hole. The lower bearing shell has a continuous oil groove from one end of the shell to the other. These grooves maintain registry with the oil holes in the crankshaft journals, thereby providing a constant supply of lubricating oil to the connecting rod bearings and to the piston pin bushings and spray nozzle through the oil passage in the connecting rod.

Remove Bearing Shells from Connecting Rod (Connecting Rod, Piston and Liner in Place)

1. Drain the engine lubricating oil.
2. Remove the oil pan.
3. Disconnect and remove the oil pump inlet tube assembly.
4. Remove one connecting rod bearing cap. Push the connecting rod and piston assembly up into the cylinder liner far enough to permit removal of the upper bearing shell. Do not pound on the edge of the shell with a sharp tool.
5. Inspect the upper and lower bearing shells as outlined under "Inspection".
6. Install the bearing shells and bearing cap as outlined in this section before another cap is removed.

Inspection

Visual inspection, as well as dimensional measurements, should be made to determine whether the used bearings are satisfactory for further service or must be replaced. Bearing failures may result from deterioration (acid formationl or contamination of the oil or loss of oil which results in scratching, etching, scoring or excessive wear. An analysis of the lubricating oil may be required to determine if corrosive acid and sulphur are present which cause acid etching, flaking and pitting. Bearing seizure may be due to low oil or no lubricating oil The oil filter elements should be checked and replaced, if necessary. After removal, clean the bearings and inspect them for scoring, pitting, flaking, etching and dirt grooving. If any of these defects are present, the bearings must be discarded. However, babbitt plated bearings may develop minute cracks or small isolated cavities on the bearing surface during engine operation. These are characteristics of and are, NOT detrimental to this type of bearing. The bearings should not be replaced for these minor surface imperfections. The upper bearing shells, which carry the load, will normally show signs of distress before the lower shells do.

Inspect the back of the bearing shells for bright spots which indicate they have been moving in their supports. If such spots are present, discard the bearing shells. Also inspect the connecting rod bearing bores for burrs, foreign particles, etc.

Measure the thickness of the bearing shells at point "C", 90 from the parting line, as shown in figure 6, section 1.3.4. Use a micrometer and ball attachment J4757 as illustrated in figure 7, section 1.3.4. The minimum thickness of a worn standard bearing shell should not be less then .123". In addition to this thickness measurement, check the clearance between the connecting rod bearing shells and the crankshaft journal. This clearance may be checked with the crankshaft in place by squeezing a soft plastic measuring strip between the crankshaft journal and the bearing shells. The connecting rod nuts on the ⅜"-24 bolts must be tightened to 40-45 lb-ft torque. One connecting rod bearing shell alone should not be replaced. If one bearing shell requires replacement, both the upper and lower shells should be replaced. While the connecting rod bearing cap is removed, it is very important to examine the crankshaft journal for wear or any other unsatisfactory conditions, as outlined in section 1.3, before replacement bearings are installed. Bearing shells in .010", .020", 1030" undersize are available for service with crankshafts which have worn or have been ground to a smaller journal diameter. Bearing shells which are .002" undersize are available to compensate for slight journal wear in those cases where it is unnecessary to regrind the crankshaft.

NOTE

Bearing shells are NOT reworkable from one undersize to another under any circumstances.

1.6.2 CONNECTING ROD BEARINGS

The table below gives the minimum bearing shell thickness for used standard and various undersize bearings, and the crankshaft connecting rod journal diameters corresponding to each bearing size.

Nominal size of bearing	Minimum new bearing shell thickness	Crankshaft connecting rod journal diameters
Standard	.1245"	2.499"-2.500"
.002" Undersize	.1255"	2.497"-2.498'
.010" Undersize	.1295"	*2.489"-2.490"
.020" Undersize	.1345"	*2.479"-2.480"
.030" Undersize	.1395"	• 2.469"-2.470"

*Dimension of reground crankshafts

Install Connecting Rod Bearing Shells (Connecting Rod, Piston and Liner in Place)

1. Rotate the crankshaft until the connecting rod journal is at the bottom of its travel, wipe the journal clean and lubricate it with clean engine oil.

2. Install the upper bearing shell — the one with the short groove and oil hole at each parting line — in the connecting rod. Be shure the tang on the shell fits in the groove in the rod.

3. Pull the piston and rod assembly down until the upper rod bearing seats firmly on the crankshaft journal. If there is a visible difference in the color of new upper and lower bearing shells, it is due to a change in the manufacturing process, and they should not be returned or rejected on the basis of the dissimilar appearance.

4. Place the lower bearing shell — the one with the continuous oil groove — in the bearing cap, with tang of the shell in the groove of the cap. and lubricate it with clean engine oil.

5. Note the identifying marks on the cap and the rod, and assemble the cap to the rod. Connecting rod nuts should be tightened to 40-45 lb-ft torque.

6. Install the lubricating oil pump inlet tube assembly. Replace the inlet tube seal ring or elbow gasket if hardened or broken.

7. Install the oil pan.

8. Refer to the "Lubricating Oil Specifications" in section 13.3 and refill the carnkcase to the proper level on the dipstick.

9. If new bearings were installed, operate the engine on the run-in schedule as outlined in section 13.2.1.

CYLINDER LINER

The cylinder liners are of the replaceable wet type, made of hardened alloy cast iron, and are a slip fit in the cylinder block. They are inserted in the cylinder bores from the top of the cylinder block. The flange of each liner rests on a counterbore in the top of the block. A synthetic rubber cylinder liner seal ring recessed in the cylinder block bore is used between the liner and the block to prevent water leakage into the air box (fig. 8). The upper portion of the liner is directly cooled by water surrounding the liner. The center portion of the liner is air cooled by the scavenging air which enters the cylinder through eighteen equally spaced ports. However, regardless of the type of cooling, the current cylinder liner is applicalbe to all engines. The angle of the ports in the cylinder liners creates a uniform swirling motion to the intake air as it enters the cylinder. This motion persists throughout the compression stroke and facilitates scavenging and combustion. The wear on the cylinder liners and pistons is directly related to the amount of dust and dirt (abrasive) introduced into the engine combustion chambers via the air intake. Dust, so introduced and combined with lubricating oil on the cylinder wall, forms a lapping compound and will result in rapid wear. Therefore, avoid pulling contaminated air into the blower, and service the air cleaners regularly according to the surroundings under which the engine is operating. If the worn clearance between the piston and cylinder liner becomes excessive or should the liner be badly scored resulting in unsatisfactory engine performance, the cylinder liner must be replaced.

Figure 1. Cylinder liner.

Remove Cylinder Liner

If necessary, a cylinder liner or liners may be removed from the cylinder block as follows:

1. Remove the piston and connecting rod assembly as outlined in section 1.6 under "Remove Piston and Connecting Rod".
2. If the engine has been in service for an extended period, considerable effort may be required to loosen the liner from its position. When this condition exists, the liner may be removed with tools J 7108 and J 7162, as shown in figure 2, or by tapping the liner out with a hardwood block and ham tiler.

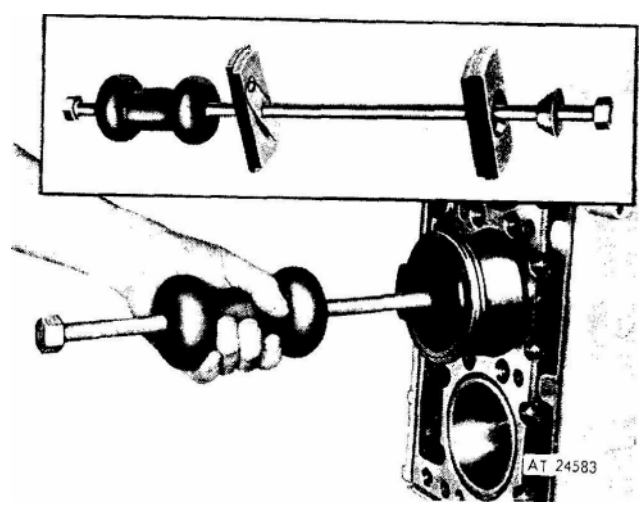


Figure 2. Removing cylinder liner.

1.6.3 CYLINDER LINER

NOTE

To avoid damage to the top land of the piston, do not at any time try to loosen the cylinder liner by inserting a long bolt or rod through the port openings in the cylinder liner and turning the crankshaft, thus pushing the liner up with the piston.

'to use the remover tools J 7108 and J 7162:

a. Slip the lower puller clamp up the puller rod and off its tapered seat. Cock the clamp so it will slide down through the liner. The clamp will drop back onto its seat in a horizontal position after it clears the bottom of the liner.

b. Slide the upper puller clamp down against the top edge of the liner.

c. With tool in place, strike the upset head on upper end of the puller rod a sharp blow with the puller weight, thus releasing the liner. Remove the I iner.

d. Remove the cylinder liner seal ring from the groove in the cylinder block bore.

Inspect Used Cylinder Liner

When the cylinder liner is removed from the engine, it should be thoroughly cleaned and checked for:

Out-of round	Scoring
Taper	Flange irregularities
Cracks	Erosion

A cracked or excessively scored cylinder liner must be discarded. A slightly scored cylinder liner may be cleaned-up and re-used. Install the cylinder liner in the block and measure the inside diameter of the liner at the various points shown in figure 3. If the taper exceeds .002" or the out-of-round exceeds .003", replace the liner. To check these dimensions, use a dial bore gage which has a dial indicator calibrated in .0001" increments as shown in figure 4. Set the *gage on* zero with master ring J 8385.

NOTE

Dial bore gage setting master tool J 23059 may be used in place of the master ring gage.

When rebuilding an engine, it is often necessary to make a choice between installing new liners and new pistons or installing new liners and the used pistons. The service man must make the decision as to which one of these combinations of parts is the most economical and satisfactory for the particular unit being rebuilt.

Hone Used Cylinder Liner

If the taper or out-of-round do not exceed the limits, the liner should be honed to remove any step or ridge at the top of the ring travel and to remove the glaze caused by the rubbing action of the piston rings. Whenever a liner is honed, it mast be replaced in a fixture (a scrap cylinder block makes an excellent honing fixture). However, if it is necessary to hone a liner in the cylinder block that is to be used in building up the engine, -the -engine must be dismantled and then, after honing, the cylinder block and other parts must be thoroughly cleaned to ensure that all abrasive material is removed. The hone J 5902-01, equipped with 120 grit stones J 5902-14, should be worked up and down the full length of the liner a few times so a "criss-cross" pattern with the hone marks on a 45° axis will result. After the liner has been honed, remove it from the fixture and clean it thoroughly, Then dry it with compressed air and check the entire surface for burrs. After honing, the liner must conform to the same limits on taper and out-of-round as a new liner, and the piston-to-liner clearance must be within the specified limits shown in section 1.6.0.

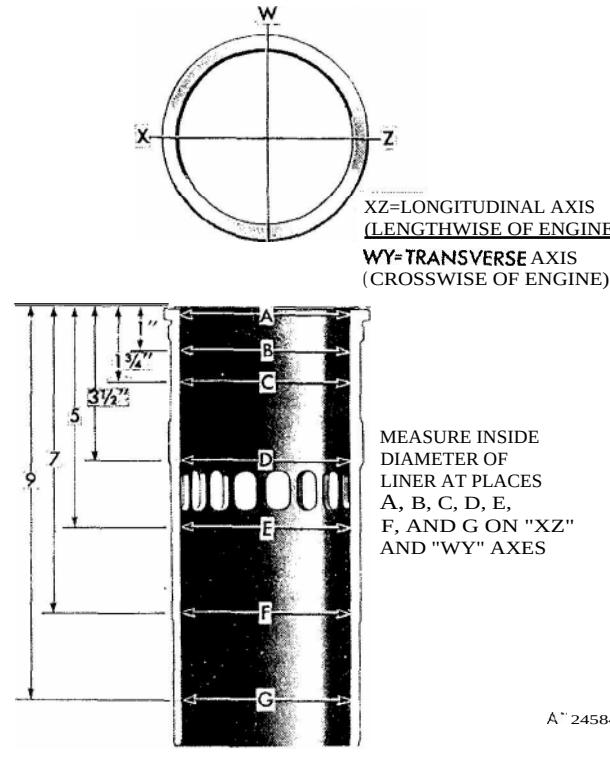


Figure 3. Cylinder liner measurement diagram.

Inspect New Cylinder Liner

Install the cylinder in the block and measure the inside diameter at the various points shown in figure 3; use a dial bore gage with a dial indicator calibrated in .0001" increments (fig. 4). Use master ring J 8385 to set the gage on zero.

NOTE

Dial bore gage setting master tool J 23059 may be used in place of the master ring gage.

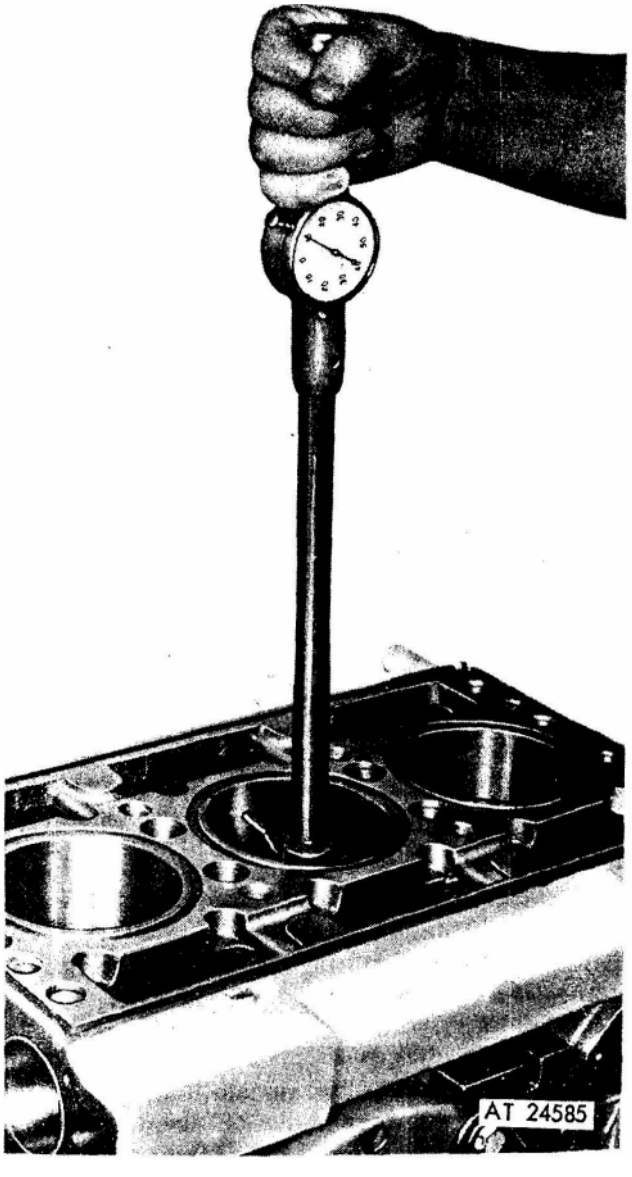


Figure 4. Checking bore of cylinder liner.

A new cylinder liner is 3.8752" to 3.8767" on the inside diameter, and should be straight from top to bottom within .001", and round within .002" total indicator reading when the liner is in place in the block.

NOTE

Do not modify the surface finish in a new service cylinder liner. Since the liner is properly finished at the factory, any change will adversely affect the seating of the piston rings.

Fitting Cylinder Liner in Block Bore

1. Wipe the inside and outside of the cylinder liner clean. Also, make sure the block bore and counterbore are clean so the liner flange will seat properly. Then, slide the liner into the block until the flange on the liner rests on the bottom of the counterbore in the block.

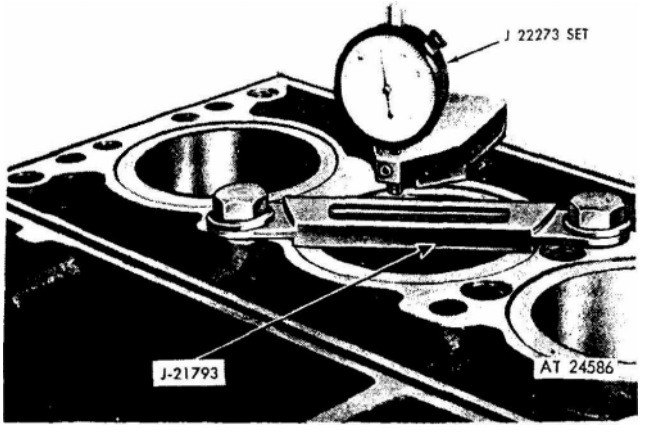


Figure 5. Checking distance of liner flange below top face of block.

CAUTION

Do not drop or slam the liner flange against the bottom of the counterbore in the block.

2. Tap the liner lightly with a soft hammer to make cretain the liner flange seats on the bottom of the counterbore.

3. Clamp the liner in place with hold-down clamp J 21793 and measure the distance from the top of the liner flange to the top of the block with tool J 22273 which consists of dial indicator J 7333-22 and holder J 4209-25 (fig. 5). The top of the liner flange should be .0465" to .050" below the top of the block; and there must not be over .0015" difference between any two adjacent liners when measured along the cylinder longitudinal center

line. If the above limits are not met, install the liner in another bore and recheck, or use a new liner.

4. Matchmark the liner and the block with chalk or paint, so the liner may be reinstalled in the same position in the same bore. Place the matchmark on serial number side of the block.

5. Remove the hold-down clamp and the liner.

Install Piston and Connecting Rod Assembly

1. With the piston assembled to the connecting rod and the piston rings in place, as outlined in sections 1.6 and 1.6.1, apply clean engine oil to the piston, rings, and the inside of the piston ring compressor J 6883.

NOTE

Inspect the ring compressor for nicks or burrs, especially at the non-tapered inside diameter end. Nicks or burrs on the inside diameter of the compressor will result in damage to the piston rings.

2. Place the piston ring compressor on a wood block (tapered end up).

3. Position (stagger) the piston ring gaps properly on the piston. Make sure that the oil control ring expanders are not overlapped.

4. Start the top of the piston straight into the ring compressor ; then, push the piston down until it contacts the wood block (see operation 1, fig. 6).

5. Note the position of the matchmark on the liner and place the liner on a wood block.

6. Place the ring compressor and the piston and rod assembly on the liner, so the numbers on the rod and cap are aligned with the matchmark on the liner (see operation 2, fig. 6).

NOTE

The numbers on the side of the connecting rod and cap identify the rod with the cap and indicate the particular cylinder in which they are used. If a new service connecting rod is to be installed, the same identification number must be stamped or etched in the same location as on the connecting rod that was replaced.

7. Push the piston and rod assembly down into the liner until the piston is out of the ring corn pressor.

CAUTION

Do not force the piston into the liner.

8. Remove the connecting rod cap and the ring compressor.

9. Push the piston down into the liner until the corn pression rings pass the liner parts.

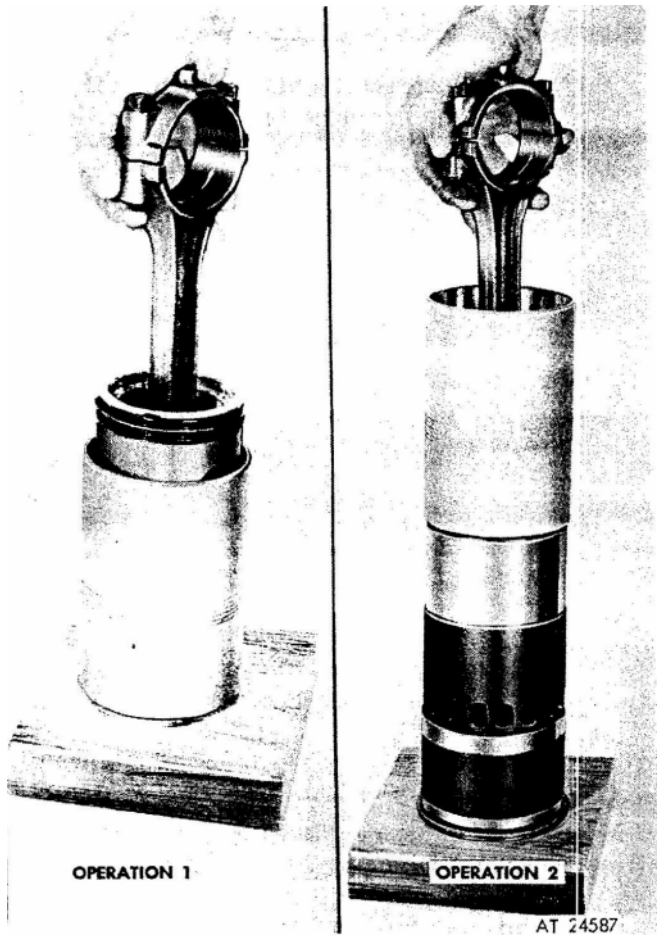


Figure 6. Installing piston and connecting rod assembly in ring compressor and cylinder liner.

Install Cylinder Liner, Piston and Connecting Rod Assembly

After the piston and connecting rod assembly have been installed in the liner, the entire assembly may be installed in the engine as follows:

1. Make sure the seal ring groove in the cylinder block is clean. Then, install the seal ring.

NOTE

The cylinder block has an additional seal ring groove approximately ⅛" below the original top groove (fig. 8). This groove will

permit further use of the cylinder block where corrosion or erosion of the upper seal ring groove has occurred.

2. Apply hydrogenated vegetable type shortening or permanent type antifreeze solution to the inner surface of the seal ring.

3. If any of the pistons and liners are already in the engine, use hold-down clamps (fig. 5) to retain the liners in place when the crankshaft is rotated.

4. Rotate the crankshaft until the connecting rod journal of the particular cylinder being worked on is at the bottom of its travel, wipe the journal clean, and lubricate it with clean engine oil.

5. Install the upper bearing shell — the one with a short groove at each parting line — in the connecting rod. Lubricate the shell with clean engine oil.

6. Hold the piston, rod, and liner in line with the block bore (fig. 7) so the identification number on the rod is facing the engine serial number side (In-line engine). Also, align the match-marks on the liner and block. Now slide the entire assembly into the block bore and seal ring, being careful not to damage the seal ring.

7. Pull or push the piston and connecting rod down until the upper bearing shell seats firmly on the crankshaft journal. Use care so the bearing shell will not be dislodged from the rod.

8. Place the lower bearing shell — the one with the continuous oil groove — in the connecting rod cap with the tang on the groove in the notch in the cap. Lubricate the bearing shell with clean engine oil.

9. Install the bearing cap and shell on the connecting rod with the number on the cap and rod adjacent to each other. Connecting rod nuts should be tightened to 40-45 lb-ft torque.

10. Check the connecting rod side clearance. The clearance between the side of the rod and the crankshaft should be .006" to .12" with new parts.

11. Remove the liner hold-down clamps.

12. Install new compression gaskets and water and oil seals as outlined in section 1.2. Then, install the cylinder head.

13. Install any other parts which were removed from the engine.

14. After the engine has been completely reassembled, refer to the "Lubricating Oil Specifications" in section 13.3 and refill the crankcase to the proper level on the dipstick.

15. Close all of the drains and fill the cooling system.

16. If new parts such as pistons, rings, cylinder liners or bearings were installed, operate the engine on the RUN-IN schedule given in section 13.2.1.

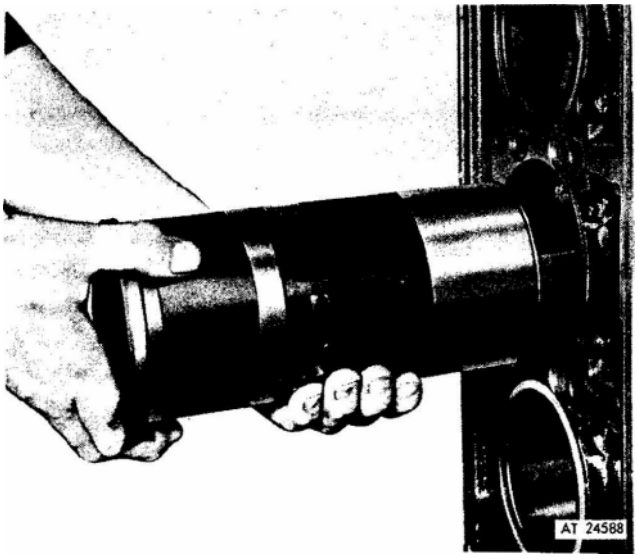


Figure 7. Installing piston, connecting rod and liner assembly in cylinder block.

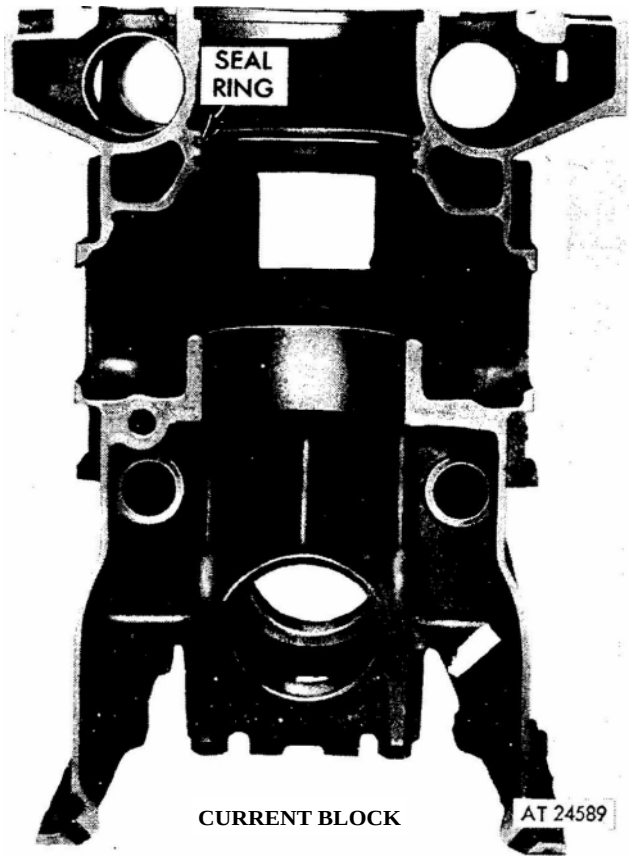


Figure 8. Cylinder liner seal ring locations in in-line cylinder block bores.

SPECIFICATIONS-SERVICE TOOLS

Specifications

Table of Specifications, Nev · Clearances, and Wear Limits

Engine part (standard size)	New parts		Wear Limits
	Minimum	Maximum	
CYLINDER BLOCK			
Cylinder Liner Cotmterbore			
Diameter	4.8200"	4.8350"	
Depth	.3000"	.3020"	
CYLINDER LINERS			
Outside Diameter (Upper Seal Ring Surface)	4.4850"	4.4860"	
Outside Diameter (Lower Seal Ring Surface)	4.3550"	4.3560"	
Inside Diameter	3.8752"	3.8767"	
Out-of Round		.0020"	.003"
Taper-Liner		.0010"	.002"
Depth of Liner Flange Below Block	.0465"	.0500"	.050"
CRANKSHAFT			
Journal Diameter-Connecting Rod-In-Line Engine	2.4990"	2.5000"	
Journal Out-of-Round		.00025"	
Journal Taper		.0005"	.003"
PISTON			
Diameter (At Skirt)	3.8693"	3.8715"	
Clearance—Piston-to-Liner	.0037"	.0074"	.010"
Out-of-Round		.0005"	
Taper		.0005"	
Piston Pin Bushing-Inside Diameter	1.3775"	1.3780"	
PISTON PINS			
Diameter	1.3746"	1.3750"	
Clearance-Pin-to-Piston Bushing	.0025"	.0034"	.010"
Clearance-Pin-to-Rod Bushing	.0010"	.0019"	.010"
PISTON RINGS			
Compression Rings			
Gap (Chrome ring)	.0200"	.0460"	.060"
C lea ra nce—Ring-to-Groove			
Top (No. 1)	.0030"	.0060"	.012"
No. 2	.0070"	.0100"	.014"
No. 3 and 4 (21:1 - Piston)	.0045"	.0070"	.012"
Oil Rings			
Gap	.0100"	.0250"	.044"
Clearance-Ring-to-Groove	.0015"	.0055"	.008"
CONNECTING RODS			
Length-Center-to-Center	8.7990"	8.8010"	
Lower Bore-Diameter-In-Line Engine	2.7515"	2.7525"	
Upper Bore-Diameter	1.6000"	1.6010"	
Bushing Inside Diameter	3760"	1.3765"	
Normal Rod Side Clearance-In-Line Engine	.0060"	.0120	
CONNECTING ROD BEARINGS			
Bearing Inside Diameter (Vertical Axis)			
In-Line Engine	2.5015"	2.5035"	
Bearing Thickness-90° from Parting			
Line-In-Line Engine	.1245"	.1250"	.1230"
Clearance—Bearing-to-Crankshaft			
Journal-In-Line Engine	.0015"	.0046"	.006"

*These clearances also apply to oversize or undersize parts.

1.6.0 SPECIFICATIONS

Standard Bolt and Nut Torque Specifications

Size nut or bolt	Torque (lb-ft)	Size nut or bolt	Torque (lb-ft)	Size nut or bolt	Torque (lb-ft)
1/4 - 20	7-9	7/16 - 20	57-61	3/4 - 10	240-250
1/4 - 28	8-10	1/2 - 18	71-75	3/4 - 16	290-300
5/16 - 18	13-17	1/2 - 20	83-93	7/8 - 9	410-420
5/16 - 24	15-19	9/16 - 12	90-100	7/8 - 14	475-485
3/8 - 16	30-35	9/16 - 18	107-117	1 - 8	580-590
3/8 - 24	35-39	5/8 - 11	137-147	1 - 14	685-695
7/16 - 14	46-50	5/8 - 18	168-178		

Exceptions to Standard Bolt and Nut Torque Specifications

Application	Size nut or bolt	Torque (lb-ft)
Connecting Rod Nuts—In-Line and V-Engine (Lubrited)	3/8 - 24	40-45

Service Tools

Tool No.	Tool name
J 593-14	Swivel Assembly (Part of J 5438)
J 1513-02	Piston and Connecting Rod Bushing Installing and Removing Set
J. 1513-1	Piston Holding Fixture
J 1513-2	Driver Handle
J. 1686-5	Guide
J 3174-01	Feeler Gage Pack (Part of J 5438)
J 22273	Cylinder Block Checking Fixture
J 4209-25	Holder
J 7333-22	Dial Indicator
J 4757	Micrometer Ball Attachment
J 4895-01	Piston Pin Retainer Installer
J 4970-4	Piston Bushing Reamer
J 4970-5	Guide
J 4971-4	Connecting Rod Bushing Reamer
J 4971-6	Guide
J 4972-2	Piston Pin Bushing Installer
J 4972-4	Piston Pin Bushing Remover
J 5273	Piston Bushing Reaming Fixture
J 5347	Bore Gage
J 5438	Piston-to-Liner Feeler Gage Set
J 5902-01	Cylinder Hone Set
J 5902-14	Stone (120 Grit)
J 6883	Piston Ring Compressor
J 22490	Cylinder Liner Remover Set
J 7108	Slide Hammer
J 7169	Cylinder Liner Remover Shoes
J 7587-1	Piston Bushing Spacer
J 7608-01	Connecting Rod Bushing Reamer Set
J 7608-3	Spacer
J 7608-4	Fixture and Arbor Assembly
J 7632	Connecting Rod Holder
J 8128	Piston Ring Remover and Installer
J 8129	Spring Scale (Part of J 5438)
J 8385	Master Ring—Cylinder Liner
J 8995	Spray Nozzle Remover
J 21793	Hold-down Clamp
J 23059	Dial Bore Gage Master Setting Fixture

CAMSHAFT, BALANCE SHAFT AND BEARINGS

The camshaft and balance shaft are located just below the top of the cylinder block. The shafts are supported by bearings (bushing type) that are pressed into bores in the cylinder block. The balance shaft is supported by front and rear bearings only, whereas the camshaft is supported by end, intermediate and center bearings. The camshaft is supported by two *end* bearings and two intermediate hearings. To facilitate assembly, letters signifying the engine model are stamped *on* the ends of the shaft. The letters on the timing gear end of the camshaft must correspond with the engine model. For example, the letters RB will be stamped on a camshaft used in an RB model engine.

Lubrication is supplied under pressure to the camshaft and balance shaft end bearings via oil passages branching off from the main oil gallery direct to the camshaft end bearings. In addition, oil is forced through an oil passage in each camshaft which lubricates the camshaft intermediate bearings. The camshaft and balance shaft bearings incorporate small slots through which lubricating oil from the bearings is directed to the cam follower rollers.

Remove Camshaft or Balance Shaft

Whenever an engine is being completely reconditioned or the bearings, thrust washers, or the gears on the shafts need replacing, the shafts should be removed from the engine in the following manner:

1. Drain the engine cooling system.
2. Remove all accessories and assemblies witl

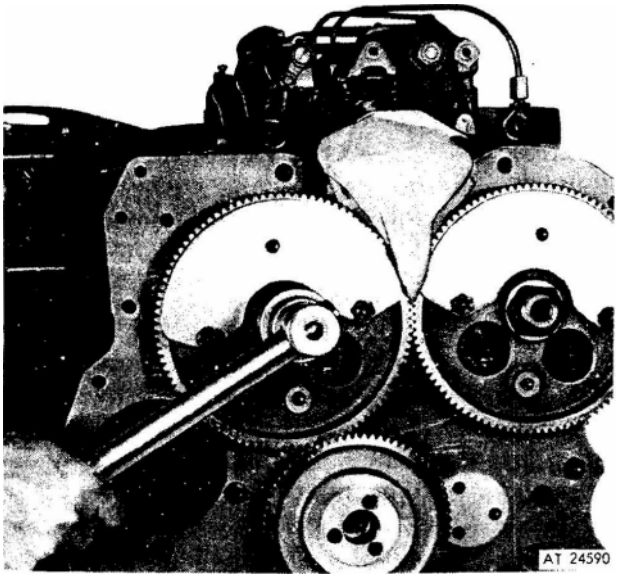


Figure 1. Removing or installing nut on camshaft or balance s na

their attaching parts necessary to mount engine on overhaul stand Procedures for removing accessories and assemblies from the engine will be found in their respective sections of this manual.

3. Mount the engine on an overhaul stand. Be sure the engine is securely mounted on the stand before releasing the lifting sling.
4. Remove the cylinder head. Follow the procedure given in section 1.2.
5. Remove the flywheel and the flywheel housing as outlined in sections 1.4 and 1.5.
6. Remove the bolts which secure the gear nut retainer plates to the gears; then remove the retainer plates.
7. Wedge a clean rag between the gears as shown in figure 1; then, remove the nuts from each end of both shafts with a socket wrench.

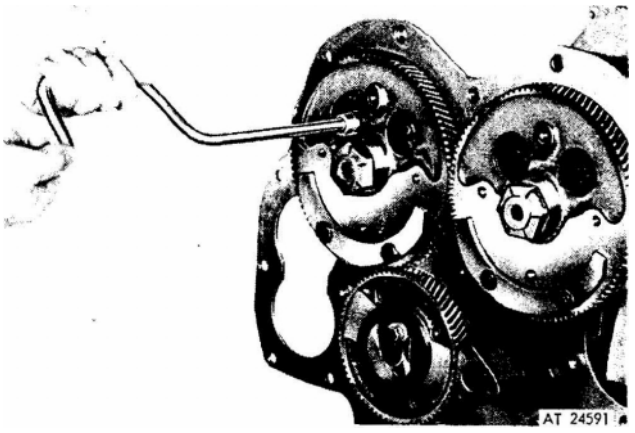


Figure 2. Removing or installing thrust washer retaining bolts.

8. Remove the balance weights from the from end of the shafts as outlined in section 1.7.1.
9. Remove the upper engine front cover (sec.
10. Remove the oil slinger from the front end of both shafts.
11. Remove the two thrust washer retaining bolts securing the camshaft or balance shaft thrust washer to the cylinder block, by inserting a socket through a hole in the web of the gear as shown in figure 2.
12. Withdraw the shaft, thrust washer, and gear, as an assembly, from the rear end of the cylinder block.

Disassemble Camshaft or Balance Shaft

1. Remove the gear from the shaft (sec. 1.7.3).
2. To permit cleaning out any foreign material that may be lodged at the ends of the oil passage, remove the end plugs from the camshaft as follows:

1.7 CAMSHAFT, BALANCE SHAFT AND BEARINGS

a. Clamp the camshaft in a vise equipped with soft jaws. Use care to prevent damage to the cam lobes and machined surfaces of the shaft.

I). Make an indentation in the center of one of the end plugs with a 31 / 64" carboloy tip drill.

c. To aid in breaking through the hardened surface of the plug, punch a hole as deeply as possible with a center punch,

d. Then, use a ¼" carboloy tip drill to drill a hole through the center of the plug.

e. Redrill the end plug with a 5 / 16" carboloy tip drill.

f. Thread the hole in the plug with a ⅜"-16 *tap.*

g. Remove the end plug from the camshaft with ⅜"-16 adaptor J 8183 and slide hammer J 6171-1.

It. Insert a ⅜' steel rod in the camshaft oil *gallery* and drive the remaining plug out. If a steel rod is not available, perform steps "a" through "g" to remove the remaining plug.

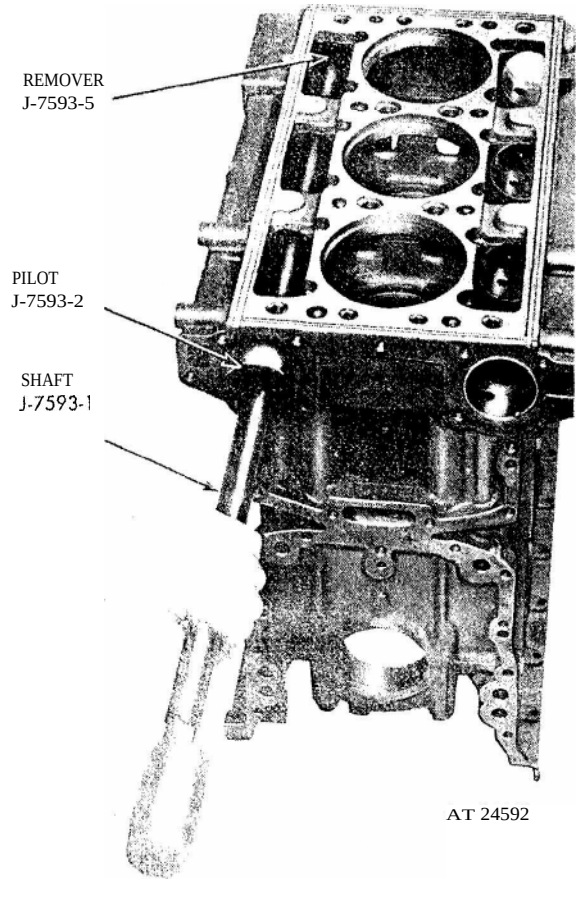


Figure 3. Removing end hearing.

Inspection

Glean all parts with fuel oil and dry with compressed air. Be sure the oil holes in the cam shaft(s) are clean. Sludge accumulations, which might restrict the oil flow, must be removed. Install new end plugs in the camshaft and balance shaft, if removed. Inspect the cams and journals and, :if they are badly scored or worn, replace the camshaft. If cams are scored, the cam followers should also be inspected. See section 1.2.1.

Examine both faces of the thrust washers. If either face is scored or if the thrust washers are worn excessively, replace the washers. New thrust washers are .208" to .210" thick. Also, examine surfaces which the thrust washers contact; if these surfaces are scratched but not severely scored, they may be smoothed down with an oil stone. However, if score marks are too deep to be removed, or if parts are badly worn, new parts must be used. The clearance between new shafts and new bearings is front .0045" to .006", or a maximum of .008" with worn parts. Excessive clearance between the shafts and the bearings will cause low oil pressure and excessive backlash between the gears. *Bearings are* available in .010" and .020" undersize for use with worn or reground shafts. Oversize camshaft and balance shaft bearings are available in sets, .010" oversize on the outside diameter, to permit reuse of a cylinder blockhaving one or more scored block bearing bores. To use the oversize bearings the camshaft and balance shaft block bores must be carefully line bored (machined) to the dimensions shown in the following chart.

Camshaft and Balance Shaft Cyliner
Block Bore Machining Chart

Engine	Bearing location	Dimension	
		Minimum	**Maximum**
3	End	2.385"	2.386"
3	**Intermediate**	2.375"	2.376"
53	Center	2.365"	2.366"

Remove Bearings

The end bearings must be removed prior to removing the intermediate bearings.

CAUTION

When removing bearings be sure to note the position of the hearings in the bore with respect to the notch in the bearings. Replacement bearings must be installed in the same position.

1. Remove all accessories and assemblies with their attaching parts as is necessary so that tool set J 7593-03 may be used as shown in figure 3, and in A of figure 6. Tool set J 7593-03, designed for use with standard size bearings, may be used to remove and install .010" undersize and .020" undersize bearings by reducing the pilot diameter of the pilot **J** 7593-2, installer **J** 7593-3, remover **J** 7593-5, installer J 7593-6, and installer J 7593-15. The

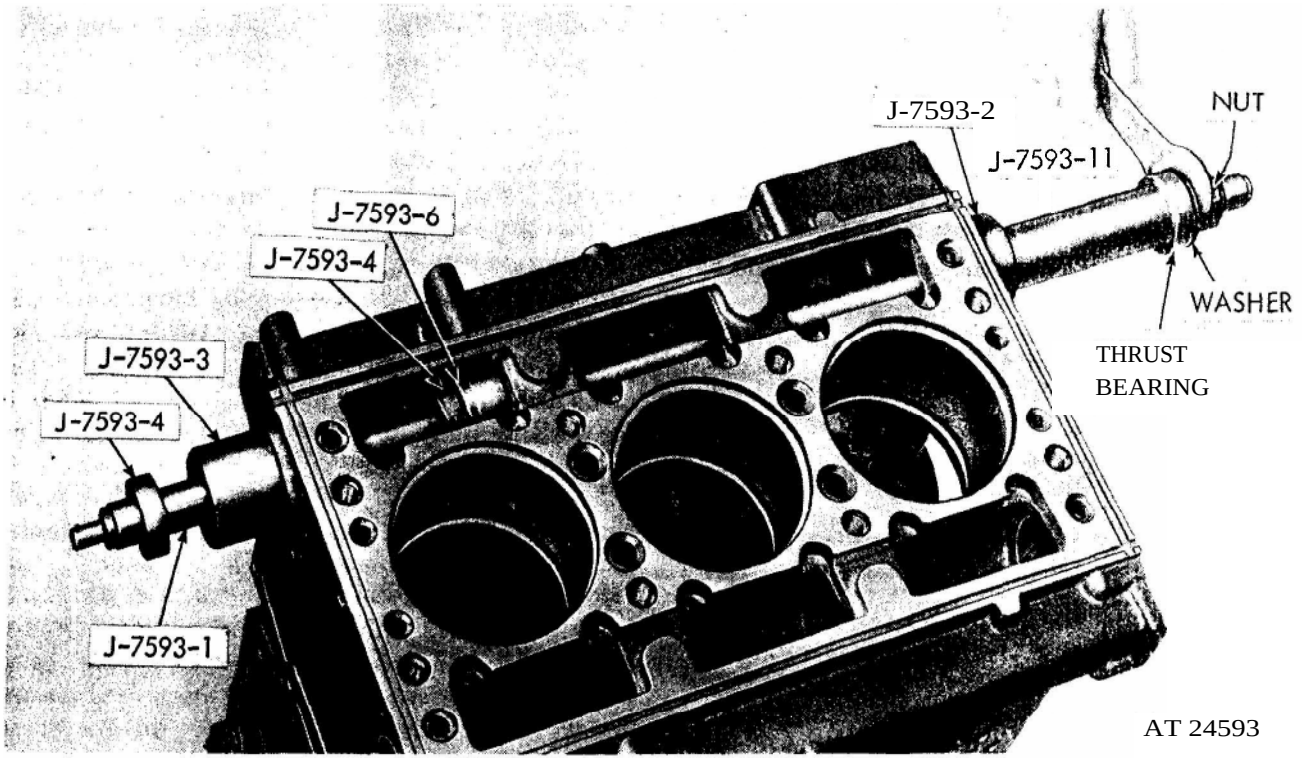


Figure **4.** ***Installing intermediate camshaft bearing.***

pilot diameter of these tools should be reduced by .020". This reduction in tool diameter does not materially effect usage on standard size bearings. If the tools are used frequently, however, it may be advisable to purchase additional standard pieces. Reduced diameter tools have not been released.

2. Insert the small diameter end of pilot J 7593-2 into the end bearing.

3. Then, with the unthreaded end of the shaft J 7593-1 started through the pilot, push the shaft through the block bore until the end of the shaft snaps into the remover J 7593-5.

4. Now, drive the end bearing out of the cylinder block. The nearest intermediate bearings can he removed now in the same manner. The large diameter end of pilot J 7593-2 will fit into the camshaft bore and is used when removing the other end bearing and any remaining bearings.

Install Intermediate Camshaft Bearings

Camshaft intermediate bearings must be installed prior to installing the camshaft end bearings. The front intermediate and front bearings are installed by pressing the bearings from the front to the rear of the block.

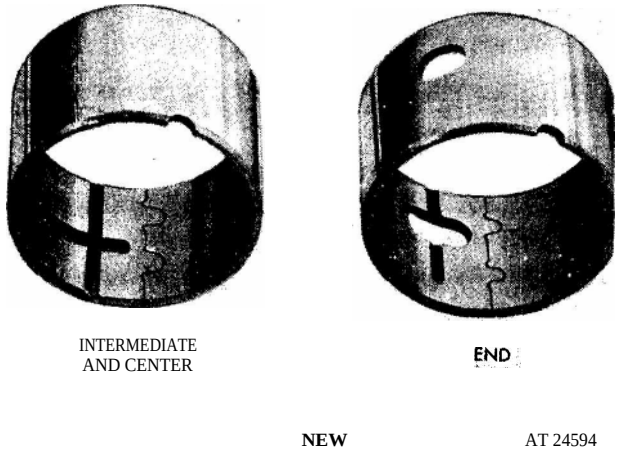


Figure 5. ***Camshaft and balance shaft bearing identification.***

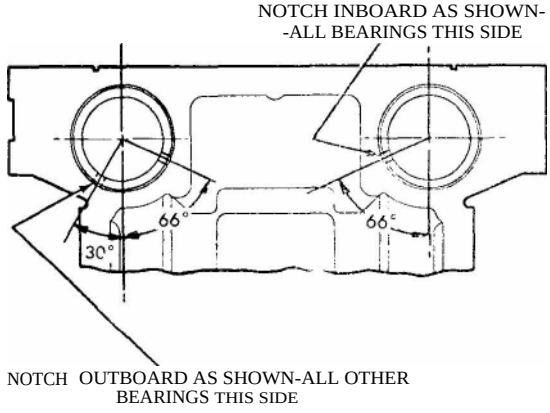


Figure 6. *Location* of notch *in relation to shaft bore centerline,*

1.7 CAMSHAFT, BALANCE SHAFT AND BEARINGS

NOTE

Current bearings incorporate lubrication grooves on the inner bearing surface (fig.

To properly install the camshaft and balance shaft bearings, refer to figure 6 for location of the notch in the bearing- in relation to the camshaft or balance shaft bore centerline in the cylinder block. Also, to facilitate assembly, the camshaft and balance shaft bearings are color coded on the side and / or end as shown in the following chart.

Camshaft and Balance Shaft Bearing Color Code Chart

Bearing position	Color code		Outside diameter	Inside diameter
	Current	Former		
End	Brown	Black	Standard	Standard, .010" and .020" U.S. Standard (only)
	Brown	Yellow	.010" Oversize	
Inter-mediate	Orange	Red	Standard	Standard, .010" and .020" U.S. Standard (only)
	Orange	Blue	.010" Oversize	

1. I nsert pilot J 7593-2 in the bore of the block as shown in figure 4. Use the small end of the pilot if an end bearing has been installed. See B and C of figure 6.
2. Insert the new intermediate bearing into the camshaft bore and position it correctly.
3. Then, with the unthreaded end of shaft J 7593-1 started through the pilot, push the shaft through the entire length of the block bore.
4. Slide installer J 7593-6 on the shaft until the locating pin registers with the notch in the bearing. Then, slide installer J 7593-3 or J 7593-15 on the shaft with the large diameter inserted into the end of the block bore. Refer to C of figure 7.
3. Next, place a spacer (if required), thrust washer, plain washer and hex nut over the threaded end of the puller. The short spacer J 7593-11, shown in figure 4, is used on the three cylinder block.
O. Align the shaft in such a way that a "C" washer, J 7593-4. can be inserted in a groove in the shaft adjacent to installer J 7593-6.
7. Place a "C" washer in the groove near the end of the shaft and, using a suitable wrench on the hex nut. draw the hearing into place until the "C" washer butts up against installer J 7593-3 and prevents the shaft from further movement.

Install End Bearings

Refer to camshaft and balance shaft color code chart and the cylinder block horn machining dimension chart when installing the end bearings.

1. Insert pilot J 7593-2 in the bore of the block as shown in "D" of figure 7. Use the small diameter of the pilot if a hearing has been installed.
2. Insert support J 7593-12 in the bore in the opposite end of the block ; then, with the unthreaded end of the shaft started through pilot J 7393-2, push the shaft through the block and support J 7593-12.
3. Place a new end bearing on installer J 7593-3 and align the notch in the bearing with the pin on the installer. Then, slide the installer and the hearing on the shaft.
4. Place "C" washer j 7593-4 in the end notch in the shaft; pull the shaft back until the washer butts against the installer.
5. Next, place a spacer (if required), thrust washer, plain washer and hex nut over the threaded end of the shaft as shown in "D" of figure 7 and, using a suitable wrench on the hex nut, draw the bearing into place until the shoulder on the installer prevents the shaft from further movement. The hearing is now installed in its correct position. Install the remaining end hearings in the same manner. Use of tool J 7593-02 assures that the bearings are properly spaced in relation to Cie end of the block. The intermediate bearings for the three cylinder block is 5.54" from the rear and front face of the block.

Assemble and Install Camshaft and Balance Shaft

1. Install the gears and thrust washers on their respective shafts as outlined in section 1.7.3.
2. Lubricate the bearings and shafts with engine oil and slide the shaft assemblies into the cylinder block being careful not to damage the bearings or the cams and journals. Make sure that the appropriate timing marks on the gears are aligned. Refer to "Gear Train and Engine Timing" in section 1.7.2.
3. Slide an oil stinger on the front end of both shafts.
4. Install the upper engine front cover (sec. 1.7.8).
5. Secure the thrust washers in place as shown in figure 2, and tighten the bolts to 30-35 lb-ft torque.
6. Install the front balance weights (sec. 1.7.1).
7. Attach the gear nut retainer plates to the gears with bolts and lockwashers and tighten the bolts to 33-39 lb-ft torque.
8. Check the clearance between the thrust washer and the gear on both shafts. The clearance should be .008" to .015", or a maximum of .019" with used parts.
9. Check the backlash between the mating gears.

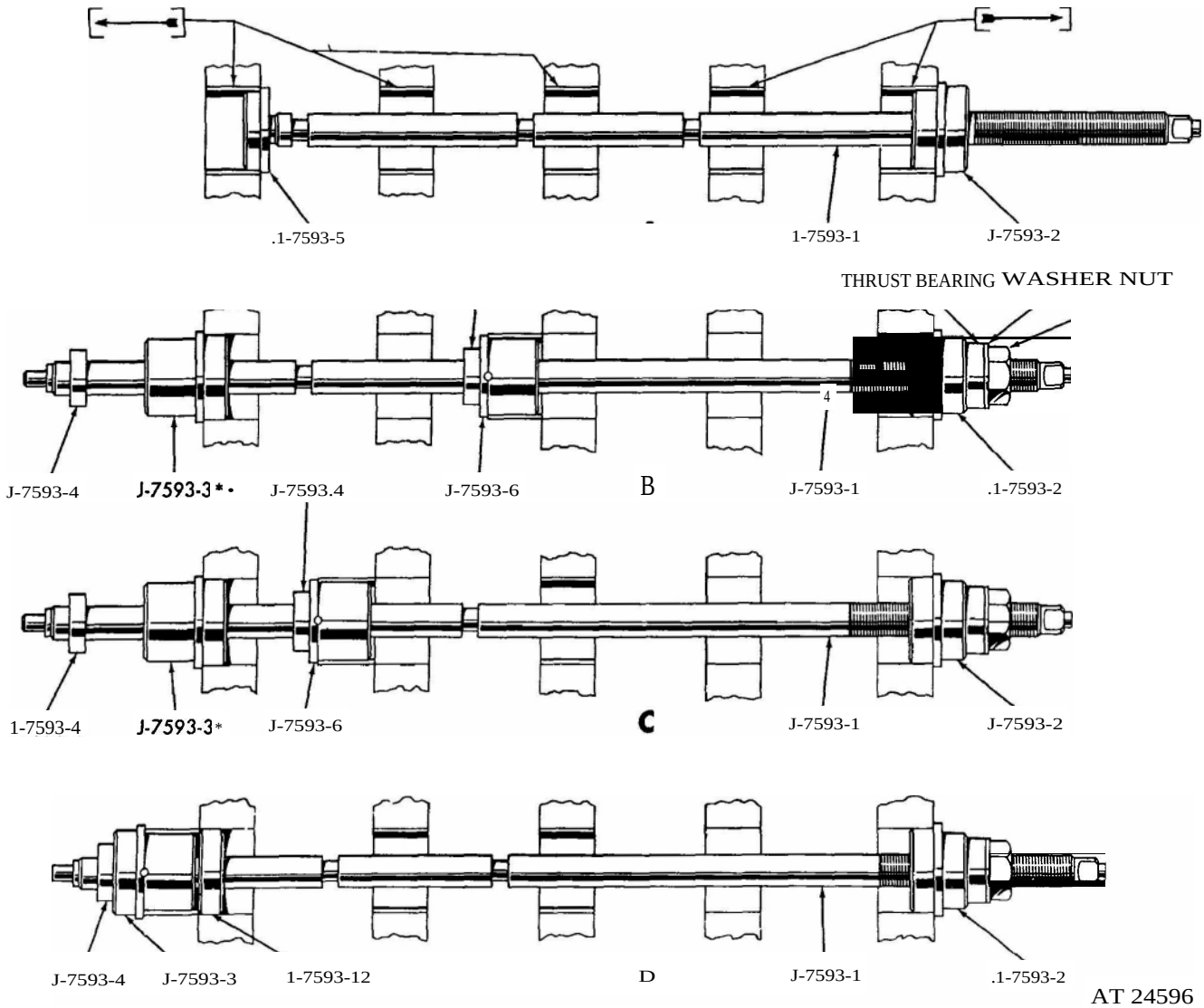
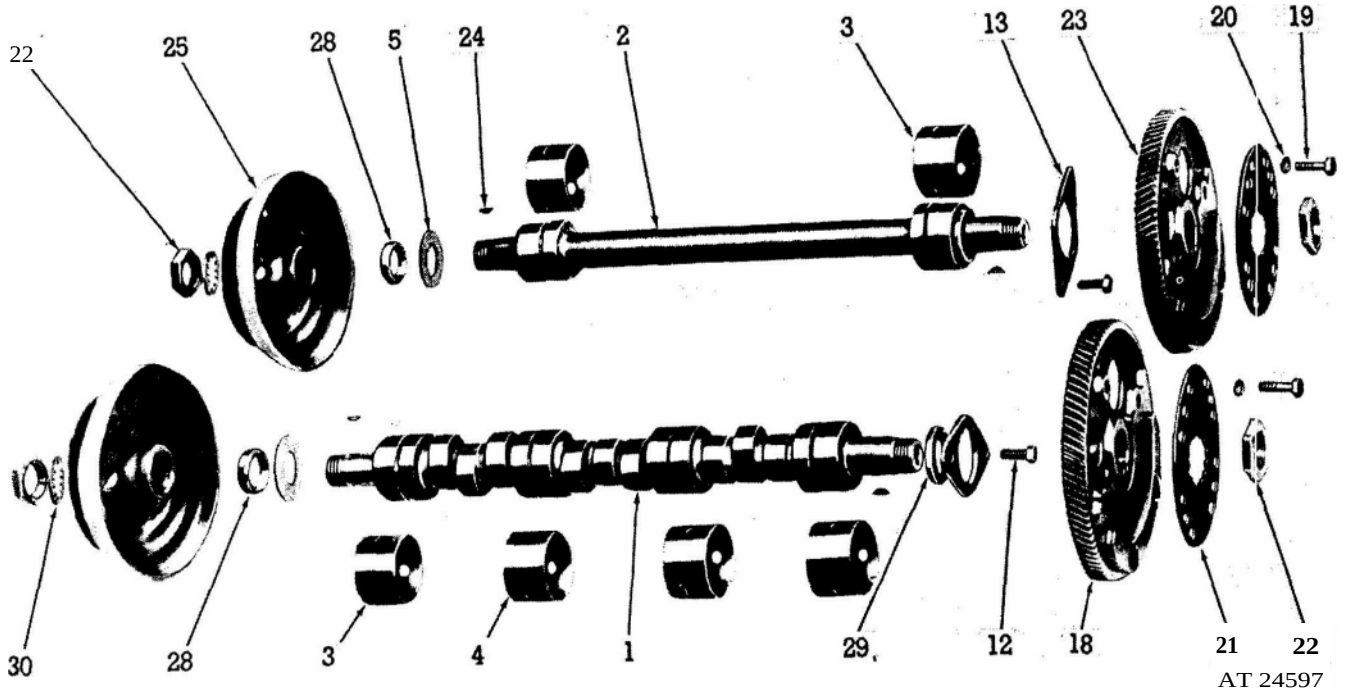


Figure 7. Removing and replacing camshaft or balance shaft bearings.

The backlash should be .003" to .005" and should not exceed .007" between used gears.

10. Install the glywheel housing and other parts or assemblies, that were removed from the engine as outlined in their respective sections of this manual.

1.7 CAMSHAFT, BALANCE SHAFT AND BEARINGS



1 Camshaft
2 Balance shaft
3 Bearing—camshaft—balance shaft—end
4 Bearing—camshaft—intermediate
5 Oil slinger
12 Bolt
13 Thrust washer
18 Gear—camshaft
19 Bolt—retainer
20 Washer
21 Retainer—gear nut
22 Nut
23 Gear—balance shaft
24 Key—woodruff
25 Pulley—camshaft—balance shaft
28 Spacer—pulley
29 Spacer—camshaft gear

Figure 8. Camshaft and balance shaft details and relative location of parts.

ENGINE BALANCE AND BALANCE WEIGHTS

In the balance of two-cycle engines, it is important to consider disturbances due to the reciprocating action of the piston masses. These disturbances are of two kinds: unbalanced forces and unbalanced couples. These forces and couples are considered as primary or secondary according to whether their frequency is equal to engine speed or twice engine speed. Although it is possible to have unbalanced forces or couples at frequencies higher than the second order, they are of small consequence in comparison to the primary forces and couples. Even the secondary forces and couples are usually of little practical significance. The reciprocating masses (the piston and upper end of the rod) produce an unbalanced couple due to their arrangement on the crankshaft. On an In-line engine, it tends to rock the engine from end to end in a vertical plane. This couple is cancelled by incorporating an integral crankshaft balance component and by placing balance weights at the outer ends of the balance shaft and camshaft (In-line engine). This balance arrangement produces a couple that is equal and opposite in magnitude and direction to the primary couple. On the balance shaft and camshaft, each set of weights (weights on the outer ends of each shaft comprise a set) rotate in, an opposite direction with respect to the other. When the weights on either end of the engine are in a vertical plane, their centrifugal forces are in the same direction and oppose the primary couple. When they are in a horizontal plane, the centrifugal forces of these balance weights oppose each other and are, therefore, cancelled. The front balance weights act in a direction opposite to the rear balance weights; therefore, rotation will result in a couple, effective only in a vertical plane. This couple, along with that built into the crankshaft, forms an elliptical couple which completely balances the primary couple. The balance weights are integral with the gears and the circular balance weights (pulleys) on the shafts. Additional weight are attached to the camshaft and balance shaft gears. Both the rotating and primary reciprocating forces and couples are completely balanced in the engines. Consequently, the engines will operate smoothly and in balance throughout their entire speed range.

Remove Front Balance Weights

I. Remove the nut at each end of both shafts, as outlined in section 1.7.

2. Force the balance weight off the end of each shaft, using two screw drivers or pry bars between the balance weight and the upper front cover, as shown in figure 1.

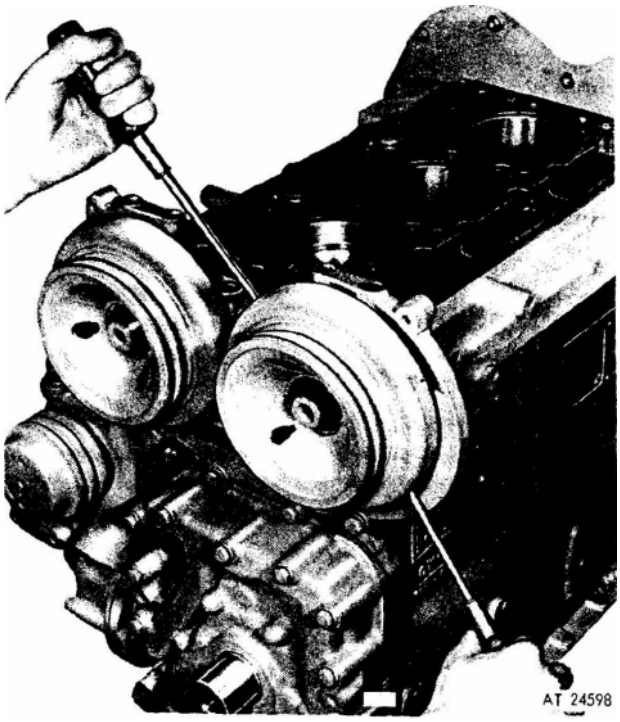


Figure 1. Removing front balance weight (pulley type).

From balance Weights

1. Reinstall the woodruff keys in the shafts, if they were removed.

2. Align the keyway in the balance weight with the key in the shaft ; then slide the weight on the shaft. If the weight does not slide easily onto the shaft, loosen the thrust washer retaining bolts at the opposite end of the shaft; then, to prevent possible damage to the thrust washer, support the rear end of the shaft while tapping the weight into place with a hammer and a sleeve. Retighten the thrust washer retaining bolts to 30-35 lb-ft torque. Install the other weight in the same manner.

3. Wedge a clean rag between the gears. Refer to figure 1, section 1.7. Then tighten the nuts on both ends of the shafts to 300 -325 lb-ft torque. Remove the rag from between the gears.

GEAR TRAIN AND ENGINE TIMING

A train of helical gears, completely enclosed between the engine end plate and the flywheel housing, is located at the rear of the Series 53 engines, as shown in figure I. The gear train on an In-line *engine* consists of a crankshaft gear, an idler gear, a camshaft gear, and a balance shaft gear, as shown in figure 1. The governor drive gear, the upper rotor gear are driven by the camshaft gear or ' al mice shaft gear. The crankshaft gear is pressed on and keyed to the end of the crankshaft. The idler gear rotates on a stationary hub. The camshaft and balance shaft gears are pressed on and keyed to their respective shafts and each gear is secured by a retaining nut and lock plate.

The camshaft and balance shaft gears have additional weights attached to the rear face of each gear. 'These weights are important in maintaining perfect engine balance. The camshaft and balance shaft gears mesh with each other and run at the same speed as the crankshaft gear. Since the former two gears must be in time with each other, and the two as a unit, in time with the crankshaft gear, timing marks have been stamped on the face of the gears to facilitate correct gear train timing. The *circle* and the triangle am the basic symbols stamped on the gears. The letter "A" on the crankshaft gear indicates advanced timing. The timing is advanced on engine Model 5033-6299 by aligning the "A" on the crankshaft gear with the circle and triangle on the idler gear. The letter"I'' represents "In-line" engine and the letter "V" represents the 6V engine. The letter "R" indicates right-hand engine rotation and the letter"L" indicates left-hand rotation. The triangle and circle symbols arc stamped in two places on each right-hand helix camshaft or balance shaft gear. A triangle and circle are stamped only once on each left-hand helix camshaft or balance shaft gear. The idler gear has a triangle symbol stamped within the circle symbol and appears in two places on the gear, 180' apart.

NOTE

On an In-line right-hand rotating engine, the circle symbol timing marks on each gear will be adjacent to the corresponding mark on its mating gear, as shown in figure

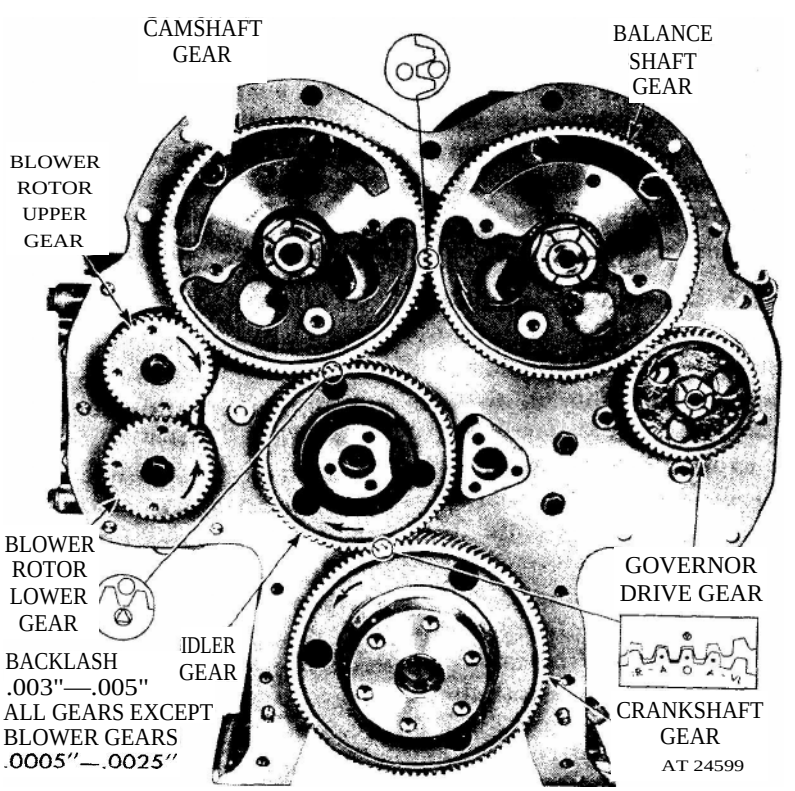


Figure 1. Gear train and timing marks (three cylinder RA engine shown).

1.7.2 GEAR TRAIN AND ENGINE TIMING

The symbol system of marking the gears makes gear train timing a comparatively easy operation. When assembling the engine, it is important to remember the engine rotation. Then, working from the crankshaft gear to the idler gear and to the camshaft gear and balance shaft gear in that order, line up the appropriate circle symbols on the gears or the appropriate triangles as each gear assembly is installed on the engine. See figure 1, for a typical gear train timing arrangement. Refer to figure 5 in the General Information section for the various gear train arrangements. There are no timing marks on the governor drive gear and blower rotor gears. Therefore, it is not necessary to align these gears in any particular position when meshing the various gears with the camshaft gear or balance shaft gear. Gear train noise is usually an indication of excessive gear lash, chipped, pitted or burred gear teeth or excessive bearing wear; therefore, when noise develops in a gear train, the flywheel housing should be removed and the conponents of the gear train inspected. The backlash between the various mating gears in the gear train should be .003" to .005" except the blower rotor gears, which should be .0005" to .0025". Maximum permissible backlash between worn blower gears is .0035", and should not exceed .007" clearance between all other gears in the gear train.

Lubrication

The gear train is lubricated by the overflow of oil from the camshaft and balance shaft pockets spilling into the gear train compartment. A certain amount of the oil also spills into the gear train compartment from the camshaft and balance shaft end bearings, and the idler gear bearing.

Engine Timing

The correct relationship between the crankshaft and camshaft must be maintained to properly control fuel injection and the opening and closing of the exhaust valves. The crankshaft timing gear can he mounted in only one position since it is keyed to the crankshaft. The camshaft gear can also be mounted in only one position due to the location of the keyway relative to the cams. Therefore, when the engine is properly timed, the markings on the various gears '" match as shown in figure 1. Pre-ignition eneven running and a loss of power may result if an engine is "out of time". When an engine is suspected of being out of time, due to an improperly assembled gear train, a quick check can he made without -removing the flywheel and flywheel housing by following the procedure outlined below.

Check Engine Timing

Access to the crankshaft pulley, to mark the top dead center position of the selected piston, and to the front end of the crankshaft or flywheel, for turning the crankshaft, is necessary when performing the timing check. Then, proceed as follows:

1. Remove the valve rocker cover.
2. Select any cylinder for the timing check.
3. Remove the injector as outlined in section 2.1.
4. Carefully slide a rod, approximately 12" long, through the injector tube until one end of the rod rests on top of the piston. Place the throttle in the NO-FUEL position; then, turn the crankshaft slowly in the direction of rotation. Stop when the rod reaches the end of its upward travel. Remove the rod and turn the crankshaft, opposite the direction of engine roation, between 1 / 16 and 1 / 8 of a turn.
5. Select a dial indicator with .001" graduations and a spindle movement of at least one inch. Provide an extension for the indicator spindle. The extension must be long enough to contact the piston just before it reaches the end of its upward stroke. Also, select suitable mounting attachments for the indicator so it can be mounted over the injector tube in the cylinder head.
6. Mount the indicator over the injector tube. Check to he sure the indicator spindle extension is free in the injector tube and is free to travel at least one inch.
7. Attach a suitable pointer to the engine lower front cover. The outer end of the pointer should extend out over the top of the crankshaft pulley.
8. Turn the crankshaft slowly, in the direction of engine rotation until the indicator hand just stops moving.
9. Continue to turn the crankshaft, in the direction of rotation, until the indicator starts to move again. Now set the indicator on zero and continue to turn the crankshaft until the indicator reading is .010".
10. Scribe a line on the crankshaft pulley in line with the end of the pointer.
11. Slowly turn the crankshaft, opposite the direction of rotation, until the indicator hand stops moving.
12. Continue to turn the crankshaft, opposite the direction of rotation, until the indicator starts to move again. Now set the indicator of zero and continue to turn the crankshaft until the indicator reading is .010".
13. Scribe the second line on the crankshaft pulley in line with the end of the pointer.

..14. Scribe the third line on the pulley half way between the first two lines. This is top dead center.

NOTE

If the crankshaft pulley retaining bolt loosened up, tighten it to the torque specified in section 1.3.7.

15. Remove the dial indicator and rod from the engine.

16. Install the injector as outlined in section 2.1. Then refer to section 14 and adjust the exhaust valve clearance and time the fuel injector.

17. Turn the crankshaft, in the direction of rotation, until the exhuast valves in the cylinder selected are completely open. Reinstall the dial indicator so the indicator spindle rests on the top of the injector follower. Then, set the indicator on zero. Next turn the crankshaft slowly, in the direction of rotation, until the center mark on the pulley is in line with the pointer.

18. Check the front end of the camshaft for an identification mark. For identification purposes, a letter "V" is stamped on each end of a low velocity camshaft. Note the indicator reading and compare it with the dimensions listed below.

LOW VELOCITY CAMSHAFT

If the indicator reading is .204" to .207", the engine is in time.

If the indicator reading is .177" to .180", the timing is retarded one tooth.

If the indicator reading is .234" to .237", the timing is advanced one tooth.

19. Remove the dial indicator; also remove the pointer attached to the front of the engine.

20. Install the valve rocker cover.

CAMSHAFT AND BALANCE SHAFT GEARS

The camshaft and balance shaft gears on an In-line engine are located at the flywheel end of the engine, and mesh with each other and run at the same speed as the crankshaft; see figure 1, section 1.7.2. Since the camshaft and balance shaft gears on In-line engines must be in time with each other, timing marks are stamped on the rim of both gears. Also, since these two gears as a unit, must be in time with the crankshaft, timing marks are located on the idler and crankshaft gears. See figure 1, section 1.7.2. The camshaft and balance shaft gears are keyed to their respective shafts and held securely against the shoulder on the shaft by a nut. A gear nut retainer, with a double hexagon hole in the center, fits over the nut, and prevents loosening of the nut. The retainer is attached to the gear by bolts threaded into tapped holes in the gear. External weights are attached to the rear face of each gear. The weights are important in maintaining perfect engine balance. When new gears are used the external weights on the old gears must be transferred to the new gears. If the weights are transferred to new gears, tighten the bolts to 45-50 lb-ft torque.

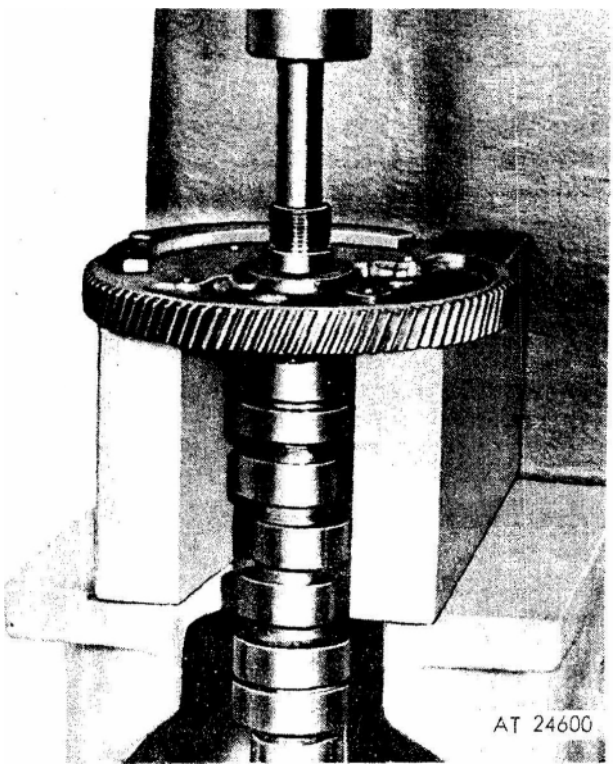


Figure 1. Removing camshaft gear.

Remove Camshaft and Balance Shaft Gears

1. Remove the camshaft and the balance shaft from the *engine* as outlined in section 1.7.

2. Place the camshaft and gear assembly in an arbor press with the gear suitably supported, as shown in figure 1.

3. Lay a wood block under the lower end of the camshaft so the threads will not be damaged when the shaft is pressed from the gear.

4. Place a short piece of 3/4" O.D. brass rod between the end of the camshaft and the ram of the press; then force the camshaft out of the camshaft gear.

5. Remove the thrust washer, Woodruff key, and spacer from the camshaft.

6. Remove the gear from the balance shaft in a similar manner.

Inspection

Clean the gears with fuel oil and dry them with compressed air. Then examine the gear teeth for evidence of scoring, pitting and wear. Replace the gears if necessary. Examine both faces of the camshaft and balance shaft thrust washer, if either face is worn or scored, replace with a new thrust washer. Also examine surface on camshaft and balance shaft which trust washer contacts. If this surface is scratched, but not severely scored, it may be smoothed up with a fine oil stone.

Install Camshaft and Balance Shaft Gears

1. Note the letters stamped on the end of the camshaft which signify the engine models in which a camshaft may be used. The letters on the timing gear end of the camshaft must correspond with the engine model of the particular engine being assembled. Refer to figures 5 and 6 in the front of this manual for engine model identification.

2. Place the rear camshaft spacer over the timing gear end of camshaft and install the woodruff key.

3. Lubricate the thrust washer with clean engine oil and place the thrust washer over the gear end of the camshaft and the spacer.

4. Start the camshaft gear over the end Of the camshaft with the key in the shaft registering with the keyway in the gear.

5. Then, with the camshaft supported in an arbor press, place a sleeve on top of the gear and under the ram of the press. Bring the ram of the press down on the sleeve and press the gear tight against the spacer on the shaft (fig. 2).

6. Measure the clearance between the camshaft thrust washer and the camshaft. This clearance should he from .008" to .015" when new parts are used. With used parts, a maximum clearance of .021" is allowable.

7. Install the gear retaining nut on the camshaft

[1].7.3 CAMSHAFT AND BALANCE SHAFT GEARS

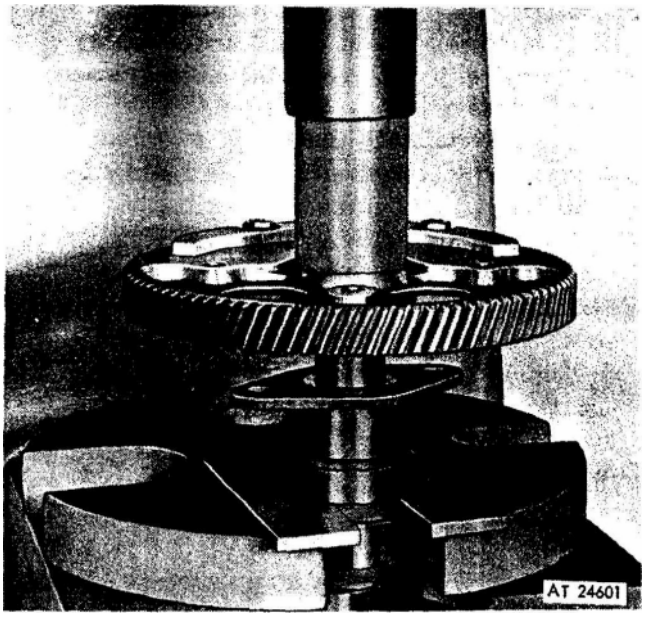


Figure 2. Installing camshaft gear.

by hand. Tighten the nut after the shaft is installed in the cylinder block.

8. Install the gear on the balance shaft in a similar manner. No rear spacer is used with the balance shaft gear, *since* the gear seats against a shoulder on the shaft.

9. Install the camshaft and balance shaft in the engine as outlined in section 1.7.

IDLER GEAR AND BEARING ASSEMBLY

The engine idler gear and bearing assembly, located at the flywheel end of the engine, meshes with the camshaft and crankshaft gears, and rotates on a stationary hub. The hub is secured directly to the cylinder block by a bolt which *passes.* through the hub (fig. 1), and three bolts which pass through the flywheel housing, hub and end plate. Two timing marks are stamped on the idler gear, a triangle symbol stamped within the circle symbol, and appears in two places on the gear diametrically opposite (180^0) to one another. The standard inside diameter of the idler gear bearing is 2.186"-2.187" and the standard outside diameter of the idler gear 'hub is 2.1825"-2.1835"; thus, the standard clearance between the idler gear hub and idler gear bearing is .0025"-.0045" with a maximum allowable wear limit of .007".

A thrust washer is provided on both sides of the idler gear and bearing assembly. The standard thickness of the idler gear and bearing assembly is 1.233"-1.234" and the standard thickness of the two thrust washers is .236"-.240"; thus, the standard clearance between the thrust washer and idler gear is .006"-.013" with a maximum allowable wear limit of .017". The idler gear is positioned on the left-hand side for the right-hand rotating engines; as viewed from the gear train end of the engine. See figure 5 under General Description. A dummy hub is cast into the flywheel housing. A shim is used between the dummy hub and the rear end plate.

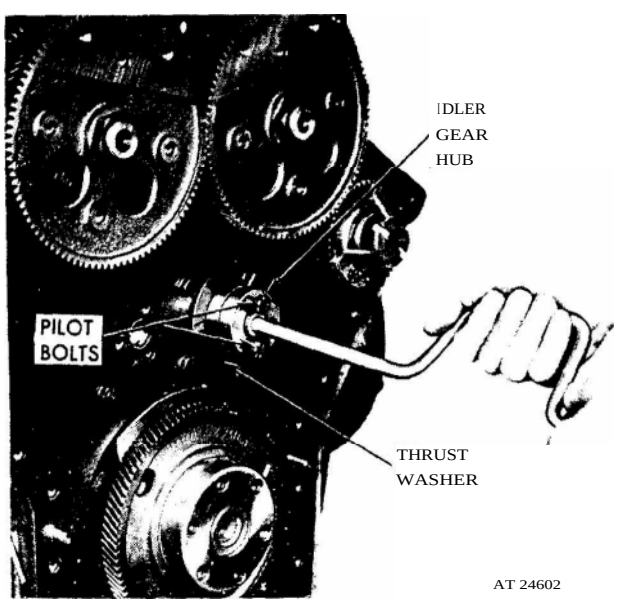


Figure 1. Installing idler gear hub.

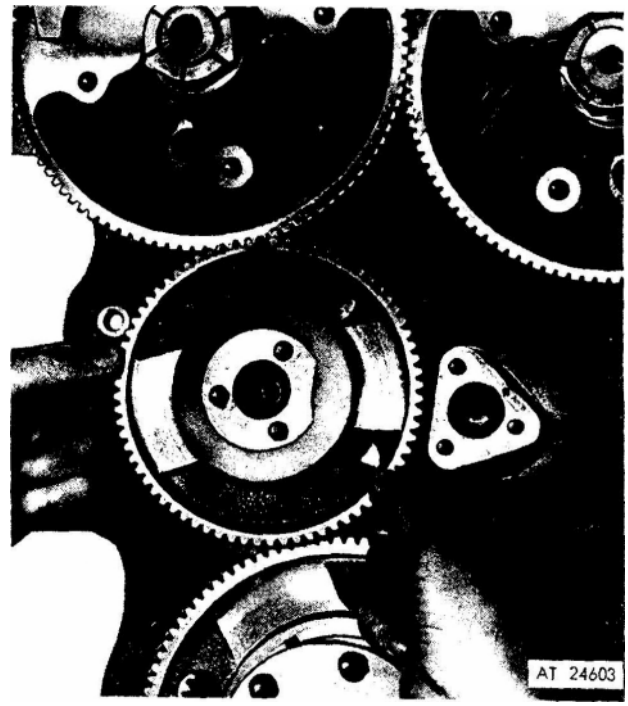


Figure 2. Installing idler gear.

Remove Idler Gear and Bearing Assembly, Hub and Thrust Washers
(Flywheel Housing Removed)

1. Remove the idler gear outer thrust washer from the idler gear hub (fig. 3).
2. Slide the idler gear straight back off of the idler gear hub.
3. Remove the bolt which secures the idler gear hub to the cylinder block. Then, remove the idler gear hub and the idler gear inner thrust washer an an assembly from the engine.

Inspection

Wash the idler gear and bearing assembly, hub and thrust washers thoroughly in clean fuel oil and dry them with compressed air. Examine the gear teeth and hearing for scoring, pitting and wear. If the gear teeth are worn or the bearing is scored, pitted or worn excessively, the gear and bearing assembly must be replaced, or a new bearing installed in the gear. Examine the outside diameter of the idler gear hub and the thrust washers; if scored or worn excessively, they must be replaced. When a new bearing is being installed in the idler gear, it must not protrude beyond the gear face on either side.

1.7.4 IDLER GEAR AND BEARING ASSEMBLY

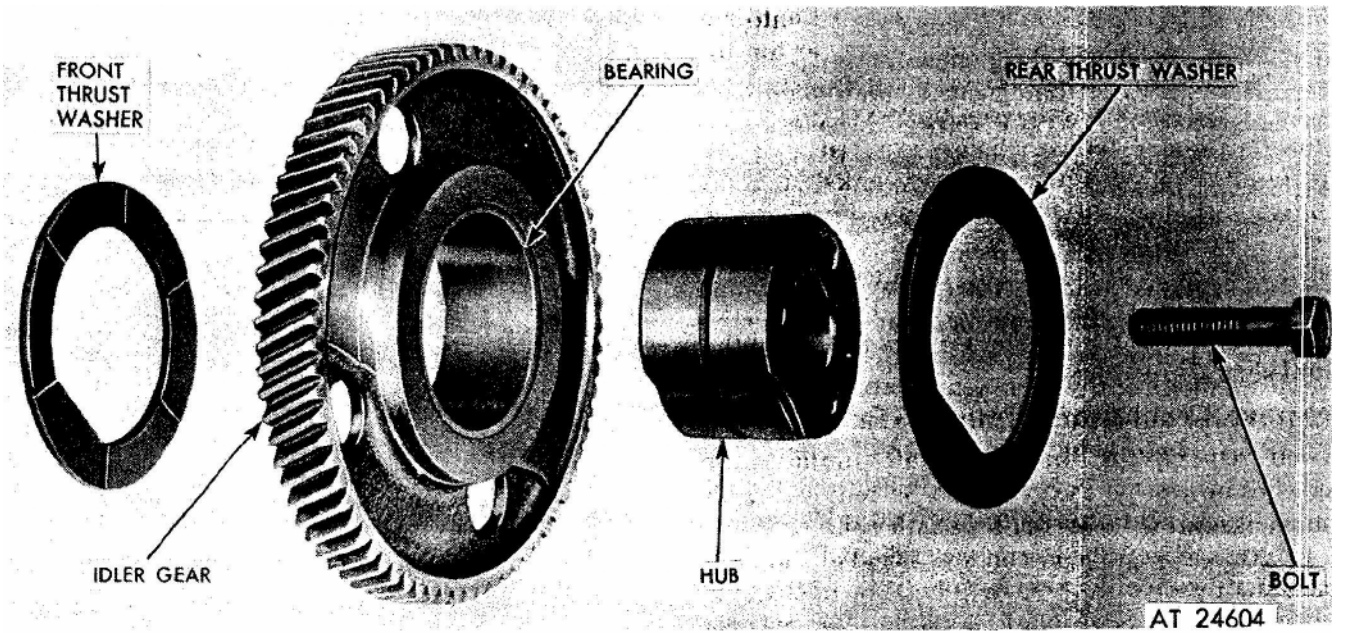


Figure 3. Idler gear details and relative location of parts.

Install Idler Gear and Bearing Assembly, Hub and Thrust Washers

I. Place the inner thrust washer on the forward end of the idler gear hub with the flat in the inner diameter of the thrust washer over the flat on the end of the gear hub, and with the oil grooves in the thrust washer facing the idler gear.

2. Place the small protruding end of the idler gear hub through the end plate and into the counterbore in the cylinder block.

3. Insert two 3/4"-16 bolts throught the idler gear hub and thread them into the cylinder block, as shown in figure 1, to be sure the bolt holes will be in alignment when the flywheel housing is installed.

4. Insert the ⅜"-16 x 13/4" spec the *center* of the idler gear bd. thread it into the cylinder block. Tighten bolt to 46-45 lb-ft torque. Then, remove the ⅜"-16 bolts previously installed for alignment of the gear hub.

5. Lubricate the idler gear hub and idler gear bearings liberally with clean engine oil.

6. Position the crankshaft gear and balance shaft gear so that their timing marks will align with those On the idler gear, see figure 1 in section 1.7.2.

7. With these timing marks in alignment , install the idler gear as shown in figure 2.

8. Apply a thin film of cup grease to the inner face (face with oil grooves) of the idler gear outer thrust washer. Then, place the thrust washer over the end of the idler gear hub with the oil grooves in the side of the thrust washer facing the idler gear,- and the fiat in the inner diameter of the thrust washer over the flat on the end of the idler gear hub.

9. Check the backlash between the mating gears. backlash should be .003" to .005" between new gears and should not exceed .007" between used gears.

CRANKSHAFT TIMING GEAR

The crankshaft gear is keyed and pressed onto the cran kshaft and drives the balance shaft gear (on In-line engines) through an idler gear. (See figures 5 and 6 under General Description.) Since the camshaft and balance shaft gears (on In-line engine) must be in time with the crankshaft gear, timing marks are located on the rim of the idler gear with corresponding *marks* stamped on the crankshaft gear, camshaft and balance shaft gears, as shown *in* figure 1, section 1.7.2. Timing marks IROVL and IR△VR are stamped on the rim of the crankshaft gear.

Remove Crankshaft Timing Gear

When removal of the crankshaft timing gear becomes necessary, the gear may be removed with the crankshaft in or out of the cylinder block.

1. Attach bar type puller J 4871 to the crankshaft gear with three long bolts or hooks, flat washers and nuts through holes in the gear as shown in figure 1.
2. Turn the center screw of the puller, and pull the crankshaft gear off the crankshaft.

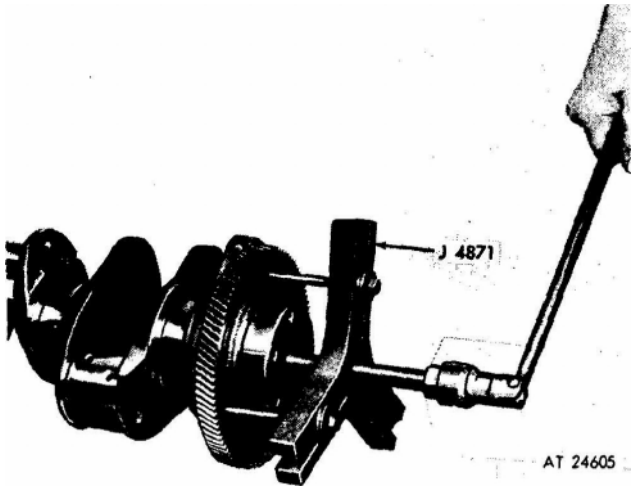


Figure 1. Removing crankshaft timing gear.

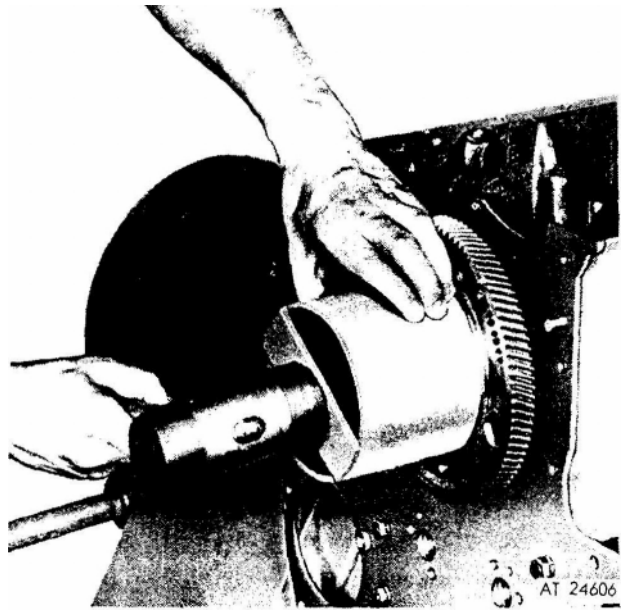


Figure 2. Installing crankshaft timing gear.

Inspection

Wash the gear in clean fuel oil and inspect the teeth for wear, pitting or scoring. Replace the gear if worn or damaged.

Install Crankshaft Timing Gear

1. If removed, install the woodruff key in the keyway in the crankshaft.
2. Start the timing gear over the end of the crankshaft with the timing marks on the outer rim of the gear facing out, and the keyway in the gear in alignment with the woodruff key in the crankshaft.
3. Place a heavy hammer against the head of the bolt in the front end of the crankshaft. Place installer J 7557 against the rear face of the timing gear, then using a heavy hammer drive the gear up against the shoulder of the crankshaft, as shown in figure 2.

UPPER ENGINE FRONT COVER

The upper engine front cover is mounted against the cylinder block at the front upper end of the *engine.* The camshaft and balance shaft oil seals (in-line engine) are pressed into the cover.

Remove Engine Front Cover (Upper)

When necessary, the oil seals may be removed without removing the upper front cover. This may be done by drilling diametrically opposite holes in the seal casing and threading metal screws, backed by flat washers, into the casing. Then the seal may he removed by pr y ing against the washers with pry bars.

Install the new seals with installer J 9790.

1. Remove the various parts and subassemblies from the engine upper front cover as outlined in their respective sections of this manual.
2. Remove the pulleys front the front end of the camshaft and balance shaft (in-line engine). Refer to section 1.7.1.
3. Remove the tipper front cover to cylinder block attaching bolts.
4. Tap the upper front cover and dowel pin assembly away front the cylinder block.
5. Remove the woodruff keys and oil seal spacers from the shafts.
6. Remove all traces of the old gasket from the cylinder block and cover.

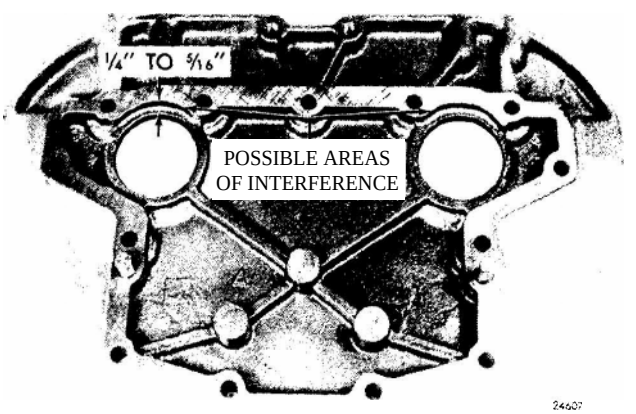


Figure 1. In-line engine upper front cover.

Inspection

Check the oil seals and the spacers for wear or (haulage, replace them if necessary.

Remove Oil Seals

I. Support the inner face of the cover on wood blocks at least one inch thick to protect the dowel pins in the cover.

2. Then, drive the oil seals out of the cover.

Install Oil Seals

1. Support the inner face of the cover on wood blocks.
2. If the outside diameter of the oil seal is not pre-coated with sealant, coat the bore in the cover with non-hardening sealant.
3. Positon an oil seal in the cover with the lip of the seal pointing toward the inner face of the cover.

CAUT ION

Keep the lip of the oil seal clean and free from scratches.

4. Press the oil seal into the cover with installer J 9 790 until the seal is flush with the bottom of the counterbore.
5. Install the second oil seal in the same manner.
6. Remove excess sealant from the cover and the seals.

Install Engine Front Cover (Upper)

1. Affix a new gasket to the cover.
2. Install the cover on the engine and secure it with bolts and lock washers. Tighten the bolts to 35 lb-ft torque.
3. Apply cut grease to the outside diameter of the oil seal spacers; then, slide them on the shafts.

NOTE

Engines use an oil slinger betweent the oil seal spacer and the shoulder on the camshaft, and betweent the spacer and the end bearing on the balance shaft (in-line engine). Addition of the oil slinger improves sealing by reducing the amount of oil in the area of the oil seals.

4. Install a woodruff key in each shaft.
5. Install the pulleys on the shafts.
6. Install and tighten the pulley retaining nuts to 300-325 lb-ft torque.

SPECIFICATIONS-SERVICE TOOLS

SPECIFICATIONS

Table of Specifications, New Clearances, and Wear Limits

Engine part (standard size)	New parts Minimum	New parts Maximum	Wear Limits
CAMSHAFT			
Shaft Diameter At Bearings	2.1820"	2.1825"	
Runout at Center Bearing (When mounted on End Bearings)		.002"	
Thrust Washer Thickness	.208"	.210"	
End Thrust	.008"	.015"	.019"
BALANCE SHAFT			
Shaft Diameter At Bearings	2.1820"	2.1825"	
Thrust Washer, Thickness	.208"	.210"	
End Thrust	.008"	.015"	.019"
CAMSHAFT AND BALANCE SHAFT BEARINGS			
Bearing Inside Diameter	2.187"	2.188"	
Clearance-Bearings-to-Shaft	.0045"	.006"	.008"
CAMSHAFT AND BALANCE SHAFT GEARS			
Backlash	.003"	.005"	.007"
IDLER GEAR			
Backlash	.003"	.005"	.007"
Idler Gear Bearing Inside Diameter	2.186"	2.187"	
Idler Gear Hub Outside Diameter	2 1825"	2.1835"	
Clearance-Bearing-to-Hub	0025"	.0045"	.007"
Thrust Washer Thickness	118"	.120"	
End Play	006-	.013"	.017"
CRANKSHAFT TIMING GEAR			
Backlash	003"	.005"	.007"
BLOWER DRIVE GEAR			
Backlash	.003"	:005"	.007"
Blower Drive Gear Shaft End Play	.004"	.006"	
GOVERNOR DRIVE GEAR			
Backlash	003"	.005"	.007"

Standard Bolt and Nut Torque Specifications

Size nut or bolt	Torque (lb ft)	Size nut or bolt	Torque (lb-ft	Size nut or bolt	Torque (lb-ft
1/ 4 - 20	7-9	7 / 16 - 20	57-61	3 / 4 - 10	240-250
1 / 4 - 28	8-10	1 /2 - 13	71-75	3 / 4 - 16	290-300
5/ 16 - 18	13-17	1 /2 - 20	83-93	7/8 - 9	410-420
5 / 16 - 24	15-19	9 /16 - 12	90-100	7 / 8 - 14	475-485
3/ 8 - 16	30-35	9 / 16 - 18	107-117	1 - 8	580-590
3/ 8 - 24	35-39	5 / 8 - 11	137-147	1 - 14	685-695
7/ 16 - 14	120-130	5 /8 - 18	168-178		

,E TOOLS

Exceptions to Standard Bolt and Nut Torque Specifications

Application	Size nut or bolt	Torque (lb-ft)
Camshaft and Balance Shaft Nuts	1-1 / 8-18	300-325
Crankshaft End Bolt	3 /4-16	200-220

Service Tools

Tool	Name
J 4871	Bar Type Puller
J 7557	Crankshaft Timing Gear Installer
J 7593-03	Camshaft and Balance Shaft Bearing Remover and Installer **Set**
J 7593-1	Shaft
J 7593-2	Pilot
J 7593-3	Installer
J 7593-4	"C" Washer
J 7593-5	Remover
J 7593-6	Installer
J 7593-10	Spacer
J 7593-11	Spacer (Short)
J 7593-12	Sup port
J 7593-15	Installer
J 6471-1	Slide Hammer
J 8183	Adapter
J 9790	Installer
J 8129	Spring Scale

SECTION 2

FUEL SYSTEM AND GOVERNORS

CONTENTS

FUEL SYSTEM

The fuel system consists of the fuel strainer, fuel pump, fuel filter, fuel lines and injectors, as shown in figures 1 and 2.

A restricted fitting is located in the cylinder head fuel return manifold outlet to maintain pressure within the fuel system.

Operation

The fuel pump draws fuel from the tank through the strainer, and forces it under pressure through the filter. From the filter, the fuel is forced through the fuel inlet passage in the cylinder head and fuel lines to the injectors.

The fuel passes through a filter element within the injector to a chamber where it is metered, displaced, and atomized through the spray tip into the combustion chamber. Heat generated during the high compression of the air ignites the fine fuel spray and combustion continues until the fuel is burned. Fuel in excess of that required for engine operation is circulated through the injectors by the fuel pump and serves as a coolant. In addition to serving as a coolant, circulation of the surplus fuel bleeds any air or vapor in the system back to the fuel tank where it is vented to the atmosphere. Surplus fuel leaving the injectors flows through the outlet fuel line to the fuel return passage and then through a restricted fitting and a tube back to the fuel tank.

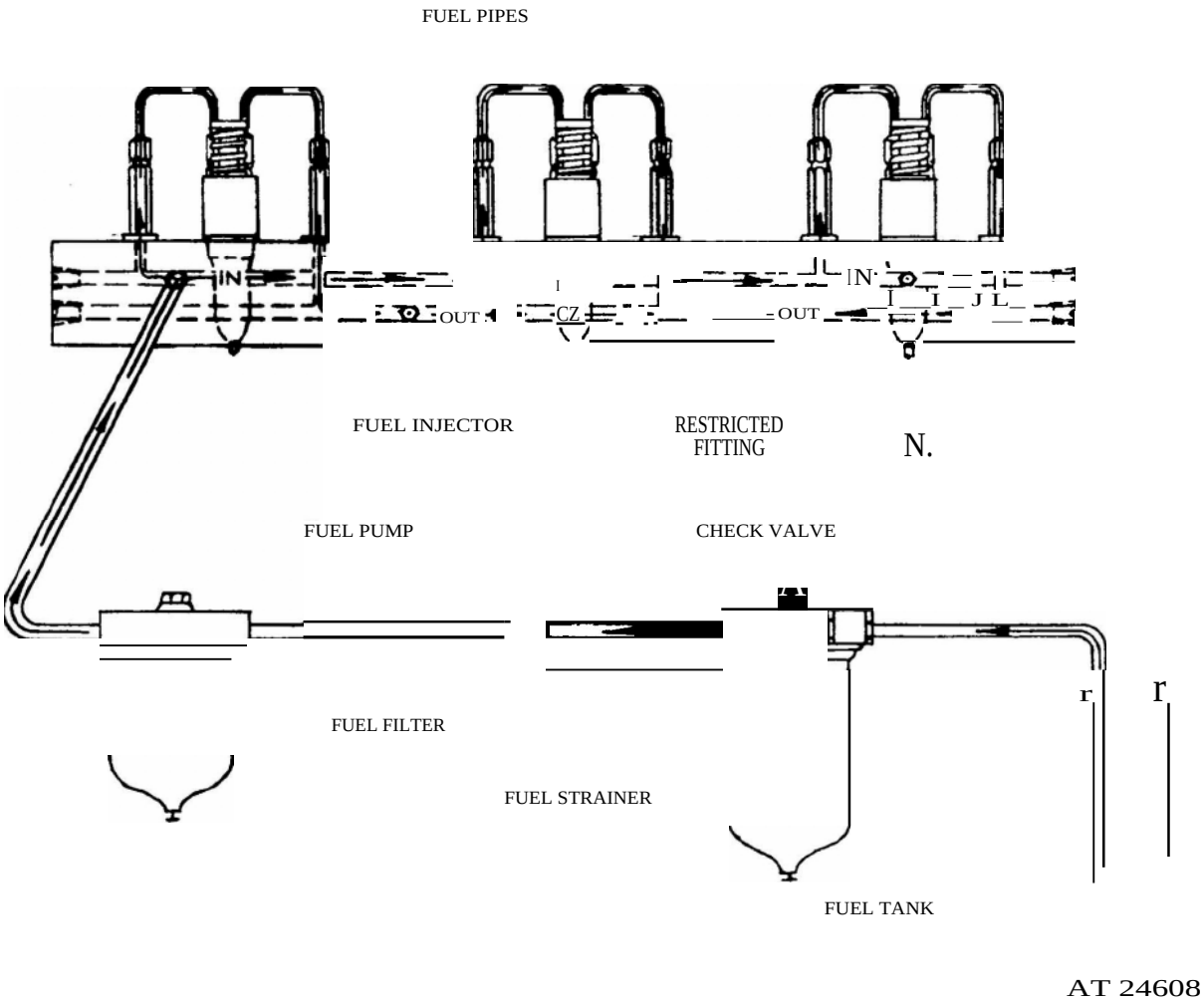


Figure 1. Typical fuel system for in-line engines.

FUEL INJECTOR (NEEDLE VALVE)

The unit fuel injector illustrated in figure 1, is a lightweight compact unit which enables quick easy starting directly on diesel fuel and permits the use of a simple open type combustion chamber. The simplicity of design and operation provides for simplified controls and easy adjustment. No high pressure fuel lines or complicated air-fuel mixing or vaporizing devices are required.

The unit fuel injector performs four functions:

1. Creates the high fuel pressure required for efficient injection.
2. Meters and injects the fuel to the exact amount required to handle the load.
3. Atomizes the fuel for mixing with the air in the combustion chamber.
4. Permits continuous fuel flow.

Combustion required for satisfactory engine operation is obtained by injecting, under pressure, a small quantity of accurately metered and finely atomized fuel oil into the cylinder. Metering of the fuel is accomplished by an upper and lower helix machined in the lower end of the injector plunger. Figure 2 illustrates the fuel metering from NO LOAD to FULL LOAD by rotation of the plunger in the hushing. Figure 3 illustrates the phases of injector operation by the vertical travel of the injector plunger. The continuous fuel flow through the injector serves, in addition to preventing air pockets in the fuel system, as a coolant for those injector parts subjected to high combustion temperatures.

To vary the power output of the engine, injectors having different fuel output capacities are used. The fuel output of the various injectors is governed by the helix angle of the plunger and the type of spray tip used. Refer to figure 4 for the identification of the injectors and their respective plungers and spray tips. Since the helix angle on the plunger determines the output and operating characteristics of a particular type of injector, it is imperative that the correct injectors are used for each engine application. If injectors of different types are mixed, erratic operation will result and may cause serious damage to the engine or to the equipment which it powers. Both the plunger and bushing are marked with corresponding numbers to identify them as mating parts. Therefore, if either the plunger or bushing requires replacement, both must be replaced as an assembly. Each fuel injector has a circular disc pressed into a recess at the front side of the injector body for identification purposes (fi. 41. The identification tag indicates the nominal output of the injector in cubic millimeters. A horizontal bar on the injector identification tag

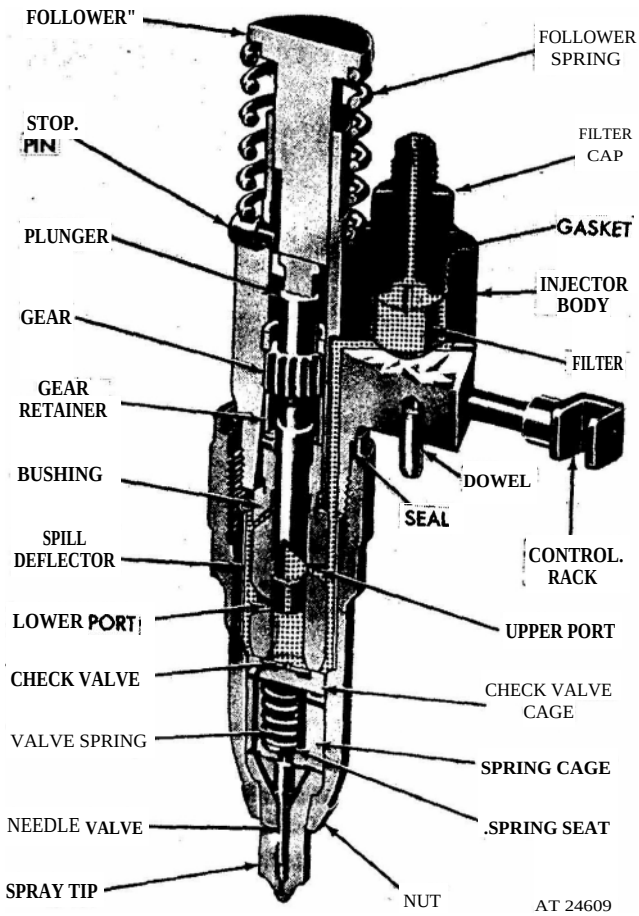


Figure I. Fuel injector assembly.

between the "GM" and the injector size identifies the needle valve injector. Each injector control rack (fig. 11 is actuated by a lever on the injector control tube which, in turn, is connected to the governor by means of a fuel rod. These levers can be adjusted independently on the control tube, thus permitting a uniform setting of all injector racks.

The fuel injector combines in a single unit all the parts necessary to provide complete and independent fuel injection at each cylinder.

Operation

Fuel, wider pressure, enters the injector at the inlet side through a filter cap and filter element, (fig. 1). From the filter element, the fuel passes through a drilled passage into the supply chamber, that area between the plunger bushing and the spill deflector, in addition to that area under the injector plunger within the hushing. The plunger operates up and down in the bushing, the bore of which is open to the fuel supply in the annular chamber by two funnel-shaped ports in the plunger bushing. The

2.1.1 FUEL INJECTOR

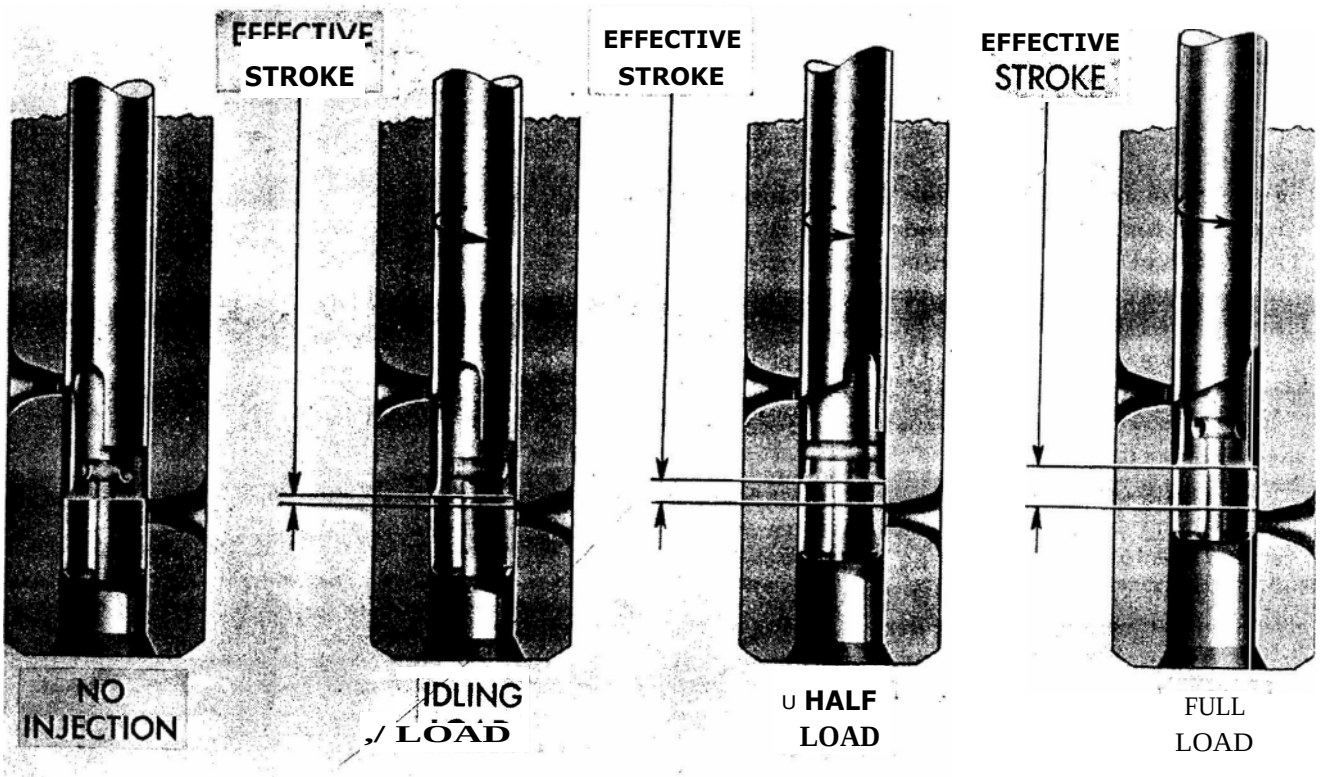


Figure 2. Fuel metering from no-load to full load

motion of the injector rocker arm is transmitted to the plunger by the follower which beats against the follower spring, (fig. 5). In addition to the reciprocating motion, the plunger can be rotated, during operation, around its axis by the gear which meshes with the rack. For metering the fuel, an upper helix and a lower helix are machined in the lower part of the plunger. The relation of the helices to the two ports changes with the rotation of the plunger. Ad the plunger moves downward, under pressure of the injector rocker arm, a portion of that fuel trapped under the plunger is displaced into the supply chamber through the lower port until the port is closed off by the lower end of the plunger. A portion of the fuel trapped below the plunger is then forced up through a central passage in the plunger into the recess and into the supply chamber through the upper port until that port is closed off by the upper helix of the plunger. With the upper and lower ports both closed off, the remaining fuel under the plunger is subjected to increased pressure by the continued downward movement of the plunger. When sufficient pressure is built up, it opens the flat, non-return, check valve. The fuel in the check valve cage and spring cage passages, tip passages and tip fuel cavity is compressed until the pressure force acting upward on the needle valve is sufficient to open the valve against the downward force of the valve spring. As soon as the needle valve lifts off its seat, the fuel is forced through the small orifices in the spray tip and atomized into the combustion chamber. When the lower land of the plunger uncovers the lower port in the bushing, the fuel pressure below the plunger is relieved, and the valve spring closes the needle valve, ending injection.

A pressure relief passage has been provided in the spring cage to permit bleed off of fuel leaking past the needle pilot in the tip assembly. A check valve, directly below the bushing, prevents leakage from the combustion chamber into the fuel injector in case the valve is accidentally held open by a small particle of dirt. The injector plunger is then returned to its original position by the injector follower spring. Figure 3 shows the various phases of injector operation by the vertical travel of the injector plunger. On the return upward movement of the plunger, the high pressure cylinder within the bushing is again filled with fuel oil through the ports. The constant circulation of fresh cool fuel through the injector renews the fuel supply in the chamber, helps cool the injector and, also, effectively removes all traces of air which might otherwise accumulate in the system and interfere with accurate metering of the fuel. The fuel injector outlet opening, through which the excess fuel oil

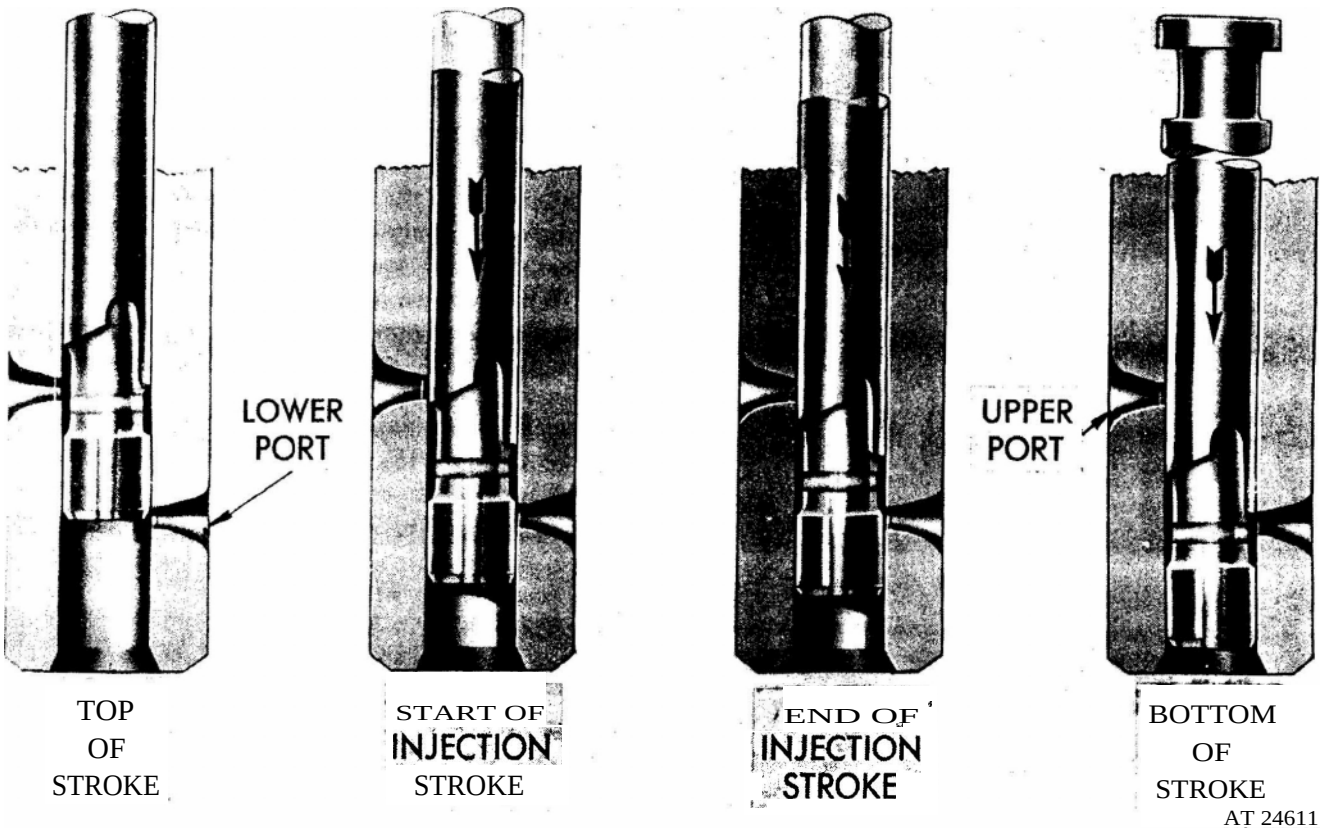


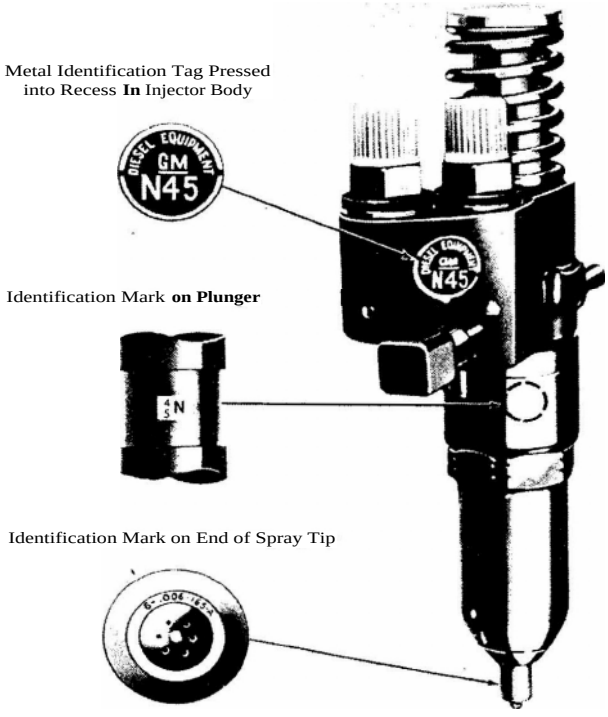
Figure 3. Phases of injector operation through vertical travel of plunger.

returns to the fuel return passage and then back to the fuel tank, is adjacent to the inlet opening and contains a filter element exactly the same as the one on the fuel inlet side. Changing the position of the helices, by rotating the plunger, retards or advances the dosing of the ports and the beginning and ending of the injection period. At the same time, it increases or decreases the amount of juel injected into the cylinder. Figure 2 shows the various plunger positions from NO-LOAD to FULL-LOAD. With the control rack pulled out all the way (no injection), the upper port is not closed by the helix until after the lower port is uncovered. Consequently, with the rack in this position, all of the fuel is forced back into the supply chamber and no injection of fuel takes place. With the control rack pushed in (full injection), the upper port is closed shortly after the lower port has been covered, thus producing a maximum effective stroke and maximum injection. From this no injection position to full injection position (full rack movement), the contour of the upper helix advances the closing of the ports and the beginning of injection.

General Instructions For Injector Care and Overhaul

The unit fuel injector is one of the most important and precisely built parts of the engine. On this unit depends the injection of the correct amount of fuel at exactly the right time into the combustion chamber. Because the injector operates against high compression in the combustion chamber, efficient operation demands that injector assemblies be maintained in first-class condition at all times. Proper maintenance of the fuel system and the use of the recommended type fuel filters and clean water-free fuel are the keys to trouble-free operation of the injectors. Servicing an injector is not a difficult task and may be performed by the average service man. However, due to the close tolerances of various injector parts, extreme cleanliness and strict adherence to service instructions is required. Perform all injector repairs in a clean, well lighted room with a dust free atmosphere. An ideal injector room is slightly pressurized by means of an electric fan which draws air into the room through a filter.

2.1.1 FUEL INJECTOR



INJECTOR	FORMER SPRAY TIP	CURRENT SPRAY TIP	PLUNGER
140	8-.0055-165A	8-.0055-165A	4l
040	8-.0055-165A	6-.006 -1654	4N
045	8-.0055.1654	6-.006 -165A	5N
N50	8-.0055-165A	6-.006 -165A	5N
M65		6-.006 -165A	8N

' First numeral indicates number of spray holes, followed by sizes of holes and angle formed by sproy from holes. AT 24612

Figure 4. Injector identification chart.

This pressure will prevent particles of dirt and dust froth entering the room through doors and windows. A suitable air outlet will remove solvent fumes along- with the outgoing air. Also provide a source for 110 volt A.C. electric power. Provide the injector repair room with a supply of filtered, moisture-proof compressed air for drying injector parts after they have been cleaned. Use wash pans of rust-proof material deep enough to permit all injector parts to be completely covered by the leanins agent, usually clean fuel oil, when submerged in wire baskets of 16 mesh wire screen. *Use* baskets which will support the parts above the bottom of the pan to avoid contact with foreign material which settles at the bottom. Never use waste or rags for cleaning injector parts since this would leave lint and other particles which could collect and clog parts of the injector when it is assembled. A lint free cleaning tissue is a good, inexpensive material for wiping injector parts.

When servicing injectors, the following instructions should be carefully followed:

1. When the fuel pipes are removed from an injector, cover the filter caps with shipping caps to keep dirt out of the injector. Also, protect the fuel pipes and fuel connectors from entry of dirt or other foreign material.

2. After an injector has been operated in an engine, do not remove the filter caps or filters while the injector is in the engine. Filter elements should be replaced only at the ,time of complete disassembly and assembly of an injector.

3. Whenever an injector has been removed and reinstalled, or a new injector has been installed in an *engine,* make the following adjustments as outlined in section 14:

a Time the injector.

b. Position the injector rack control levers.

Whenever an engine is to be out of service for an extended period, purge the fuel system then fill it with a good grade of rust preventive in accordance with instructions in section 15.1.

5. When a reconditioned injector is to be placed in stock, it should be filled with injector test oil J 8130. Do not use fuel oil. Place the injector in an upright position to prevent test oil leakage. Install shipping caps on both filter caps immediately after filling.

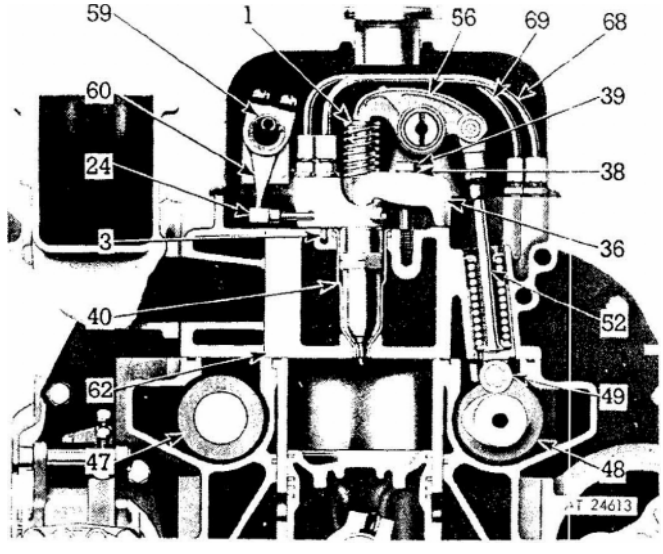


Figure 5. Fuel injector mounting.

1 Injector assembly
3 Pin—dowel
24 Rack-injector—control
36 Clamp—injector
38 Washer—clamp
39 Bolt—injector clamp
40 Tube—injector hole
47 Balance shaft
48 Camshaft
49 Cam follower assy.
52 Rod—push
56 Arm—injector rocker
59 Tube—injector control
60 Lever—rack control
62 Cylinder head
68 Pipe—fuel inlet 'supply)
69 Pipe—fuel outlet (return)

NOTE

Make sure that new filters have been installed in a reconditioned injector which is to he placed in stock. This precaution will prevent dirt particles from entering the injector due to a possible reversal of fuel flow when installing the injector in an engine other then the original unit.

Remove Injector

If it becomes necessary to remove one or more fuel injectors for inspection or replacement, follow the procedure given below:

1. Remove the valve rocker cover(s).
2. Remove the fuel pipes from both the injector and the fuel connectors. (fig. 5).

NOTE

Immediately after removal of the fuel pipes from an injector, cover the filter caps with shipping caps to prevent dirt from entering the injector. Also, protect the fuel pipes and fuel connectors from entry of dirt or foreign material.

3. Crank the engine with the starting motor to bring the push rod end — outer ends — of the injector and valve rocker arms in line horizontally.
4. Remove the two rocker shaft bracket bolts and swing the rocker arm assembly away from the injector and valves.
5. Loosen the injector clamp bolt and remove the bolt, special washer, and clamp.
6. Loosen the inner and outer adjusting screws of the injector rack control lever and slide the lever away from the injector.
7. Free the injector from its seat and lift it from the cylinder head (fig. 6).
8. Cover the injector hole in the cylinder head to keep foreign particles out of the cylinder.
9. Clean the exterior of the injector with fuel oil and dry it with compressed air.

Test Injector

If inspection does not reveal any external damage, then perform a series of tests to determine the condition of the injector to avoid unnecessary overhauling. An injector that passes all of the tests outlined below may be considered to be satisfactory for service, other than the visual check of the plunger. However, an injector that fails to pass one or more of the tests is unsatisfactory and the faults should be corrected. Perform all of the test before disassembling of the injector to correct any one condition. Identify each injector and record the pressure drop and fuel output as indicated by the following tests:

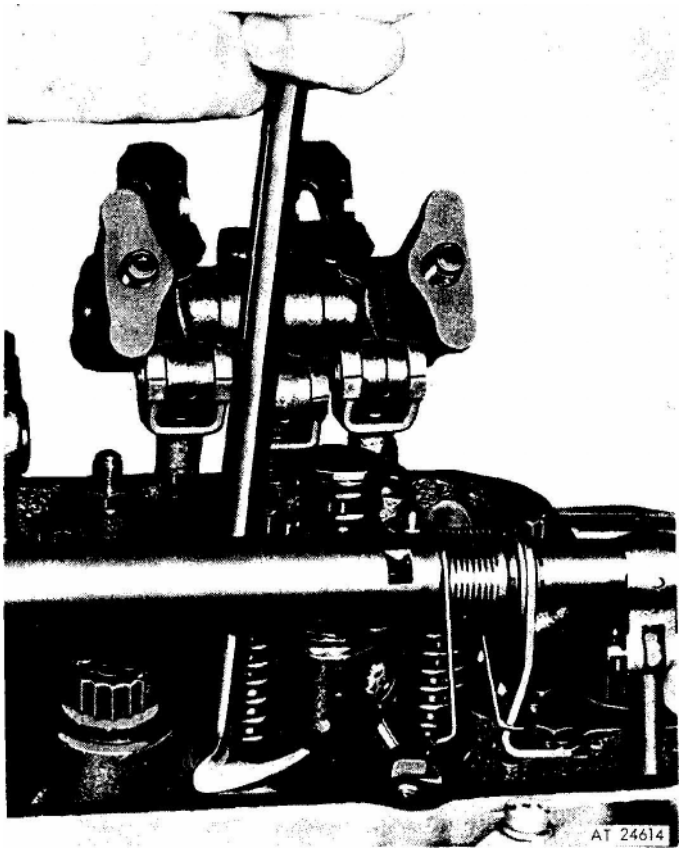


Figure 6. Removing injector from cylinder head.

INJECTOR CONTROL RACK AND PLUNGER MOVEMENT TEST

Place the injector in the injector fixture and rack freeness tester J 22396. Refer to figure 7 and place the handle on top of the injector follower. If necessary, adjust the contact screw in the handle to ensure the contract screw is at the center of follower when the follower spring is compressed. With the injector control rack held in the NO-FUEL position, push the handle down and depress the follower to the bottom of its stroke. Then, very slowly release the pressure on the handle while moving the control rack up and down as shown in figure 7, until the folio ver reaches the top of its travel. If the rack does not fall freely, loosen the injector nut. turn the "tip. then retighten the nut. Loosen and retighten the nut a couple of times if necessary. Then, if the rack isn't free, change the injector nut. Generally this will free the rack. In some cases it may be necessary to disassemble the injector to eliminate the cause of the misaligned parts.

INJECTOR HIGH PRESSURE TEST

This test is performed to discover any fuel leaks at the injector filter cap gaskets, body plugs and nut. seal ring. The high pressure test also indicates whether or not the plunger and hushing clearances are satisfactory.

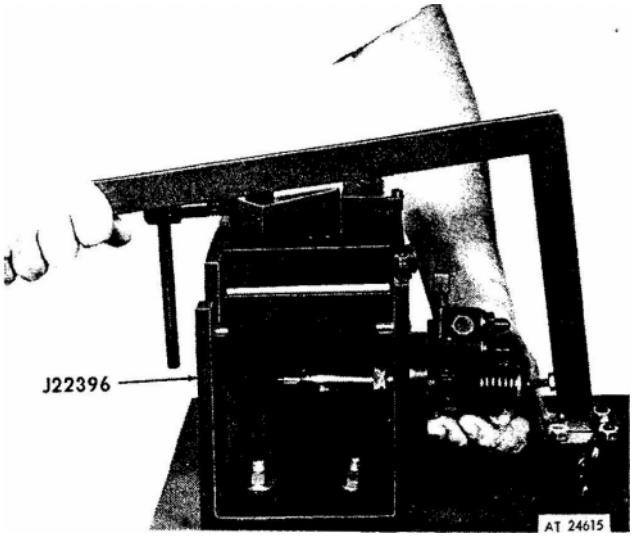


Figure 7. Checking rack and plunger for free movement.

1. install injector in tester J 9787.

CAUTION

When testing an injector just removed from an engine, the flow of fuel through the injector on the tester should be the same as in the engine. Connections on the test head of the tester may be changed to obtain the correct direction of flow.

2. Thoroughly dry the injector with compressed

3. Check the fuel connections for leaks. If leakage is noted, tighten the connections, dry the injector and recheck.

4. With the injector rack in the FULL-FUEL position and the injector tester handle locked in position by means of the handle lock (see fig. 8), operate the pump handle to build up and maintain the pressure.

Use the adjusting screw in the injector tester 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 the injector spray will decrease appreciably and a rise *in* pressure will occur. At this time, the condition of the plunger and bushing may be established. If there is excessive clearance between the plunger and bushing, pressure beyond the normal valve opening pressure cannot lie obtained. Replacement of the plunger and bushing assembly is then required. Pump up the injector tester J 9787 (fig. 8) and maintain a pressure of 1600 to 2000 psi by actuating the pump handle. Then, inspect for leaks at the injector filter cap gaskets, body plugs and injector nut seal ring.

If any of these conditions exist, refer to Trouble Shooting Chart 5 in section 2.1.0.

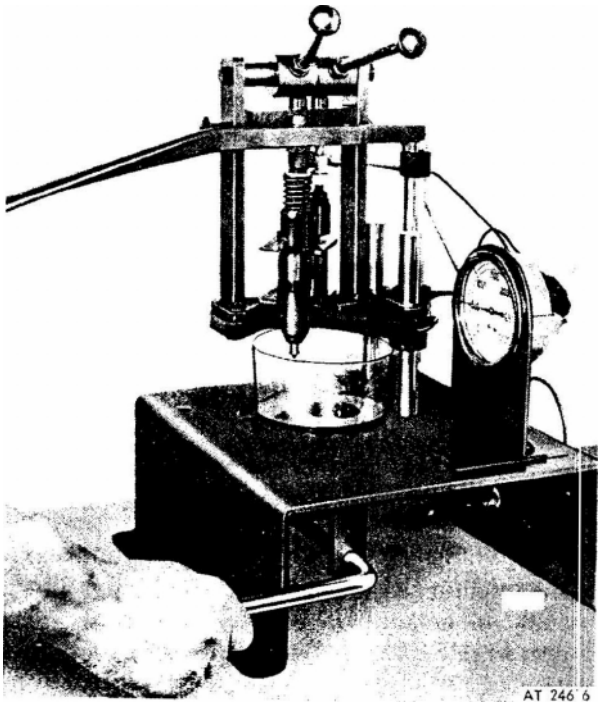


Figure 8. Injector high pressure test.

NOT E

It is normal for fuel to seep out around the rack hole due to high pressure fuel being applied to a normally low pressure area in the injector assembly. Fuel droplets at the rack indicate excessive leakage.

CAUTION

Do not permit the pressure in the injector tester to equal or exceed the capacity of the pressure gage.

INJECTOR HOLDING PRESSURE TEST

Operate the pump handle to bring the pressure up to approximately 450 psi. Close the fuel shut-off valve and note the pressure drop. The time for a pressure drop from 430 psi to 250 psi should not be less than 40 seconds.

If the injector pressure drops from 450 psi to 250 psi in less than 40 seconds, the injector must be checked for leaks as follows:

1. Thoroughly dry the injector with compressed air.

2. Open the tester fuel valve and operate the pump handle to maintain the testing pressure.

3. A leak around the spray tip or seal ring usually is caused by a loose injector nut, a damaged seal ring, or a brinelled surface on the injector nut or spray tip.

4. A leak at the filter cap indicates a loose filter cap or a damaged filter cap gasket.

5. A "dribble" at the spray tip orifices indicates leaking valve assembly due to a damaged surface or dirt.

Refer to Trouble Shooting Chart in section 2.LO.

SPRAY PATTERN TEST

After completing the valve holding pressure test, open the fuel shut-off valve, then place the injector rack in the FULL-FUEL position and operate the injector several times in succession by operating the tester handle at approximately 40 strokes per minute as shown in figure 9. Observe the spray pattern to see that all of the spray tip orifices are open and injecting evenly. The beginning and ending of injection should be sharp and the fuel injected should be finely atomized. If all the spray tip orifices are not open and injecting evenly, clean the orifices in the spray tip during injector overhaul. Also refer to Trouble Shooting Chart 6 in section 2.1.0.

CAUTION

To prevent damage to the pressure gage, do not exceed 250 psi during this test.

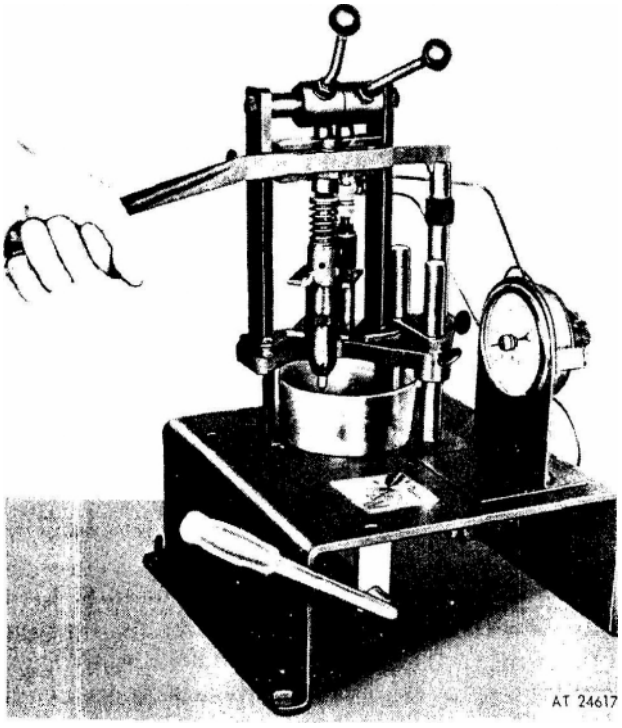


Figure 9. Spray pattern test.

VISUAL INSPECTION OF PLUNGER

An injector which passes all of the previous test 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 the plunger from the injector as follows:

1. Support the injector, right side up, in the holding fixture J 22396 (fig. 101.

2. Compress the follower spring; then using a screw driver, raise the spring above the stop pin and withdraw the pin. (fig. 10). Release the spring gradually.

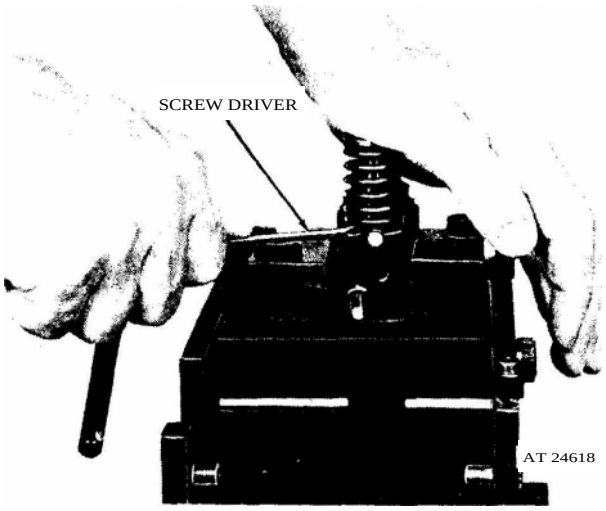
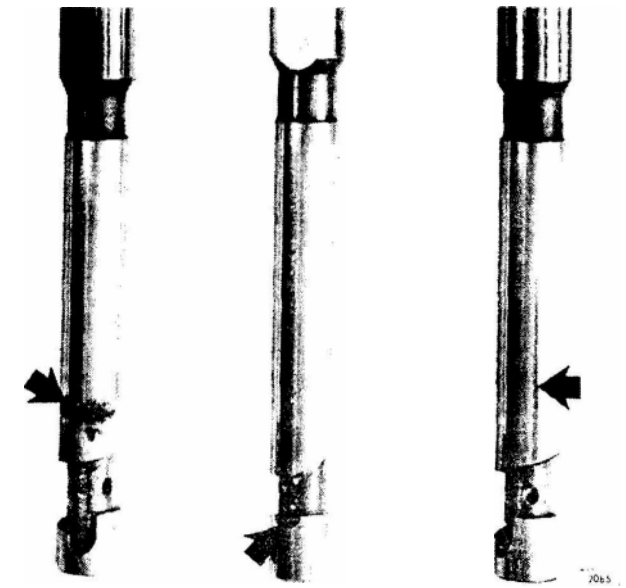


Figure 10. Removing injector follower stop pin.



Advanced stage of erosion caused by foreign matter in fuel due to improper filtration.

Chipped of lower helix.

The above condition can be caused by either lack of fuel or high speeds or water in fuel.

AT 24619

Figure 11. Unusable plungers.

3. Refer to figure 19 and lift the follower and plunger from the injector body as an assembly.

4. Inspect the plunger and, if the plunger is chipped (fig. 11), replace the plunger and bushing assembly.

5. If the plunger is in good condition, reinstall the plunger and follower as outlined under "Assemble Plunger and Follower"

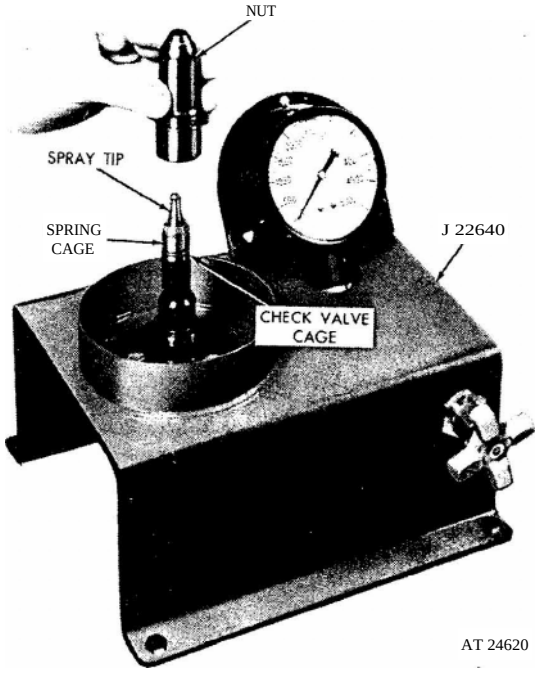


Figure 12. Installing injector valve parts on Auxiliary Tester J 22640.

NEEDLE VALVE TESTS

Remove the injector nut and remove all of the valve parts below the injector bushing as outlined under "Disassemble Injector . Clean all of the carbon off of the spray tip seats in the injector nut as outlined under "Clean Injector Parts". If the spray pattern test indicated that tip cleaning- is necessary, clean the carbon from the tip cavity below the needle valve and orifices as outlined under "Clean Injector Parts". With the injector nut and spray tip cleaned, assemble the check valve. check valve cage, spring, spring seat. spring cage. needle valve and tip assembly on auxiliary tester J 22640 (fig. 12). Carefully pilot the injector nut over the spray tip and valve parts and thread it on the body as shown in figure 12. 'lighten the injector nut to 75-85 lb-ft torque. Install the shield in the auxiliary tester as shown in figure 13 and operate the pump handle until the spray tip salve has opened several times to purge the air front the system. Operate the pump handle with smooth even strokes (40 strokes per minute) and note the pressure at which the needle valve opens. The valve should open between 2300 and 3300 psi. The opening and closing action should be sharp and produce a finely atomized spray. If the valve opening pressure is below 2300 psi' the cause is usually a worn or fatigued valve spring. Replace the spring. If the valve opening pressure is within 2300-3300 psi proceed to check for spray tip seat leakage. Actuate the pump handle several times, then hold the pressure at 1500 psi for 15 seconds by actuating the pump handle. Inspect the spray tip seat for leakage. There should be no fuel droplets although a slight wetting of the end of the valve tip is permissible.

If the spray tip seat is satisfactory, proceed to check the hold time for a pressure drop of from 1.500 to 1000 psi. The time should not be less than 5 seconds. If the valve pressure drops from 1500 to 1000 psi in less than 5 seconds, replace the needle valve and tip assembly. If the needle valve assembly passes the above test the needle valve lift check can be omitted.

To check the needle valve lift use tool J 9462-01 as shown in figure 14 as follows:

I. Zero the indicator by placing the bottom surface of the plunger assembly on a flat surface and zero the indicator dial.

2. Place the spray tip and needle valve assembly tight against the bottom of the gage with the quill of the needle valve in the hole in the plunger.

3. While holding the spray tip and needle valve assembly tight against the gage, read the needle valve lift on the indicator. This lift should be .008" to .018" if it exceeds .018", the tip assembly must be replaced. If it is less then .008", inspect for foreign material between the needle valve and tip seat

4. If the needle valve lift is with the limits, install a new needle valve spring and recheck the valve opening pressure and valve action. Low valve opening pressure or poor atomization with. a new spring indicates the spray tip and needle valve assembly must be replaced.

Reassemble the injector as outlined under "Assemble Injector" and check it in the comparator.

UEL OUTPUT TEST

When injectors are removed from an engine for output testing and, if satisfatory, reinstalled without disassembly. extreme care should be taken to avoid reversing the fuel flow. Note the direction of fuel flow through the injector before removing it front the engine. When the fuel flow is reversed, dirt trapped by the filter element is back-flushed into the injector components. To avoid reversing the fuel flow when checking injector fuel output on the comparator use the appropriate adaptor. The position of the fuel flow pipes shown in figure 15 depends on the adaptor being used End the direction of fuel flow through the injectors.

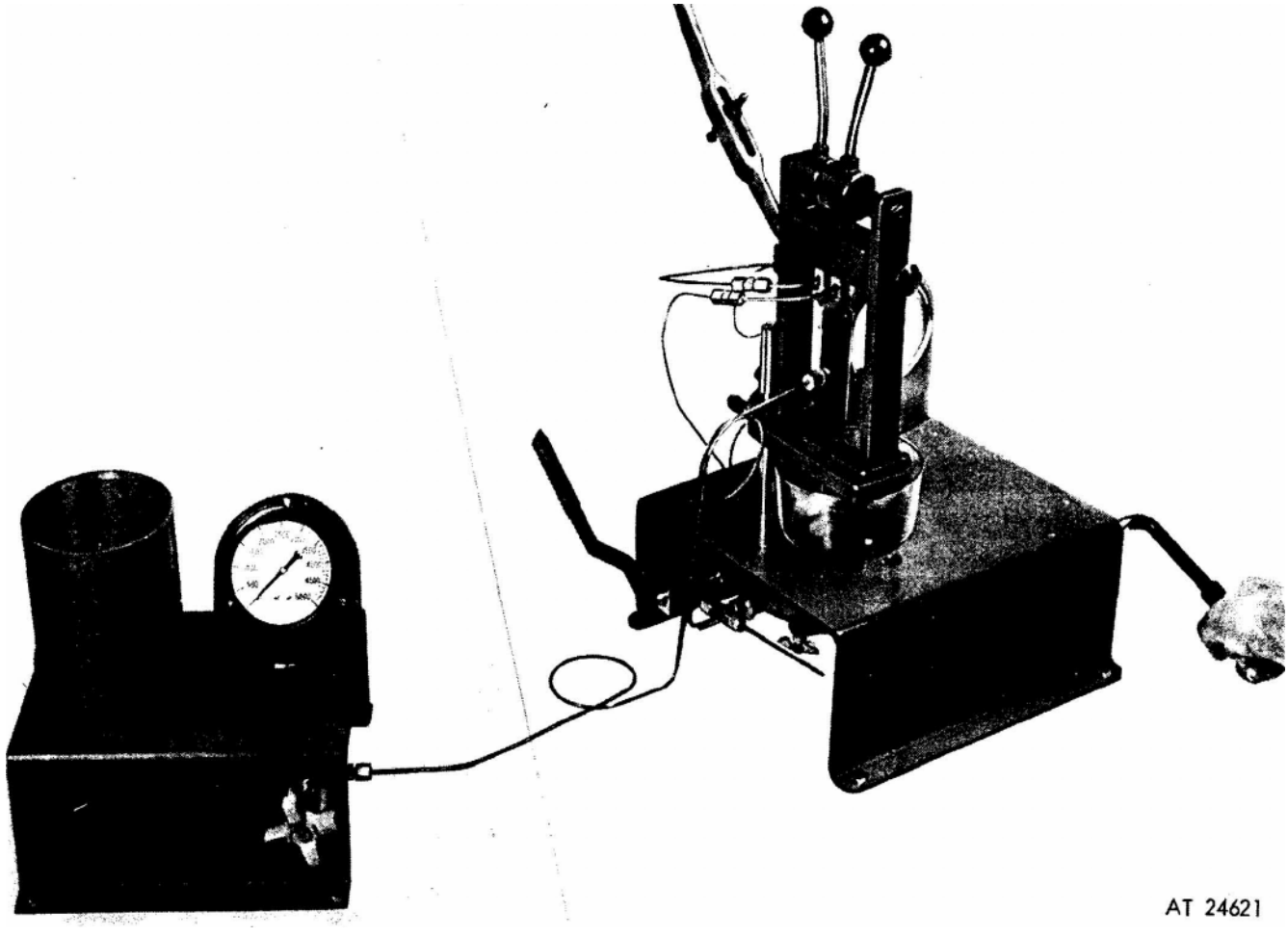


Figure 13. Injector needle valve test with auxiliary tester J 22640.

NOTE

The fuel passages in adaptor J7041-130 are cross drilled.

Operate the injector in the comparator J 7041 to check the fuel output as follows:

1. Place the injector in the comparator, as shown in figure 16. Then, turn the wheel to clamp the injector and adaptor in position.

NOTE

Make sure the counter on the comparator is preset to 1,000 strokes. If for any reason, this setting has been altered, reset the counter to 1,000 strokes by pulling the selector wheel to he changed to the right and rotating it to its proper position (fig. 17). Then, release the wheel.

2. Pull the injector rack out to the NO-FUEL pisiton.

3. Start the comparator by turning on the switch.

4. After the comparator has started, push the injector rack in to the FULL-FUEL position and allow the injector to operate for approximately 30 seconds to purge the air that may be in the system.

5. 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 1.000 strokes.

6. After the fuel stops flowing into the vial, pull the rack out to the NO-FUEL pisiton.

7. Turn the comparator off and reset the counter.

8. Observe the reading on the vial and refer to the chart and determine whether the injector fuel output falls within the specified limits. If the quantity of fuel in the vial does not fall within the specified limits, refer to Trouble Shooting Chart 6 and Shop Notes in section 2.1.0 for the cause and remedy.

2.1.1 FUEL INJECTOR

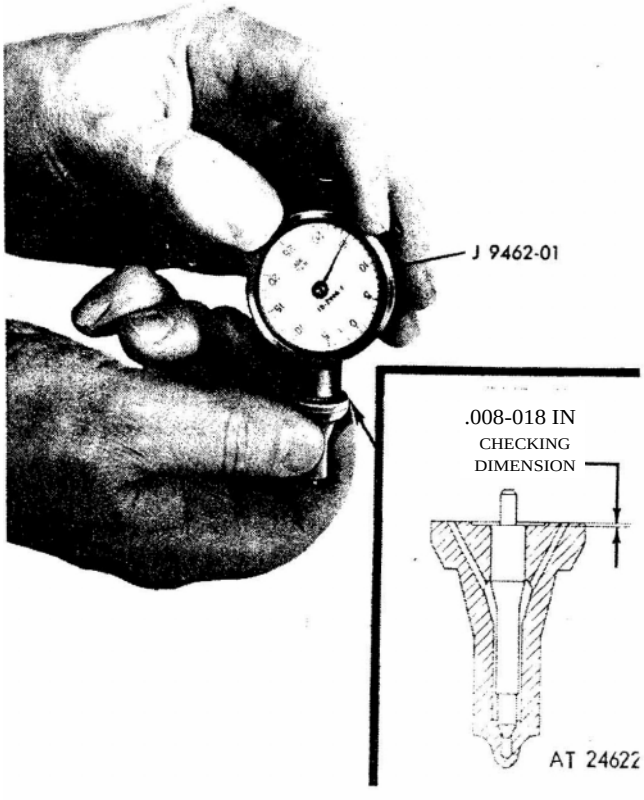


Figure 14. Checking needle valve lift.

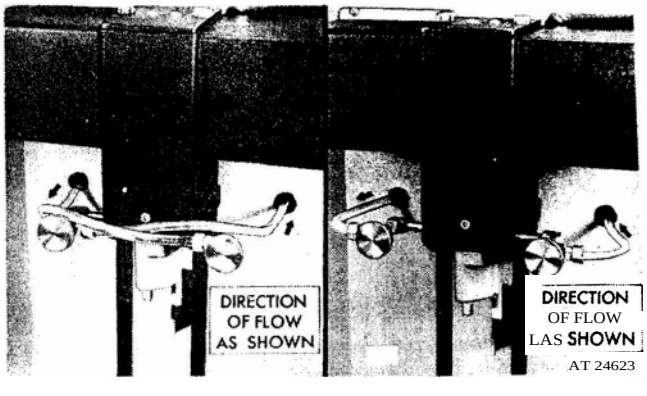


Figure 15. Position of fuel flow pipes.

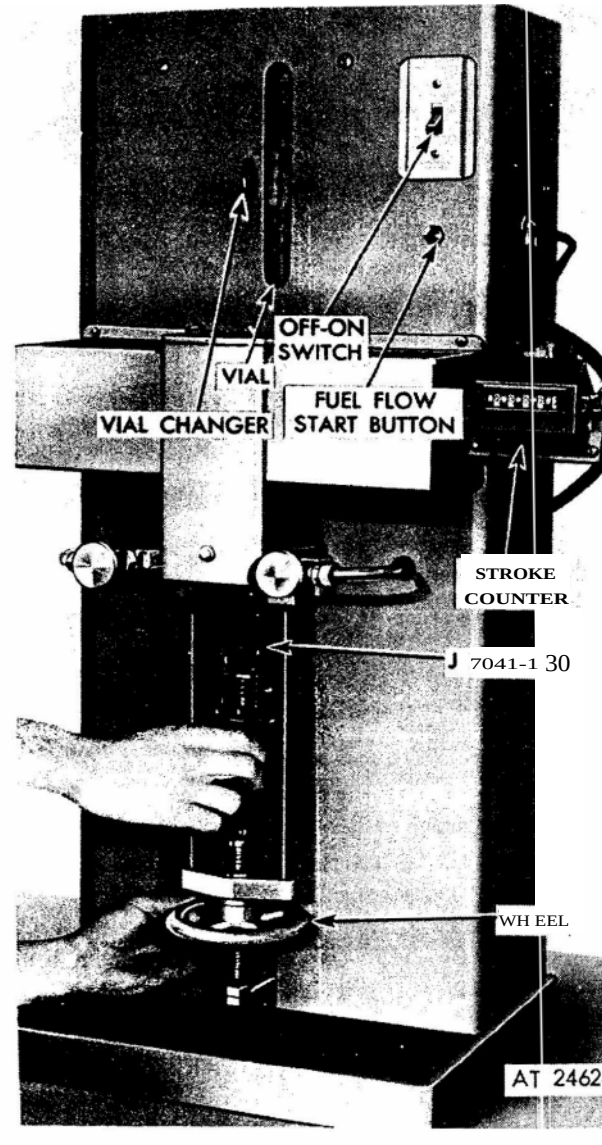


Figure 16. Placing injector in cornparato J 7011.

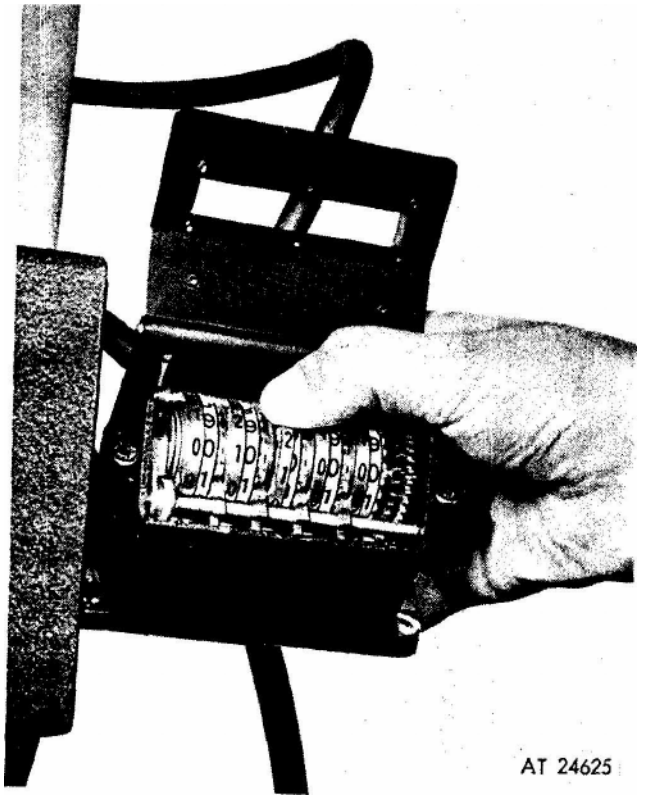


Figure 17. Setting comparator stroke counter.

Refer to section 2.1.0 for different factors that may affect the injector comparator reading.

Fuel check chart

Injector	Fuel utput	
		Max.
1,40	4	10
N40	4	10
N 45	14	20
N50	17	23
M65	39	15

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 run ning engine.

Disassemble Injector

If required. the injector may be disassembled in the following manner:

1. Support the injector upright in the injector assembl fixture. J 22396 (fig. 18). and remove the filter caps, gaskets and filter elements.

NOTE

Whenever a fuel injector is disassembled, discard the filter elements and gaskets and replace them with new filters and gaskets.

2. Compress the follower spring as shown in figure 10. Then, using a screw driver, raise the spring above the stop pin and withdraw the pin. Release the follower spring gradually.

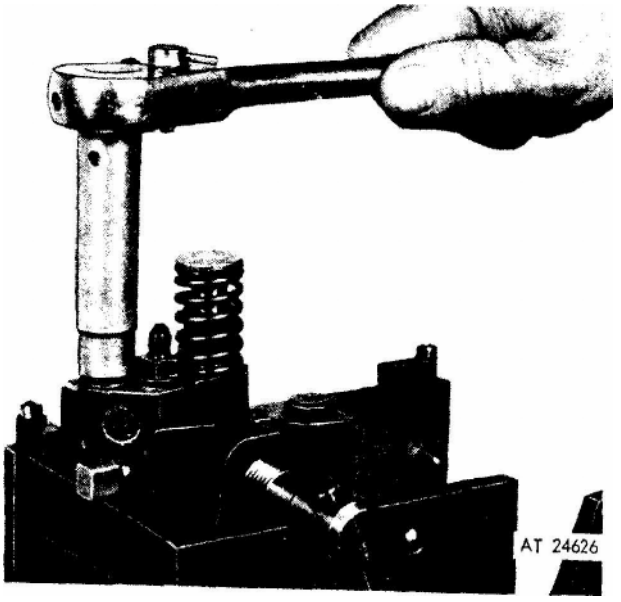


Figure 18. Removing or installing filter cap.

3. Refer to figure 19 and remove the plunger follower, plunger and spring as an assembly.

4. Invert the fixture and, using socket J 4983-01, loosen the nut on the injector body (fig. 20).

5. Lift the injector nut straight up, being careful not to dislodge the spray tip and valve parts. Remove the spray tip and valve parts from the bushing and place them in a clean receptacle. When an injector has been in use for some time, the spray

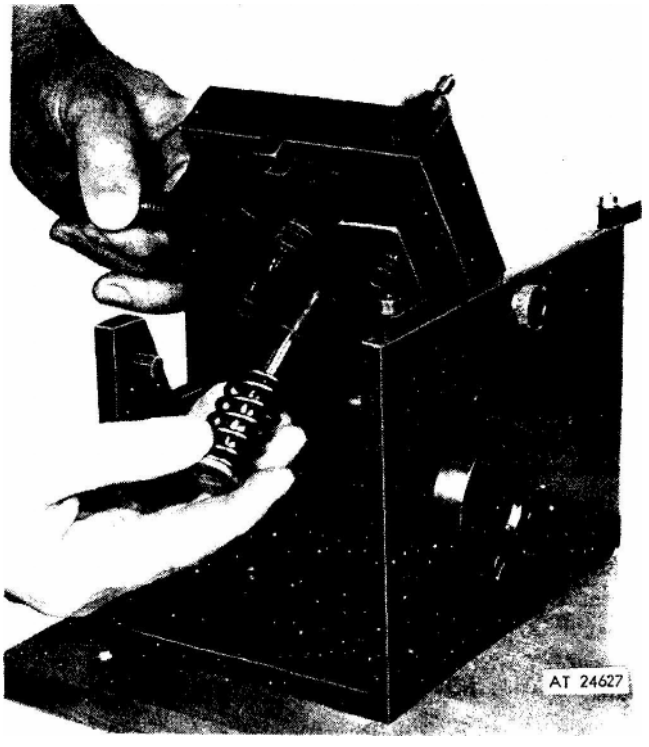


Figure 19. Removing or installing plunger follower, plunger and spring.

tip, even though clean on the outside, may not be pushed readily from the nut with your fingers. In this event, support the nut on a wood block and drive the tip down through the nut, using tool J 1291-02 as shown in figure 21.

6. Refer to figure 30, and remove the spill deflector. Then, lift the hushing straight out of the injector body.

7. Remove the injector body from the holding fixture. Turn the body upside down and catch the gear retainer and gear in your hand as they fall out of the body.

8. Withdraw the injector control rack from the injector body. Also, remove the seal ring from the body.

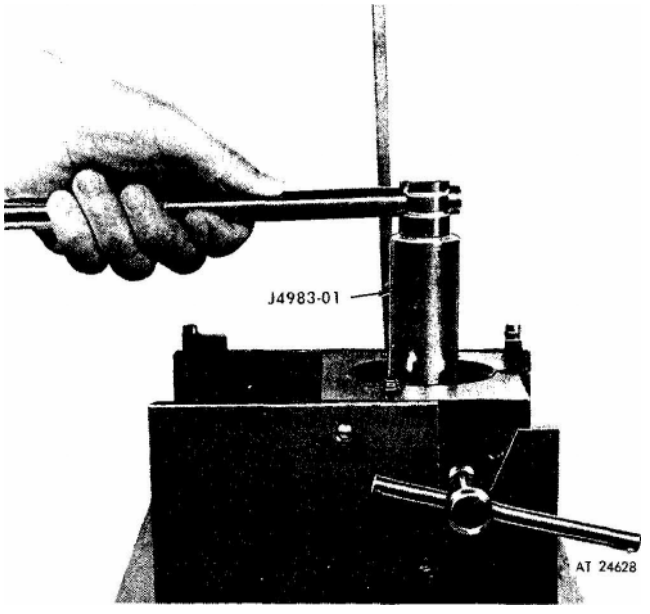


Figure 20. Removing injector nut.

Clean 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 the injector parts after cleaning and inspection. Wash all of the 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 the passages, drilled holes and slots in all of the injector parts. Carbon *on the* inside of the spray tip may be loosened for easy removal by soaking for approximately 15 minutes in a suitable solution prior to the external cleaning and buffing operation. Metyl Ethyl Ketone J 8257 solution is recommended for this purpose. Clean the spray tip with tool J 9464-01 (fig. 22). Turn the tool in a clockwise direction to remove the carbon deposits. Wash the spray tip and dry it with compressed air.

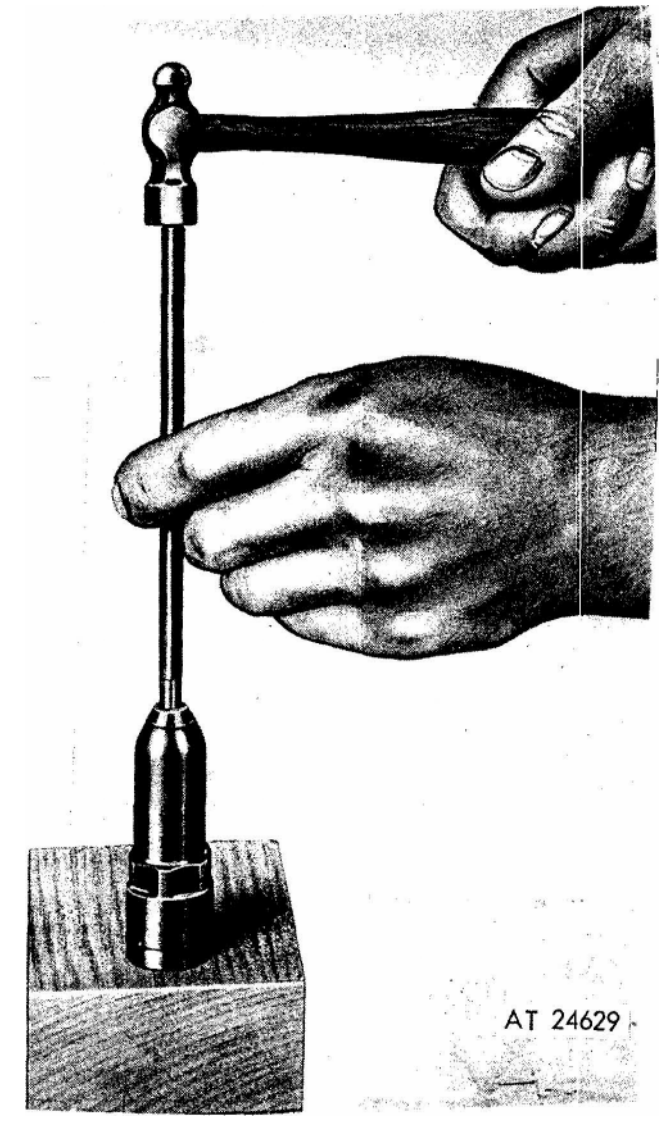


Figure 21. Removing spray tip from injector nut.

CAUTION

Care must be exercised when inserting the tool J 9464-01 in the spray tip to avoid contacting the needle valve seat in the tip.

Clean the spray tip orifices with pin vise J 4298-1 and the proper size spray tip cleaning wire. Use wire J 21461 to clean .006". diameter holes (fig. 23). Before using the wire, hone the end of the wire until it is smooth and free of burrs with stone J 8170. Allow the wire to extend ⅛'' from tool J 4298-1. The exterior surface of an injector spray tip may be cleaned by using a brass wire buffing wheel, tool J 7944. To obtain a good polishing effect and longer brush life, the buffing wheel should be installed on a motor that turns the wheel at approximately 3000 rpm. A convenient method of holding the spray tip while cleaning and polishing is to place the tip over the drill end of the spray tip cleaner tool J 1243 and hold the body of the tip

against the buffing wheel. In this way, the spray tip is rotated while being buffed.

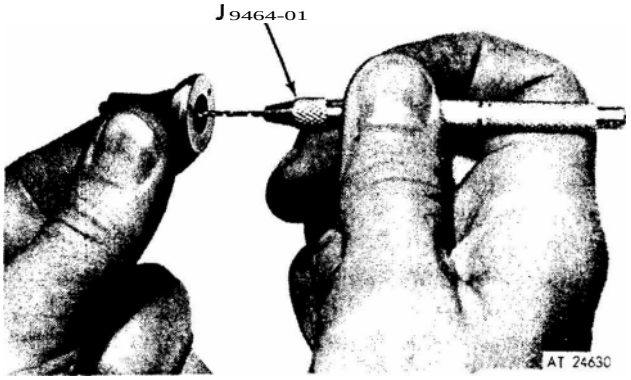


Figure 22. Cleaning injector spray tip.

When the body of the spray tip is clean, lightly buff the tip end in the same manner. This cleans the spray tip orifice area and will not plug the orifices. Wash the spray tip in clean fuel oil and dry it with compressed air after cleaning the orifices. Clean and brush all of the passages in the injector body, using fuel hole cleaning brush J 8152 and rack hole cleaning brush J 8150. Blow out the passages and dry them with compressed air. Carefully insert reamer J 21089 in the injector body (fig. 24). Turn it in a clockwise direction a few turns; then remove the reamer and check the face of the ring for reamer contact. If the reamer does not make contact over the entire face of the ring. repeat the reaming procedure until the reamer makes contact with the entire face of the ring. Clear up the opposite side of the ring in the same manner. Carefully insert a .375" diameter straight fluted reamer inside the ring bore in the injector body Turn the reamer in a clockwise direction and remove any burrs inside the ring bore. Then, wash the injector body in clean fuel oil and dry it with compressed air. Carefully insert carbon remover tool J 9418-1 in the injector nut. Turn it in a

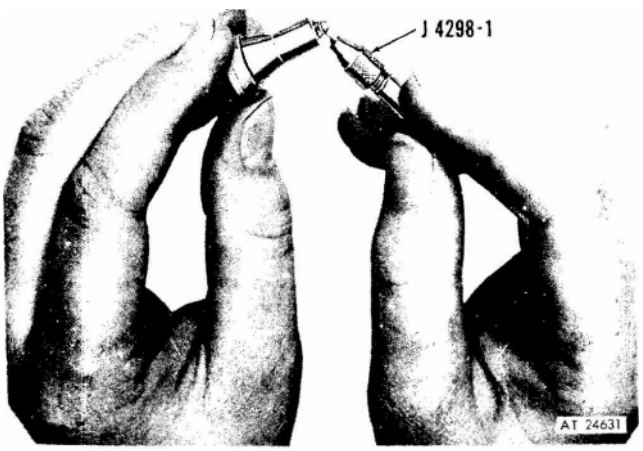


Figure 23. Cleaning spray tip orifices.

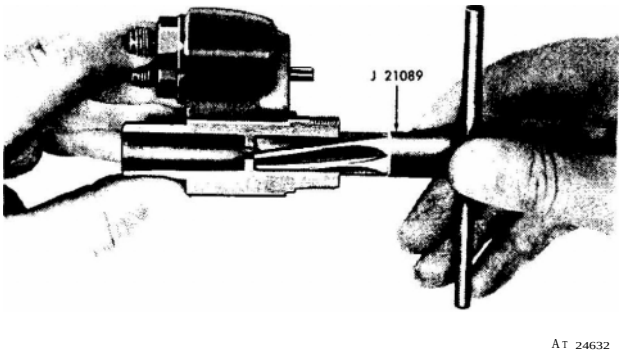


Figure 24. Cleaning injector body ring.

clockwise direction to remove the carbon deposits on the flat spray tip seat as shown in figure 25. Remove the carbon deposits from the lower end of the injector nut with carbon remover tool J 9418-5 (fig. 25) in the same manner. Use care to avoid removing any metal or setting up burrs on the spray tip seat.

Wash the injector nut in clean fuel oil and dry it with compressed air. Carbon deposits on the spray tip seating surfaces of the injector nut will result in poor sealing and consequent fuel leakage around the spray tip. When handling the injector plunger, do not touch the finished plunger surfaces with your fingers. Wash the plunger and bushing with clean fuel oil and dry with compressed air. Be sure the high pressure bleed hole in the side of the bushing is not plugged. If this hole is plugged fuel leakage will occur at the upper end of the bushing where it will drain out of the injector body vent and rack holes, during engine operation, causing a serious oil dilution problem. Keep the plunger and bushing together as they are mated parts. After washing, submerge the parts in a clean receptacle containing clean fuel oil, Keep the parts of each injector assembly together.

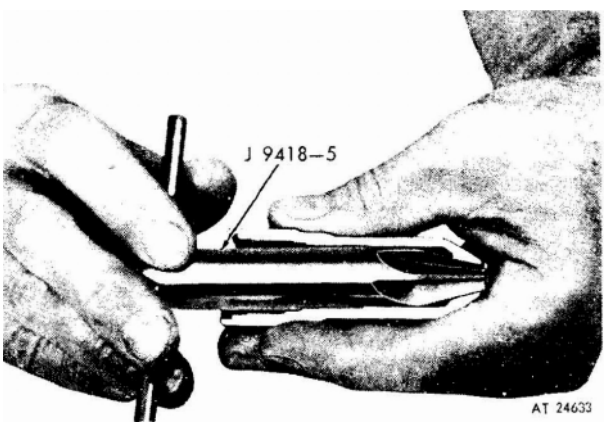


Figure 25. Cleaning injector nut spray tip seat.

2.1.1 FUEL INJECTOR

Inspect Injector Parts

Inspect the teeth on the control rack and control rack gear for excessive wear or damage. Also, check for excessive wear in the bore of the gear. Replace darn aged or worn parts. Inspect the injector follower and pin for wear. Refer to section 2.1.0. Inspect both *ends* of the spill deflector for sharp edges or burrs which could create burrs on the injector body or injector nut and cause particles of metal to be introduced into the spray tip and valve parts. Remove burrs with a 500 grit stone. Inspect the follower spring for defects and check the spring with spring tester J 9666 and an accurate torque wrench. The injector follower spring has a free length of approximately 1.504" and should be replaced when a load of less than 70 lbs. will compress it to 1.028". Check the seal ring area on 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. A faulty sealing surface at this point will result in high fuel comsumption and contamination of the lubricating oil. Replace any loose injector body plugs or a loose dowel pin. Install the proper number tag on a service replacement injector. Inspect the injector plunger and bushing for scoring, erosion, chipping or wear. Check for sharp edges on that portion of the plunger which rides in the gear. Remove any sharp edges with a 500 grit stone. Wash the plunger after stoning it. Injector Bushing Inspectalite J 21471 can be used to check the post holes in the inner diameter of the bushing for cracks or chipping. Slip the plunger into the bushing and check for free movement. Replace plungers and bushings as an assembly if any of the above damage is noted, since they are mated parts. Use new mated factory parts to assure the best performance from the injector. Injector plungers cannot be reworked to change the output. Grinding will destroy the hardened case at the helix and result in chipping and seizure or scoring of the plunger.

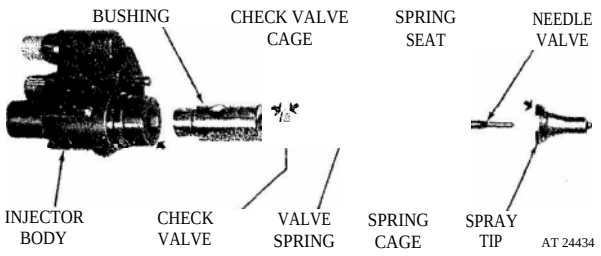


Figure 26. Sealing surfaces which may require lapping.

Part name	Minimum th ickness
Tip, Spray (Shoulder)	.199
Cage, Check Valve	.165-. b3
Valve, Check	.022
Cage, Valve Spring	.602

Examine the spray tip seating surface of the injector *nut* for nicks, burrs, or brinelling. Reseat the surface or replace the nut if it is severely damaged. Inspect the sealing surfaces of the injector parts indicated by arrows in figure 26. The sealing surfaces should be examined with a magnifying glass, as shown in figure 27. The slightest perfections will prevent the injector from operating properly. Check for burrs, nicks, erosion, cracks, chipping and excessive wear. Also, check for enlarged orifices in the spray tip. Replace damaged or excessively worn parts. Check the minimum thickness of the lapped parts as noted in the above chart. Examine the seating area of the needle valve for wear or damage. Also, examine the needle quill and its contact point with the valve spring seat. Replace damaged or excessively worn parts. Examine the needle valve seat area in the spray tip for foreign material. The smallest particle of such material can prevent the needle valve from seating properly. Polish the seat area with polishing stick J 22964. Coat only the tapered end of the stick with polishing compound J 23038 and insert it directly inn) the center of the spray tip until it bottoms. Rotate the stick 6 to 12 times applying a light pressure with the thumb and forefinger.

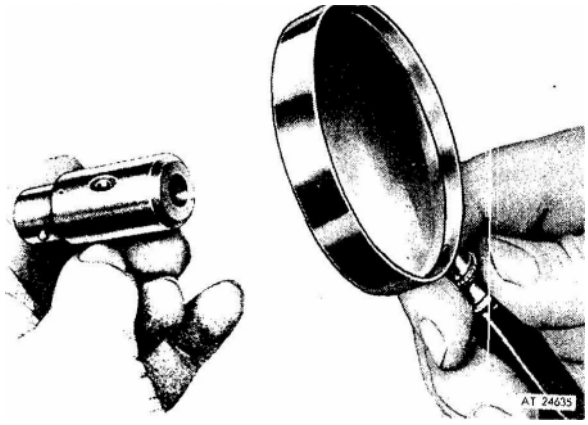


Figure 27. Examining sealing surface with a magnifying glass.

CAUTION

Be sure that no compound is accidentally placed on the lapped surfaces located higher up in the spray tip. The slightest lapping action on these surfaces can alter the near-perfect fit between the needle valve and tip.

Before reinstalling used injector parts, lap all the sealing surfaces indicated by arrows *in* figure 25. It is also good practice to lightly lap the sealing surfaces of new injector parts which may become burred or nicked during handling.

Lapping Injector Parts

Lap the sealing surfaces indicated in figure 26 as follows:

1. Clean the lapping blocks, J 22090, 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 on the block as shown in figure 28 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 he 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 (refer to chart on minimum thickness).
5. When the part is flat, wash it in cleaning solvent and dry it with compressed air.
6. Place the dry part on the second 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 the part in cleaning solvent and dry it with compressed air.
7. Place the dry part on the 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. Wash all of the lapped injector parts in clean fuel oil and dry them with compressed air.

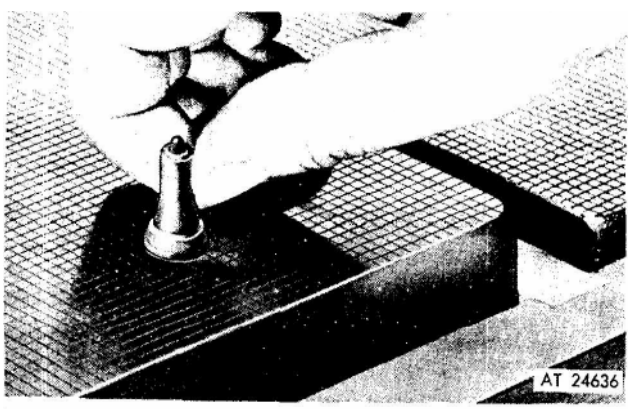


Figure 28. Lapping spray tip.

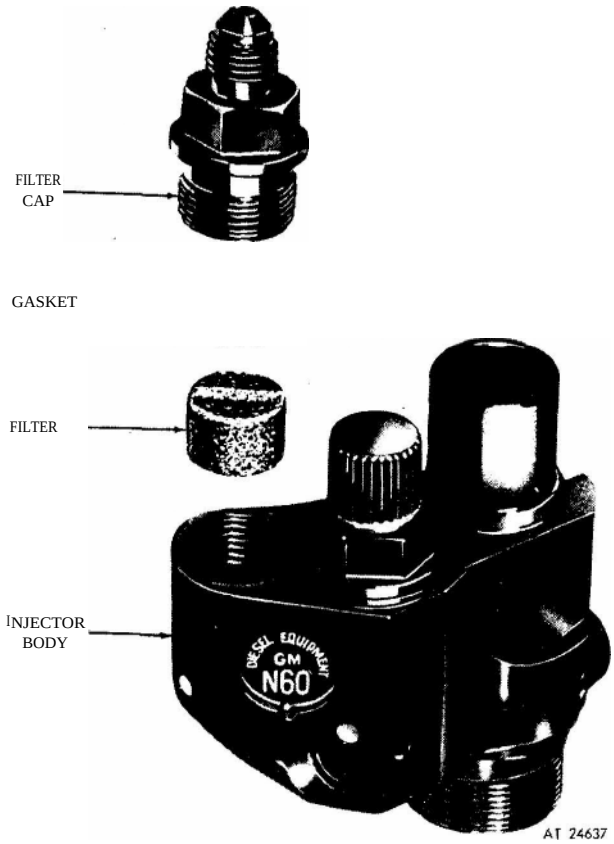


Figure 29. Details of injector filter and cap showing their location relative to injector body.

Assemble Injector

Use an extremely clean bench to work on and to place the parts when assembling an injector. Study figures 29 through 31 for the proper relative positions of the injector parts then proceed as follows:

ASSEMBLE INJECTOR FILTERS

Always use new filters and gaskets when reassembling an injector.

1. Insert a new filter, dimple end down, and slooted end up, in each of the fuel cavities in the top of the injector body (fig. 29).
2. Place a new gasket on each filter cap. Lubricate the threads and install the filter caps. Tighten the filter caps to 65-75 lb-ft torque with a 9 / 16- deep socket (fig. 18).
3. Purge the elements after installation by directing compressed air or fuel through the filter caps.
4. Install clean shipping caps on the filter caps to prevent dirt from entering the injector.

ASSEMBLE RACK AND GEAR

Refer to figure 30 and note the drill spot marks on the control rack and gear; then proceed as follows:

2.1.1 FUEL INJECTOR

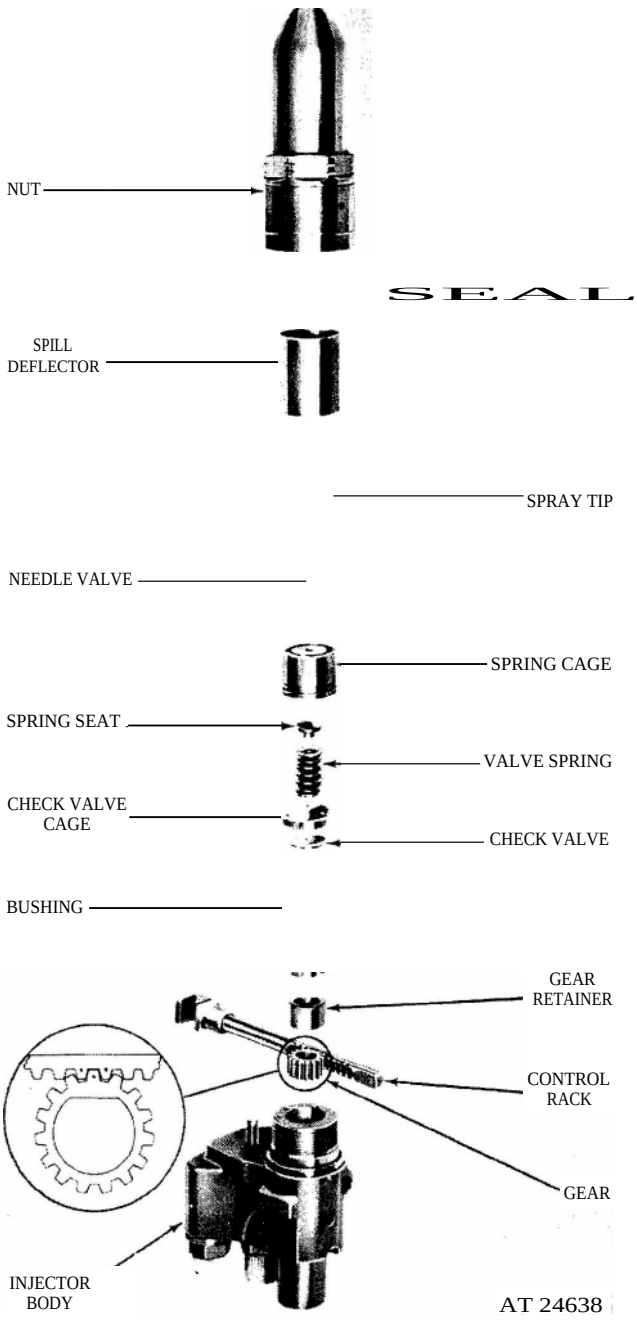


Figure 30. Injector rack. gear, spray tip, and valve assembly details and relative location of parts.

1. Hold the injector body bottom end up and slide the rack through the hole in the body. Look into the body bore and move the rack until you can see the drill marks. Now hold the rack in this position.
2. Place the gear in the injector body so the teeth mesh as shown in the inset in figure 30.
3. Place the gear retainer on top of the gear.
4. Align the locating pin in the bushing with the slot in the injector body; then slide the end of the hushing into place.

ASSEMBLE SPRAY TIP, SPRING CAGE AND CHECK VALVE ASSEMBLIES

Refer to figures 1 and 30 and assemble the parts in the following manner:

1. Support the injector body, bottom end up, in injector assembly fixture J 22396.
2. Place a new seal ring on the shoulder of the body. Then, slide the spill deflector over the barrel of the bushing.
3. Place the check valve centrally on top of the bushing. Then, place the check valve cage over the check valve and against the hushing.
4. Insert the spring seat in a new valve spring; then, insert the assembly into the spring cage, spring seat first.

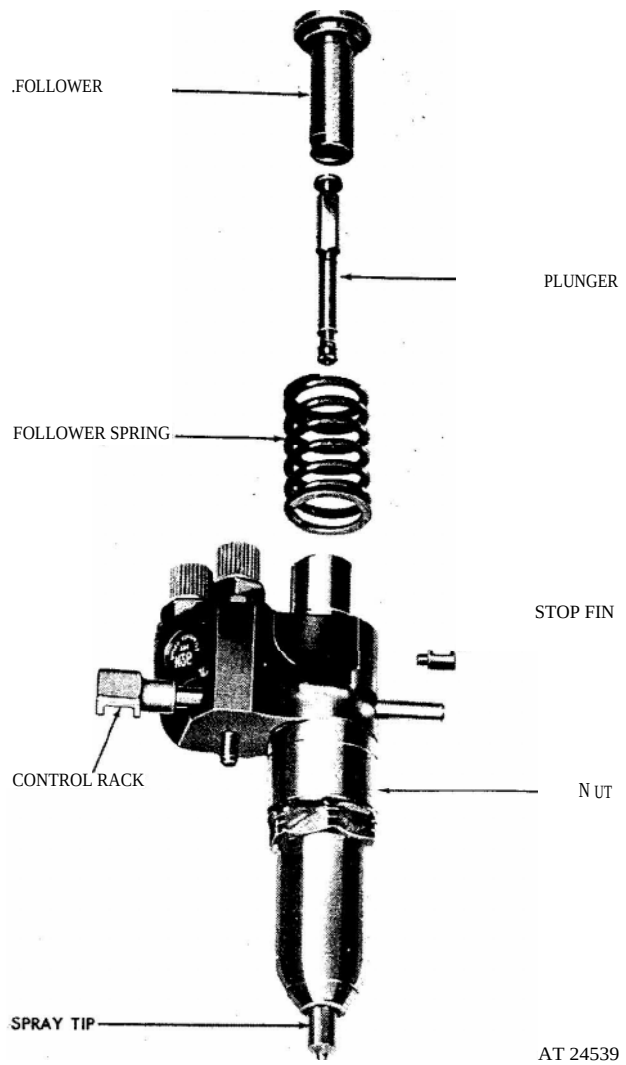


Figure 31. Injector plunger, follower and relative location of parts.

5. Place the spring cage, spring seat, and valve spring assembly (valve spring down) on top of the check valve cage.

6. Insert the needle valve, tapered end down, inside the spray tip (fig. 1). Then, place the spray tip and needle valve on top of the spring cage with the quill end of the needle valve in the hole in the spring cage.

7. Lubricate the threads in the injector nut and carefully thread the nut on the injector body by hand. Rotate the spray tip between your thumb and first finger while threading the nut on the injector body (fig. 33). Tighten the nut as tight as possible by hand. At this point there should be sufficient force on the spray tip to make it impossible to turn with your fingers.

8. Use socket J 4983-01 and a torque wrench and tighten the injector nut to 75-85 lb-ft torque (fig. 341.

NOTE

1)0 not exceed the specified torque. Otherwise, the nut may be stretched and result in improper sealing of the lapped surfaces in a subsequent injector overhaul.

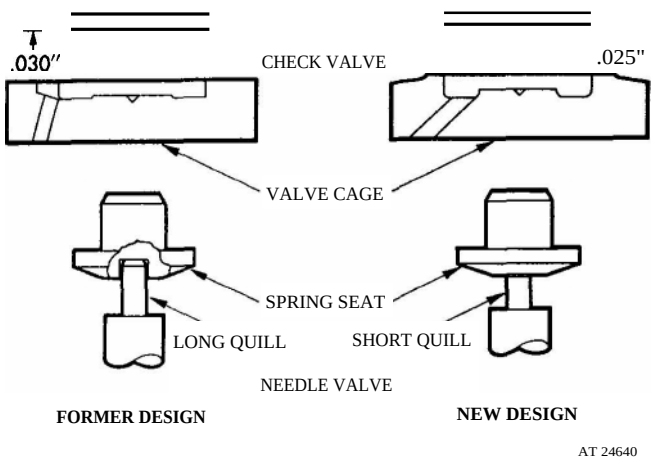


Figure 32. Comparison of former and new design injector parts.

ASSEMBLE PLUNGER AND FOLLOWER

1. Refer to figures 19 and 31 and slide the head of the plunger into the follower.

2. Invert the injector in the assembly fixture (filter cap end up) and push the rack all the way IN. Then, place the follower spring on the injector body.

3. Refer to figures 35 and 36 and place the stop pin on the injector body so that the tighter wound end of the follower spring reasts on the narrow flange of the stop pin. This end has been cut so that

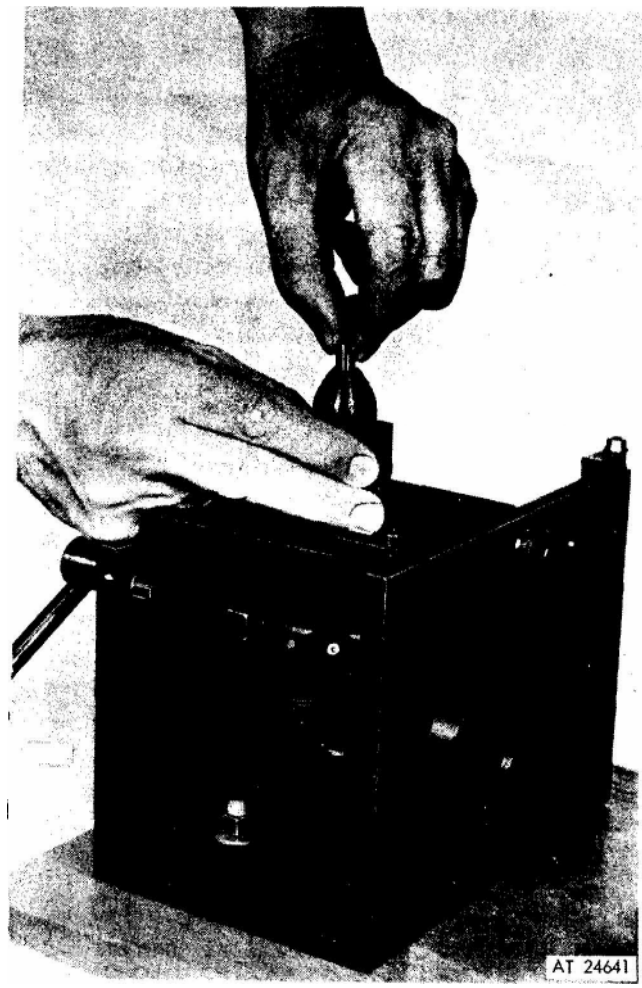


Figure 33. Tightening injector nut by hand

the end point is to the outside. Then, align the slot in the follower with the stop pin hole in the injector body. Next, align the flat side of the plunger with the slot in the follower. Then insert the free end of the plunger in the injector body. Press down on the follower and at the same time press the stop pin in place. When in place, the spring will hold the stop pin in position.

Check Spray Tip Concentricity

To ensure correct alignment, check the concentricity of the spray tip as follows:

1. Place the injector in the concentricity gage J 5119 as shown in figure 37.

2. Adjust the dial indicator to "0". Rotate the injector 360° and note the total runout as indicated on the dial.

3. if the total run-out exceeds .008", remove the injector from the gage. Loosen the injector nut, recenter the spray tip, tighten the nut to 75-85 lb-ft torque and recheck the concentricity. If, after several attempts, the spray tip cannot he positioned satisfactorily, replace the injector nut.

2.1.1 FUEL INJECTOR

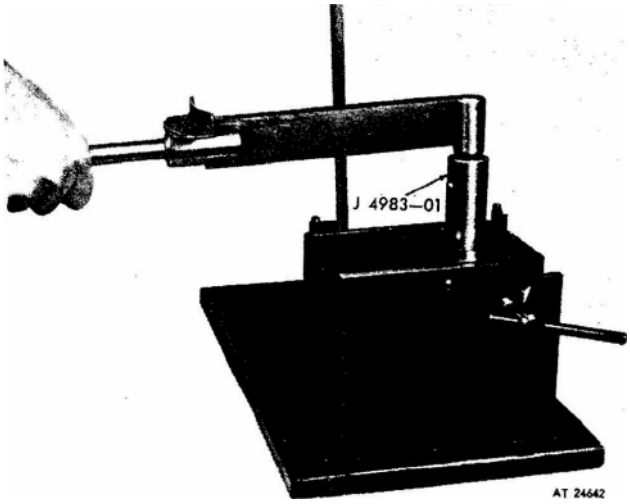


Figure 34. Tightening injector nut with torque wrench.

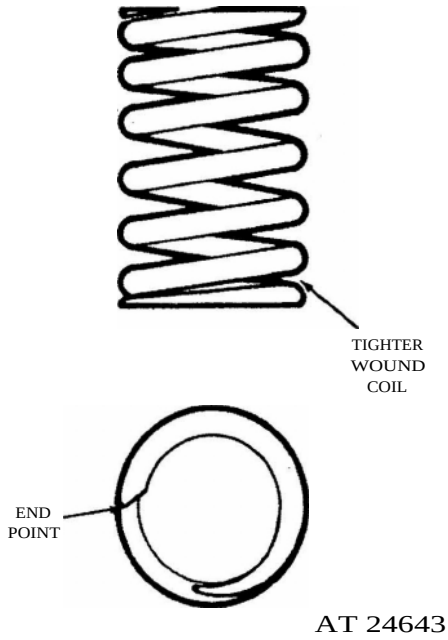


Figure 35. Follower spring identification.

Test Reconditioned Injector

Before placing a reconditioned injector in service, perform all of the tests (except the visual inspection of the plunger) previously outlined under "Test Injector . The injector is satisfactory if it passes these tests. Failure to pass any one of the tests indicates that defective or dirty parts have been assembled. In this case, disassemble, clean, inspect, reassemble, and test the injector again.

Install Injector

Before installing an injector in an engine, remove the carbon deposits from the beveled seat of the injector tube in the cylinder head. This will assure correct alignment of the injector and prevent any

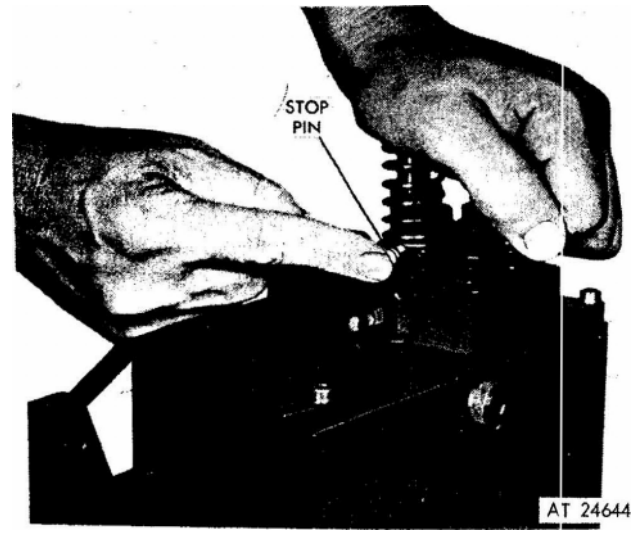


Figure 36. Installing injector follower stop pin.

undue stresses from being exerted against the spray tip. Use injector tube bevel reamer J 5286-9, section 2.1.4, to clean the carbon from the injector tube. Exercise care to remove ONLY the carbon so that the proper clearance between the injector body and the cylinder head is maintained. Pack the flutes of the reamer with grease to retain the carbon removed from the tube. Be sure the fuel injector is

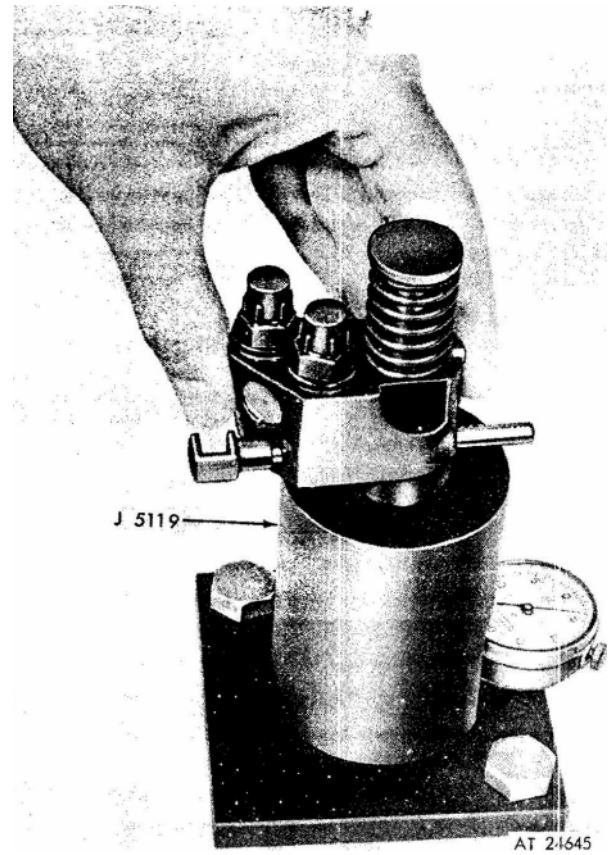
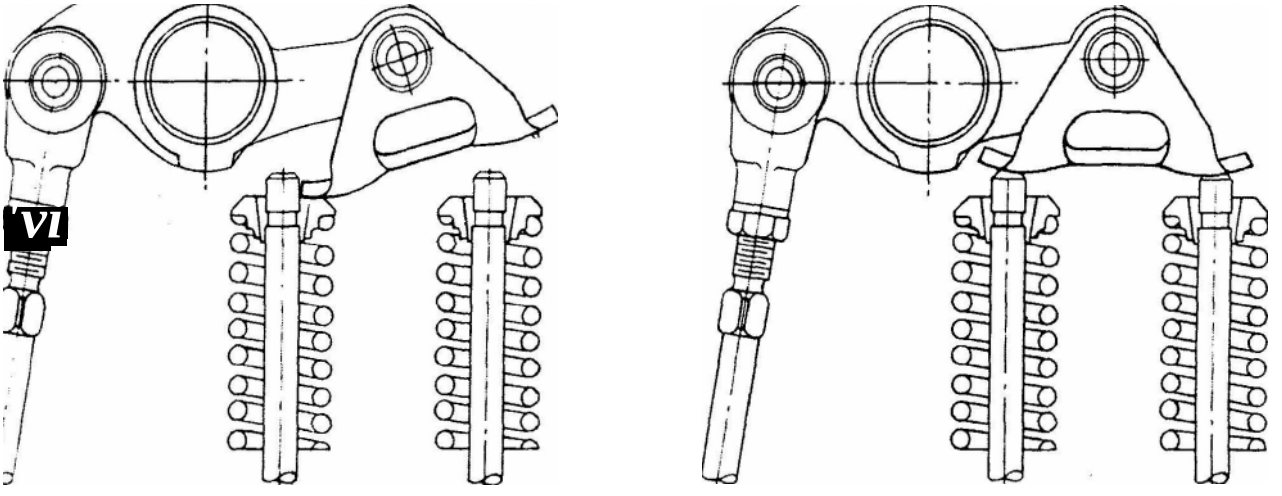


Figure 37. Checking injector spray tip concentricity.



BRIDGE IMPROPERLY POSITIONED

BRIDGE PROPERLY POSITIONED

AT 24646

Figure 38. Relationship between ex haust valve bridge and valve stems.

filled with fuel oil. If necessary, add clean fuel oil at the inlet filter cap until it runs out the outlet filter cap.

Install the injector in the engine as follows:

. Refer to figure 5 and insert the injector in the injector tube. Be sure the dowel pin in the injector body registers with the dowel pin hole in the cylinder head. Next, position the injector rack control lever so the lower end of the lever engages the injector rack.

2. install the injector clamp, special washer, and bolt. Tighten the bolt to 20-25 lb-ft torque. Then, check to make sure the clamp does not interfere with the injector follower spring or the exhaust valves.

NOTE

Check the injector rack for free movement. Excess torque can cause the injector control rack to stick or bind.

3. Move the rocker arm assembly into position and secure the rocker arm brackets to the cylinder head by tightening the bolts to the torque specified in section 2.1.0.

CAUTION

On four valve cylinder heads, there is a possibility of damaging the exhaust valve if the exhaust valve bridge is not resting on the ends of the exhaust valves when tightening the rocker shaft bracket bolts. Therefore, note the position of the exhaust valve bridge before, during, and after tightening the rocker shaft bracket bolts.

4. Remove the shipping caps. Then align the fuel pipes and connect them to the injector and the fuel connectors. Use socket J 8932-01 and a torque wrench to tighten the connections to 12-15 lb-ft torque.

CAUTION

Do not bend the fuel pipes and do not exceed the specified torque. Excessive tightening will twist or fracture the flared end of the fuel line and result in leaks. Lubricating oil diluted by fuel oil can cause serious damage to the engine bearings.

5. After installing the injectors in the engine, perform a complete engine tune-up as outlined in Section 14. However, if only one injector has been removed and replaced and the other injectors, and the governor adjustment have not been disturbed, it ill only be necessary to adjust the valve clearance and time the injector for the one cylinder, and to position the injector rack control levers.

FUEL INJECTOR TUBE

The bore in the cylinder head for the fuel injector is directly through the cylinder head water jacket as shown in figure 5 of section 2.1.1. To prevent cooling water from contacting the injector and still maintain maximum cooling of the injector, a tube is pressed into the injector, bore. This tube is sealed at the top with a neoprene ring and upset into a flare on the lower side of the cylinder head to create water-tight joints at the top and bottom.

Remove Injector Tube

When removal of an injector tube is required, the operation may be carried out with use of injector tube service tool set J 22525 as follows :

1. Remove, disassemble and clean the cylinder head as outlined in section 1.2.
2. Place tool J 5286-4 in the injector tube; then, thread tool J 5286-5 into the end of tool J 5286-4 (fig. 1).
3. Loosen the injector tube with a hammer as shown.
4. Withdraw the injector tube and tools from the cylinder head.

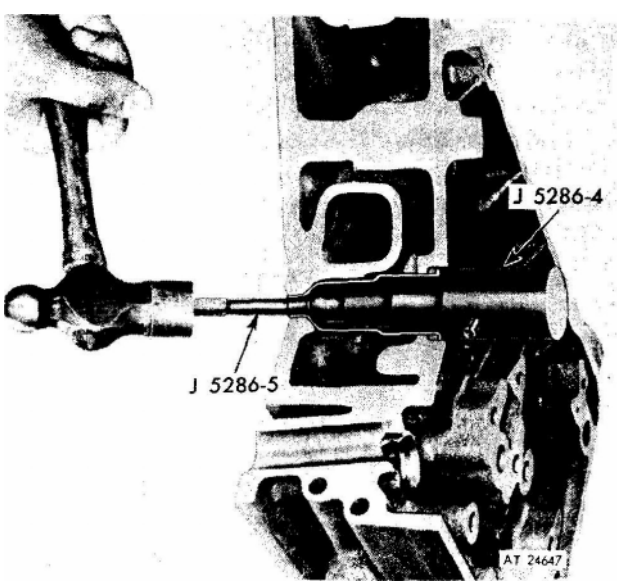


Figure 1. Fe moving injector rune.

Install Injector Tube

Thoroughly clean the injector tube hole in the cylinder head; remove all dirt, burrs, or foreign material that may prevent the tube from seating at the lower end or sealing at the upper end. Then install the tube as follows:

1. Place the new injector tube sealing ring in the cylinder head injector tube counterbore.
2. Place the driver J 5286-4 in the injector tube, then, insert the pilot J 5286-5 through the small opening of the injector tube and thread the pilot into the tapped end of the driver (fig. 2).

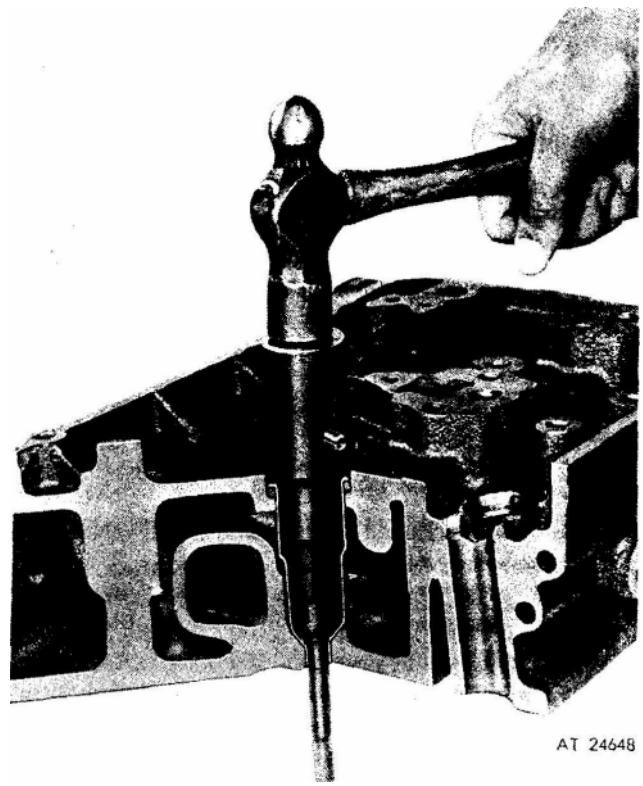


Figure 2. Installing injector tube with installer J5286-4 and Pilot J 5286-5.

3. Slip the injector tube into the injector bore and drive it into place as shown in figure 2. The flange at the upper end of the tube will seat on the seal ring in the counterbore of the cylinder head when the injector tube is properly positioned.
4. With the injector tube properly positioned in the cylinder head, upset (flare) the lower end of the injector tube as follows:

a. Turn the cylinder head bottom side up, remove the pilot J 5286-5 and thread the upsetting die J 5286-6 into the tapped end of the installer J 5286-4. (fig. 3).

b. Then, using a socket and a torque wrench, apply approximately 30 lb-ft torque on upsetting die..

c. Remove the injector tube installing tools a ream the injector tube as outlined below.

Ream Injector Tube

After an injector tube has been installed in a cylinder head, it must be finished in three operations: First, hand reamed, as shown in figure 4, to receive injector body nut and spray tip; second, *spot-faced* to remove excess stock at the lower end of injector tube; and third, hand reamed, as shown in figure 5, to provide a good seating surface for the bevel or the lower end of the injector nut. Reaming must be done carefully and without

2.1.4 INJECTOR TUBE

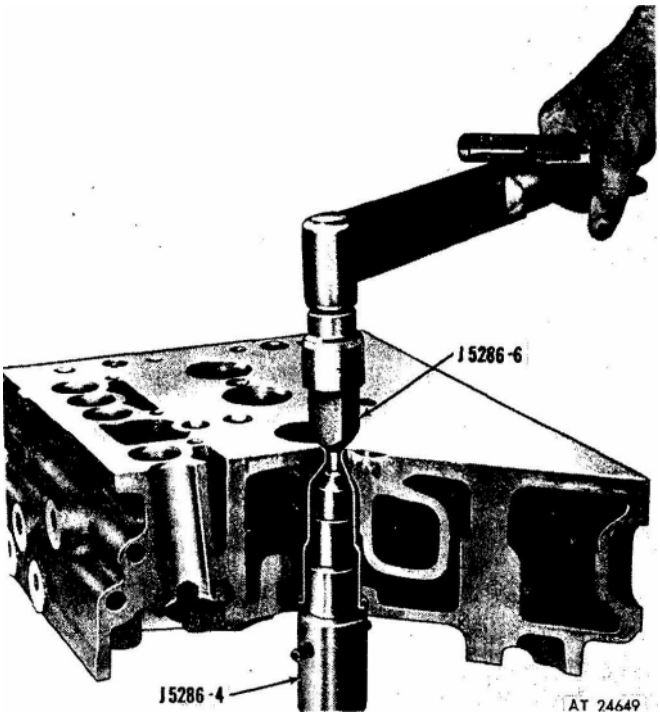


Figure 3. Upsetting injector tube with installer .15286-4 and Die J 5286-6.

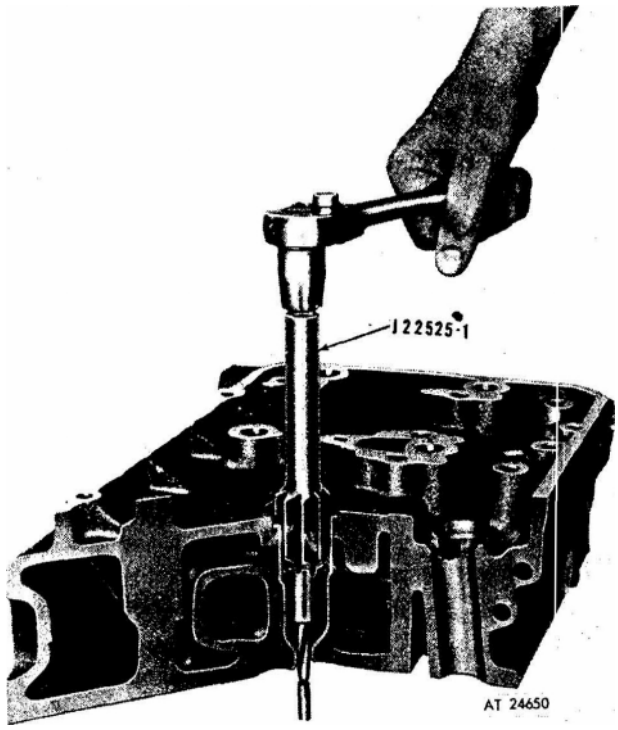


Figure 4. Reaming injector tube for injector body and spray tip with reamer J 22525-1.

undue force of speed so as to avoid cutting through the thin wall of the injector tube. The reamer should be turned in a clockwise direction only, both when inserting and when withdrawing the reamer because movement in the opposite direction will dull the (sharpened) cutting edges of the flutes.

1. Ream Injector Tube for Injector Nut and Spray Tip — With the cylinder head right side up and the injector tube free from dirt, proceed with the first reaming operation as follows:

a. Place a few drops of light cutting oil on the reamer flutes, then carefully position the reammer J 22323-1 in the injector tube.

b. Turn the reamer in a clockwise direction, (withdrawing reamer frequently for removal of chips) until the lower shoulder of the reamer contacts the injector tube. See figure 4. Clean out all chips.

2. Remove Excess Stock:

a. With the cylinder head bottom side up, insert pilot of cutting tool J 3286-8 into small hole of injector tube.

b. Then, using a socket and a speed handle, remove excess stock so that the lower end of the injector tube is from flush to .005" below the finished surface of the cylinder head.

3. Ream Bevel Seat in Injector Tube. The tapered lower end of the injector tube must provide a smooth and true seat for the lower end of the injector nut to effectively seal the cylinder pressures and properly position the injector tip in the combustion chamber. Therefore, to determine the amount of stock that must be reamed from the bevel seat of the tube, the injector assembly should he installed in the tube and the relationship between the numbered surface of the spray tip to the fire deck of the cylinder head noted 6). With the first reaming operation completed and the injector tube spot-faced, wash interior of injector tithe with trichloroethylene or clean fuel oil and dry with compressed air. Then perform the second reaming operation as follows:

NOTE

Service replacement injector tubes are semi-finished and have a narrow land machined at the beveled seat to reduce reaming time. Extreme care must be exercised while reaming the bevel seat to prevent the reamer from cutting too deeply and possible through the thin wall of the tube.

a. Place a few drops of cutting oil on the bevel seat of the tube. Carefully lower the reamer J 5286-9 into the injector tube until it contacts the bevel seat.

h. Make a trial cut by turning the reamer steadily without applying any downward force on the reamer. Remove the reamer, blow out the chips, and look at the bevel seat to see what portion of the seat has been cut.

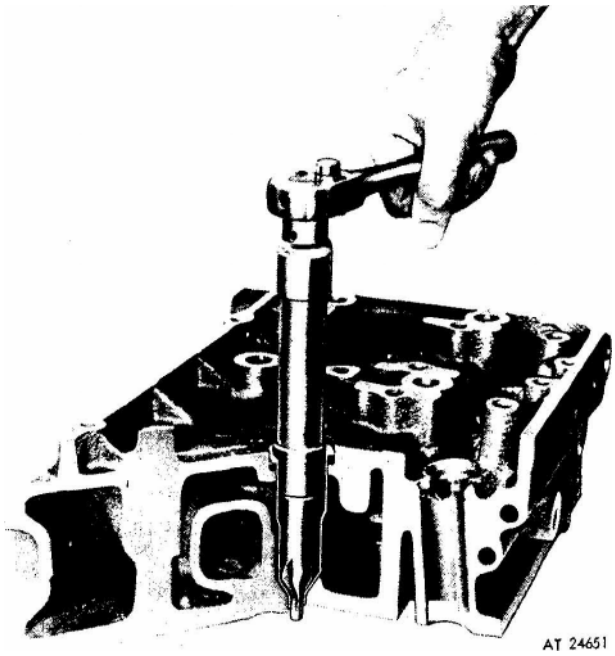


Figure 5. Reaming injector tube for injector nut with reamer J 5286-9.

c. Proceed carefully with the reaming operation, withdrawing the reamer occasionally to observe the reaming progress.

d. Remove the chips from the injector tube and, using an injector as a gage, continue the reaming operation until the shoulder of the spray tip is flush to .015" recessed in the cylinder head (fig. 6).

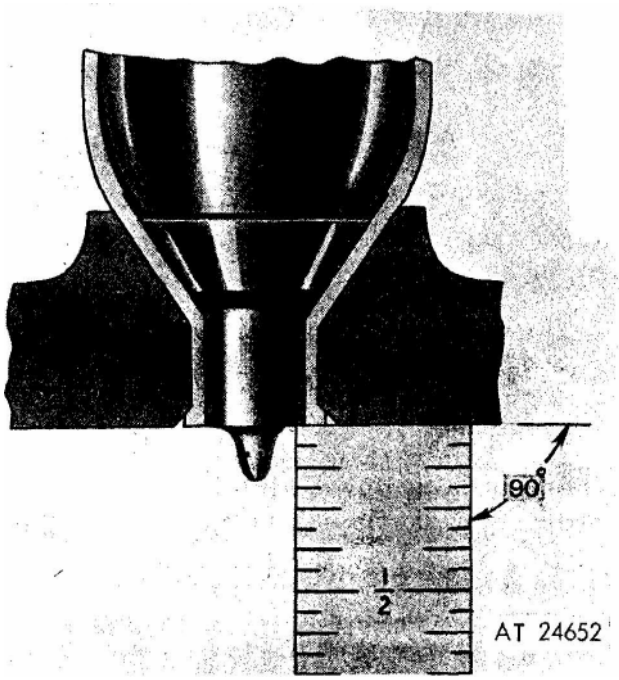


Figure 6. Checking location of injector spray tip relative to lower surface of cylinder head.

SHOP NOTES-TROUBLE SHOOTING-SPECIFICATIONS-SERVICE TOOLS

SHOP NOTES

CHECKING INJECTOR TESTER J 9787

The injector tester J 9787 should be checked monthly to be sure it is operating properly. The following can be made very quickly using test block J 9787-49. Fill the supply tank in the injector tester with clean injector test oil J 8130. Open the valve in the fuel supply line. Place the test block on the injector locating plate and secure the block in place with the fuel inlet connector clamp. Operate the pump handle until all the air is out of the test block ; then clamp the fuel outlet connector onto the test block. Break the connection at the gage and operate the pump handle until all the air bubbles in the fuel system disappear. Tighten the connection at the gage. Operate the pump handle to pressurize the tester fuel system to 2400-2500 psi. Close the valve on the fuel supply line. After a slight initial drop in pressure, the pressure should remain steady. This indicates that the injector tester is operating properly. Open the fuel valve and remove the test block. If there is a leak in the tester fuel system, it will be indicated by a drop in pressure. The leak must be located, corrected and the tester rechecked before checking an injector.

Occasionally dirt will get into the pump check valve in the tester, resulting in internal pump valve leakage and the inability to build up pressure in the tester fuel system. Pump valve leakage must be corrected before an injector can be properly tested. When the above occures, loosen the fuel inlet connector clamp and operate the tester pump handle in an attempt to purge the dirt from the pump check valve. A few quick strokes of the pump handle will usually correct a dirt condition. Otherwise, the pump check valve must be removed, lapped and cleaned, or replaced. If an injector tester supply or gage line is damaged or broken, install a new replacement line (available from the tester manufacturer). Do not shorten the old lines or the volume of test oil will be altered sufficiently to give an inaccurate valve holding pressure test. If it is suspected that the lines have been altered, i.e. by shortening or replacing with a longer line, check the accuracy of the tester with a master injector on which the pressure holding time is known. If the pressure holding time does not agree with that recorded for the master injector, replace the lines.

REFINISH LAPPING BLOCKS

As the continued use of the lapping blocks will cause worn or low spots to develop in their lapping surfaces, they should be refinished from time to time. It is a good practice, where considerable lapping work is done, to devote some time each day to refinishing the blocks. The quality of the finished work depends to a great degree on the condition of the lapping surfaces of the blocks. To refinish the blocks, spread some 600 grit lapping powder of good quality on one of the blocks. Place another block on top of this one and work the blocks together as shown in figure 1. Alternate the blocks from time to time. For example, assuming the blocks are numbered 1, 2 and 3, work 1 and 2 together, then 1 and 3 and finish by working 2 and 3 together. Continue this procedure until all of the blocks are perfectly flat and free of imperfections. Imperfections are evident when the blocks are clean and held under a strong light. The blocks are satisfactory when the entire surface is a solid dark grey. Bright or exceptionally dark spots indicate defects and additional lapping is required. After the surfaces have been refinished, remove all the powder by rinsing the lapping blocks in trichloroethylene and scrubbing them with a bristle brush. Protect the lapping blocks against damage and dust when not in use by storing them in a close fitting wooden container.

Figure 1. Refinishing lapping blocks.

INJECTOR TIMING

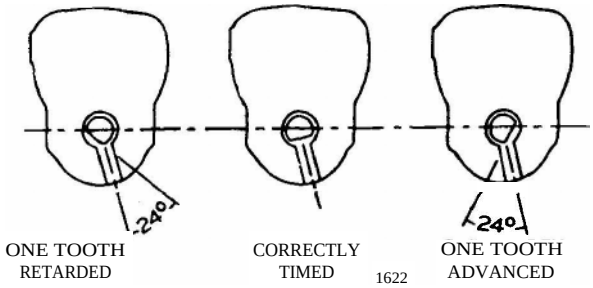


Figure 2. Injector rack-to-gear timing.

The injector rack-to-gear timing may be checked visually through a hole located in the injector body, on the side opposite the identification tag. When the rack is all the way in (full-fuel position), the flat side of the plunger will be visible, indicating that the injector is "in time". If the flat side of the plunger does not come into full view (fig. 21, the injector must be disassembled and the rack-to-gear timing corrected.

FUEL INJECTOR SPRAY TIPS

Due to a slight variation in the size of the small orifices in the end of each spray tip the fuel output or an injector may be varied by replacing the spray tip. Flow gage J 21085 may be used to select a spray tip that will increase or decrease fuel injector output for a particular injector after it has been rebuilt and tested on the comparator.

EFFECTS OF PRE-IGNITION ON FUEL INJECTOR

Pre-ignition is due to ignition of fuel or lubricating oil in the combustion chamber before the normal injection period. The piston compresses the burning mixture to excessive temperatures and pressures, and may eventually cause burning of the injector spray tip and lead to failure of the injectors in other cylinders. When pre-ignition occurs, remove all of the injectors and check for burned spray tips or enlarged spray tip orifices. Before replacing the injectors, check the engine for the cause of pre-ignition to avoid recurrence of the problem. 'Check for oil pull-over from the oil bath air cleaner, damaged blower housing gasket, defective blower oil seals, high crankcase pressure, plugged air box drains, ineffective oil control rings, and dilution of lubricating oil.

FUEL INJECTOR PLUNGERS

The fuel output and the operating characteristics of an injector are, to a great extent, determined by the type of plunger used. Three types of plungers are illustrated in figure 3. The beginning of the injection period is controlled by the upper helix angle. The lower helix angle retards or advances the end of the injection period. Therefore, it is imperative that the correct plunger is installed whenever an injector is overhauled. If injectors with different type plungers (and spray tips) are mixed in an engine, erratic operation will result and may cause serious damage to the engine or to the equipment which it powers. Injector plungers cannot be reworked to change the output or operating characteristics. Grinding will destroy the hardened case and result in chipping at the helices and seizure or scoring of the plunger.

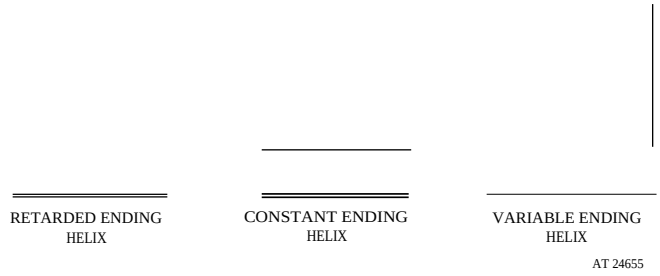


Figure 3. Types of injector plungers.

BLUING INJECTOR BODIES AND NUTS

The appearance of the injector body and nut of a rebuilt injector can be enhanced with an oxide finish obtained through a dipping process known as "bluing". Pre-mixed compounds are available commercially for preparing the necessary solutions. Detailed instructions are usually provided with the commercial compounds. An effective biding solution can be prepared in the service shop by nixing the following materials: 6 lbs. of sodium hydroxide per gallon of water; 3 ½ lbs. of sodium nitrite per gallon of water; 1 ounce of phosphoric acid per gallon of water.

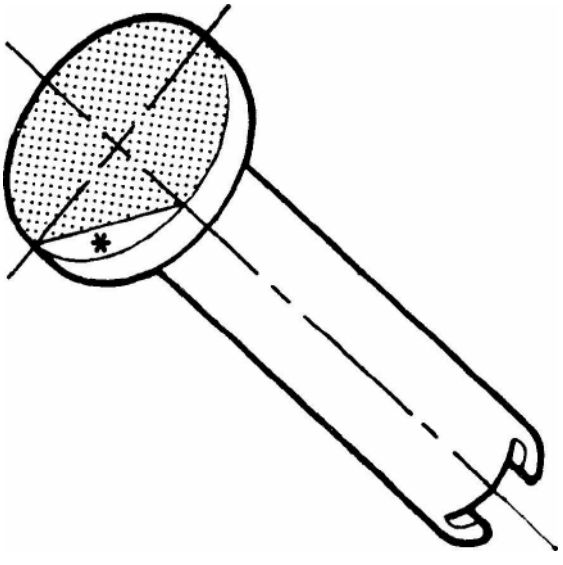
The procedure usually follows five (5) steps in sequence:

I. An alkaline solution bath (180 ^{0}-212°F.) to preel van.
2. A hot or cold water rinse.
3. The bluing solution bath.
4. A cold water rinse.
5. An engine lubricating oil bath (180°-212°F.) to rust proof.

'Hie bluing tank should be a double walled, 1½" insulated type of 10 gauge steel. The temperature of the sodium hydroxide—nitrite—phosphoric acid solution for bluing steel parts should be 295° F to 305°F. the boiling point of the solution is directly related to its concentration. Therefore, when the boiling point is too high, the solution is too concentrated and the volume of water is probably low. When this occurs, the boiling point can be reduced to 300 F. by adding water. The parts should be placed in the solution for 15 to 30 minutes.

It is extremely important that the parts be free of oil before placing them in the bluing bath. Oil will produce a varied color part. There are several important safety precautions to be followed for preparing and using the solutions. Protective clothing such as rubber gloves, rubber arm guards, rubber aprons and protective face shields contribute to the safety of personnel carrying out the procedures. When preparing the solutions, the compounds should be added to the water and not water added to the compounds. The dipping tanks should he properly vented and all fumes exhausted to the outside atmosphere. Since temperatures of the caustic solutions exceed the boiling point of water, any splashing encountered while adding take-up water can cause serious burns. Always add water slowly and with extreme care. When the parts to he dipped are cold, caution should be taken to avoid splashing that might occur when the cold parts *come* in contact with the hot solutions. A heavy wire screen type basket, suitable for holding a quantity of injector bodies, is recommended for dipping the parts in the solutions

REFINISHING FACE OF INJECTOR FOLLOWER



*** PORTION OF SURFACE USED FOR INJECTOR TIMING**

AT 24656

Figure 4. Injector follower.

When refinishing the face of an injector follower, it is extremely important that the portion the follower surface used for injector timing not be refinished. If the timing area shown in figure 4 is refinished, the height of the follower in relation to the injector body will be altered and proper injector tinting cannot be realized.

NOTE

.010" is the maximum amount of metal that can be removed from the injector follower head and still ensure a sufficiently hardened surface for rocker arm contact.

INJECTOR COMPARATOR READINGS

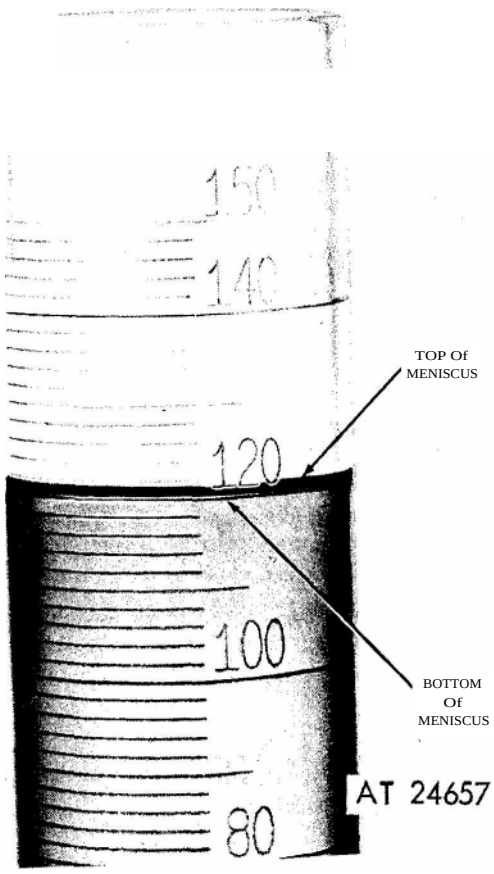


Figure 5. Checking fuel output.

Several factors affect the injector comparator output readings. The four major items are

1. Operator Error: If the column of liquid in the vial is read at the top of the meniscus instead of at the bottom, a variation of 1 or 2 points will result. Refer to figure 5.

2. Air In Lines: This can he caused by starting a test before the air is purged from the injector and lilies, or from an air leak on the vacuum side of the luau p.

3. Counter Improperly Set: The counter is set at the factory to divert the injector output at 1,000 strokes. This sould not be confused with counter overrun that will vary from 2 to 6 digits, depending upon internal friction. The fuel diversion is accomplished electrically and will occur at 1,000 strokes (if properly set) although the counter may overrun several digits.

4. Test Oil: A special test oil is supplied with the J 7041 Comparator and should always be *used.* If regular diesel fuel oil (or any other liquid) is used, variations are usually noted because of the effect of the oil on the solenoid valve and other parts. The fuel oil introduced into the test oil when the fuel injector is placed in the corn parator for a calibration check contaminates the test oil. Therefore, it is important that the comparator have the test oil and test oil filter changed every six months, or sooner if required. In addition, other malfunctions such as a slipping drive belt, low level of fuel oil, a clogged filter, a defective fuel pump and leaking line connections all could cause bad readings. A frequent check should be made for any of these tell-tale conditions.

TROUBLE SHOOTING CHARTS (Needle Valve Injectors)

Chart 4

LOW OR HIGH VALVE OPENING PRESSURE

LOW VALVE OPENING PRESSURE	HIGH VALVE OPENING PRESSURE
Probable Cause	**Probable Cause**
1. WORN OR ERODED NEEDLE VALVE OR VALVE SEAT IN TIP	6. CARBON OR FOREIGN MATERIAL IN SPRAY TIP
2. WORN OR DAMAGED NEEDLE VALVE QUILL	7. CARBON IN TIP ORIFICES
3. WORN OR DAMAGED NEEDLE VALVE SPRING SEAT	
4. WORN OR BROKEN VALVE SPRING	
5. DIRT OR FOREIGN MATERIAL IN INJECTOR	

SUGGESTED REMEDY

1. Replace the needle valve and spray tip assembly.
2. Replace the needle valve and spray tip assembly.
3. Replace The spring seat.
4. Replace the valve spring.
5. Disassemble and clean the injector.
6. Carbon in the spray tip should be removed with tool J 9464 which is especially designed and ground for this purpose.
7. Check the size of the spray tip orifices. Then, using tool J 4298-1 with the proper size wire, clean the orifices.

Chart 5

INSUFFICIENT INJECTOR HOLDING TIME

Probable Cause

1. POOR BUSHING TO BODY FIT
2. INJECTOR NUT NOT TIGHTENED TO SPECIFIED TORQUE
3. CRACKED SPRAY TIP
4. WORN OR ERODED NEEDLE VALVE
5. WORN OR ERODED NEEDLE VALVE SEAT IN SPRAY TIP
6. WORN OR BROKEN NEEDLE VALVE QUILL
7. WORN OR BROKEN VALVE SPRING
8. WORN OR DAMAGED VALVE SPRING SEAT
9. DEFECTIVE SEAL RING
10. BODY PLUG LEAKS
11. FILTER GASKET LEAK
12. POOR SEALING SURFACES ON FUEL FITTINGS
13. DIRT OR FOREIGN MATERIAL IN INJECTOR

SUGGESTED REMEDY

1. Lap the injector body.
2. Tighten the nut to a 75-85 lb-ft torque. Do not exceed the specified torque.

3, 4, 5 & 6. Replace the needle valve and spray tin assembly.

7. Replace the valve spring.
8. Replace the valve spring seat.
9. Replace the seal ring.
10. Install new body plugs.
11. Replace the filter cap gaskets and tighten the filter caps to 65-75 lb-ft torque.
12. Clean up the sealing surfaces or replace the filter caps, if necessary. Replace the filter if a cap is replaced.
13. Disassemble and clean the injector.

Chart 6

INCORRECT FUEL OUTPUT

Probable Cause

1. SPRAY TIP OR ORIFICES PARTIALLY PLUGGED
2. SPRAY TIP ORIFICES ENLARGED
3. WORN OR DAMAGED NEEDLE VALVE QUILL
4. WORN OR DAMAGED NEEDLE VALVE SPRING SEAT
5. WORN OR BROKEN VALVE SPRING
6. CRACKED CHECK VALVE CAGE, SPRING CAGE, OR SPRAY TIP
7. CRACKED BUSHING
8. POOR LAPPED SURFACES
9. FOREIGN MATERIAL BETWEEN VALVE AND SEAT
10. RACK AND GEAR NOT IN TIME

SUGGESTED REMEDY

1. Clean the spray tip as outlined under "Clean Injector Parts"

2 & 3. Replace the needle valve and spray tip assembly.

4. Replace the spring seat.

5. Replace the valve spring.

6. Replace the cracked parts.

7. Replace the plunger and bushing assembly.

8. Lap the sealing surfaces.

9. Disassemble and clean the injector.

10. Assemble the gear with the drill spot mark on the tooth engaged between tie two marked teeth on the rack.

SPECIFICATIONS

Standard Bolt and Nut Torque Specifications

Size nut or bolt	Torque (lb-ft)	Size nut or bolt	Torque (lh-ft)	Size nut or bolt	Torque (lb-ft)
1/4 - 20	7-9	7 / 16 - 20	57-61	3/4 10	240-250
1 /4 - 28	8-10	1/2 - 13	71-75	3/4 - 16	290-300
5/16 - 18	13-17	1/2 - 20	83-93	7 / 8 - 9	410-420
5/16 - 24	15-19	9/16 - 12	90-100	7/8 - 14	475-485
3/8 - 16	30-35	9/16 - 18	107-117	1 - 8	580-590
3/8 - 24	35-39	5/8 - 11	137-147	1 - 14	685-695
7/16 - 14	46-50	5/8 - 18	168-178		

Exceptions to Standard Bolt and Nut Torque Specifications

Application	Size nut or bolt	Torque (lb-ft)
Injector Clamp Bolt	3 / 8 - 16	20-25
Fuel Line Connector	3 / 8 - 24	20-28
Rocker Arm Bracket Bolt	7/16 - 14	50-55
Injector Filter Caps	5 / 8 - 24	65-75
Injector Nut (Needle Valve)	5/16 - 24	75-85

Service Tools

Tool No.	Name
INJECTOR TOOLS	
J 1241-05	Injector Service Tool Set
J 1234	Spray Tip Cleaner
J 1291-02	Spray Tip Remover and Bushing Cleaner
J 4298-1	Injector Spray Tip Hole Cleaner
J 4983-01	Injector Nut Socket Wrench
J 4986-01	Injector Nut Tip Seat Reamer
J 7174	Injector Valve Seat Deburring Tool
J 8150	Injector Rack Hole Brush
J 8152	Injector Body Brush
J 8170	Injector Wire Honing Stone
J 5119	Injector Tip Concentricity Gage
J 9666	Spring Tester
J 9418-1	Injector Nut Tin Seat Reamer (Needle 17. •• Injector)
J 9418-5	Injector Nut Tin Seat Reamer (Needle Valve Injector)
J 7041	Injector Comparator
J 7041-130	Adaptor
J 8130	Injector Test Oil (One Gallon)
J 8257	Metyl Ethyl Keytone Solvent (One Gallon)
J 8932-01	Socket
J 9462-01	Needle Valve Lift Gage
J 9464-01	Injector Tin Carbon Remover (Needle Valve Inj.)
J 9464-1	Special Drill
J 9787	Injector Tester
J 9787-49	Test Block
J 8538-10	Adaptor
J 21089	Injector Body Reamer
J 22800-3	Pin Vise
J 22090	Lapping Block Set
J 21471	Injector Bushing Inspectalite
J 22396	Injector Holding Fixture
J 22640	Needle Valve Injector Auxiliary Tester
J 22964	Polishing Stick Set
J 23038	Lapping Compound

2.1.0 SERVICE TOOLS

Service Tools—Continued

INJECTOR TUBE TOOLS

J 3087-01	Cylinder Head Holding Plate Set
J 22525	Injector Tube Service Tool Set
J 22525-1	Reamer
J 5286-4	Installer Body
J 5286-5	Installer Pilot
J 5286-6	Installer Flaring Die
J 5286-8	Tube Tip Refinisher
J 5286-9	Reamer
J 5286-10	Tool Box
J 22525-2	Reamer Body (part of J 22525-1)
J 22525-3	Reamer Pilot (part of J 22525-1)

FUEL PUMP

The fuel pump, illustrated in figure 1, is the positive displacement gear-type. The pump circulates, or transfers, fuel from the fuel tank to the fuel injectors. The pump circulates the excess supply of fuel through the injectors and the unused protion returns to the fuel tank by means of a fuel return manifold and fuel return line. The fuelpumpcover and body are positioned by means of two dowels. The dowels aid in maintaining gear shaft alignment. The mating surfaces of the pump body and cover are ground perfectly flat. No gasket is used between the cover body since the pump clearances are set up on a metal-to-metal contact basis. A very thin coating of sealant provides a seal against any minute irregularities in the mating surfaces. Cavities in the pump cover accommodate tile ends of the drive and driven shafts. The fuel pump body is recessed to provide space for the pump gears (fig. 2). Recesses are also provided at the inlet and outlet positions of the gears. The small hole "A" permits the fuel oil in the inlet side of the pump to lubricate the relief valve at its outer end and to eliminate the possibility of a hydrostatic lock which would render the relief valve inoperative. Pressurized fuel contacts the relief valve through hole "B" and provides for relief of excess discharge pressures. Fuel re-enters the inlet side of the pump through hole "C" when the discharge pressure is great enough to move the relief valve back from its seat. Part of the relief valve may be seen through hole "C". The cavity "D" provides excape for the fuel oil which is squeezed out of the gear teeth as they mesh together on the discharge side of the pump. Otherwise, fuel trapped at the root of the teeth would tend to force the gears apart, resulting in undue wear on the gears, shafts, body and cover. Two oil seals are pressed into the bore in the flanged side of the pump body with the sealing lips of the seals facing away from the fuel pump gears, as shown in figure 1. Two tapped holes in the underside of the pump body, between the seals, furnish a means of attaching piping for draining off any leakage. *If leakage exceeds one drop per minute, the seals must be replaced.* The fuel pump should maintain a fuel pressure at the fuel inlet passage of 45 to 70 psi at 1800 rpm engine speed in the cylinder head. The drive and driven gears are a line-to-line to .001" press fit on their shafts. However, only the drive gear is provided with a gear retaining ball to locate the gear on the shaft. See figure 2. A spring-loaded relief valve incorporated in the pump body normally remains in the closed position, operating only when pressure on the outlet side (to fuel filter) reaches approximately 65 psi. The fuel pump is mounted on the flywheel housing and is driven by the governor gear.

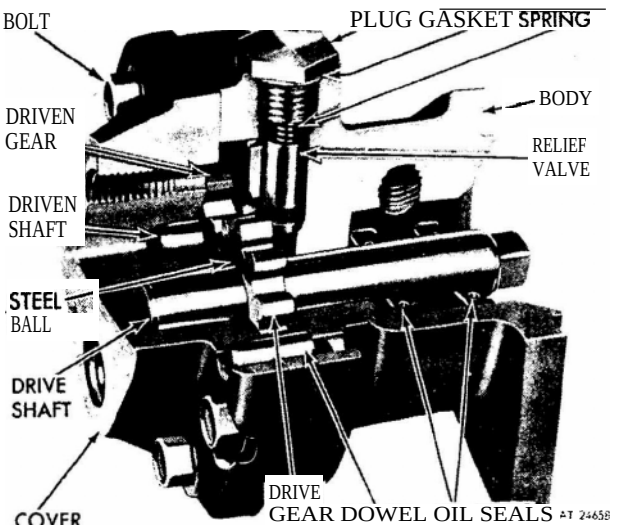


Figure 1. Typical fuel pump assembly.

Operation

In operation, fuel enters the pump on the suction side and fills the space between the gear teeth which are exposed at that instant. The gear teeth then carry the fuel oil to the discharge side of the pump and, as the gear teeth mesh in the center of the pump, the fuel oil is forced out into the outlet cavity. Since this is a continuous cycle and fuel is continually being forced into the outlet cavity, the fuel flows from the outlet cavity into the fuel lines and through the engine fuel system under pressure. The pressure relief valve relieves the discharge pressure by by-passing the fuel from the outlet side of the pump to the inlet side when the discharge pressure reaches approximately 65 to 75 psi. If engine operation indicates an insufficient supply of fuel to the injectors and the fuel level is not low in the supply tank, check the fuel flow betweent the restricted fitting in the fuel return passage in the cylinder head and the fuel supply tank.

To check the fuel flow:

1. Disconnect the flexible fuel return hose from the fitting at the fuel tank or source of supply and hold the open end of the hose in a convenient receptacle.
2. Start and run the engine at 2500 rpm and measure the fuel flow return for one minute.

2.2 FUEL PUMP

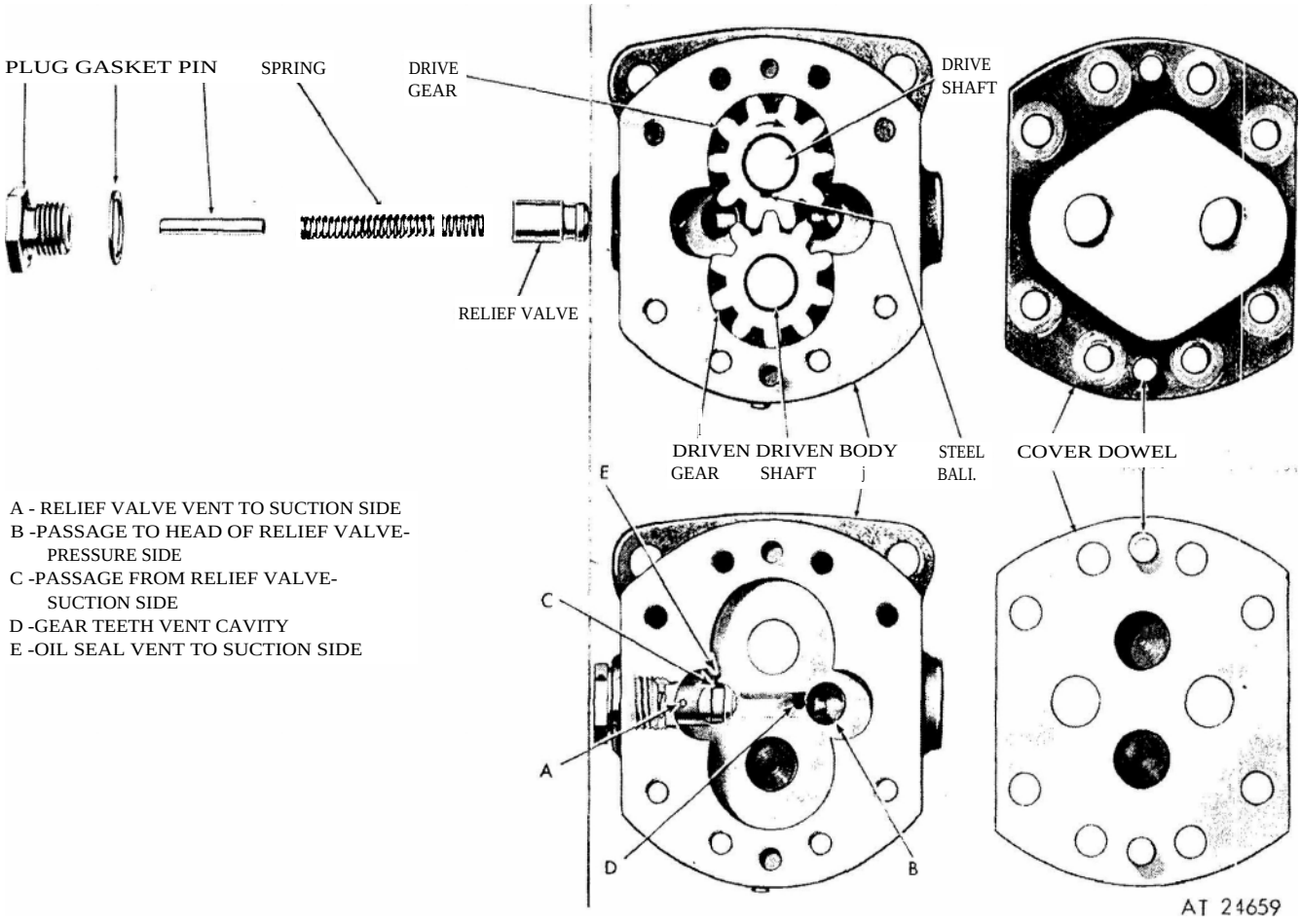


Figure 2- Fuel pump valuing and rotation (right hand pump shown).

Approximately .6 gallon of fuel should flow from the return hose per minute.

3. Be sure all hose connections between the fuel supply and the pump are tight so that no air will be drawn into the fuel system ; then immerse the end of the fuel tube in the fuel container. Air bubbles rising to the surface of the liquid will indicate a leak on the suction side of the pump.

4. If the fuel flow is insufficient for satisfactory engine performance, then

a. Replace the element in the strainer as outlined in section 2.3. Start the engine and run it at 2500 rpm to check the fuel flow. If the fuel flow is still unsatisfactory, perform Step "b" below.

b. Replace the element in the filter. If the fuel flow is unsatisfactory do as instructed in "c".

c. Substitute another fuel pump that is known to be in good condition and again check the flow. When changing a fuel pump, clean all fuel lines with compressed air and be sure all fuel line connections are tight after replacing the pump.

Check Fuel Pump

If the fuel pump fails to function satisfactorily, check for a broken pump shaft, or dirt in the relief valve, before removing the pump from the engine:

1. Insert the end of a wire through one of the pump body drain holes, then crank the engine momentarily and see if the wire vibrates. Vibration will he felt if the pump shaft is rotating.

2. Without removing the pump from the engine, unscrew the valve plug, figure 2, then remove the spring, pin and valve. Wash the parts and blow out the valve cavity with compressed air. Reinstall the valve parts.

Remove Fuel Pump

. Disconnect the fuel lines from the inlet and outlet openings of the fuel pump.

2. Disconnect the drain line from the fuel pump, if used.

3. Unscrew the three pump attaching bolt and washer assemblies and withdraw the pump.

4. Check the drive coupling or fork and it is broken, replace it.

Disassemble Fuel Pump

With the fuel pump removed from the engine, refer to figures 1 and 2 and disassemble the pump as follows:

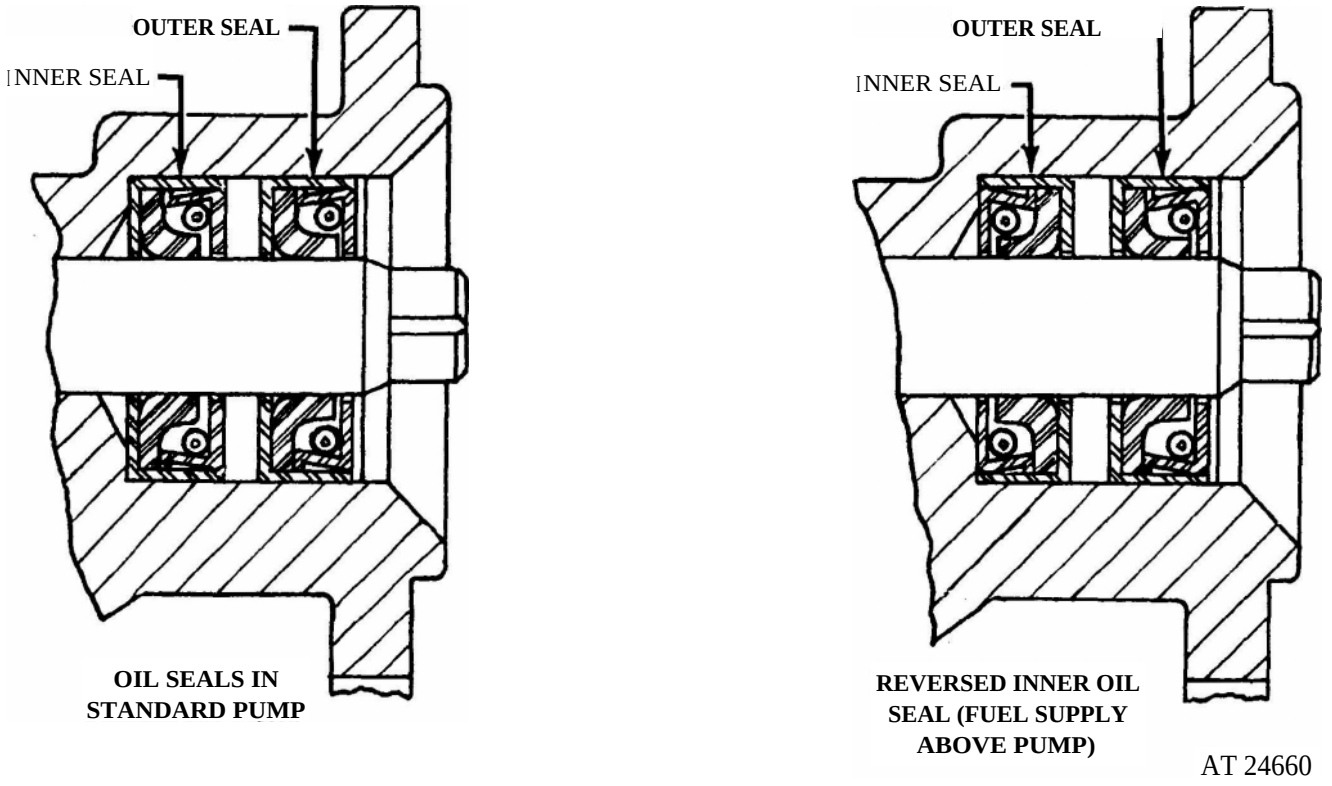


Figure 3. Fuel Pump oil seal arrangements.

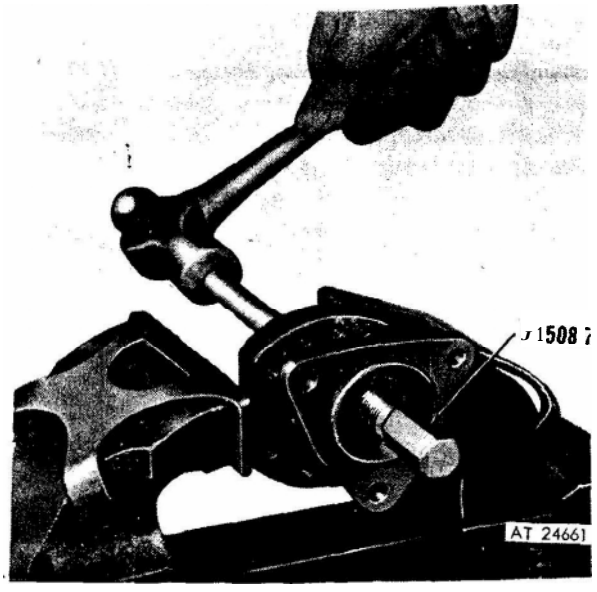


Figure 4. Removing oil seals from fuel pump body.

. Remove the eight cover bolts and withdraw the pump cover from the pump body and off the two cover dowels.

2. Withdraw the drive shaft, drive gear and gear retaining ball as an assembly from the pump body.

3. Press the drive shaft just far enough to remove the steel locking ball. Then, invert shaft and gear assembly and press the shaft from gear. Do not misplace the steel ball. Do not *press* the squared end of the shaft through the gear as slight score marks will damage the oil seal contact surface.

4. Remove the driven shaft and gear *as an* assembly from the pump body. Do not remove the gear from the shaft. The driven gear and shaft are serviced as an assembly.

5. Remove the relief valve plug.

6. Remove the spring, pin, and valve from the valve cavity in the pump body.

7. If the oil seals need replacing, remove them ith tool J 1508-7, as show in figure 4, by clamping the pump body in a bench vise and screwing the threaded end of the tool shaft into the outer oil seal (seal *nearest* to bolting flange). Then tap the pilot end of the shaft with a hammer thus removing the seal. Repeat this operation to remove the inner seal.

Inspection

After the fuel pump has been disassembled, all parts should be washed in clean fuel oil, blown dry ith compressed air and inspected. The oil seals once removed from the pump body should be discarded and replaced with new seals. The lips of the oil *seals* must fit snug around the pump shaft and must be free of nicks or cracks. Check the pump gear teeth for scoring or chipping. If the gear

2.2 FUEL PUMP

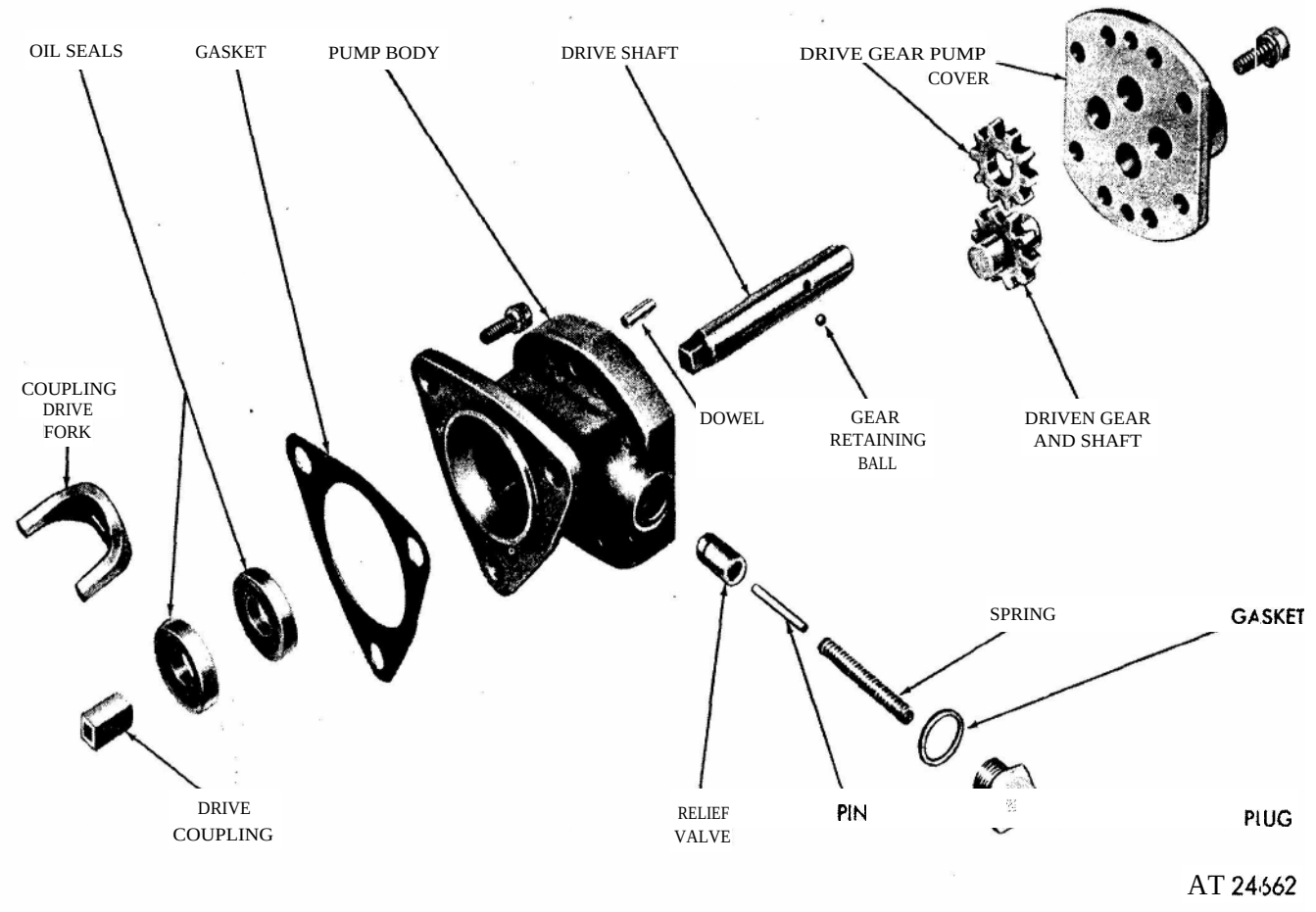


Figure S. Fuel pump details and relative location of parts (right hand pump shown).

teeth are scored or chipped, the gear assemblies should be replaced.

The mating faces of the pump body and cover must he flat and smooth and fit tightly together. The relief valve must be free from score marks and must fit in its seat in the pump body. If the relief valve is scored and cannot be cleaned up with crocus cloth the valve must be replaced. A fuel pump overhaul kit which contains the oil seals, gaskets, shaft and gear assemblies and relief valve parts is available for complete overhaul of the fuel pump.

Assemble Fuel Pump

After the fuel pump parts have been cleaned and inspected and the necessary new parts made available, refer to figures 1, 2 and 5 and reassemble pump as follows:

1. Install oil seals in the pump body as follows:

a. Insert the oil seal installer J 1508-8 in an oil seal so that the lip of the seal faces toward the shoulder on the tool.

b. With the pump body supported on wood blocks, insert the oil seal and tool in the pump body and drive the seal in until it bottoms in the counterbore as shown in figure 6

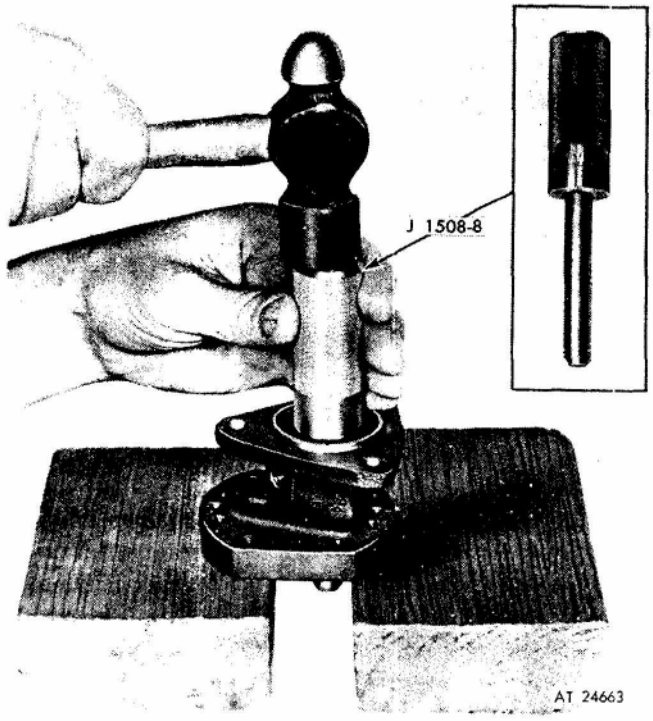


Figure 6. Installing inner oil seal in pump body.

c. Place the adaptor J 1508-9 on the pilot end of the installer with the shorter end of the adaptor against the shoulder on the installer. Position the outer oil seal on the adaptor with the lip of the seal facing the adaptor, then insert the pilot of the installer into the pump so the seal starts straight in the pump flange and drive seal into pump body until the shoulder of the adaptor contacts the body. See figure 7.

2. Clamp the pump body in a bench vise (equipped with soft jaws) with the relief valve cavity up. Lubricate the outside diameter of the relief valve and place the valve in the cavity, hollow end up. Insert the spring inside the valve and the pin into the spring. With the gasket in place, next to the head of the valve plug, place the plug over the spring and thread it into the pump body.

3. Install fuel pump drive gear, if removed, over the end of the drive shaft which is not squared (with slot in gear facing plain end of shaft). This installation is very important, otherwise, fine score marks caused by pressing the gear into position form the square end of the shaft may cause rapid wear of the oil seals. Press the gear beyond the locking ball retaining hole. Then place the ball in the hole, and press the gear back until the end of the slot contacts the ball.

4. Lubricate the pump shaft and insert the square end of the shaft into the opening at the gear side of the pump body and through the two oil seals.

5. Place the driven gear shaft and gear assembly into the pump body with the chamfered end of the gear teeth facing the pump body.

6. Lubricate the gears and shafts with clean engine oil.

7. Apply a thin coat of quality sealer on the face of the pump cover outside of the gear pocket area, then place the cover (fig. 2) against the pump body with the two dowel pins in the cover entering the holes in the pump body.

CAUTION

The coating of sealant must be extremely thin since the pump clearances have been set up on the basis of metal-to-metal contact. Too thick a coating of sealant could increase the clearances and affect the efficiency of the pump. Use care that sealant is not squeezed into the gear compartment, otherwise damage to gears and shafts may result.

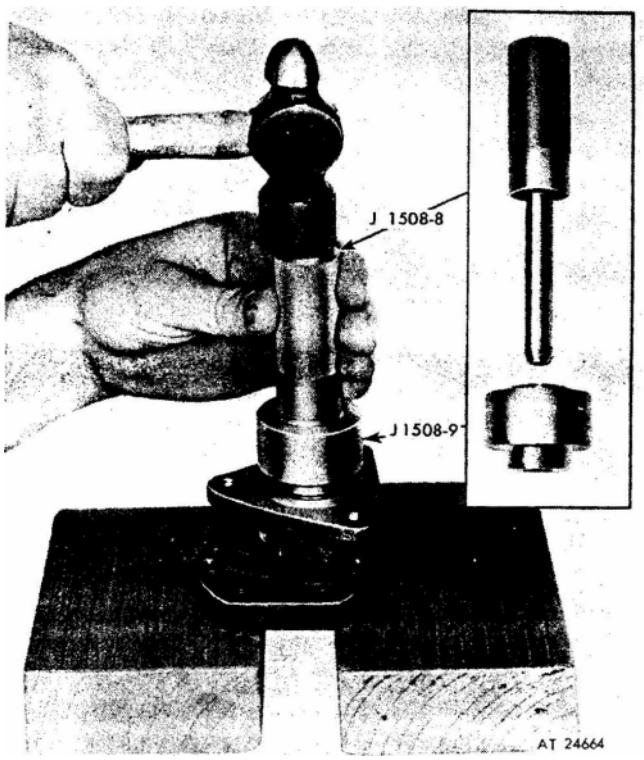


Figure 7. Installing outer oil seal in pump body.

8. Secure the cover in place with eight bolts and lock washers.

9. After assembly rotate the pump shaft by hand to make certain that the parts rotate freely. When the shaft does not rotate freely, attempt to free it by tapping a corner of the pump.

10. If pump is not to be installed immediately, use plastic shipping plugs in inlet and outlet openings to prevent dirt or other foreign material from entering the pump.

Install Fuel Pump

I. Affix a new gasket to the pump body and locate the pump drive coupling or fork over the square end of the fuel pump drive shaft.

2. Install the fuel pump on the engine and secure it with three bolt and washer assemblies.

3. Connect the inlet awl outlet fuel lines to the fuel pinup.

FUEL PUMP DRIVE

The fuel pump on the engine is driven with the governor weight shaft, by means of a drive coupling.

Remove the bolts and detach the fuel pump drive adaptor from the gear.

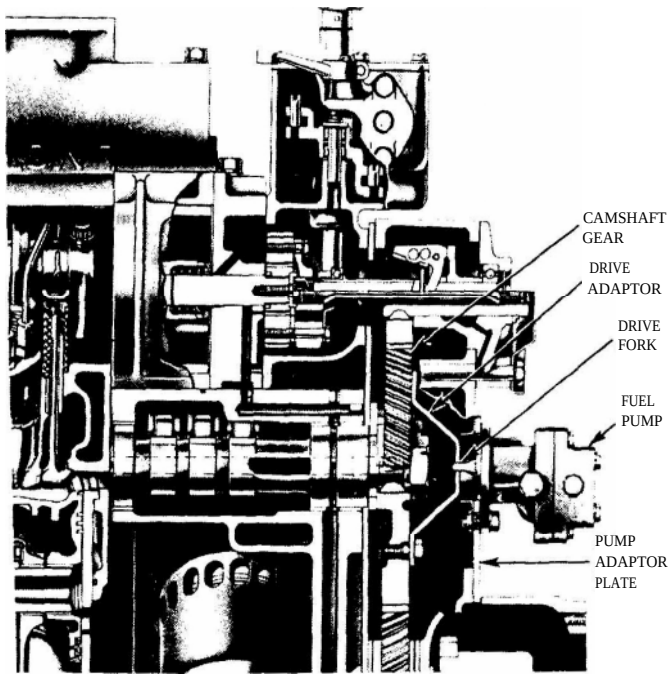


Figure 1. Camshaft drive for fuel pump (6V engine shown).

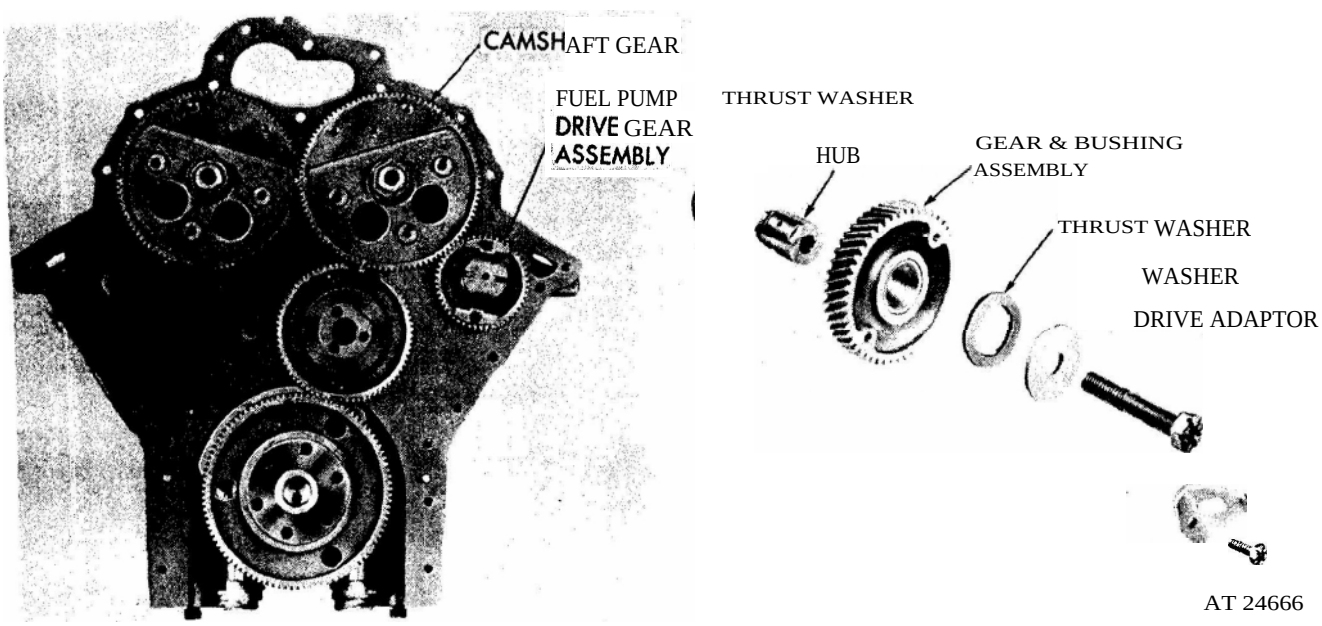


Figure 2. Fuel pump drive gear mounting and details (6 V engine shown).

FUEL STRAINER AND FUEL FILTER

A fuel strainer (primary) and fuel filter (secondary) (fig. 1) are used to remove impurities from the fuel. The fuel strainer is located between the fuel tank and the fuel pump. The replaceable density-type element is capable of filtering out particles of 30 microns (a micron is approximately .00004"). The fuel filter is installed between the fuel pump and the fuel inlet manifold. The replaceable paper-type element (fig. 2) can remove particles as small as 10 microns. The fuel strainer and fuel filter illustrated in figures 3 and 4 consist essentially of a shell, a cover, and a replaceable filtering element. The filtering element sets over the central stud, which is welded to the shell. The shell and element are attached to the cover by a nut or bolt that threads on or into the central stud. A shell gasket and cover bolt gasket *seal* the assembly against leakage.

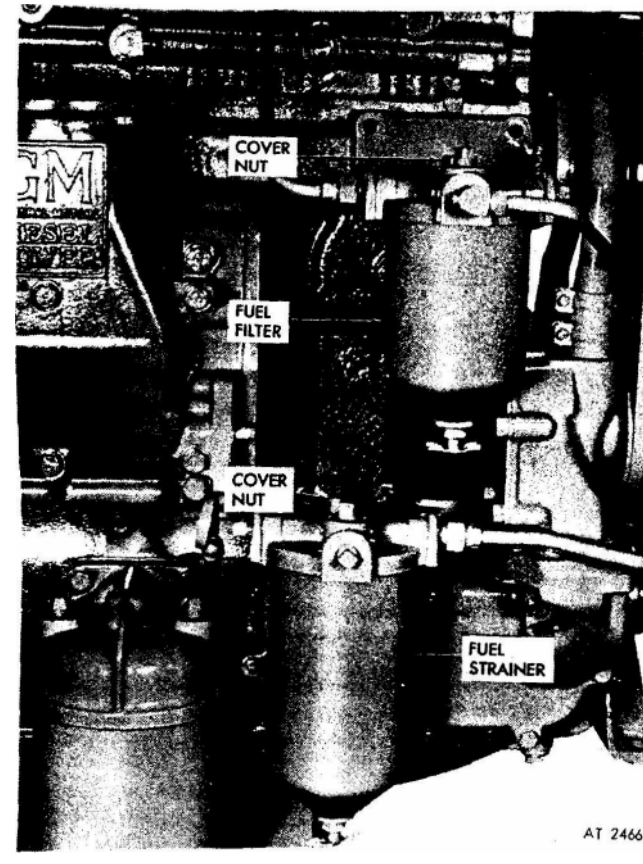


Figure I. Typical mounting of fuel strainer and fuel filter.

Operation

Since the fuel strainer is located between the fuel tank and the fuel pump, it functions under suction. The fuel filter, installed between the fuel pump and the fuel inlet manifold in the cylinder head, operates under pressure. Fuel enters the shell through the inlet passage in the cover and surrounds the filtering element. Pressure or suction created by the pump causes the fuel to flow through the element where any impurities are removed. The clean fuel then flows to the interior, up through the central passage in the cover and into the outlet passage.

Replace Fuel Filter and Strainer Elements

Refer to figures 3 and 4 and replace the element as follows:

1. With the engine stopped, place a container under the strainer or filter and open the drain cock. Loosen the cover bolt or nut just enough to allow the fuel to drain out freely. Then, close the drain cock.

CAUTION

The wiring harness, starting motor, or other electrical eqiupment must be shielded during the filter change, since fuel oil can permanently damage the electrical insulation.

2. While supporting the shell, unscrew the cover nut or bolt and remove the shell and the element.

3. Remove and discard the element, the shell gasket, the cover nut or bolt gasket, and, if so equipped, the cover bolt snap ring.

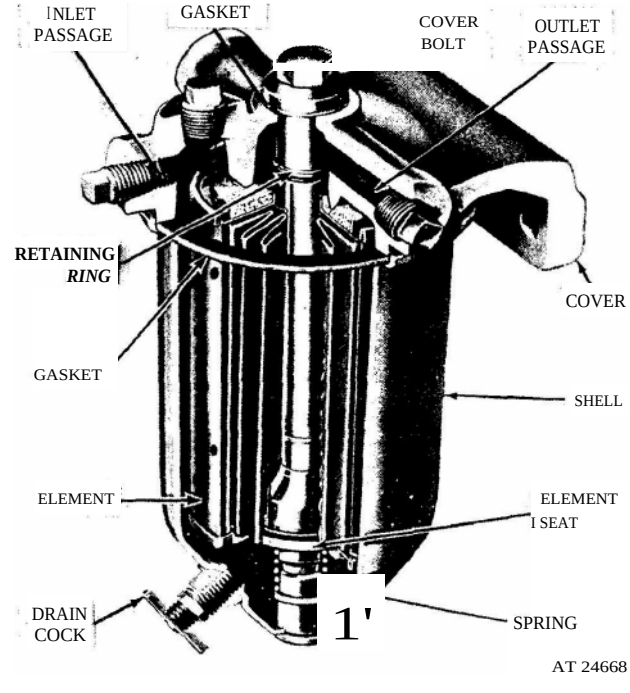


Figure 2. Fuel filter assembly.

2.3 FUEL STRAINER AND FUEL FILTER

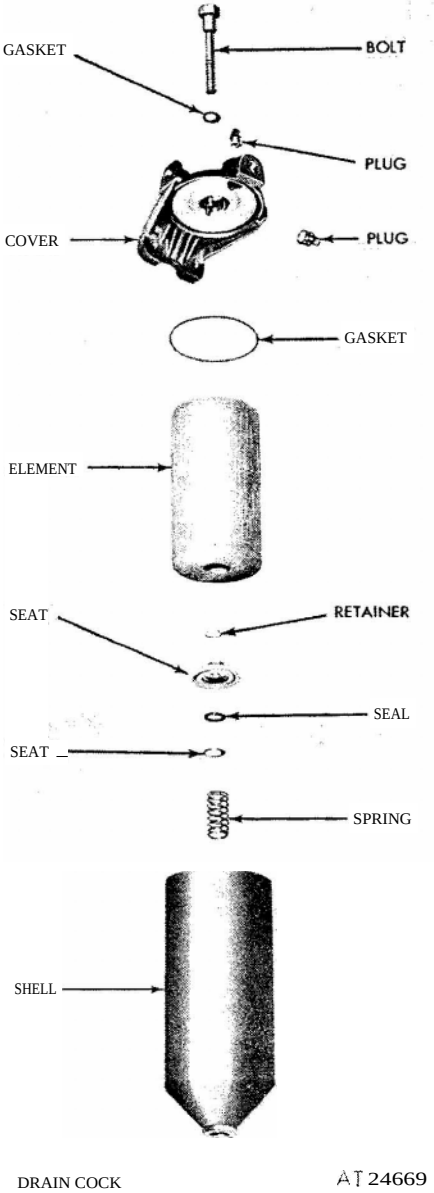


Figure 3. Fuel strainer details and relative location of parts.

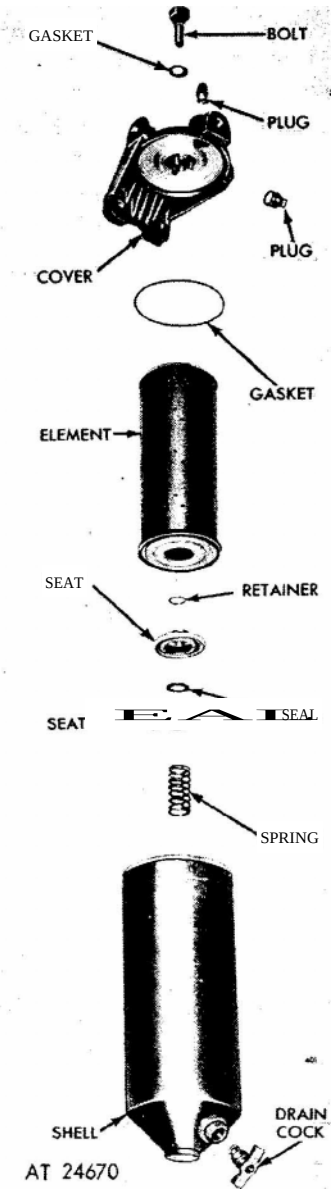


Figure 4. Fuel filter details and relative location of parts.

CAUTION

Only filter elements designed for fuel oil filtration should be used to filter the fuel.

4. Wash the shell thoroughly with fuel oil and dry it with compressed air.

5. Examine the element seat and the retaining ring to make sure they have not slipped out of place. Check the spring by pressing on the element seat. When released, the seat must return against the retaining ring.

NOTE

The element seat, spring, washer and seal cannot be removed from the strainer shell. If necessary, the shell assembly must be replaced. However, the components of the filter shell are serviced. Examine the filter retainer seal for hardening or cracking. If necessary, replace the seal.

6. Place a new element over the stud and down against the seat. Make sure the drain cock is closed; then, fill the shell about two-thirds full with clean fuel oil.

NOTE

Thoroughly soak the density-type strainer element in clean fuel oil before installing it. This will expel any air entrapped in the element and is conducive to a faster initial start.

7. Install a new gasket in the recess of the shell.
8. Place the shell and element in position under the cover. Then, with a new gasket over the cover bolt, thread the bolt into the stud.
9. With the shell and gasket properly positioned, tighten the cover bolt just enough to prevent fuel leakage.
10. Remove the filler plug in the cover and complete filling of the shell with fuel. Primer J 5956 may he used to prime the entire fuel system.
1. Start the engine and check the fuel system for leaks.

MECHANICAL GOVERNOR

Horsepower requirements on an engine may vary due to fluctuating loads; therefore, some method must be provided to control the amount of fuel required to hold the engine speed reasonably constant during load fluctuations. To accomplish this control, a governor is introduced in the linkage between the throttle control and the fuel injectors.

Check Governor Operation.

Governor difficulties are usually indicated by speed variations of the engine; however, it does not necessarily mean that all such speed fluctuations are caused by the governor. Therefore, when improper speed variations are present, the engine should be checked as follows:

I. Make sure the speed changes are not the result of excessive load fluctuations.

2. Check the engine to be sure that all of the cylinders are firing properly (refer to section 15.21. If any cylinder is not firing properly, the injector must be removed, tested and, if necessary, reconditioned as outlined in section 2.1.1.

3. Check for bind that may exist in the governor operating mechanism or in the linkage between the governor and the injector control tube. With the fuel rod connected to the injector control tube lever, the mechanism should be free from bind throughout the entire travel of the injector racks. If friction exists in the mechanism, it may be located and corrected as follows:

1. If an injector rack sticks or moves too hard, it may be due to the injector hold-down damp being too tight or improperly positioned. To correct this condition, loosen the injector clamp, reposition it, and tighten the clamp bolt to 20-25 lb-ft torque.

2. An injector which isn't functioning properly may be caused by a defective plunger and bushing or a bent injector rack. Recondition a faulty injector as outlined in section 2.1 or 2.1.1.

3. An injector rack may bind as the result of an improperly positioned rack control lever. Loosen the control rack adjusting screws. If this relieves the hind, relocate the lever on the control tube and position the rack as outlined in section 14.

4. The injector control tube may bind in its support brackets, thus preventing free movement of the injector racks to their no-fuel position due to tension of the return spring. This condition may be corrected by loosening and realigning the control tube supporting brackets. If the control tube support brackets were loosened, realigned and tightened, the injector racks must be repositioned as outlined in section 14.

5. A bent injector control tube return spring may cause friction in the operation of the injector control tube. If the spring has been bent or otherwise distorted, install a new spring.

6. Check for bind at the pin which connects the fuel rod to the injector control tube lever; replace the pin, if necessary. If, after making these checks, the governor fails to control the engine properly, it should he removed and reconditioned.

LIMITING SPEED MECHANICAL GOVERNOR

The limiting speed mechanical governor shown in figure 1 performs the following functions:

1. Controls the engine idle speed.
2. Limits the maximum operating speed of the engine. The mechanical engine governors are identified by a name plate attached to the governor housing. The letters D.W.-L.S. stamped on the name plate denote a double weight limiting speed governor. The governor is mounted on the rear end plate of the engine. The governor is driven by a gear that extends through the end plate and meshes with the balance shaft gear.

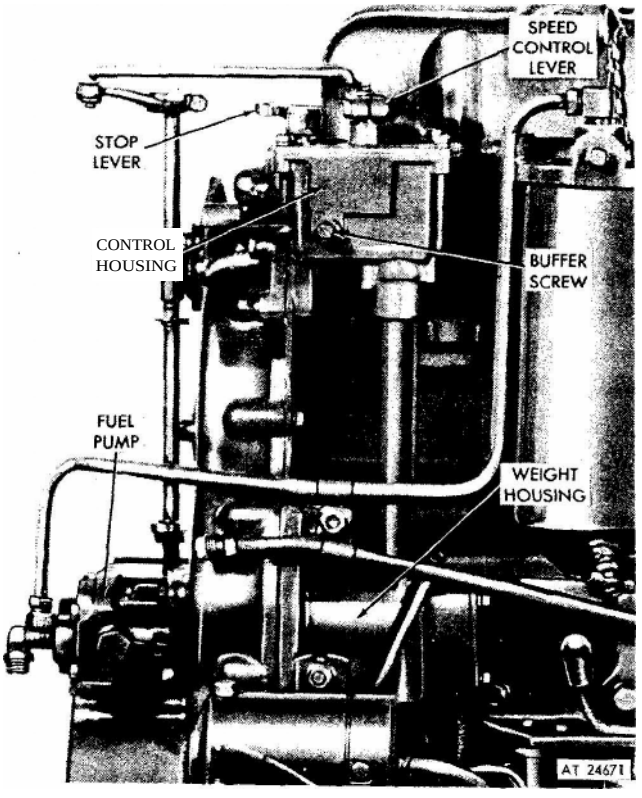


Figure 1. Limiting speed governor mounting.

Operation

The governor holds the injector racks in the advanced fuel position for starting when the throttle control lever is in the idle position. Immediately after starting. the governor moves the injector racks to that position required for idling. The centrifugal force of the revolving governor low and high speed weights is converted into linear motion which is transmitted through the riser and operating shaft to the operating shaft lever. One end of this lever operates against the high and low speed springs through the spring cap, while the other end provides a moving fulcrum on which the differential lever pivots. When the centrifugal force of the revolving governor weights balances out the tension on the high or low speed spring (depending on the speed range), the governor stabilizes the engine speed for a given setting of the throttle control lever. In the low speed range, the centrifugal force of the low and high speed weights together operates against the low speed spring. As the engine speed increases, the centrifugal force of the low and high speed weights together compresses the low speed spring until the low speed weights are against their stops, thus limiting their travel, at which time the low speed spring is fully compressed and the low speed spring cap is within .0015" of the high speed plunger.

Throughout the intermediate speed range the operator has complete control of the engine because the low speed gap is closed and the low speed weights are against their stops, and the high speed weights are not exerting enough force to overcome the high speed spring. As the speed continues to increase, the centrifugal force of the high speed weights increases until this force can overcome the high speed spring and the governor again takes control of the engine, limiting the maximum engine speed. A fuel rod connected to the differential lever and injector control tube lever, provides a means for the governoor to change the fuel settings in the injector rack control levers. The engine idle speed is determined by the force exerted by the governor low speed spring. When the governor throttle control lever is placed in the idle position, the engine will operate at the speed where the force exerted by the governor low speed weights will equal the force exerted by the governor low speed spring.

Adjustment of the engine idle speed is accomplished by changing the force on the low speed spring by means of the idle adjusting screw. Refer to the tune-up section for idle speed adjustment. The engine maximum no-load speed is determined by the force exerted by the high speed spring. When the throttle control lever is placed in the maximum speed position, the engine will operate at a speed where the force exerted by the governor high speed weights will equal the force exerted by the governor high speed spring. Adjustment of the maximum no-load speed is accomplished by changing the tension on the high speed spring. Refer to the tune-up section for the maximum no-load speed adjustment.

Lubrication

The governor is lubricated by oil splash from the engine gear train and by an oil line. The oil passes through the governor weight housing on to the shaft and weight assemblies. The oil is distributed to the various moving parts within the governor by the revolving weights. Surplus oil drains from the

governor through holes in the governor bearing retainer back to the engine gear train.

Remove Governor from Engine

The governor operation should be checked as outlined in section 2.7 before a governor is removed. H the governor fails to control the engine properly, after performing these checks, remove and recondition it (fig. 1).

1. Disconnect the linkage to the governor levers.
2. Remove the governor cover and gasket.
3. Remove two bolts and lock washers and detach the spring housing from the governor housing.
4. Loosen the high speed spring retainer lock nut with spanner J 5345-5 and remove the spring assembly.

NOTE

On engines equipped with the vehicle type governor, use J 5895 and remove the high speed spring retainer and the spring assembly.

5. Loosen the fuel rod cover hose clamps.
6. Remove the rocker cover from the cylinder head.
7. Disconnect the fuel rod from the injector control tube lever. Remove the clip holding the fuel rod to the differential lever and lift the fuel rod from the lever.
8. Disconnect the fuel lines from the fuel pump. Remove three bolts and remove the fuel pump. Also disconnect the oil line, if used.
9. Remove five bolts securing the governor weight housing and two bolts securing the governor control housing.
10. Remove the governor and the gasket from the engine.

Disassemble Governor Cover

1. Remove the return spring and clip from single lever cover only, then loosen the governor speed control lever retaining bolt and lift the lever from the speed control shaft (fig. 2).
2. Remove the retaining ring and washer. Withdraw the speed control shaft from the cover.
3. Remove the seal ring from the cover.

NOTE

The single lever cover has the seal ring at the top of the cover. The double lever cover has the seal ring at the bottom of the cover.

4. Loosen the governor stop lever retaining bolt and lift the lever from the stop lever shaft.
5. Remove the retaining ring and washers and withdraw the stop lever shaft from the cover.
6. Remove the seal ring from the top of the cover.

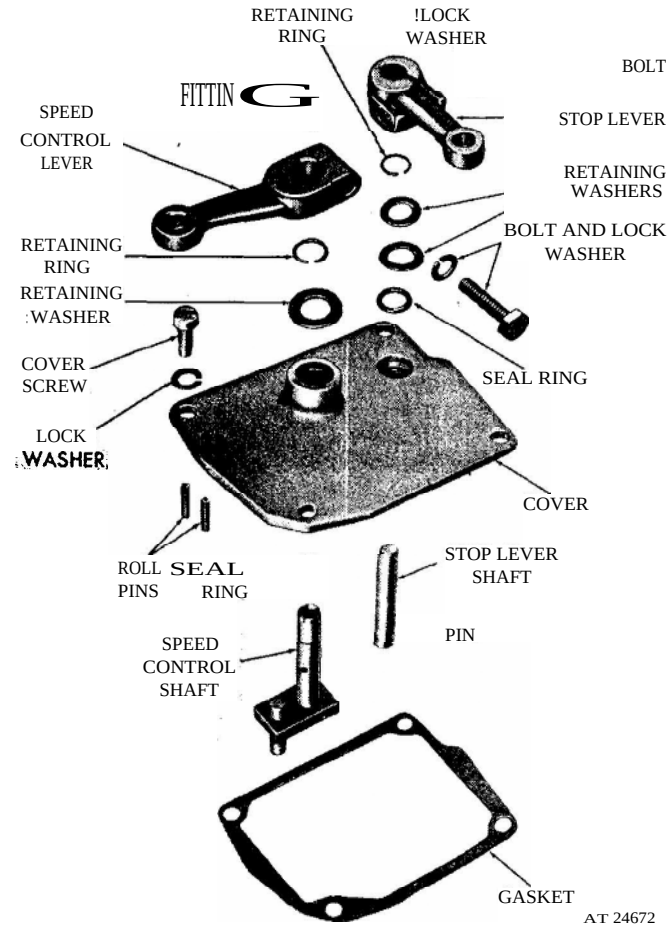


Figure 2. Governor cover details and relative location of parts.

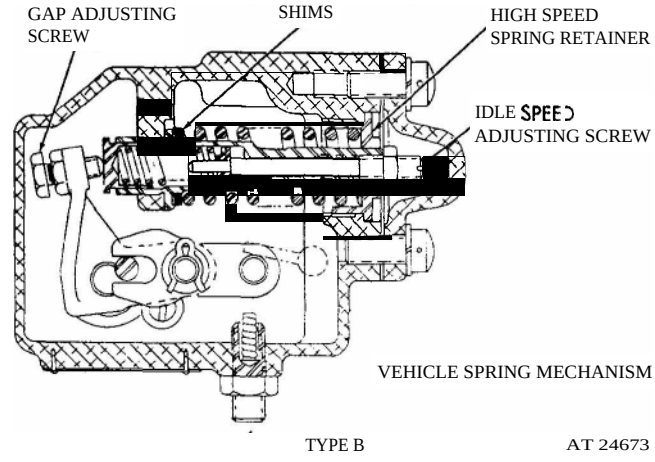


Figure 3. Differences between industrial and vehicle type governor assemblies.

Disassemble Governor Weight Housing

1. Remove the gear retaining nut from the shaft, then, remove the gear, key and spacer from the shaft.

Figure 4. Removing the fork from the operating shaft.

2. Remove the small screw holding the bearing retainer in place.

3. Turn the bearing support until the large opening is centered over the fork on the operating shaft.

4. Lift up on the weight shaft until there is enough clearance for a 5/ 16" socket wrench to be placed on the screws that hold the fork to the operating shaft (fig. 4). Then remove the two screws and washers.

5. Lift the shaft and weight assembly out of the governor weight housing.

6. Remove the screw and washers holding the bearing in the control housing and lift the shaft assembly out of the housing.

7. Place a rod approximately 18" long through the control housing and knock the plug out of the bottom of the weight housing.

8. Remove the snap ring and press the bearing from the weight housing.

9. Remove the spring pin and washer from the governor operating shaft lever and remove governor differential lever.

10. Press the bearing and the operating shaft lever from the operating shaft, if necessary.

11. If necessary, disassemble the control housing from the weight housing.

Disassemble Weight Shaft Assembly

1. Press the bearing retainer from the weight shaft.

2. If necessary, remove the snap ring and press the bearing from the bearing retainer.

3. Remove the weight pin retainers from the governor weight pins, then drive the pins out of the carrier and weights. Remove the governor weights.

NOTE 1

Drive the pins out of the carrier from the weight pin retainer end.

NOTE 2

Punch mark the carrier at the retainer end of the weight pins so the pins may be placed in the proper position when reinstalling the weights in the carrier.

4. Slide the riser and bearing assembly from the shaft. Do not disassemble the bearing since the riser and bearing are serviced only as an assembly.

Inspection

Clean all of the parts with fuel oil and dry them with compressed air. Inspect all of the governor components and replace worn or damaged parts. Revolve the ball bearings slowly by hand. Replace bearings which indicate rough or tight spots. Also, replace bearings which are corroded or pitted. The lower governor drive components have been revised to reduce the clearance between the riser and the weight shaft. With this change, additional lubrication is provided to the governor by an oil line connected between the oil gallery in the cylinder block and the governor weight housing. When replacing the riser assembly, shaft and carrier assembly, or the complete governor assembly, the *new* oil line must be installed to provide adequate lubrication.

Examine the riser thrust bearing for excessive wear, flat spots or corrosion. If any of these conditions exist, install a new riser and bearing assembly. Inspect the weight carrier, weights and retaining pins for wear. The current singel-weight carrier replaces the former double-weight carrier. Inspect the fuel pump drive end of the weight shaft. Replace the shaft if the end is worn or rounded. Inspect the bushing in the weight housing. Replace the bushing if it is worn excessively. Inspect the spring seats, plungers, adjusting screws, lock nuts, and other parts of the control housing for defects that might affect the governor operation.

Assemble Governor Cover

I. Place a new seal ring in the counterbore of the cover (fig. 2).

NOTE

The single lever cover has the seal ring at the top of the cover. The double lever cover

has the seal ring at the bottom of the cover.

2. Lubricate the speed control shaft with engine oil, then slide the shaft through the cover. Install the washer and the retaining ring on the shaft.

3. Place the speed control lever over the shaft and secure it with the bolt and lock washer.

4. On double lever covers lubricate the top lever shaft with engine oil, then slide the shaft through the cover.

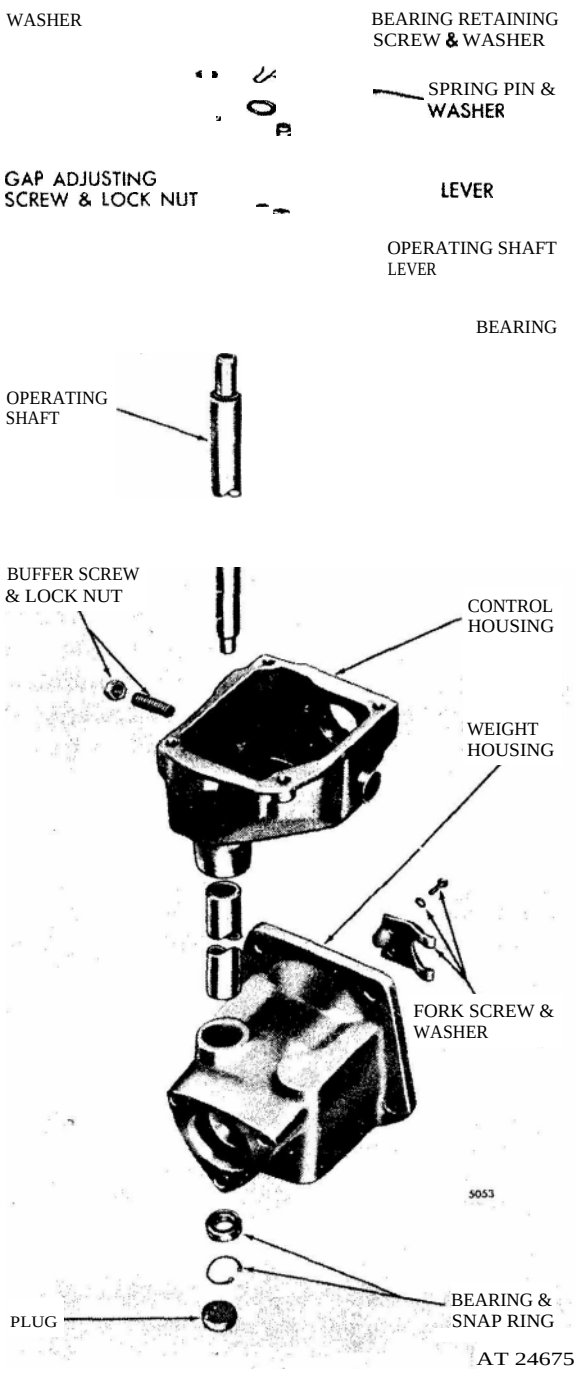


Figure 5. Governor housings and relative location of parts.

5. Place the seal ring in the counterbore of the shaft opening, then install the washer over the shaft. Lock the shaft in place with the retaining ring.

6. Place the stop lever on the shaft and secure it with the bolt and lock washer.

Assemble Control Housing

1. Install a ⅛" pipe plug in the tapped in the side of the control housing.

2. If necessary, assemble the control housing to the weight housing, using a good quality sealant between the tube and the housings.

3. Install the governor operating shaft lower hearing, numbered side out, in the weight housing. Install the snap ring to secure the bearing (fig. 5). Apply a quality sealant around the *edge* of the *plug* and tap it in place, using a hammer.

4. Start the governor operating shaft upper hearing over the upper end of the operating shaft. Support the lower end of the shaft on the bed of an arbor press. Use a sleeve and press down on the inner race of the hearing until it contacts the shoulder of the operating shaft.

5. Place the operating lever on the shaft with the flat surface on the shaft registering with the flat surface on the lever. Press the lever tight against the hearing on the shaft.

6. Lubricate both upper and lower bearings with engine lubricating oil. Insert the lever and operating shaft assembly in the control housing. Guide the lower end into the bearing.

7. Secure the upper operating shaft bearing with the round head retaining screw and washers.

8. Place the fork on the operating shaft with the two cam faces facing the fuel pump.

9. Secure the fork to the operating shaft with two screws and lock washers.

10. Place the differential lever over the operating shaft lever pin and secure in place using the washer and spring pin.

Assemble Governor Weight and Shaft Assembly

1. If the weight carrier was removed from the weight shaft, press the carrier on the shaft. so as to allow a *clearance* of .001" to .006" between the shaft shoulder and the rear face of the weight carrier.

2. Press the governor weight shaft hearing into the bearing retainer by pressing on the outer race of the bearing (fig. 6).

3. Install the snap ring into the retainer with the flat side of the ring facing the bearing.

4. Press the bearing retainer onto the weight shaft until the bearing is against the shoulder of the shaft.

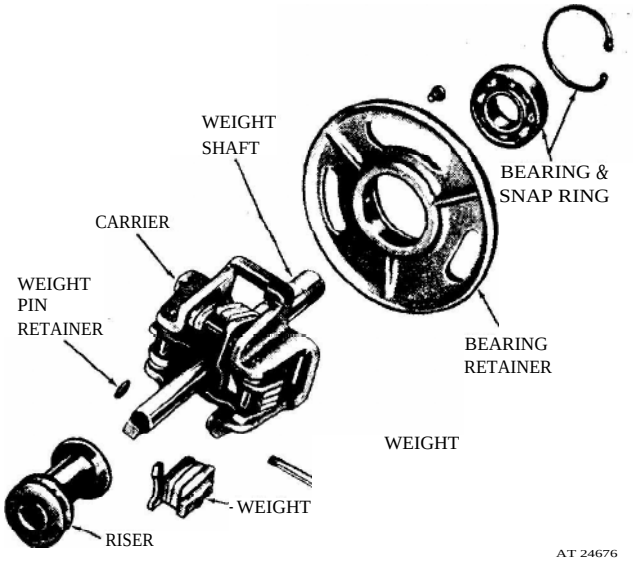


Figure 6. Governor weight details and relative location of parts.

NOTE

To prevent any damage, press only on the inner race of the bearing.

5. Place the riser on the weight shaft.

6. Position the low speed weights, identified by the short cam arm and three center laminations, each approximately 9 / 64" thick, on the weight carrier. Drive the weight pins in place and install in weight pin retainer.

i. Install the high speed weights the same way. The high speed weights are identified by the long cam arm and three center laminations; the midddle lamination is 3 / 16" thick and the outer ones are ⅛" thick.

NOTE

The weight pins must be reinstalled in the same positions from which they are removed.

8. Slide the shaft and weight assembly into the weight housing with the riser bearing placed behind the fork.

9. Turn the bearing retainer until the large opening is over the fork on the operating shaft. Tighten the two screws holding the fork to the operating shaft with a 5 / 16" socket wrench.

10. Turn the bearing retainer until the counterbored hole in the retainer and housing line up. Install the screw to secure the bearing retainer to the weight housing.

11. Place the drive gear spacer on the shaft. Install the key in the keyway and place the gear on the shaft.

12. Tap the gear until the spacer is against the hearing. Install the drive gear retaining nut and tighten it to 125-135 lb-ft torqu.

Install Governor

Refer to figure 1 and install the governor on the engine as follows:

1. Attach the fuel rod to the differential lever and secure it in place with a washer and spring pin.

2. Attach a new gasket to the governor weight housing.

3. Insert the end of the fuel rod through the hose and clamps and into the opening in the cylinder head and position the governor weight housing against the engine rear end plate; the teeth on the governor drive gear must mesh with the teeth on the camshaft gear or balance shaft gear.

4. Install the three 12-point head bolts with copper washers in the governor weight housing next to the cylinder block. Install the two remaining bolts with steel washers and lock washers. Tighten the bolts to 35 lb-ft torque.

5. Install the two governor control housing attaching bolts and lock washers. Tighten the bolts to 10-12 lb-ft torque.

6. On current engines, install the lubricating oil line and fittings from the weight housing to the cylinder block.

7. Align and tighten the hose clamps On the fuel rod covers.

8. Attach the fuel rod to the injector control tube lever with a pin and cotter pin.

9. Assemble the vehicle governor spring as follows:

a. Back off the lock nut at the outer end of the adjusting screw to within 1 / 16" of the slotted end of the screw.

b. Slip the shims, if used, and the high speed spring over the plunger. Position the retainer ever the high speed spring and insert the adjusting screw into the plunger.

c. Position the seat and cap on the ends of the low speed spring and insert the assembly into the hollow end of the plunger.

d. Insert the spring and plunger assembly the control housing and tighten die retainer not with spanner wrench J 5895.

10. Thread the spring retainer and spring assembly into the governor; the lock nut should be finger tight until engine tune-up is performed.

11. Use a new gasket when installing the governor cover and lever assembly. Be sure the speed control pin engages the slot in the differential lever and the stop lever is in the correct position. Secure the cover to the housing with four screws and lock washers.

2.7.1 LIMITING SPEED GOVERNOR

12. Install the return spring and spring clip (single lever cover only).
13. Add lubricant to the speed control shaft through the grease fitting on top of the shaft.
14. Connect the linkage to the governor control levers.
15. Install the fuel pump and fuel lines.
16. Perform a tune-up as outlined in section 14.

SPECIFICATIONS- SERVICE TOOLS

SPECIFICATIONS

Standard Bolt and Nut Torque Specifications

Size nut or bolt	Torque (lb-ft)	Size nut or bolt	Torque (lb ft)	Size nut or bolt	Torque (lb-ft)
1 / 4 - 20	7-9	7/16 -	57-61	3/ 4 - 10	240-250
1/ 4 - 28	8-10	1 /2 - 13	71-75	3/ 4 - 16	290-300
5/16 - 18	13-17	1/ 2 - 20	83-93	7 / 8 - 9	410-420
5/16 - 24	15-19	9/16 - 12	90-100	7 / 8 - 14	475-485
3/8 - 16	30.35	9/16 - 18	107-117	1 - 8	580-590
3/ 8 - 24	35-39	5/8 - 11	137-147	1 - 14	685-695
7 / 16 - 14..	46-50	5/8 - 18	168-178		

Exceptions to Standard Bolt and Nut Torque Specifications

Application	Size nut or bolt	Torque (lb-ft)
Governor Control Housing to Flywheel Housing	5/ 16 - 18	10-12
Variable Speed Spring Lever Set Screw	5 / 16 - 24	12-15
Governor Weight Shaft Bearing Retaining Bolt	5 / 16 - 24	15-19
Blower Drive Assembly to Flywheel Housing	3/8 - 16	20-25
Injector Clamp Bolt	3/ 8 - 16	20-25
Governor-to-Engine End Plate (In-Line Engine)	3/8 - 24	35
Governor Drive Gear Retaining Nut (In-Line Engine)	5/8 - 18	125-135

Service Tools

Tool No.	Tool name
J 5895	Governor Spring Retainer Nut Wrench
J 8994	Governor Weight Carrier Spacer
J 8985	Control Link Operating Lever Bearing Remover and Installer
J 9196	Variable Speed Governor Spring Housing Bearing Installer Set
J 9196-1	Installer Body
J 9196-2	Installer Body Rod
J 21068	Governor Co er Bearing Installer
J 21967	Governor Co er Bearing Remover and Installer
J 21995	Governor Operating Fork Installer Set
J 21995-1	Support Pin
J 21995-2	Support Disc

SECTION 3

AIR INTAKE SYSTEM

CONTENTS

AIR INTAKE SYSTEM

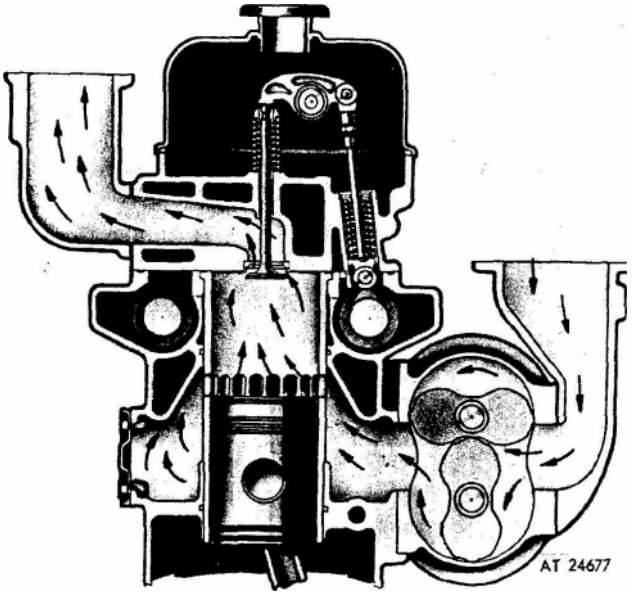


Figure 1. Air Intake system through blower and engine (in-line engine).

In the scavenging process emplued in the Series 53 engines, a charge of air is forced into the cylinders by the blower and thoroughly sweeps out all of the burnt gases through the exhaust valve ports. This air also helps to cool the internal engine parts, particularly the exhaust valves. At the beginning of the compression stroke, each cylinder is filled with fresh, clean air which provides for efficient combustion. The air, entering the blower from the air silencer or air cleaner, is picked up by the blower rotor lobes and carried to the discharge side of the blower. The continuous discharge of fresh air from the blower enters the air chamber of the cylinder block and sweeps through the intake ports of the cylinder liners. The angle of the ports in the cylinder liners creates a uniform swirling motion to the intake air as it enters the cylinder. This motion persists through out the compression stroke and facilitates scavenging and combustion.

BLOWER

The blower supplies fresh air required for combustion and scavenging. Its operation is similar to that of a gear type oil pump. Two hollow double lobe rotors revolve in a housing bolted to the cylinder block. The revolving motion of the rotors provides a continuous and uniform displacement of air. The blower rotors are pinned to the steel rotor shafts. The rotor shafts are steel and the blower end plates are aluminum, providing for a compatible bearing arrangement. Gears located on the splined end of the rotor shafts assist in spacing the rotor lobes. As the lobes of the upper and lower rotors do not touch at any time, no lubrication is required. Normal gear wear will have some material effect on the rotor-to-rotor clearance. A combination of gear and rotor shaft bearing surface wear will result in a decrease of rotor to housing clearance. Lip type oil seals are incorporated in both the front and the rear end plates on current engines (fig. 2). The seals prevent air leakage past the blower rotor shaft bearing surfaces and keep the oil, used for lubricating the blower timing gears, from entering the rotor compartment.

Inspect Blower (Attached to Engine)

The blower may be inspected on the engine by removing the air filter and air inlet housing or the air silencer.

CAUTION

When inspecting the blower with the engine running, keep your fingers and clothing away from moving parts of the blower and run the engine at low speeds only.

Dirt or chips, drawn through the blower, will make deep scratches in the rotors and housing and throw up burrs around such abrasions. If burrs cause interference between the rotors or between the rotors and the housing, remove the blower from the engine and remove the burrs to eliminate the interference, or replace the rotors if they are too badly scored. Leaky oil seals are usually indicated by the presence of oil on the blower rotors or inside surfaces of the housing. This condition may be checked by running the engine at low speed and directing a light into the rotor compartment at the end plates and the oil seals. A thin film of oil radiating away from the seal is indicative of an oil leak.

A worn blower drive resulting in a loose, rattling sound within the blower may be detected with the engine operating at approximately 500 rpm. If a worn blower is suspected, the blower must be removed from the engine before repairing or replacing it. Loose rotor shafts or worn rotor shaft bearing surfaces will result in contact between the rotor lobes, rotors and end plates, or rotors and housing. Excessive back-lash between the blower timing gears usually results in the rotor lobes rubbing throughout their entire length.

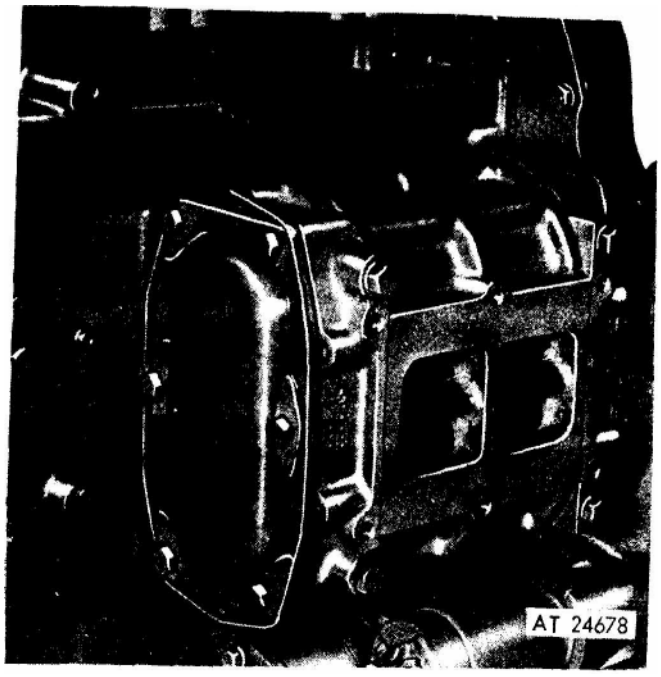


Figure 1. Blower mounting.

Remove and Disassembly Blower

Refer to figure 2 and proceed in the following manner:

1. Remove the six bolts (30), special washers (31) and reinforcement plates (34) securing the blower assembly to the engine end plate and the flywheel housing. Note the location of the two shorter bolts. Then, lift the blower front end plate cover (26) and gasket (28) away from the blower.

2. Remove the four blower-to-block blots (62) and special washers (63) and lift the blower away from the engine.

3. Wedge a clean cloth between the blower rotors (6) to prevent their turning (fig. 3). Then, remove the blower gear retaining bolts (44) and rotor gear washers (48).

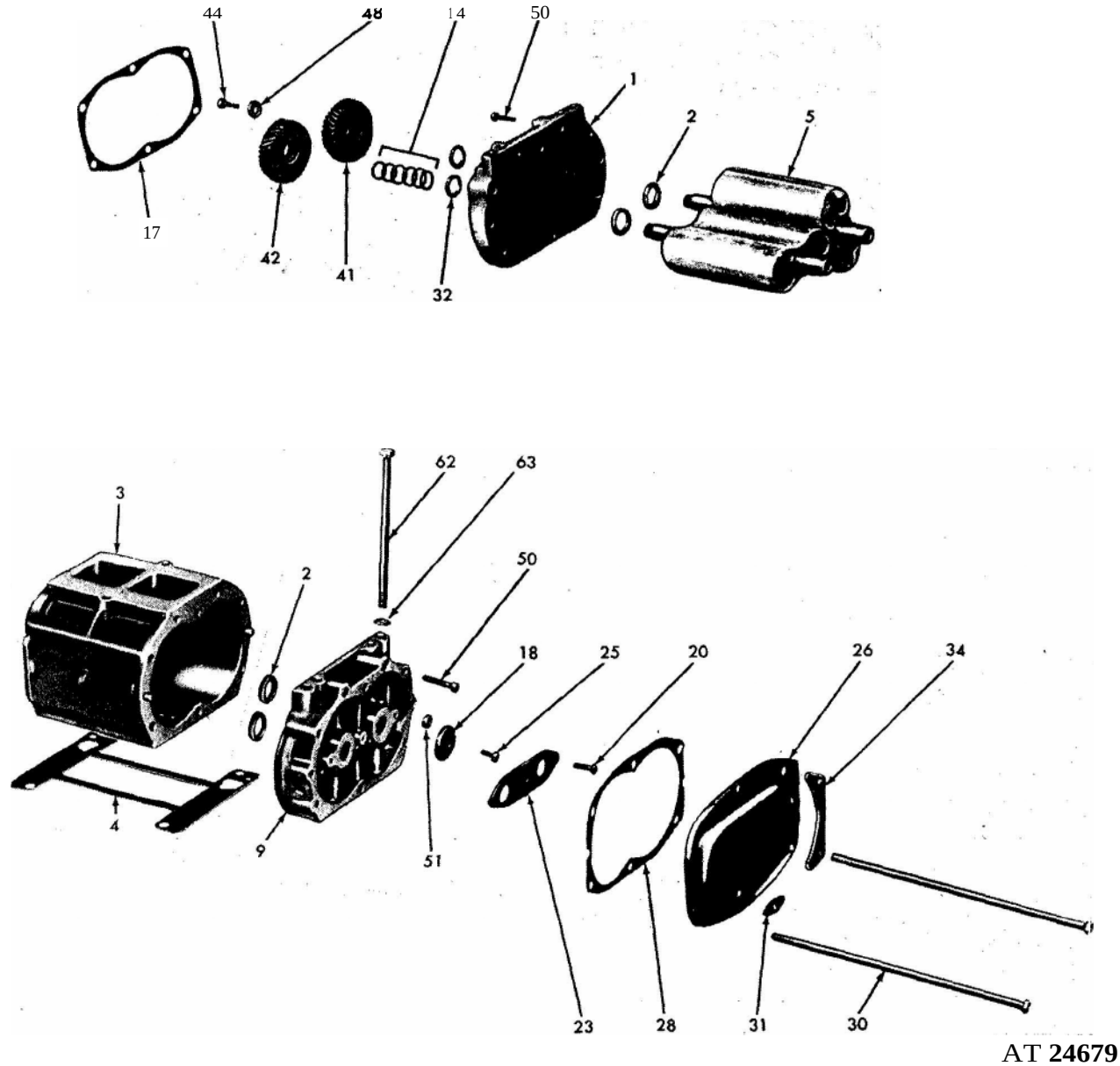
4. For identification, mark the R.H. helix gear (41). Then remove the blower rotor gears (41 and 42) with pullers J 5825-01 as follows (fig. 3) :

a. With the pullers in place under the gears, place a brass bar approximately 1" long and ⅝" diameter between the point of each puller bolt and blower rotor shaft.

Caution

If the brass bar is larger than ⅝" diameter, the serrations in the blower gear may be damaged.

3.4 BLOWER (IN-LINE and 6V-53)



1 End plate—rear (Current)
2 Seal—oil (current)
3 Housing—blower
4 Gasket—blower to block
5 Rotor (current)
6 Rotor (former)
8 Shaft—rotor
9 End plate—front (current)
10 Seal—washer (former)
11 "O" ring—oil seal (former)
12 Retainer—" 0' ring (former)
13 Spring—retainer (former)
14 Shim—rotor
17 Gasket—blower to end plate
18 Washer-thrust
20 Bolt—thrust plate
21 End plate—front (former)
22 End plate—rear (former)
23 Plate—thrust
24 Dowel
25 Bolt—thrust
26 Cover—front end Plate
28 Gasket—front end Plate cover
30 Bolt—cover to end Plate
31 Washer—special, blower end plate cover
32 Spacer—blower rotor Gear
34 Reinforcement plate Blower end plate cover
41 Gear—blower rotor (R.H. Helix)
42 Gear—blower rotor (L.H. Helix)
44 Bolt—Blower gear
48 Washer—rotor gear
50 Screw—end plate to Housing
51 Spacer—thrust plate

Figure 2. Typical blower details and relative location of parts (three cylinder engine).

b. Alternately turn the bolt in each puller until the gears are off the shafts.

5. Remove the rotor shims and the gear spacers and place them with their respective gears to ensure correct assembly.

6. At the other end of the blower, remove the three thrust plate bolts (20), the thrust plate (23) and three thrust plate spacers (51). Remove the bolts (25) and thrust washers (18).

7. Remove the two cap screws (50) securing the end plate (21) to the blower housing (3). Tap the end plate off of the dowel pins (24) and housing (3) with a soft plastic hammer, being careful not to damage the mating surfaces of the end plate and housing.

8. Remove the blower rotors (6) from the housing. Then, remove the end plate (22) from the housing.

9. Remove and discard the oil seals (2) from the end plates.

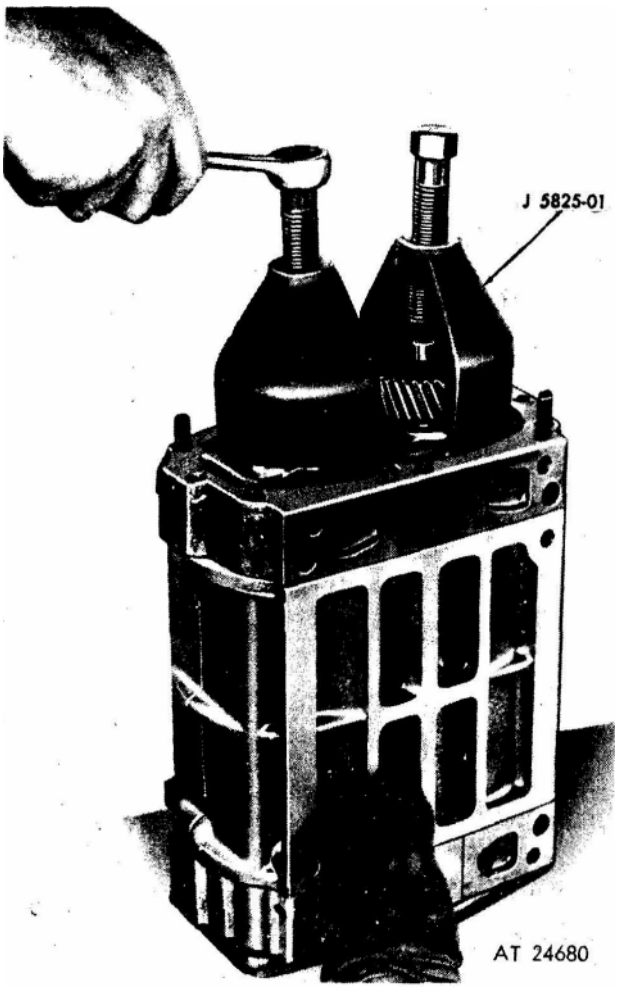


Figure 3. Removing blower rotor gears.

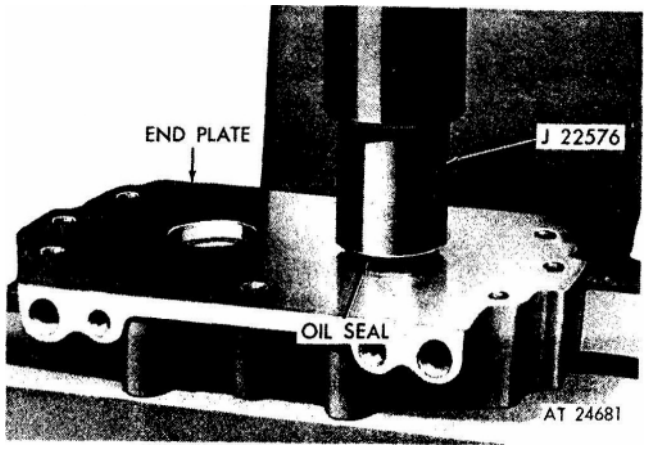


Figure 4. Installing oil seal (lip type) in end plate.

Inspect Blower

Thoroughly clean and dry all of the blower parts. The finished inside face of the end plates must be smooth and flat. Slight scoring may be cleaned up with a fine grit emery cloth. However, if the surface is badly scored, replace the end plate. Inspect the surfaces of the rotors and blower housing for burrs or scratches and remove them with an oil stone. Inspect the rotor shaft and gear serrations for burrs or wear. Check the blower gears for wear or damage. Check the bearing surfaces of the rotor shafts and end plates.

Assemble Blower

1. Install new lip type oil seals in each end plate in blower as follows:

a. Place the end plate on the bed of an arbor press.

b. Lubricate the outer diameter of a new seal and, using installer J 22576, press the seal (lip face down) into the counterbored hole until the shoulder on the installer contacts the end plate (fig. 4).

NOTE

A step on the installer will position the oil seal below the finished face of the end plate within the .002" to .008" specified.

2. Place the front end plate on two wood blocks; then install the rotors, gear end up, on the end plate as shown in figure 5.

NOTE

To prevent inadequate lubrication or low oil pressure, care must be exercised in the assembly of the front and rear blower end plates to the blower housing. The rear end plate does not have tapped holes for the thrust washer plate bolts and no thrust washer lubricating oil holes.

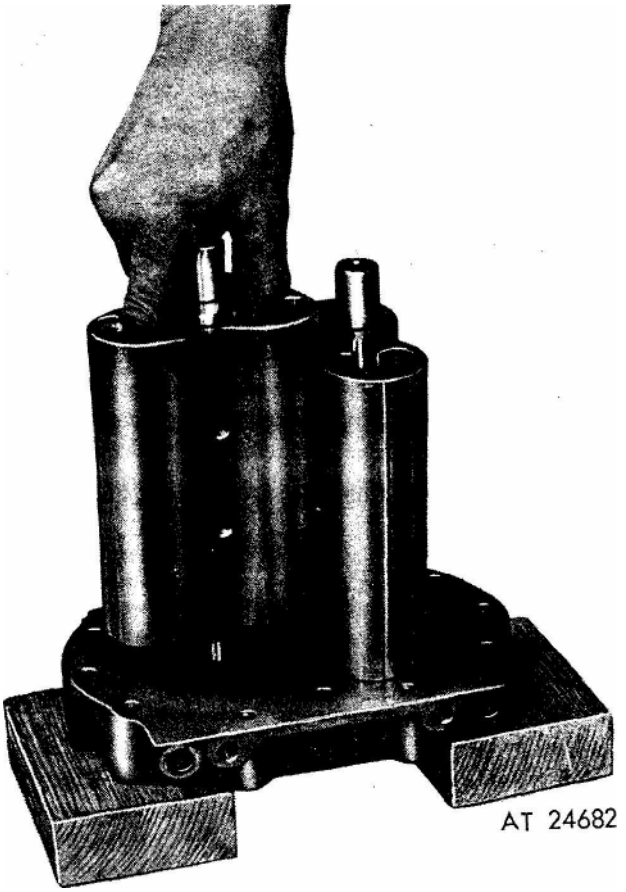


Figure 5. ***Installing blower rotors into front end plate.***

3. Install the blower housing over the rotors as shown in figure 6.

4. Place the rear end plate over the rotor shafts as shown in figure 7. Be sure that the seals are properly positioned on the rotors. Then, secure the end plates to the blower housing with screws (50).

5. Attach two thrust washers (18) to the front end of the blower with bolts (25). On a blower equipped with ⅜"-24 thrust washer bolts, tighten them to 54-59 lb-ft torque.

6. Attach tree spacers (51) and thrust plate (23) to the front end of the blower with three thrust plate bolts (20). Tighten the bolts to 7-9 lb-ft torque. Then check the clearance between the thrust plate and the thrust washers. The clearance should be .001" to .003".

7. Position the rotors so that the missing serrations on the gear end of the rotor shafts are 90° apart. This is accomplished by placing the rotors in a "T" shape with the missing serration in the upper rotor facing to the left, and the missing serration in the lower rotor facing the bottom (fig. 14). Install the shims (14) and spacers (32) in the counterbore in the rear face of the rotor gears. Place the gears on the ends of the shafts with the missing serrations in alignment with the missing serrations on the shafts.

8. Tap the gears lightly with a soft hammer to seat them on the shafts. Then rotate the gears until the punch marks on the face of the gears match. If the punch marks do not match, reposition the gears.

9. Wedge a clean cloth between the blower rotors. Use the blower rotor gear retaining bolts and plain washers to press the gears on the rotor shafts (fig. 8). Turn the bolts uniformly until the gears are tight against the shoulder on the shafts.

10. Remove the bolts and plain washers; then place the blower gear washers (48) on the gears. Start the gear retaining bolts (44) into the rotor shafts and tighten them to 25-30 lb-ft torque.

11. Backlash between the blower gears can be checked by using a suitable dial indicator. The backlash should be .0005" to .0025" with new gears. Replace the gears if the backlash exceeds .0035". Check the rotor end plate clearances, rotor to housing clearances and blower rotor clearances as described under "Time Blower Rotors".

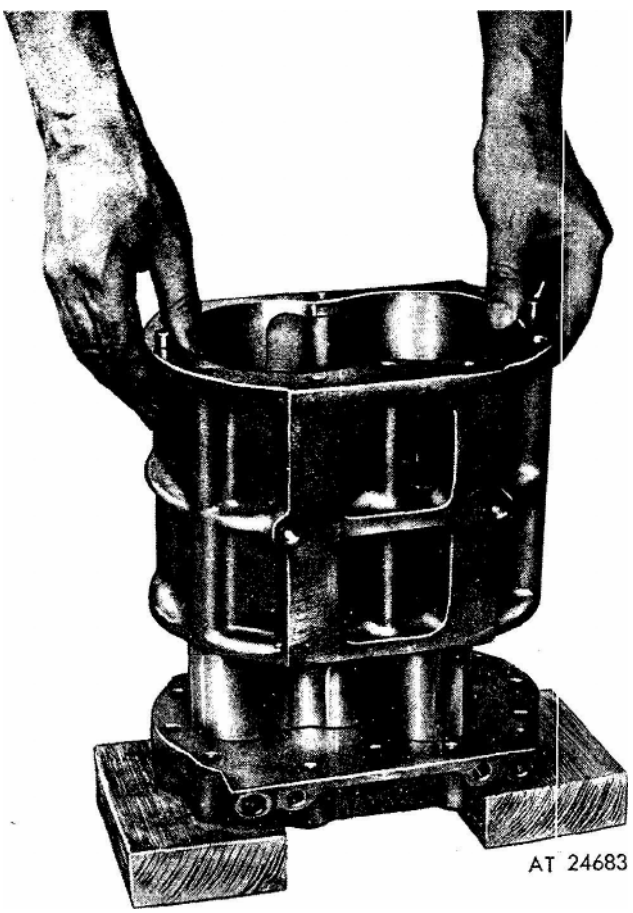


Figure 6. Installing blower housing over rotors.

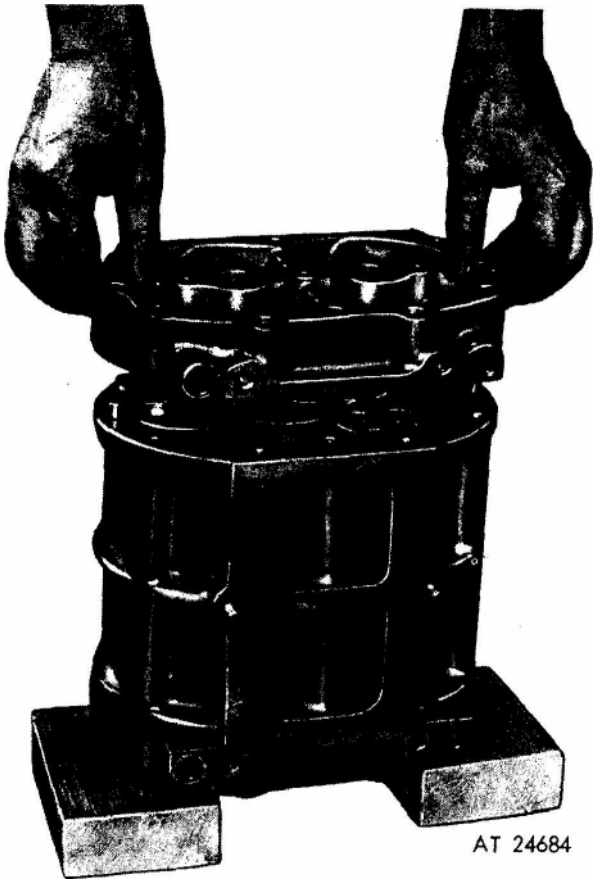


Figure 7. Installing mar end plate on blower rotors and housing.

Install Blower on Engine

1. Examine the inside of the blower for any foreign material. Also, revolve the rotors by hand to be sure they turn freely. Foreign particles in the blower may score the rotors and impair blower efficiency.

2. Affix a new blower-to-block gasket (4), Fig. 2, on the side of the cylinder block. Use Scotch Grip Rubber Adhesive No. 4300, or equivalent, on the block side of the gasket only.

3. Position the blower front end plate cover (26) and gasket (28) on the end of the blower and install six bolts (30) with two special washers (31) on the center bolts and the reinforcement plates (34) on the two top and the two bottom bolts. Install a new engine end plate gasket (17) over the threaded ends of the bolts (30). Apply Scotch Grip Rubber Adhesive No. 4300, or equivalent, on the engine end plate side of the gasket.

NOTE

The front and rear end plate gaskets are identical and may be used in either position.

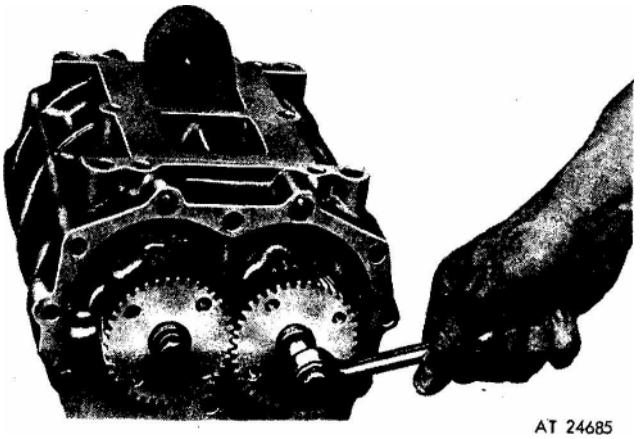
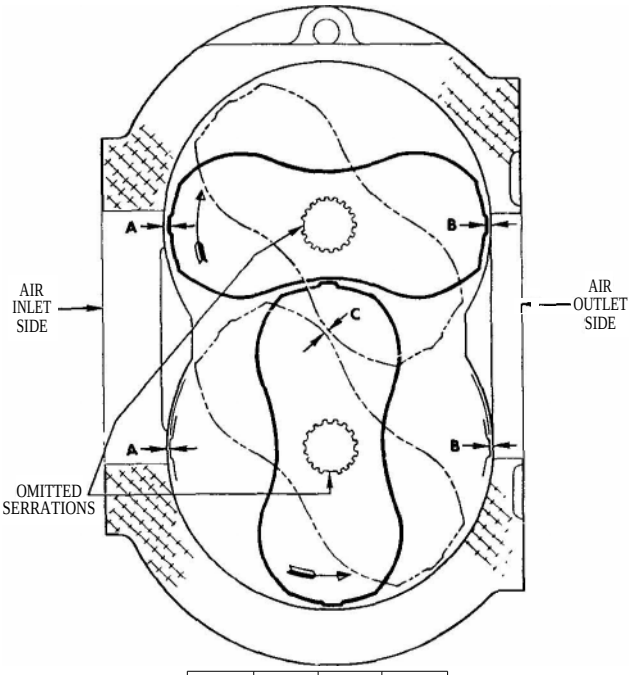


Figure 8. Installing blower rotor gears on rotor shafts.

4. Place the blower on the cylinder block locating flanges and, while holding the blower in place, install six bolts (30) finger tight in the rear engine end plate and the flywheel housing. Then install the blower to block mounting bolts (62) and washers (63) and tighten them to 10-15 lb-ft torque.



	A	B	C
2-53	.0075"	.004"	.010"
3-53	.0075"	.004"	.010"
4-53	.0075"	.004"	.010"
6,53	.010"	.004"	.010"
6V-53T	.010"	.004"	.010"

MINIMUM BLOWER ROTOR CLEARANCES

AT 24686

Figure 9. Minimum blower rotor clearances.

5. Secure the center bolts (30) first and then the top and bottom bolts to 20-25 lb-ft torque. Then. tighten the blower-to-block bolts (62) to 55-60 lb-ft torque.

6. Check the backlash between the upper rotor gear and the camshaft or balance shaft gear. The backlash should be .003" to .007".

7. Check the backlash between the blower gears. The backlash should be .0005" to .0025" with new gears. Replace the gears if the backlash exceeds .0035".

8. After the blower rotors and gears have been installed, the blower rotors must be timed. The rotors, when properly positioned, run with a slight clearance between the lobes and the walls of the housing. The clearances between the rotors may be established by moving one of the helical gears out or in on the shaft relative to the other gear. Moving the gears OUT or IN on the rotors is accomplished by adding or removing shims between the gear hub and the rotor spacers.

It is preferable to measure the clearances with a feeler gage comprised of two or more feelers since a combination is more flexible than one single feeler gage. Measurements shoud be taken from both the inlet and outlet sides of the blower. The clearance between the rotor lobes and the housing is measured as shown in figure 11. Take measurements across the entire length of each rotor lobe to be certain that a minimum clearance of .004" exists at the air outlet side of all blowers; and a minimum clearance of .0075" exists at the air inlet side of the In-line blowers. Similarly, measure the clearance between rotor lobes across the length of the lobes. By rotating the gears, position the lobes so that they are at their closest relative position as shown in figure 9. The clearance between the lobes should be a minimum of .010". The clearance between the end of the rotor and the blower end plate is measured with a feeler gage as shown in figure 10.

NOTE

Push and hold the rotor toward the front end plate when that clearance is being checked and toward the rear when the rear end plate-to-rotor clearance is being taken.

Refer to the chart for the required minimum clearances.

Blower Rotor End Clearances
(Minimum)

Engine	Front end plate	Rear end plate
3-53	.006"	.008"

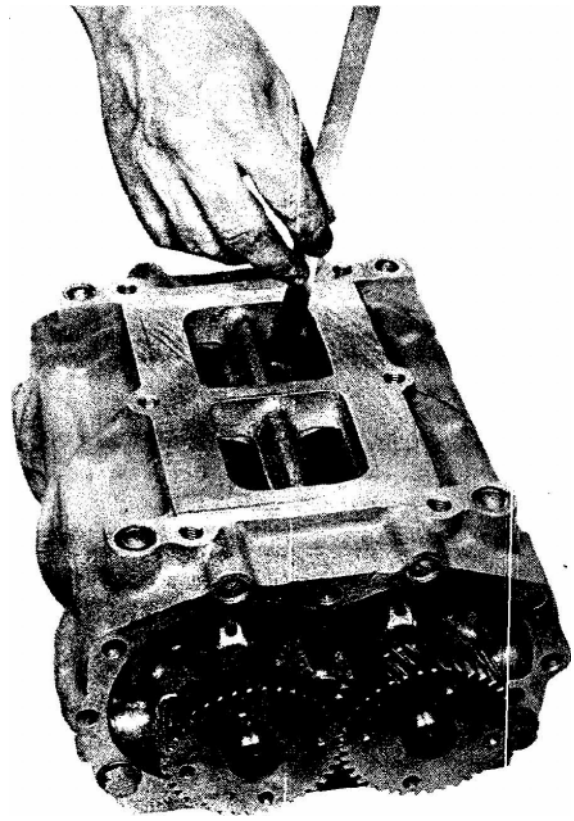
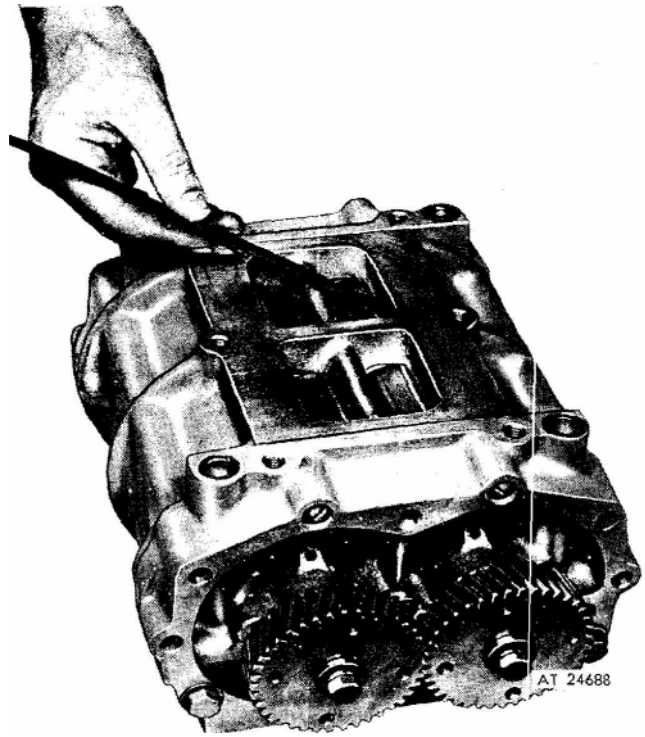


Figure 10. Measuring rotor lobe to end plate clearance.



SPECIFICATIONS

Standard Bolt and Nut Torque Specifications

Size nut or bolt	Torque (lb-ft)	Size nut or bolt	Torque (lb-ft)	Size nut or bolt	Torque (lb-ft)
1/4 - 20	7-9	7/16 - 20	57-61	3/4 - 10	240-250
1/4 - 28	8-10	1/2 - 13	71-75	3/4 - 16	290-300
5/16 18	13-17	1/2 - 20	83-93	7/8 - 9	410-420
5/16 - 24	15-19	9/16 - 12	90-100	7/8 - 14	475-485
3/8 - 16	30-35	9/16 - 18	107-117	1 - 8	580-590
3/8 - 24	35-39	5/8 -Al	137-147	1 - 14	685-695
7/16 - 14	46-50	5/8 - 18	168-178		

Exceptions to Standard Bolt and Nut Torque Specifications

Application	Size nut or bolt	Torque (lb-ft)
Blower Drive Gear Pilot Bolt (In-Line)	5 / 16"-24	25-30
Blower Timing Gear-to-Rotor Shaft Bolts (In-Line)	5/16"-24	25-30
Blower Thrust Washer Retaining Bolt (In-Line)	5 / 16"-24	25-30
Blower-to-Engine Rear End Plate and Flywheel Housing Bolts (3-53)	3/8" -16, 3/8"-24	20-25
Blower Thrust Washer Retaing Bolt (In-Line)	3 / 8" -24	54-59
Blower End Plate-to-Block Bolts (In-Line and 6V-53)	7/16 - 14	55-60

Service Tools

Tool No.	Tool name
J 1698-02	Blower Clearance Feeler Gage Set
J 5825-01	Gear Puller (2 and 3-53)
J 7079-2	Handle
J 21672	Blower Service Tool Set (includes the following)
J 21672-7	Gear Pullers
J 21672-10	Rotor Shaft Ball Bearing Installer
J 21672-11	Oil Seal and Bearing Remover
J 21672-12	Oil Seal and Roller Bearing Installer
J 2167246	Oil Seal Sleeve and Roller Bearing Inner Race Installer
J 21672-17	Spanner Wrench
J 21672-20	Oil Seal Sleeve and Roller Bearing Inner Race Remover
J 22576	Oil Seal Installer

SECTION 4

LUBRICATION SYSTEM

CONTENTS

LUBRICATION SYSTEM

The engine lubrication system, illustrated in figure 1 includes an oil intake screen and tube assembly, an oil pump, an oil pressure regulator valve, a full flow oil filter with a by-pass valve, an oil cooler, and a oil c000ler by-pass valve. The rotor type oil pump is bolted to the back of the engine lower front cover and is driven directly by the crankshaft. Lubricating oil from the pump passes from the lower front engine cover through short gallery passages in the cylinder block. From the block, the oil flows to the full flow filter, then through the oil cooler and back into the front engine cover and cylinder block oil galleries for distribution to the various engine bearings. The oil drains from the cylinder head and other engine parts back to the oil pan. Clean engine oil is assured at all times by the use of a replaceable element type full-flow filter. With this type filter, which is installed between the oil pump and oil cooler, all the oil is filtered before entering the engine. Should the filter become plugged, the oil will flow through a by-pass valve, which opens at approximately 18-21 psi directly to the oil cooler.

If the cooler becomes clogged, the oil flow will be to a by-pass valve in the lower engine front cover and then to the cylinder block oil galleries. The by-pass valve opens at approximetely 52 psi.

Stabilized lubricating oil pressure is maintained within the engine at all speeds, regardless of the oil temperature, by means of a regulator valve located in the lower front engine cover. The regulator valve, located in the pump oulet passage, opens at 51 psi and returns excess oil directly to the crankcase.

Lubricating Oil Distribution

Oil from the oil c000ler on the In-line engine is directed to the lower engine front cover and then to a longitudinal main oil gallery in the cylinder block. As shown in fugure 1, this gallery distributes the oil, under pressure, to the main bearings and t a horizontal transverse passage at one end of the block and to vertical passages at each corner of the block which provide lubrication for the balance shaft and camshaft bearings. The camshaft bearings incorporate small slots through which lubricating oil is directed to the cam follower rollers. Oil for lubricating the connecting rod bearings, piston pins, and for cooling the piston head is provided through the drilled crankshaft from the adjacent forward main bearings. The gear train is lubricated by the overflow of oil from the camshaft pocket through a communicating passage into the flywheel housing. Some oil spills into the flywheel housing from the bearings of the camshafts, balance shaft (In-line engine), idler gears.

4 LUBRICATION SYSTEM

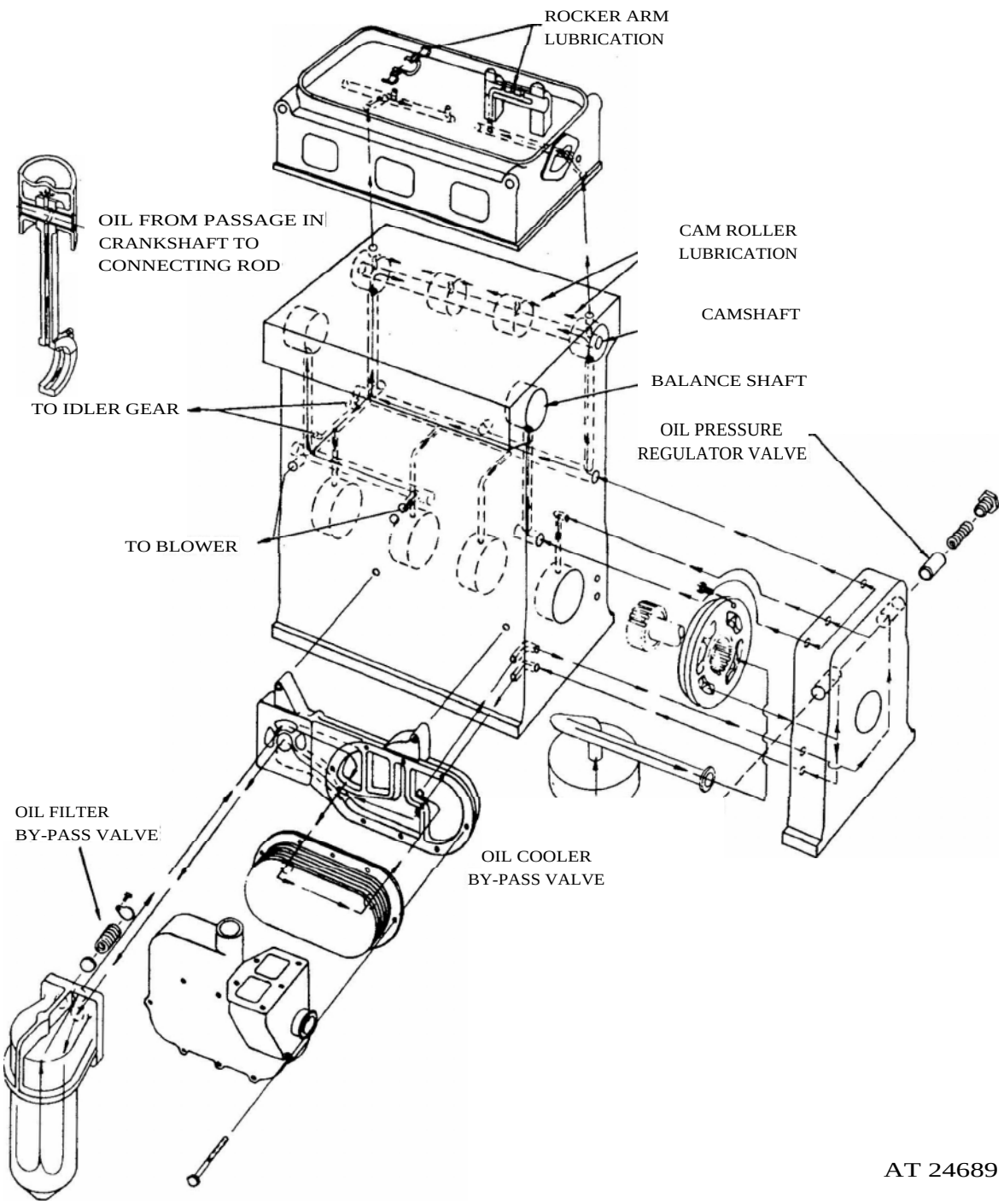


Figure 1. Schematic diagram of in-line engine lubrication system.

Drilled oil passages on the camshaft side of the cylinder head (fig. 1) are supplied with oil from the bores located at each end of the cylinder block. Oil from these drilled passages enters the drilled rocker shaft brackets at the lower ends of the drilled bolts, and lubricates the rocker arm bearings and push rod clevis bearings. Excess oil from the rocker arms lubricates the lower ends of the push rods and cam followers, then drains to cam pockets in the top of the cylinder block, from which the cams are lubricated. When these pockets are filled, the oil overflows through holes, at each end of the cylinder block, and then through the flywheel housing and front cover to the crankcase. The blower bearings are pressure lubricated by oil from drilled passages in the cylinder block which connect matching passages in the blower end plates which, in turn. lead to the bearings. On current engines lubricating oil is supplied directly to the front and rear right bank camshaft end bearings and supplies oil to the blower bearings. Excess oil returns to the crankcase via drain holes in the blower end plates which lead to corresponding drain holes in the cylinder block. On an In-line engine, the blower drive gear bearing is lubricated through an external pipe from the rear horizontal oil passage of the cylinder block.

Cleaning Lubrication System

Thorough flushing of the lubrication system is required at times. Should the engine lubrication system become contaminated by ethylene glycol antifreeze solution or other soluble material, refer to Section 5 for the recommended cleaning procedure.

LUBRICATING OIL PUMP

The gear type oil pump is located in the lower engine front crankshaft cover. The pump consists of (41 spur gears which mesh together and ride in a cavity inside the cover. One pair of gears is used for scavenging. The oil pump drive gears also have internal splines that mesh with the oil pump drive coupling which is pressed on the front end of the crankshaft. The pump driven gears are much smaller and ride on bushings and hardened steel shafts. One end of each gear shaft is pressed into the outercover and the other end is supported in the oil pump gear retaining plate.

Openings are provided for attaching the oil pump and scavenging pump inlet tube and screen assemblies. The scavenging pump inlet tube is also supported by brackets. Oil which normally flows to the rear of the engine during inclined operation of the engine is transferred to the front of the oil pan by the scavenging pump and is then picked up by the oil pump for distribution throughout the engine.

OPERATION

As the gears revolve, a vacuum is formed on the inlet side of the pump and oil is drawn from the oil pan through the intake screen and pipe into a passage in the front cover leading to the inlet cavity and then into the gear compartment of the pump. Oil is drawn into the cavities between the gears and is then forced out under pressure through the discharge cavity into a passage in the cover, around the gears which leads to the lubricating oil filter and cooler and then to the front cover and is then distributed throughout the engine.

If a check of the lubrication system indicates improper operation of the oil pump, it may be removed and disassembled as outlined below.

REMOVE OIL PUMP

1. Drain the lubricating oil.
2. Remove the crankshaft pulley.
3. Remove the oil pan and discard the old gasket.
4. Remove the two oil pump inlet elbow to front cover attaching bolts and one support bracket bolt. Remove the elbow, gasket and screen assembly.
5. Remove bolts from the scavenging pump inlet tube and screen support bracket and remove the tube and screen assembly.
6. Remove the lower engine front cover and oil pump assembly. Remove and discard the old gasket or any traces of gasket from the cylinder block or the pump cover plate.

DISASSEMBLE OIL PUMP

1. Remove the bolts which fasten the front cover, inner cover and the cover plate together
2. Separate the front cover from the inner cover. Remove the seal from the groove in the inner cover. Discard the seal.
3. Remove one of the oil pump drive gears and one small driven gear. Lift the cover plate from the inner cover and remove the gasket. Remove the remaining drive and driven gears.

INSPECTION

After the pump is dis-assembled, clean all of the parts in fuel oil, dry them with compressed air, and inspect.

The greatest amount of wear in the oil pump is imposed on the internal drive and driven gears. This wear may be kept to a minimum by keeping the lubricating oil clean and acid free. If dirt and sludge are allowed to accumulate in the lubricating system, pronounced gear wear may occur in a comparatively short period of time. Proper servicing of oil filters will increase life of the gears. Examine the oil pump gear cavity in the front crankshaft cover for wear, scoring or errosion. Replace parts if necessary.

Inspect the driven gear shafts for excessive wear or scoring and replace if necessary. Add a very small amount of sealer "Lock-Tite Type AA" or equivalent on the shafts and press them into the outer cover to a height of 1.82".

After complete assembly the shaft must be flush to .020" below the finished surface of the cover plate.

Inspect the teeth of the oil pump gears and the oil pump drive hub for scoring, wear or chipping. Install new gears if necessary. Check the bushings in the small gears for wear or scoring. If worn or scored excessively, replace the gear and bushing assembly. The bushing-to-shaft clearance with new parts is .001" to .0025". In an efficient oil pump, the gears should have a free-running fit (with no perceptible looseness) in the pump housing. The use of excessively worn gears will result in low engine oil pressure which, in turn, may lead to serious damage throughout the engine. The gear side clearance in the pump housing on the lubricating side is .002" to .005".

ASSEMBLE OIL PUMP

After the oil pump parts have been cleaned and inspected, assemble the pump as follows:

4.1 LUBRICATING OIL PUMP

1. Lightly coat one pair of gears with engine oil; then, place the gears in the cavity of the inner cover.
2. Place a new seal in the groove of the inner cover. Trim seal flush after assembly.
3. Position the front cover over the inner cover. Guide the driven gear shaft through the oil pump driven gear. Install the cover bolts and tighten to 30-35 lb-ft torque. Tighten the one 5 16" x 18" bolt to 13-17 lb-ft torque.
4. Coat the other two gears with engine oil. Place tile drive gear in the rear cavity of the inner cover. Place the driven gear on the shaft and position the gear in the inner cover.
5. Place a new gasket on the inner cover. Then, position the cover plate over the gasket and install the cover attaching bolts. Tighten the bolts to 30-35 lb-ft torque.

REMOVE OIL PUMP DRIVE GEAR FROM CRANKSHAFT

With the lower engine front cover and oil pump assembly removed from the engine, the 01 pump coupling gear may, if necessary, be removed from the end of the crankshaft as follows:

I. Thread the crankshaft pulley retaining bolt in the end of the crankshaft.
2. Attach the jaws of a suitable gear puller behind the gear and locate the end of the puller screw at the center of the pulley retaining bolt.
3. Turn the puller screw clockwise to remove the gear from the crankshaft.

INSTALL OIL PUMP DRIVE GEAR ON CRANKSHAFT

1. Lubricate the inside diameter of the oil pump drive gear with engine oil; then, start t he gear straight on the crankshaft. Reinstallation of a used gear is not recommended.
2. Using a suitable installer force the gear on the crankshaft up against the shoulder.

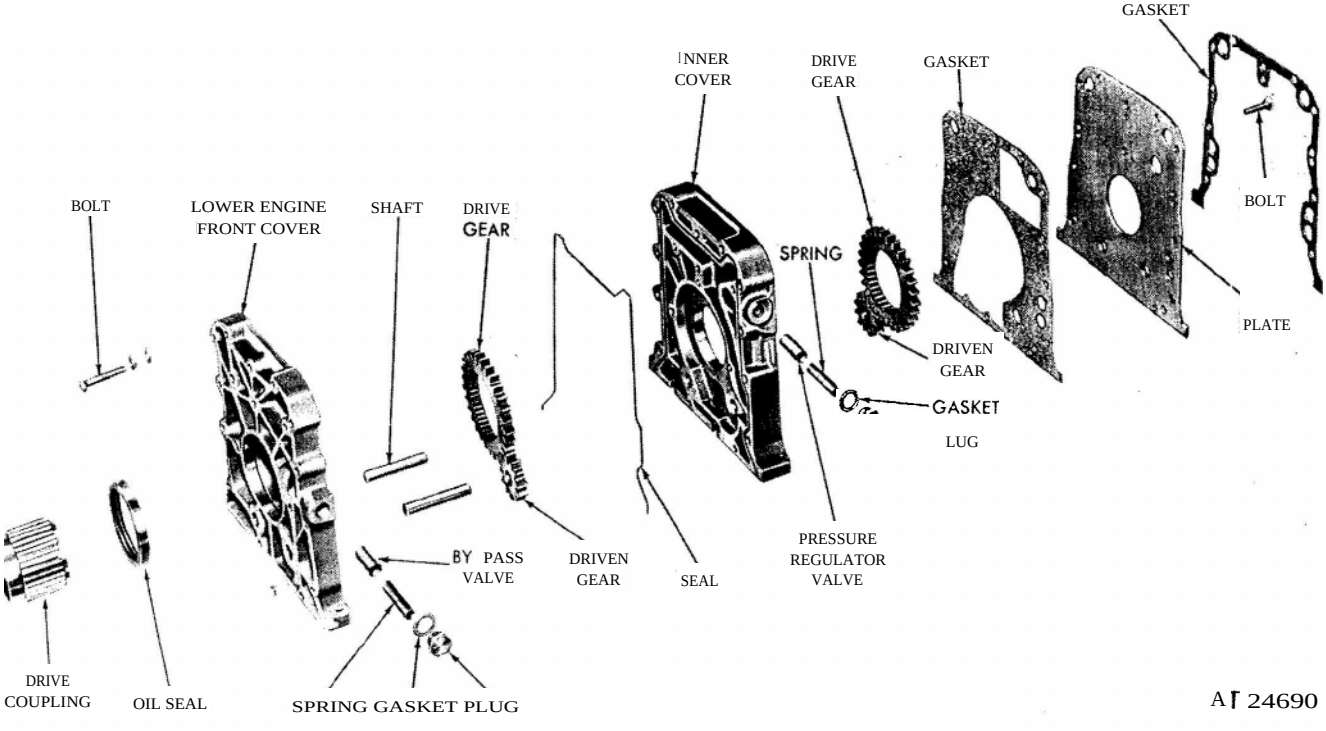


Figure I. Lubricating oil pump details and relative location of parts.

LUBRICATING OIL PRESSURE REGULATOR

Stabilized lubricating oil pressure is maintained within the engine at all speeds, regardless of oil temperature, by a pressure regulator valve installed in the engine lower front cover as shown in figure 1. The regulator assembly consists of a hollow piston type valve, a spring, gasket and plug. The valve is located in an oil gallery within the lower front cover and is held tight against a counterbored valve seat by the compressed valve spring and plug. When the oil pressure exceeds a given value as shown in the following chart, the valve is forced from its seat and the lubricating oil is by passed into the engine oil pan.

Engine	Front Cover	Valve opening pressur (psi)
In-line	Current	51

Under normal conditions, the pressure regulator valve should require very little attention. If sludge should accumulate in the lubricating system, the valve may not work freely, thereby remaining open or failing to open at the normal operating pressure Whenever the lubricating oil pump is removed for inspection, the regulator valve and spring should also be removed, thoroughly cleaned in fuel oil and inspected.

Remove Oil Pressure Regulator

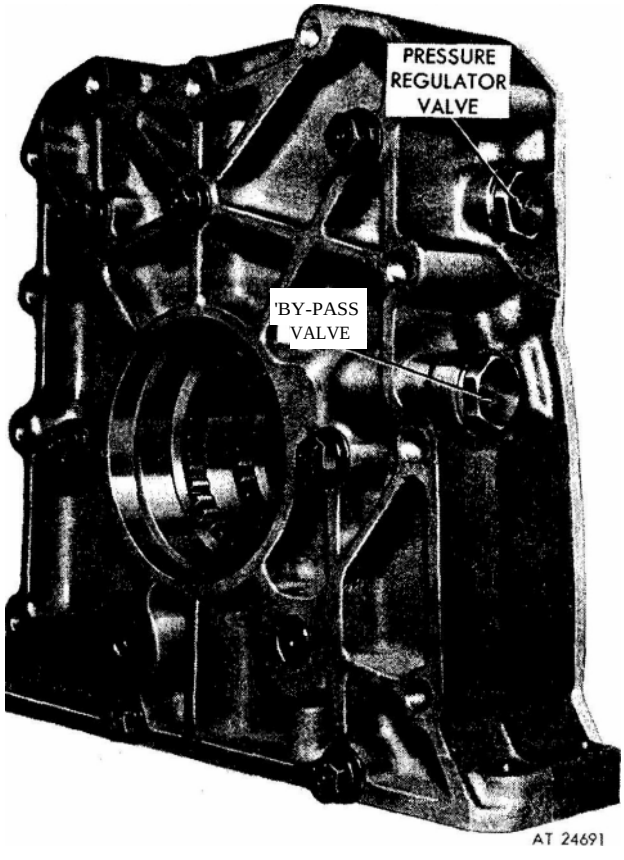
1. Remove the plug and washer from the engine lower front cover.
2. Withdraw the spring and the valve from the cover.

Inspect Oil PRessure Regulator Parts

Clean all of the regulator parts in fuel oil and dry them with compressed air. Then, inspect the parts for wear or damage. The regulator valve must move freely in the valve body. **If** the valve is scored and cannot be cleaned up with crocus cloth, it must be replaced. Replace a fractured or pitted spring.

Install Oil Pressure Regulator

1. Apply clean engine oil to the outer surface of the valve and slide it into the opening in the engine lower front cover (closed end first).
2. Install a new copper gasket on the plug.
3. While compressing the spring, start the plug in the side of the cover. Tighten the plug.



Figre 1. Location of current oil pressure regulator valve—inline engine shown.

LUBRICATING OIL FILTER

The engine is equipped with *a* full-flow filter.

Full-Flow Filter

Each engine is equipped with *a* lubricating oil filter of the full flow type. The oil filter shell is mounted in a downward or rearward position. The filter assembly consists of a replaceable element enclosed within a shell which is mounted on a base (fig. 1). When the filter shell is in place, the element *is* restrained from movement by a coil spring at the bottom. All of the oil supplied to the engine by the oil pump passes through the filter before reaching the various parts of the engine. The lubricating oil is forced by the pump pressure through a passage in the filter bass to the space surround the filter element. Impurities are filtered out as the oil is forced through the element to *a* central passage surrounding the center stud and out through another passage in the filter base and then to the oil cooler. A valve which opens at approximately 18-21 psi, is located in the filter base and will by-pass the oil directly to the oil cooler should the filter become clogged. It is recommended that a new filter center stud gasket be installed each time the element is changed.

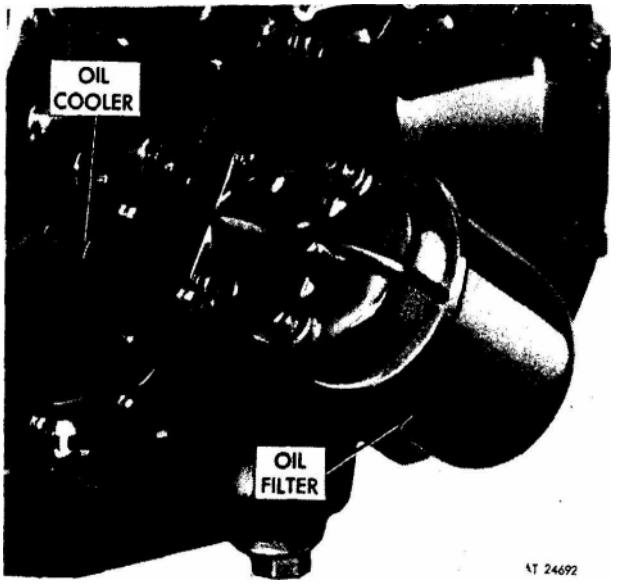


Figure 1. Typical full flow filter mounting.

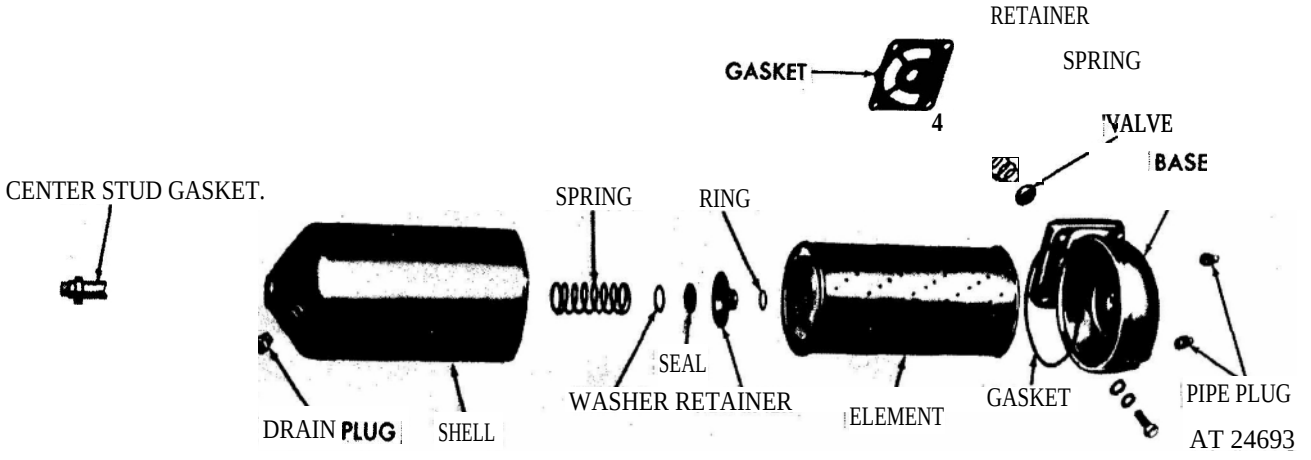


Figure 2. Full flow details and relative location of parts.

Remove and Install By-Pass Valve

1. Remove the oil filter base from the oil cooler adaptor. Then, remove the retaining plug and gasket or retainer and screw (if used) and withdraw the spring and valve from the base.

2. Wash all of the parts in clean fuel oil and dry them with compressed air. Inspect the parts for wear or damage.

3. Reassemble the by-pass valve (fig. 3). Place a new gasket on the oil cooler adaptor. The small protrusion on the oil filter base gasket must mate with the boss on the filter base regardless of position in which the filter is assembled. If the gasket is not correctly positioned, the flow of oil may be obstructed. Secure the oil filter base to the oil cooler adaptor.

4. Start the engine and check for and eliminate any oil leaks that are detected.

Operation

Unfiltered lubricating oil is forced by the pump through the inlet passage in the filter base or in the side of the filter shell, depending upon the type of

filter used, to the annular passage surrounding the filter element. Still under pressure, the oil is forced through the filter element where the impurities are removed, then through a small hole in the center stud wall, down through the hollow stud to the outlet passage leading back to the engine crankcase via an outlet tube.

Remove and Install Filter Element

Periodic servicing of the lubricating oil filter is very important. Install a new element as follows:

1. Remove the drain plug at the bottom of the filter shell or in the filter base (figs. 1 and 4) depending upon the mounted position of the filter and drain the oil.
2. Unscrew the center stud or the cover nut and lift the shell, element and stud as an assembly off the base, or remove the cover, whichever the case may be . Discard the filter element.
3. Remove the center stud and discard the stud gasket.

NOTE

Remove the snap ring or thin nut on the full-flow filter center stud, slide the stud out of the shell and discard the stud gasket. Then examine the retainer seal (fig. 3) for hardening or cracking. If necessary, replace the seal.

4. Clean the filter shell and the base.
5. Install a new center stud gasket and slide the stud through the filter shell. Install the spring (also washer, seal and retainer on the full-flow filter) on the stud.
6. Install a new shell gasket in the filter base.
7. Position the new filter element carefully over the center stud and within the shell. Then, place the shell, element, and stud assembly in position on the filter base and tighten the center stud to 40-50 lb-ft torque.
8. Install the drain plug.
9. Start and run the engine for a short period and check for oil leaks. After any oil leaks have been corrected and the engine has been stopped long enough for the oil from various parts of the engine to drain back to the crankcase, bring the oil to the proper level on the dipstick.

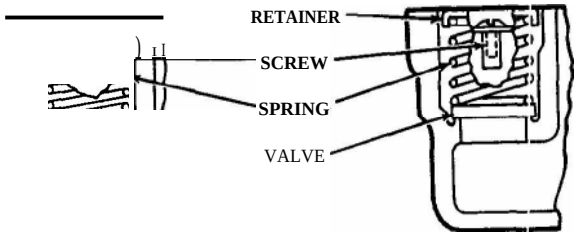


Figure 3. Former and current by-pass valve secured by retainer and screw in the filter, base or junction housing.

LUBRICATING OIL COOLER

Engine oil c000lers are provided for **all** engines. The oil cooler is mounted on the side of the cylinder block at the lower front corner (fig. 1). To assure engine lubrication should the oil cooler become plugged, a by-pass valve located near the top of the lower engine front cover by-passes oil from the oil pump discharge port directly to the oil galleries in the cylinder block. The by-pass valve opens at approximately 52 psi. The valve components are the same as and serviced in the same manner as the oil pressure regulator valve in section 4.1.1.

Cooling water circulated through the oil cooler completely surronds the oil cooler core. Therefore, when ever an oil cooler is assembled, special care must be taken to have the proper gaskets in place and the retaining bolts tight to assure good sealing.

The oil cooler housing on the In-line engines is attached to an oil cooler adaptor which, in turn, is attached to the cylinder block. The flow of oil is from the oil pump through a passage in the oil cooler adaptor to the full flow oil filter, which is also mounted on the oil cooler adaptor, and then through the oil cooler core and the cylinder block oil galleries.

Remove Lubricating Oil Cooler Core

1. Drain the cooling system by opening the draincock at the bottom of the oil cooler housing.
2. Remove any accessories or other equipment necessary to provide access to the cooler.
3. Loosen and slide the clamps and hose back on the water inlet elbow on the cylinder block.
4. Loosen and slide the clamps and hose back on the tube leading from the thermostat to the water pump.
5. Remove the bolts and lock washers which attach the water pump to the oil cooler housing.
6. Remove the bolts and lock washers which attach the oil cooler housing to the adaptor or cylinder block and remove the housing and core as an assembly. Be careful when withdrawing the assembly not to drop or damage the cooler core.
7. If the adaptor is to be removed, the oil filter must first be removed as outlined in a previous section. Then, remove the bolts and lock washers which attach the adaptor to the cylinder block. Wihtdraw the adaptor and gaskets.
8. Remove all traces of gasket material from the cylinder block and the oil cooler components.

Clean Oil Cooler Core

1. Clean Oil Side of Core — Remove the core from the oil cooler. Circulate a solution of trichloroethylene through the core passages with a force pump to remove the carbon and sludge.

CAUTION

This operation should be done in the open or in a well ventilated room when trichloroethylene or other toxic chemicals are used for cleaning.

Clean the core before the sludge hardens. If the oil passages are badly clogged, circulate an Oakite or alkaline solution through the core and flush thoroughly with clean, hot water.

2. Clean Water Side of Cooler — After cleaning the oil side of the core, immerse it in the following solution : Add one-half pound of oxalic acid to each two and one-half gallons of solution composed of one-third muriatic acid and two-thirds water. The cleaning action is evidenced by bubbling and foaming.

The process must be carefully watched and, when bubbling stops (this usually takes from 30 to 60 seconds), the core should be removed from the cleaning solution and thoroughly flushed with clean, hot water. After cleaning, dip the core in light oil.

NOTE

Do not attempt to clean an oil cooler core when an engine failure occurs in which metal particles from worn or broken parts are released into the lubricating oil. Replace the oil cooler core.

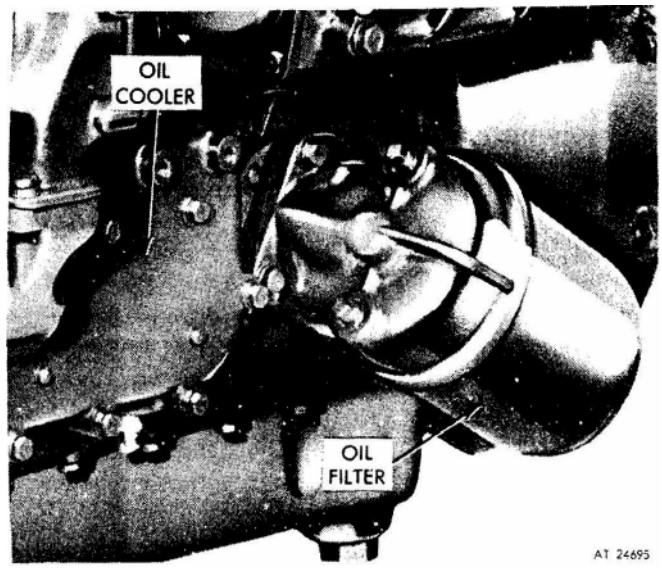


Figure 1. Typical oil cooler mounting.

4.4 LUBRICATING OIL COOLER

Pressure Check

After the oil cooler core has been cleaned, it may be checked for leaks as follows:

1. Make a suitable plate and attach it to the flanged side of the cooler core. Use a gasket made from rubber to assure a tight seal, The plate should be drilled and tapped to permit an air hose fitting to be attached at the inlet side of the core (fig. 2).
2. Attach an air hose and apply approximately 75 psi air pressure and submerge the cooler core and plate assembly in a container of water heated to 180°F. Any leaks will be indicated by air bubbles in the water. If leads are indicated, replace the core.
3. After the pressure check is completed, remove the plate and air hose from the cooler core, then dry the core with compressed air.

Install Lubricating Oil Cooler Core

1. If the oil cooler adaptor (In-line engines) was removed from the cylinder block, remove the old gasket material from the bosses where the adaptor sets against the block. Affix new adaptor gaskets (fig. 3) then secure the adaptor to the cylinder block with five bolts and lock washers.
2. Clean the old gasket material from both faces of the core flange and affix new gaskets to the inner and outer faces (figs. 3 and 4). Insert the core inside of the cooler housing.

NOTE

The inlet and outlet openings in the oil cooler *core* are stamped "IN" and "OUT". Whenever the core is removed from the housing, it must be installed in the same position as when it was removed, otherwise there is the possibility of foreign particles and sludge, which accumulate on the fins of the the core and may not be removed in the cleaning process, being Circulated through the engine and damaging the internal working parts.

8. Install the oil filter if previously removed.
9. Make sure the draincock in the bottom of the cooler housing is closed, Then fill the cooling system to the proper level.

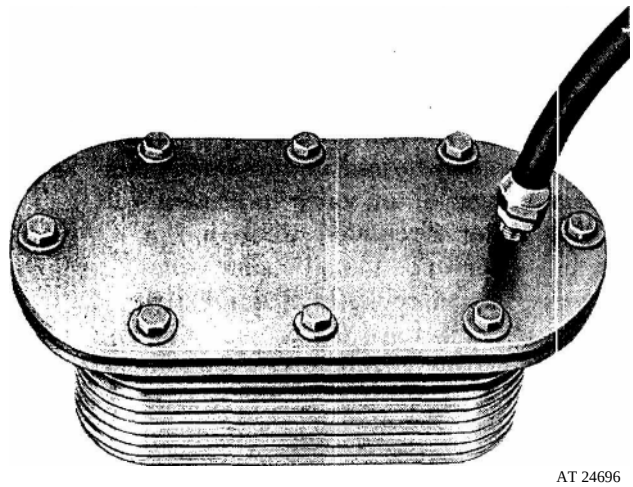


Figure 2. Preparing oil cooler core for pressure test.

3. Set the housing with the cooler core against the adaptor and secure it with bolts and lock washers.
4. Slide the hose and clamps in position between the cylinder block water inlet elbow and the oil cooler. Secure the clamps in place.
5. Place a new gasket between the fresh water pump and the cooler housing, and secure the pump to the cooler housing.
6. Position the hose and clamps in place between the water pump and tube to the thermostat housing. Secure the clamps.
7. Install any accessories or equipment previously removed.

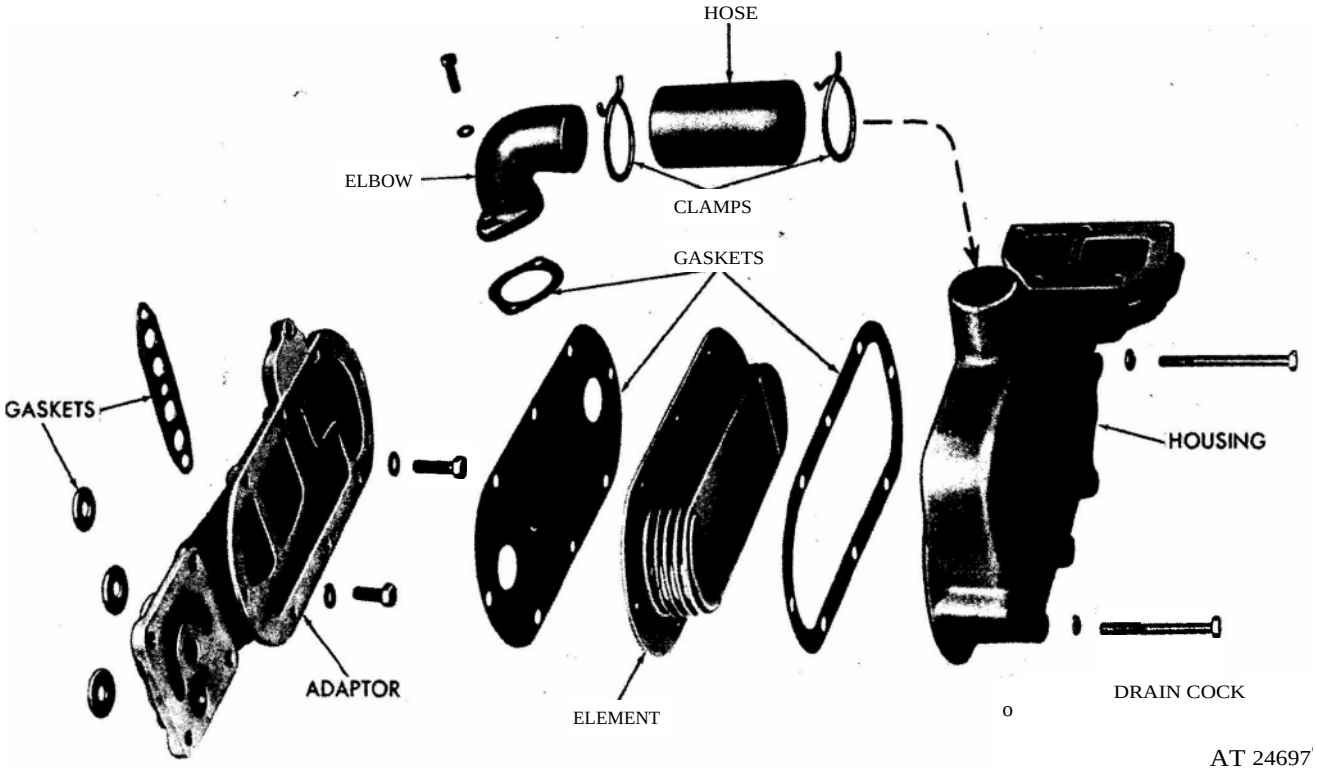


Figure 3. Oil cooler details and relative location of parts.

OIL LEVEL DIPSTICK

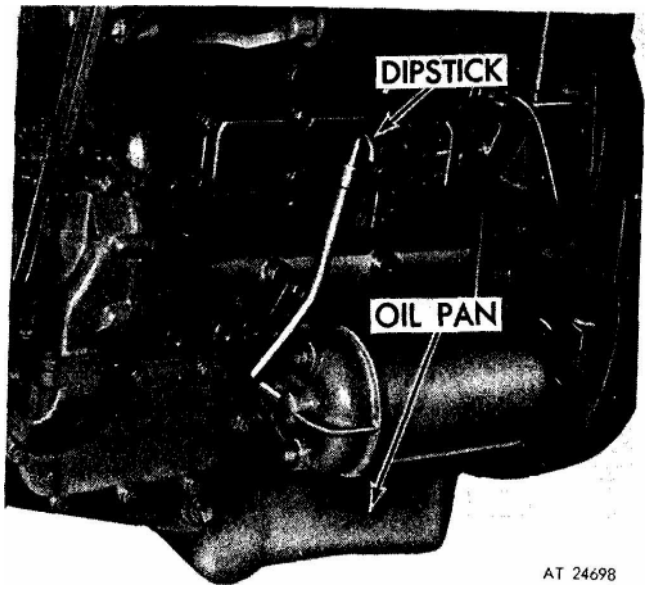


Figure 1. Typical oil dipstick mounting.

A steel ribbon type oil level dipstick is mounted in an adaptor on the side of the engine (fig. 1) to check the amount of oil in the engine oil pan. The dipstick has markings to indicate the LOW and FULL oil level.

The engine should not be operated if the oil level is below the LOW mark and no advantage is gained by having the oil quantity above the FULL mark.

OIL PAN

The oil pan is made of cast aluminum. A one-piece oil pan gasket is used with stamped steel pans. A four-piece gasket is used with the cast oil pans.

Removing and Installing Oil Pan

On some engine applications it may be possible to remove the oil pan without removing the engine. It is recommended that if the engine is to be taken out of the unit, the oil pan be left in place until the engine is removed. The procedure for removing the oil pan without taking the engine out and after taking the engine out of the unit will vary, however, the following will generally apply.

1. Remove the drain plug and drain the engine lubricating oil.
2. Detach the oil pan ; take precautions to avoid damaging the oil pump inlet pipe and screen.
3. Remove the oil pan gasket completely.
4. Clean the oil pan with a suitable solvent; dry the oil pan.
5. Inspect a cast oil pan for porosity or cracks. Check for misaligned flanges or raised surfaces surrounding the bolt holes by placing the pan on a surface plate or other large flat surface.
6. When replacing the pan, use a new gasket and tighten the bolts evenly to avoid damaging the gasket or springing the pan.
7. Replace and tighten the oil drain plug. Tighten the 18 mm drain plug with nylon washer to 25-35 lb-ft torgue. Replenish the lubricating oil supply and after the engine is started check for leads.

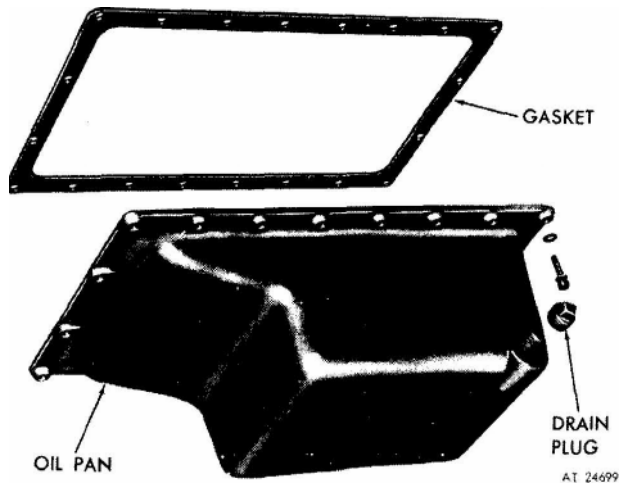


Figure 2. Typical oil pan.

SECTION 5

COOLING SYSTEM

CONTENTS

COOLING SYSTEM

To effectively dissipate the heat generated by the engine, one of three different types of cooling systems is used on a Series 53 engine: radiator and fan. heat exchanger and raw water pump or keel cooling. A centrifugal type water pump is used to circulate the engine coolant. The system incorporates thermostats to maintain a normal operating temperature of 160°-185°F. Typical In-line engine cooling system is shown in figure 1.

Radiator and Fan Cooling System

The engine coolant is drawn from the lower portion of the radiator by the water pump and is forced through the oil cooler and into the cylinder block. From the cylinder block, the coolant passes up through the cylinder head(s) and, when the engine is at normal operating temperature, through the thermostat housing(s) and into the upper portion of the radiator. Then the coolant passes down a series of tubes where the coolant temperature is lowered by the air stream created by the rovolving fan.

Upon starting a cold engine or when the coolant is below operating temperature, the coolant is restricted at the thermostat housings) and a by-pass provides water circulation within the engine during the warm-up period.

Engine Coolant

The function of the engine coolant is to absorb the heat, developed as a result of the combustion process in the cylinders, from component parts such as exhaust valves, cylinder liners, and pistons which are surrounded by water jackets. In addition, the heat absorbed by the oil is also removed by the engine coolant when oil-to-water oil coolers are used.

The recommended coolant is clean, soft water, with as low a mineral content as possible plus a good commercial rust inhibitor. The rapid formation of scale on the surfaces of the water jackets, as a result of using hard water with high lime deposits, will impede the transfer of heat and restrict the flow of the coolant. A water filter will remove foreign substances in the coolant as well as inhibit scale deposit and rust formation and reduce electrolytic action between dissimilar metals in the system.

Cooling System Capacity

The capacity of the basic engine cooling system, (cylinder block, head, thermostat housing and oil cooler housing) is shown in the following chart.

Cooling System Capacity Chart
(Basic Engine)

Engine	Capacity (quarts)
3-53	8

To ascertain the complete amount of coolant in the cooling system of a unit, the additional capacity of the radiator, hoses, etc., must be added to the capacity of the basic engine. The capacity of the radiator and related equipment should be obtained from the equipment supplier or the capacity of a particular cooling system may be determined by filling the system with water and draining it and measuring the amount of coolant.

Antifreeze Solutions

High boiling point type antifreeze solutions are used in diesel engines during the winter because of the high coolant temperature encountered in their

operation. Alcohol base antifreeze has too low a boiling point. An alcohol base antifreeze solution protecting a unit to —20°F. would begin to boil at 180° F. Whereas, a high boiling point type ethylene glycol antifreeze solution protecting a unit to —20°F. would begin to boil at 223°F. Most high boiling point type antifreeze solutions include a corrosion inhibitor which will protect the cooling system through the winter season. No additives should be added to a system that is protected by this antifreeze solution. In the spring, the antifreeze solution should be drained and discarded. The use of glycol ether antifreeze solutions should be approached with some caution. Before adding a glycol ether antifreeze solution to an engine that has been in service for a time, the entire cooling s ystem should be drained and flushed with clean water and chemically cleaned, making sure to follow the cleaner manufacturer's instructions closely.

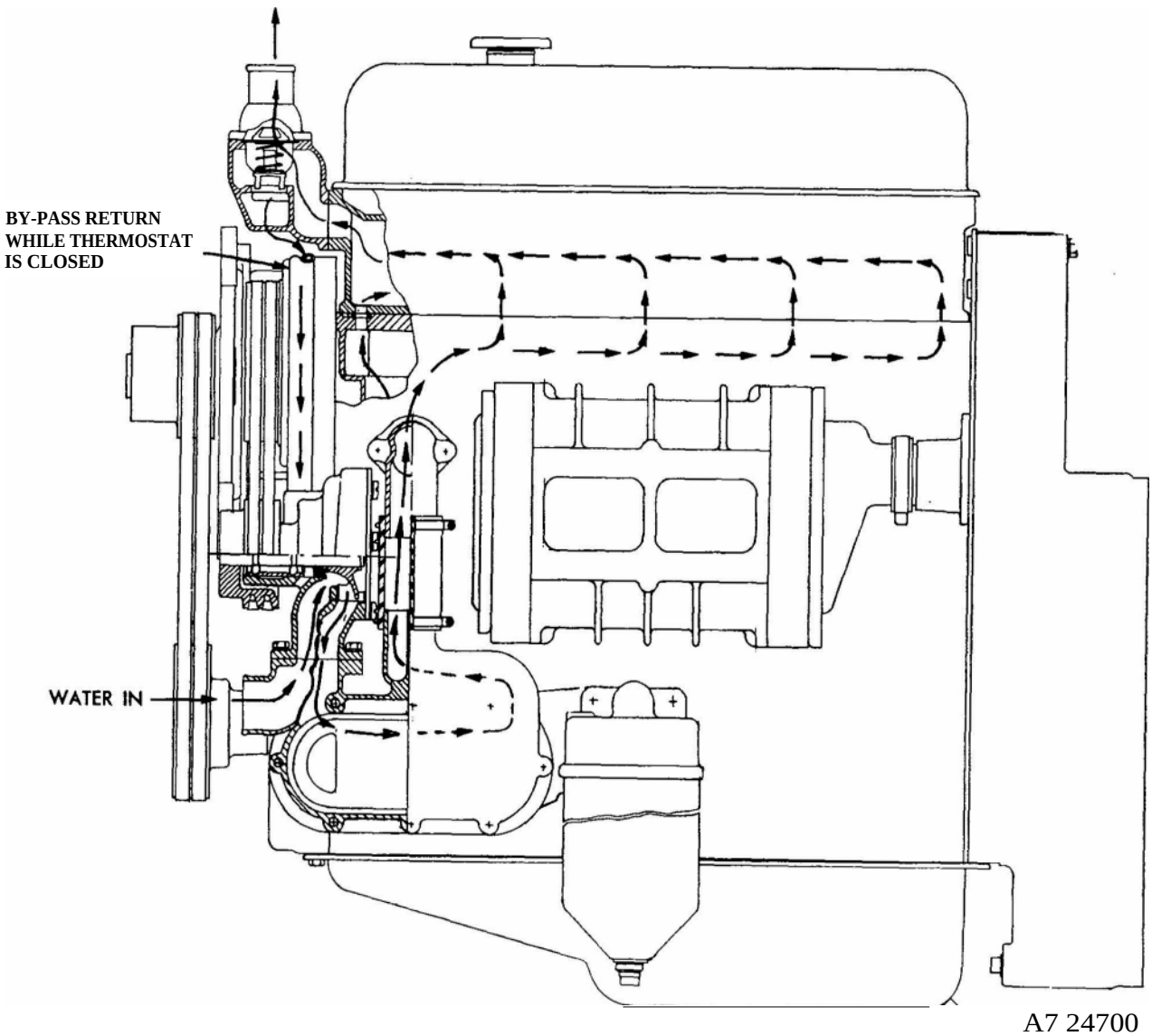


Figure 1. Typical cooling system for an in-line engine.

NOTE

'The corrosion inhibitor in a used antifreeze solution will not be of sufficient strength to protect the system from corrosion the following winter. The addition of a corrosion inhibitor to an antifreeze solution to permit reuse, could cause a reaction within the solution. A precipitation could result and clog the cooling passages, necessitating extensive engine and radiator cleaning.

Corrosion Inhibitor

A soluble oil type corrosion inhibitor should be added to the water in the cooling system during the summer. Corrosion inhibitors coat the metal surfaces within the water jackets with a thin film which prevents the oxygen in the water or in the system from coming in contact with the surfaces and forming rust. When using the soluble oil type corrosion inhibitor, the concentration should not exceed 1 per cent of the total cooling system water capacity. Should a loss of coolant develop as a result of a leak, a proper proportion of inhibitor must be mixed with water before adding the make-up solution to the coolant in the system to prevent any lowering of the concentration. However, if water in the cooling system boils off, the concetration of inhibitor will become too great and a possibility of thickening or congealing may occur. In this case, only water must be added to the cooling system to reduce the concentration to normal.

Drain Cooling System

Drain the cooling system by opening the cylinder block and radiator drain cocks and removing the cooling system filler cap. Removal of the filler cap permits air to enter the cooling passages and the coolant to drain completely from the system. Drain cocks are located as indicated in the coolant drain cock chart. Radiators that do not have a drain cock are drained through the oil cooler housing drain. If freezing weather is anticipated and the engine is not protected by antifreeze, the cooling system must be completely drained when the engine is not in use. Should any entrapped water in the cylinder block, radiator, or other parts freeze, it will expand and may result in damage to the engine. Before starting an engine fill the cooling system completely.

Coolant Drain Valves

Engine	Oil cooler or coolant inlet side of block	Side of black opposite oil cooler or coolant inlet
3-53	Bottom of oil cooler and coolant inlet	Just forward of blower mounting pad

Fill Cooling System

Before starting the engine, close all of the drain cocks and fill the cooling system with water. The use of soft, clean water in the cooling system will eliminate the need for using de-scaling solutions to clean the system. A hard mineral-laden water should be made soft by using water softener chemicals before it is poured into the cooling system. These water softeners modify the minerals in the water and greatly reduce or eliminate the formation of scale. Start the engine and, after normal operating temperature has been reached, allow the coolant to expand to its maximum, then, check the coolant level. The coolant level should be within 2" of the filler neck.

Excessive amounts of air in the cooling system may hinder the flow of water due to pump cavitation or result in hot spots when air collects at low velocity points in the water passages. Therefore, whenever the cooling system is filled or make-up water is added, the air must be thoroughly vented from the system. The thermostat housing(s) on the Series 53 engines provides a vent hole to release the air to the atmosphere while the cooling system is being filled. In addition, the cooling system should be vented at the time normal operating temperature is reached after starting the engine, and again after the engine has been in operation for 30 to 45 minutes.

Should a daily loss of coolant be observed, and there are no apparent external leaks, there is a possibility of leakage of gases past the cylinder head water seal rings into the cooling system. The presence of air or gases in the cooling system may be detected by connecting a rubber tube from the overflow pipe to a water container. Bubbles in the water of the container during engine operation will indicate this leakage. Another method for observing entrained air in the cooling system is by inserting a transparent tube in the water outlet line.

Cooling System Maintenance

A properly maintained and clean cooling system will reduce engine wear and increase the satisfactory engine operating time between engine overhauls. This is accomplished by the elimination of hot spots within the engii.e. Thus, when operating within the proper engine temperature range and when not exceeding the recommended horsepower output of the unit, all engine parts will be within their operating temperature ranges and at their proper operating clearances.

The use of soft, clean water in the cooling system will eliminate the need for using de-scaling solutions to clean the system. A hard mineral-laden water should be made soft by using water softener chemicals before it is poured into the cooling system. These water softeners modify the minerals

in the water and greatly reduce or eliminate the formation of scale.

Flushing

The cooling system should be flushed each spring and fall. The flushing operation cleans the system of antifreeze solution in the spring and removes the summer rust inhibitor in the fall, preparing the cooling system for a new solution. The flushing operation should be performed as follows:

1. Drain the previous season's solution from the engine.
2. Refill the cooling system with soft clean water. If the engine is hot, fill slowly to prevent rapid cooling and distortion of the engine castings.
3. Start the engine and operate it for 15 minutes to circulate the water thoroughly.
4. Drain the cooling system completely.
5. Refill the system with the solution required for the coming season.

Cooling System Cleaners

If the engine overheats and the fan belt tension and water level are satisfactory, it will be necessary to clean and flush the entire cooling system. Scale formation should be removed by using a quality descaling solvent. Immediately after using the solvent, neutralize the system with the neutralizer. It is important that the directions printed on the container of the descaling solvent be thoroughly read and followed. After the solvent and neutralizer have been used, completely drain the engine and radiator and flush with clean water. Then, fill the system with the coming season's cooling solution.

CAUTION

Whenever water is added to a hot engine, it must be done slowly to avoid distortion and possible cracking of engine castings, resulting from too rapid cooling.

Reverse Flushing

After the engine and radiator have been thoroughly cleaned, they should be reverse flushed. The water pump should be removed and the radiator and engine reverse-flushed separately to prevent dirt and scale deposits clogging the radiator tubes or being forced through the pump. Reverse-flushing is accomplished by hot water, under air pressure, being forced through the cooling system in a direction opposite to the normal flow of coolant, thus loosening and forcing scale deposits out.

Reverse-flush the radiator as follows:

1. Remove the radiator inlet and outlet hoses and replace the radiator cap.
2. Attach a hose at top of the radiator to lead water away from the unit.
3. Attach a hose to the bottom of the radiator and insert the flushing gun in the hose.
4. Connect the water hose of the gun to the water outlet and the air hose to the compressed air ,cutlet.
5. Turn on the water and, when the radiator is full, turn on the air in short blasts, allowing the radiator to fill between air blasts.

CAUT ION

Apply air gradually. Do not exert more than 30 pounds (psi) air pressure. Too great a pressure may rupture a radiator tube.

6. Continue flushing until only clean water is expelled from the radiator.

Reverse-flush the cylinder block and cylinder head water passages as follows :

1. Remove the thermostat(s) and the water pun p.
2. Attach a hose to the water inlet of the cylinder block to drain the water away from the unit.
3. Attach a hose to the water outlet at top of the engine and insert the flushing gun in the hose.
4. Turn on the water and, when the water jackets are filled, turn on the air in short blasts, allowing the engine to fill with water between air blasts.
5. Continue flushing until clean water is expelled from the engine.

If scale deposits in the radiator cannot be removed by chemical cleaners or reverse-flushing as outlined above, it may be necessary to remove the upper tank and rod out the individual radiator tubes with flat steel rods. Circulate water through the radiator core from the bottom to the top during this operation.

Miscellaneous Cooling System Checks

In addition to the above cleaning procedures, the other components of the cooling system sould be checked periodically to keep the engine operating at peak efficiency. The cooling system hoses, thermostats and radiator pressure cap should be checked and replaced if found to be defective. All external leaks should be corrected as soon as detected. The fan belt must be adjusted to provide the proper tension and the fan shroud must be tight against the radiator core to prevent recirculation of air which may lower cooling efficiency.

Contaminated Engine

When the cooling or lubricating system on an engine becomes contaminated, it should be flushed thoroughly to remove the contaminants before the engine is seriously damaged. One possible cause of such contamination, that is damaging to the engine if it is not corrected immediately, is a cracked oil cooler core. With a cracked oil cooler core, oil will

be forced into the cooling system while the engine is operating, and when it is stopped coolant will leak into the lubricating system.

Coolant contamination of the lubricating system is especially harmful to engines during the cold season when the cooling system is normally filled with an ethylene glycol antifreeze solution. If mixed with the oil in the crankcase, this antifreeze forms a varnish which quickly immobilizes moving engine parts. To remove such contaminants from the engine, both the cooling system and lubrication system must be thoroughly flushed as follows:

COOLING SYSTEM

If the engine has had a failure resulting in the contamination of the cooling system with lubricating oil, this flushing procedure is recommentded.

1. Prepare a mixture of Calgon, or its equivalent, and water at the rate of two ounces (dry measure) to one gallon of water.
2. Remove and check the thermostat(s).
3. Fill the cooling system with the Calgon solution.
4. Rim the engine for five minutes.
5. Drain the cooling system.
6. Repeat Steps 3,4 and 5.
7. Fill the cooling system with clean water.
8. Let the engine run five minutes.
9. Drain the cooling system completely.
10. Install the thermostat(s).
11. Close all the drains and refill with fresh coolant.

LUBRICATION SYSTEM

When the engine lubricating system has been contaminated by an ethylene glycol antifreeze solution, or other soluble material, the following cleaning procedure, using Butyl Cellosolve or its equivalent is recommended.

CAUTION

Use extreme care in the handling of these chemicals to prevent serious injury to the person or damage to finished surfaces. Wash off spilled fluid immediately with clean water.

If the engine is still in running condition, proceed as follows:

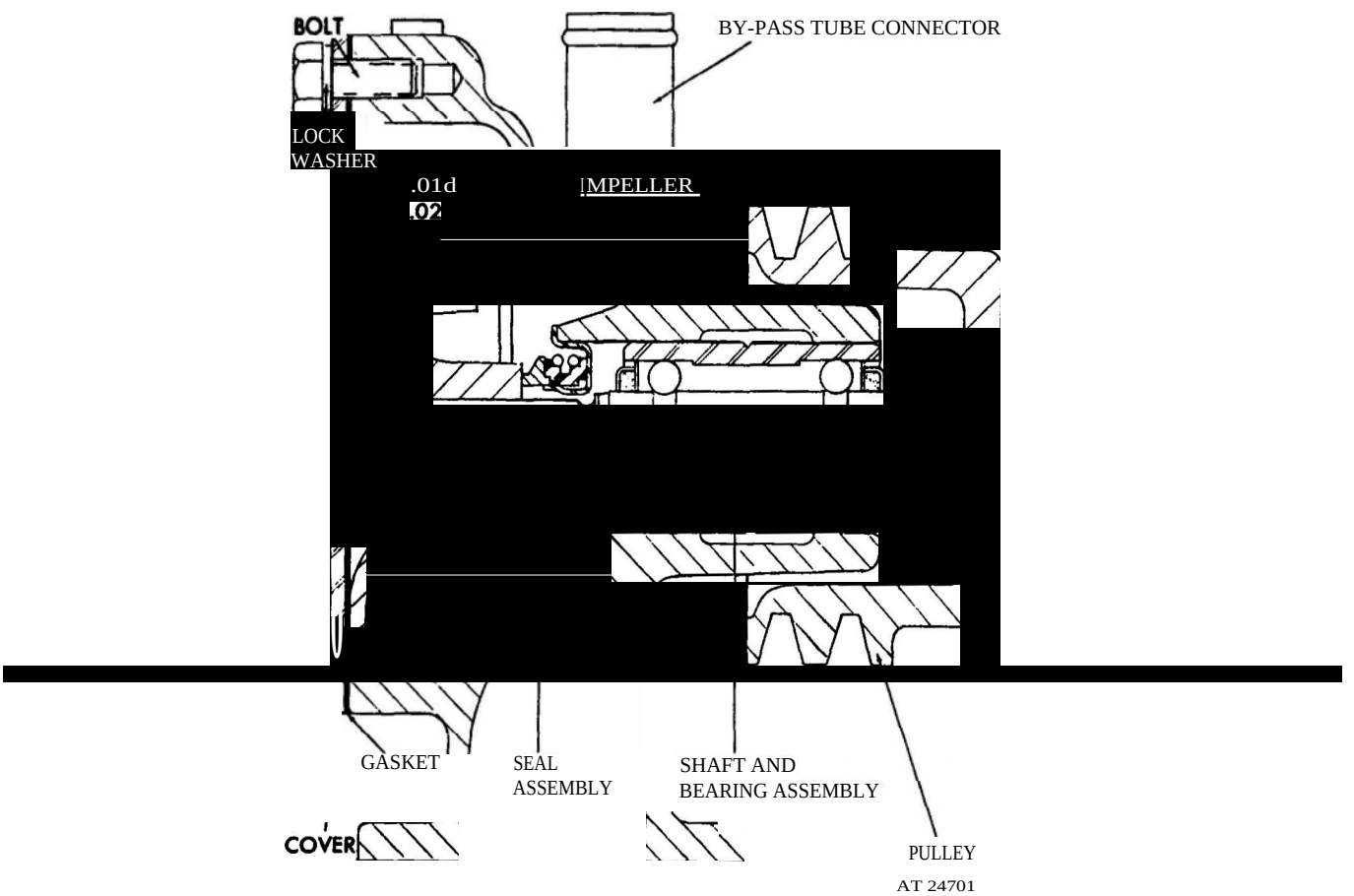
1. Drain all the lubricating oil.
2. Remove and discard the oil filter element. Clean and dry the filter shell and replace the element.
3. Mix two parts of Butyl Cellosolve or its equivalent with one part SAE 10 engine oil. Fill the crankcase of the engine to the proper operating level with the mixture.
4. Start and run the engine at a fast idle (1000 to 1200 rpm) for 30 minutes to one hour. Check the oil pressure frequently.
5. After the specified time, stop the engine and immediately drain the crankcase and the filter. Sufficient time must be allowed to drain all of the fluid.
6. Refill the crankcase with SAE 10 oil after the drain plugs are replaced, and run the engine at the same fast idle for ten or fiteen minutes and again drain the oil thoroughly.
7. Remove the filter element, clean the filter shell and reinstall a new element.
8. Replace the drains and fill the crankcase to the proper level with the oil recommended for normal engine operation.
9. To test the effectiveness of the cleaning procedure, it is recommended that the engine be started and run at a fast idle (1000 to 1200 rpm) for approximately 30 minutes. Then, stop and immediately restart the engine. There is a possibility that the engine is not entirely free of contaminant deposits if the starting speed is slow.
10. If the procedures for cleaning the lubricating oil system were not successful, it will be necessary to disassemble the engine and to clean the affected parts thoroughly.

MAKE CERTAIN THAT THE CAUSE OF THE INTERNAL COOLANT LEAK HAS BEEN CORRECTED BEFORE RETURNING THE ENGINE TO SERVICE.

FRESHWATER PUMP

A centrifugal-type fresh water pump (fig. 1) is mounted on top of the engine oil cooler housing, *as* shown in figure 2. It circulates the coolant through the oil cooler cylinder block, cylinder head and a radiator. The pump is belt driven, by the balance shaft.

An impeller is pressed onto one end of the water pump shaft and *a* water pump drive pulley is pressed onto the opposite end. The pump shaft is supported on a sealed double-row combination radial and thrust ball bearing. Coolant is prevented from creeping along the shaft toward the bearing by *a* seal. The shaft and bearing constitute an assembly and are serviced as such since the shaft serves as the inner race of the ball bearing. The sealed water pump shaft ball bearing is filled with lubricant when assembled. No further lubrication is required.



I. Water pump assembly.

5.1 FRESH WATER PUMP

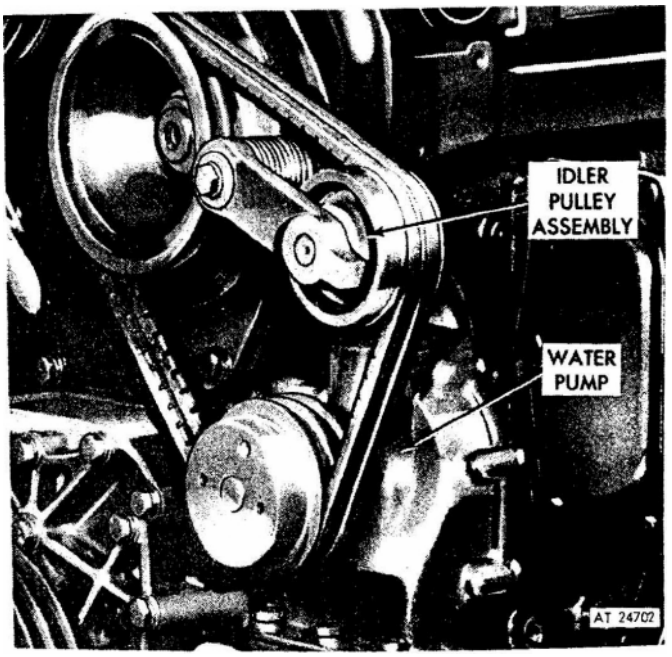


Figure 2. Typical water pump mounting.

Removal

Remove the water pump as follows (fig. 2):

1. Drain the fresh water cooling system.
2. Loosen and remove the Dum P drive belts.

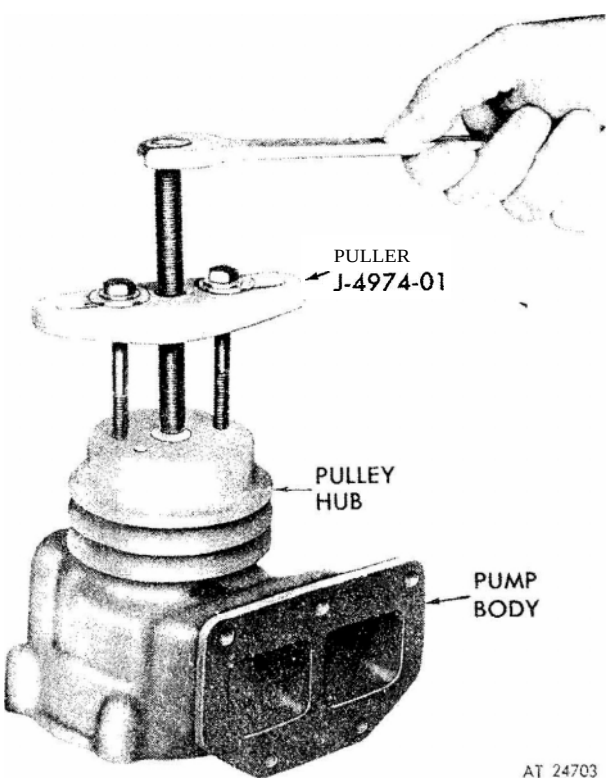


Figure 3. Removing pulley.

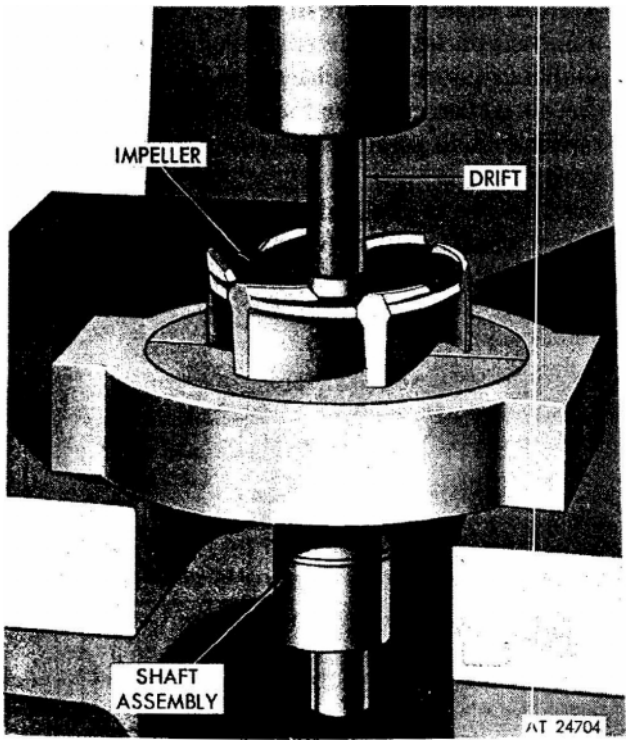


Figure 4. Removing shaft from impeller with tools J 8329 and J 358-1.

3. Loosen the hose clamps on the water by-pass tube; then, slide the hose up on the water by-pass tube.
4. Remove the five bolts and secure the water pump to the oil cooler housing. Then, lift the pump away from the engine.

Disassembly

Disassemble the water pump in the following manner:

1. Note the position of the pulley on the shaft so that the pulley can be reinstalled in the same position when the pump is assembled. Remove water pump pulley as shown in figure 3.
2. Remove pump cover and gasket (fig. 6).
3. Press the shaft and bearing assembly, seal, and impeller out of the pump body as an assembly, by applying pressure on bearing outer race with tool J 1930 (fig. 5).

CAUTION

The bearing will he damaged if the purr I p is disassembled by pressing on the end of the pump shaft.

4. Press the end of the shaft out of the impeller as shown in figure 4, using plates J 8329 and holder J 358-1.
5. Remove the seal assembly from the pump shaft. Discard seal assembly.

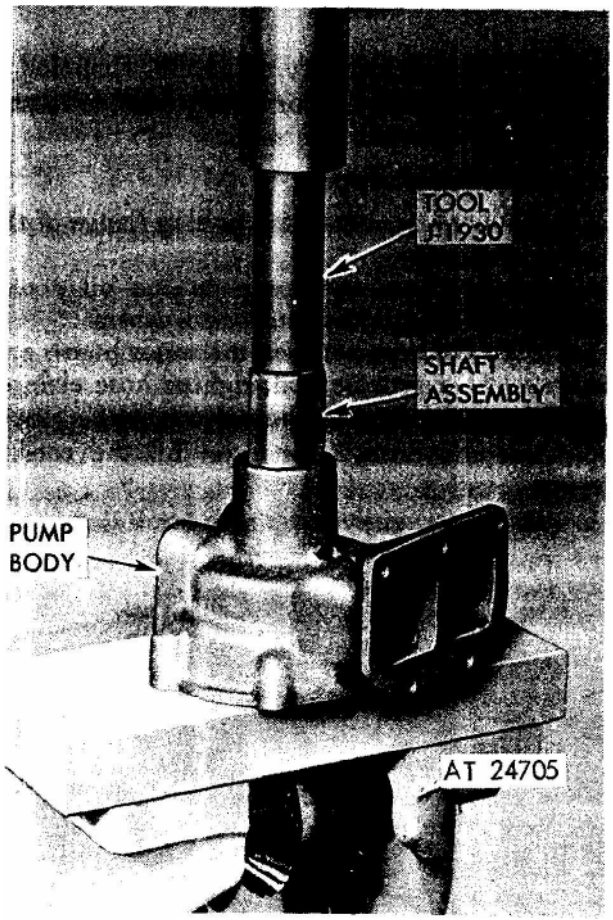


Figure 5. Pressing shaft assembly into water pump.

Inspection

Wash all of the **pump parts,** except the bearing and shaft assembly, in clean fuel oil and blow dry with compressed air.

NOTE

The pump shaft bearings should not be washed in fuel oil. If the bearings are immersed in cleaning fluid, dirt may be washed in and the fluid could not be entirely removed from the bearings.

Examine the impeller for damage and for excessive wear on the impeller face which contacts the seal. Replace the impeller if it is worn or damaged. Revolve the shaft bearings slowly by hand ; if rough or tight spots are detected, the bearing and shaft assembly must be replaced.

Assembly

1. Using tool J 1930, apply pressure to the outer race of the bearing as shown in figure 5. Press the shaft and bearing assembly into the pump body until the outer race of the bearing is flush with the outer face of the body.

CAUTION

The bearing will be damaged if the bearing and shaft assembly is installed by applying pressure on the end of the shaft.

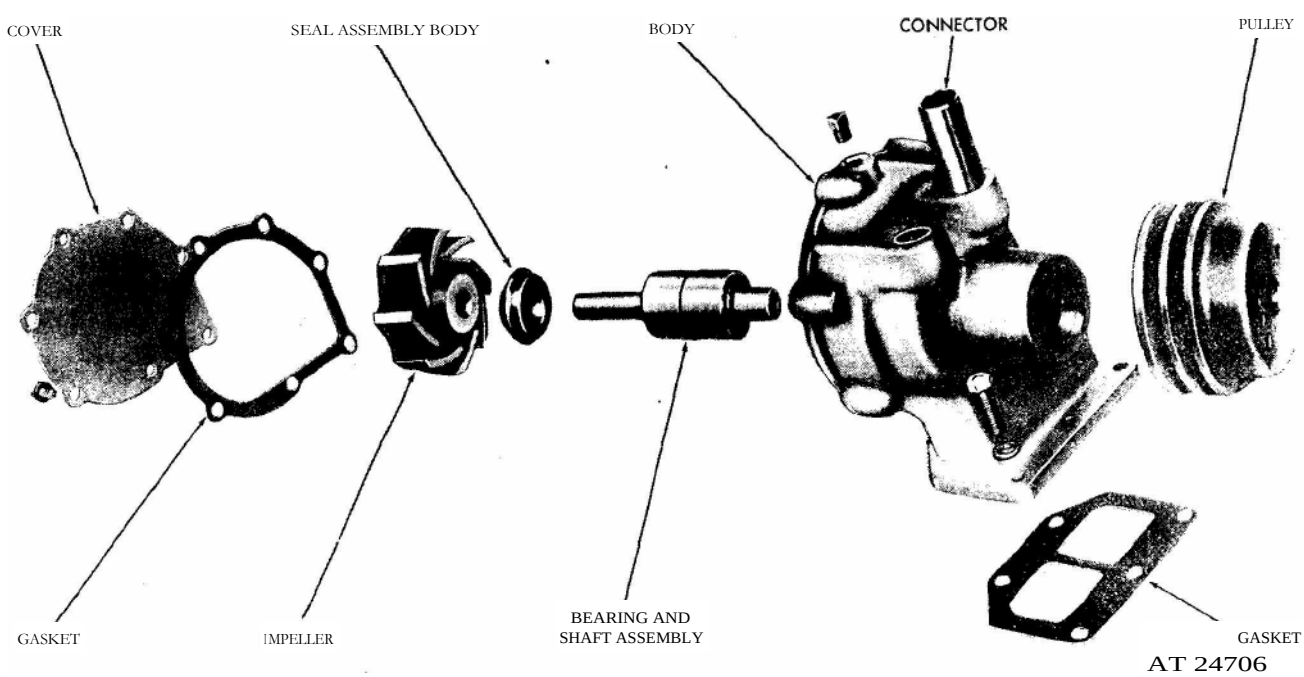


Figure 6. Fresh water pump details and relative location of parts.

5.1 FRESH WATER PUMP

2. Lightly coat the outside diameter of the new seal with sealing compound. Then, with the face of the body and the bearing outer race supported, install the seal by applying pressure on the seal outer flange only, until the flange contacts the body (fig. 1). Wipe the face of the seal with a chamois to remove dirt and metal particles.

3. Support the pulley end of the shaft on the bed of an arbor press and press the impeller on the shaft until the impeller is flush with the large end of the body.

4. Place the pulley on the bed of an arbor press and using a suitable rod between the ram of the Press and the impeller end of the shaft, press the ;haft into the pulley until the pulley *is* in its original position on the shaft.

5. Install the cover and a new gasket on the pump body. Tighten the cover bolts to 6-7 ft-lb torque.

6. Hun the pump dry at 1200 rpm for a minimum of 30 seconds, or as required, to assure satisfactory seating of the seaL

Install Water Pump

1. Affix a new gasket to the bolting flange of the water pump body.

2. Secure the water pump to the oil cooler housing with five bolts and lock washers.

3. Install the hose between the water pump and the water by-pass tube and, tighten hose clamps.

4. Install and tighten the drive belts.

5. Close the drain valves and fill the cooling system.

6. Start the engine *and* check for leaks.

FRESHWATER PUMP IDLER PULLEY ASSEMBLY

The fresh water pump idler pulley assembly: is mounted on the upper engine front cover (fig. 1).

Remove Idler Pulley Assembly

Remove two attaching bolts and lift the pulley assembly away from the front cover and drive belts.

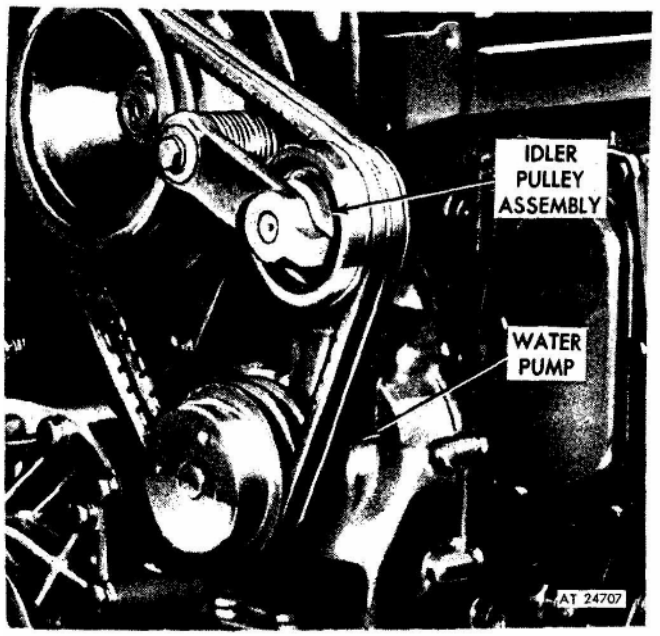


Figure 1. Typical fresh water pump idler pulley mounting.

Disassemble Idler Pulley Assembly

1. Support the pulley, then press the shaft and bearing assembly and bracket from the pulley by applying pressure to the outer race of the bearing (fig. 2).

2. Support the bracket, then press the shaft and bearing assembly from the idler pulley bracket by applying pressure on the shaft only.

Inspection

Wash the idler pulley bracket and pulley in clean fuel oil and blow them dry with compressed air. The idler pulley shaft and bearing assembly must not be washed in fuel oil. If the bearing is immersed in cleaning fluid, dirt may be washed in and the fluid and dirt could not be entirely removed from the bearing. Examine the bracket and pulley for excessive wear or cracks. Revolve the shaft in the bearing slowly by hand, If rough or tight spots are detected, the bearing and shaft assembly must be replaced.

Assemble Idler Pulley Assembly

1. Apply a minimum of 2500 lbs pressure only on the outer race of the bearing as shown in figure 3,

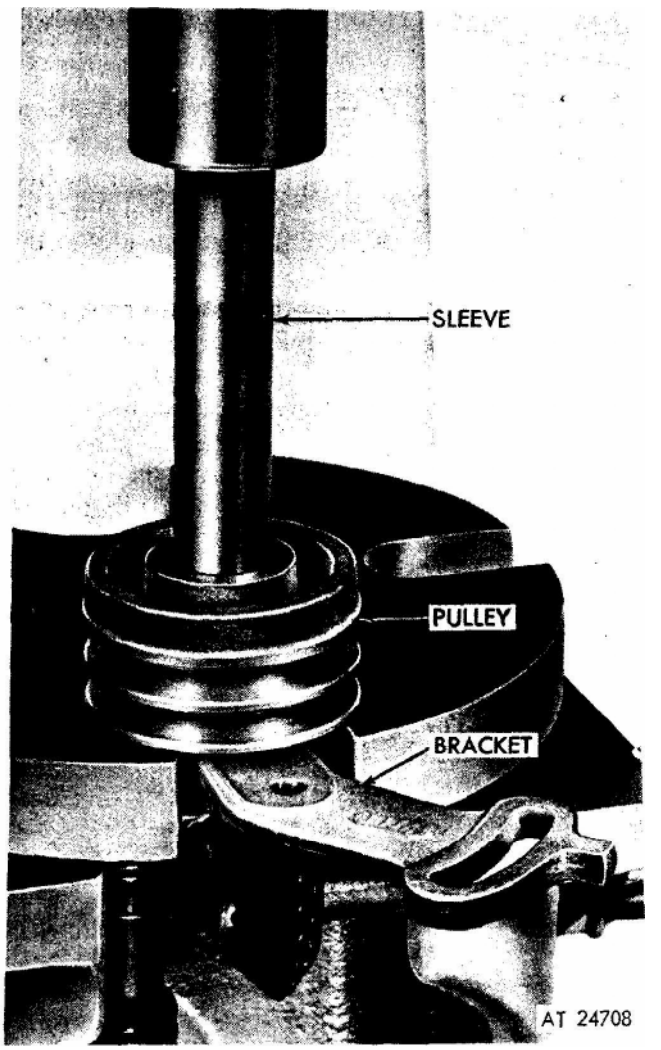


Figure 2. Removing shaft and bearing assembly and bracket from idler pulley.

and press the bearing and shaft assembly into the idler pulley until the outer race of the bearing is flush with the inside surface of the pulley.

2. With a short rod, apply pressure on the shaft only (fig. 4), and press the shaft and bearing assembly with the pulley into the idler pulley bracket. The distance between the outer edge of the pulley and the bracket must be .160".

Install Idler Pulley Assembly

1. Attach the idler pulley assembly to the front cover with two bolts and lock washers.

2. Install the water pump drive belts, if removed.

3. Adjust the idler pulley assembly so that the drive belts have the proper tension and tighten the bolts.

5.1.1 FRESH WATER PUMP IDLER PULLEY

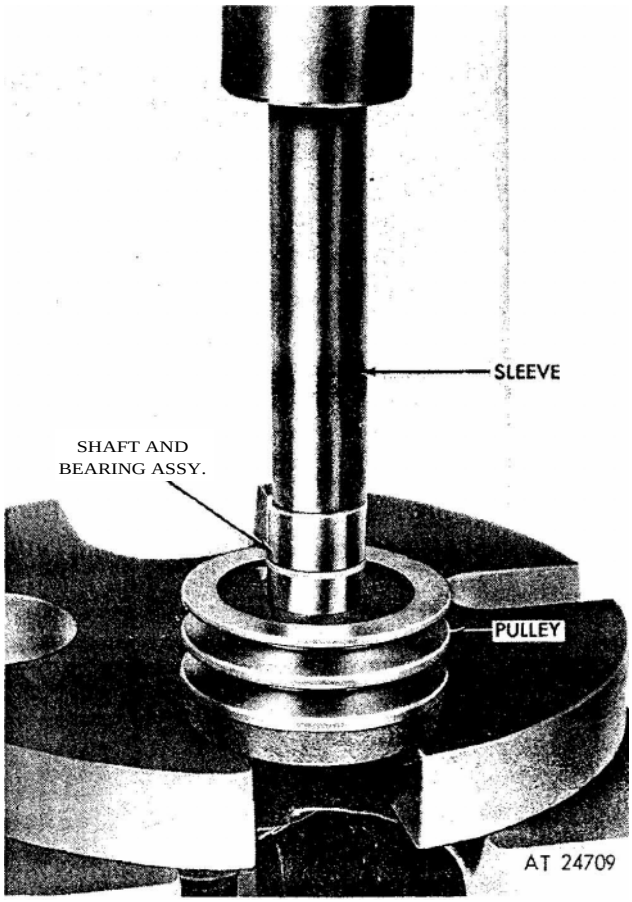


Figure 3. Installing shaft and bearing assembly in idler pulley.

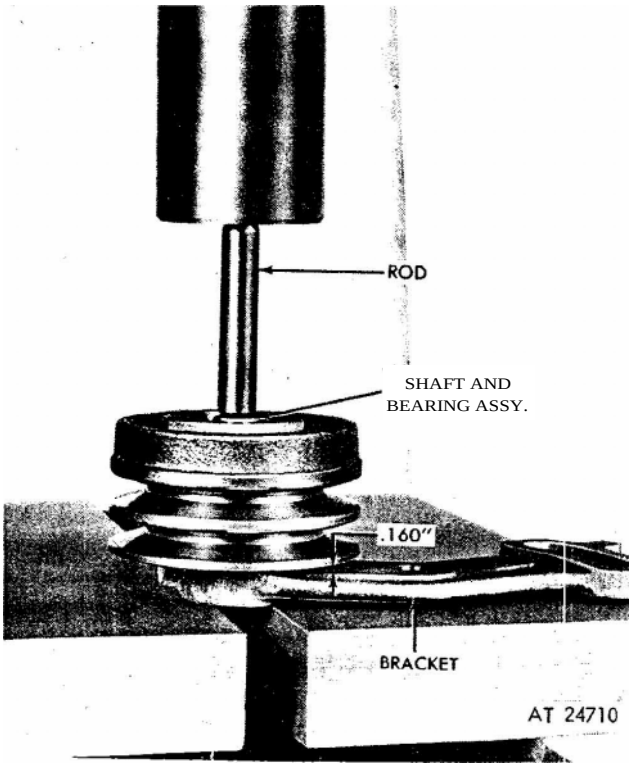


Figure 4. Installing shaft and bearing assembly and pulley in bracket

THERMOSTAT

The temperature of the engine coolant is automatically controlled by a blocking type thermostat located in a housing attached to the water outlet end of the cylinder head. A single thermostat is used. A by-pass tube is attached between the thermostat housing and the water pump.

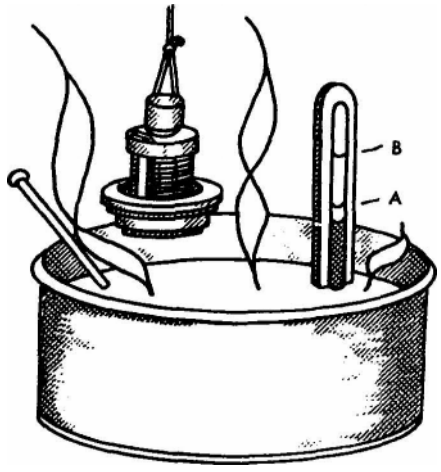
At coolant temperatures below approximately 170°F., the thermostat valve remains closed and blocks the flow of coolant through the radiator. During this period, the coolant circulates through the cylinder block and head and then back to the suction side of the pump via the by-pass tube. As the coolant temperature rises, the thermostat valve begins to open, restricting the by-pass system, and permits the coolant to circulate through the radiator. However, with the valve fully opened, a very small portion of the coolant will continue to circulate through the by-pass tube, while the major portion will pass through the radiator. A properly operating thermostat is essential for efficient operation of the engine. If the engine operating temperature deviates from the normal range of 160°-185°F., the thermostat should be removed and checked.

Remove Thermostat

1. Drain the cooling system to the necessary level by opening the drain valve.
2. Remove the hose connection(s) between the thermostat housing water outlet elbow and radiator.
3. Loosen the bolts and remove the water outlet elbow from the thermostat housing on an In-line engine. Remove the thermostat and if used, remove and discard the thermostat seal.

Inspection

If the action of the thermostat has become impaired due to accumulated rust and corrosion from the engine coolant so that it remains closed, or only partially open, thereby restricting the flow of water, overheating of the engine will result. A thermostat which is stuck in a wide open position may not permit the engine to reach its normal operating temperature. The incomplete combustion of fuel due to cold operation will result in a build-up of carbon deposits on the pistons, rings, and valves. The operation of the thermostat may be checked by ¡mmersing it in a container of hot water (fig. 1). Place a thermometer in the container, but do not allow it to touch the bottom. Agitate the water to maintain an even temperature throughout the container. As the water is heated, the thermostat valve should begin to open wnen the temperature



A—STARTS TO OPEN
B—FULLY OPEN

AT 24711

Figure 1. Method of checking thermostat operation.

reaches 167 -172° F. The opening temperature is usually stamped on the thermostat. The thermostat should be fully open at approximately 190°-192° F. Clean the thermostat sealing surface in the thermostat housing and base or water outlet elbow.

Install Thermostat

Refer to figure 2 and install the thermostat as follows:

1. If used, install a new seal in the thermostat housing. Position the seal so the lip faces away from the thermostat. Press the seal in with seal installer J 22091 and handle J 7092-2.
2. Affix a new gasket to the thermostat housing base.
3. Place the thermostat in the housing.
4. Install the water outlet elbow and secure it to the housing with two bolts and lock washers.
5. Connect the hose from the radiator or heat exchanger to the water outlet elbow and secure it with the clamps.

After the thermostat has been installed, close all of the drain cocks and fill the cooling system. Vent the system as outlined in section 5. Then, start the engine and check for leaks.

5.2.1 THERMOSTAT

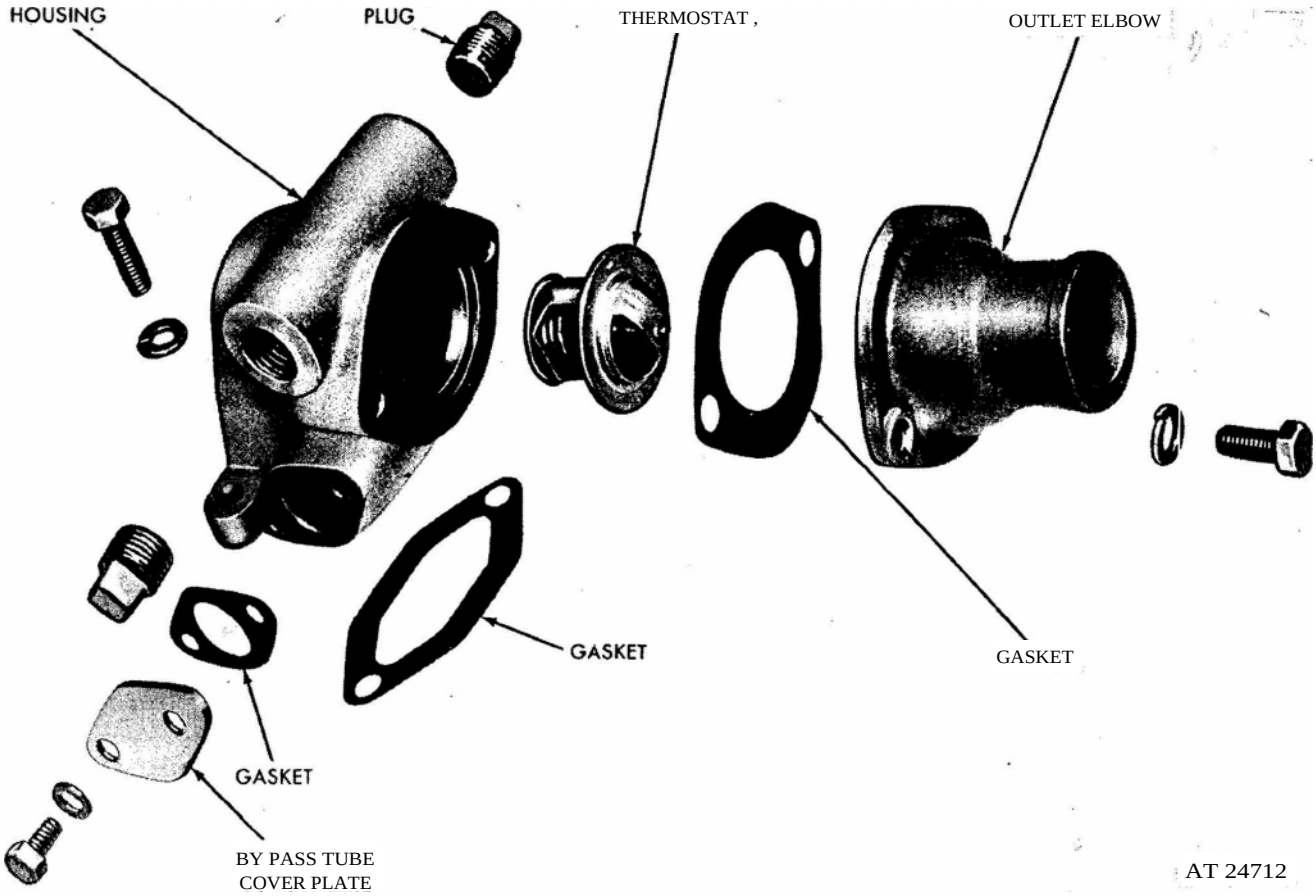


Figure 2. Thermostat housing details and relative location of parts.

FAN

The engine cooling fan is driven by a pair of V-drive belts from the crankshaft pulley. The belt driven fan is bolted to a combination fan hub and pulley which turns on a sealed ball bearing assembly.

Lubrication

The sealed ball bearing, used in the fan hub assembly is pre-lubricated.

Fan Belt Inspection and Adjustment

Inspect the fan belts for cracks, ruptures, wear, and tension. Also, check the condition of the grooves in the pulleys. Replace both belts if either one is worn or damaged. Since belts stretch with use, a new belt paired with an old belt will carry most of the load and an early failure is likely. Do not pry belts off or on the pulleys since a screw driver or pry bar may rupture or otherwise damage the belts.

The fan belts should be neither too tight nor too loose. Belts which are too tight impose an excessive load on the fan hub bearings and shorten the life of the belts. Insufficient tension will cause the belts to slip, resulting in possible overheating of the engine due to reduced fan speed. Each belt should have just enough slack so it can be pushed in approximately ½" to ¾", at a point midway between the pulleys, from a straight edge held against the rims of the pulleys.

The bolt holes in the adjusting bracket are slotted to provide a means of adjusting the belt tension. To adjust the belts, loosen the bracket bolts and the adjusting bolt on top of the bracket (if one is provided) and move the bracket up or down to obtain the proper tension. Then, retighten the bolts, also refer to section 15.1.

Remove Fan, Hub and Adjusting Bracket

The fan blades must rotate in a vertical plane parallel with and a sufficient distance from the radiator core. Bent fan blades reduce the efficiency of the cooling system, may throw the fan out of balance, and are apt to damage the radiator core. Before removing the fan blades, check the blades for alignment. Do not rotate the fan by pulling on the fan blades.

1. Remove the attaching bolts and lock washers and remove the fan and spacer (if used).

2. Loosen the fan hub adjusting bracket bolts and remove the drive belts. Then withdraw the bolts and washers and remove the hub and bracket assembly from the engine.

Disassemble Hub and Adjusting Bracket

I N-LINE ENGINES:

1. Measure the distance between the rear face of the rim on the pulley and the rear face (machined) of the fan adjusting bracket. Record this measurement for reassembly purposes.

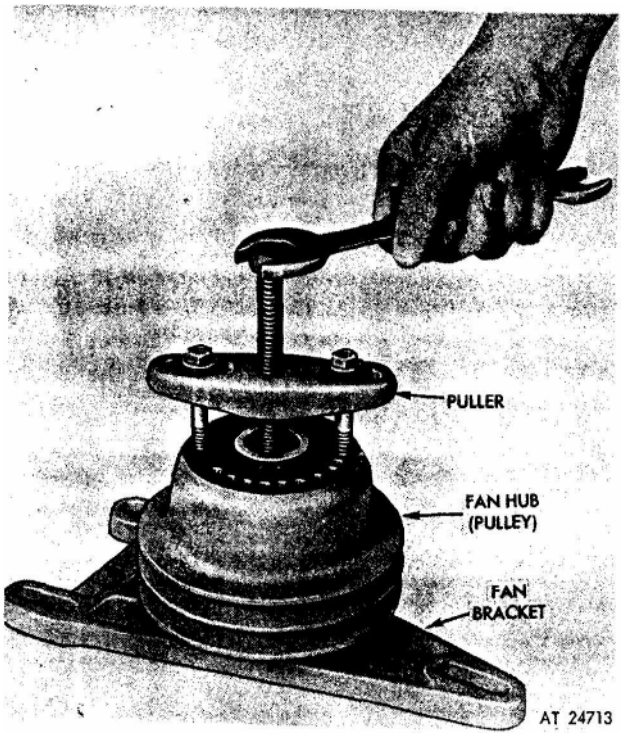


Figure 1. Removing fan hub (pulley).

2. Remove the fan hub from the shaft with a puller as shown in figure 1.

3. Place the bracket assembly in an arbor press. Then, place a suitable sleeve over the shaft and against the outer race of the bearing and press the bearing and shaft assembly from the bracket.

CAUT ION

Damage to the bearing will result if force is applied to the shaft.

Inspection

Wash the fan and fan hub parts thoroughly with fuel oil, dry them with compressed air, and inspect them for wear or damage.

NOTE

Do not wash the permanently sealed bearing which is used in the In-line engine hub assembly. Wipe the bearing and shaft assembly with a clean lintless cloth.

Hold the inner race (shaft of sealed ball bearing assembly) and revolve the outer race of each bearing slowly by hand. H rough or tight spots are detected, replace the bearing. Examine the ban blades for cracks. Replace the fan if the blades are badly bent, since straightening may weaken the

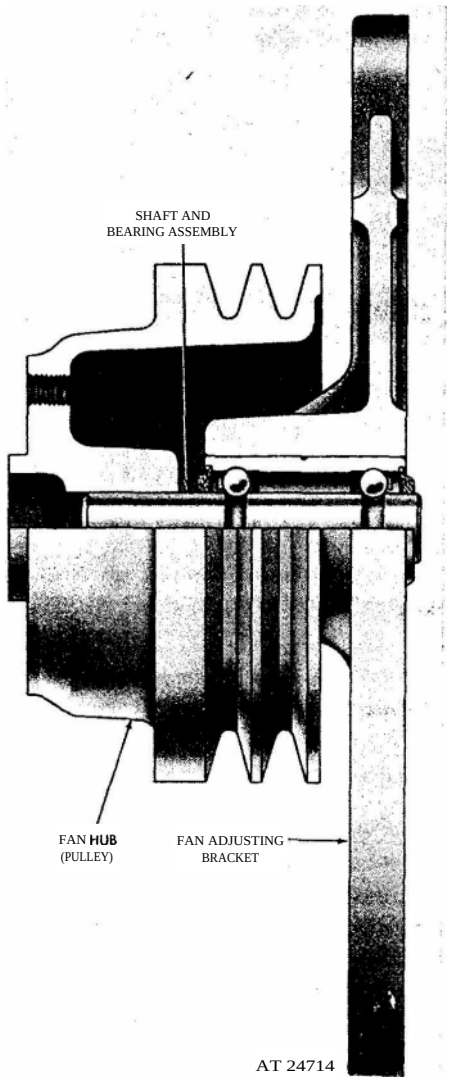


Figure 2. Fan hub assembly (in-line engine).

blades, particularly in the hub area. Remove any rust or rough spots in the grooves of the fan pulley and crankshaft pulley. If the grooves are damaged or severely worn, replace the pulleys.

Assemble Hub and Adjusting Bracket

Refer to figures 2 and 3 and assemble the fan hub and adjusting bracket as follows:

1. Press the shaft and bearing assembly into the adjusting bracket by applying pressure on the outer race of the bearing, using a suitable sleeve, until the bearing is flush with the pulley end of the bracket
2. Measure the shaft diameter and the pulley bore. It is important that a .001" — .002" press fit be maintained. Then support the bearing end of the shaft and press the fan hub (pulley) on the shaft to the original dimensions taken during disassembly. This will assure proper alignment and clearance of the parts.

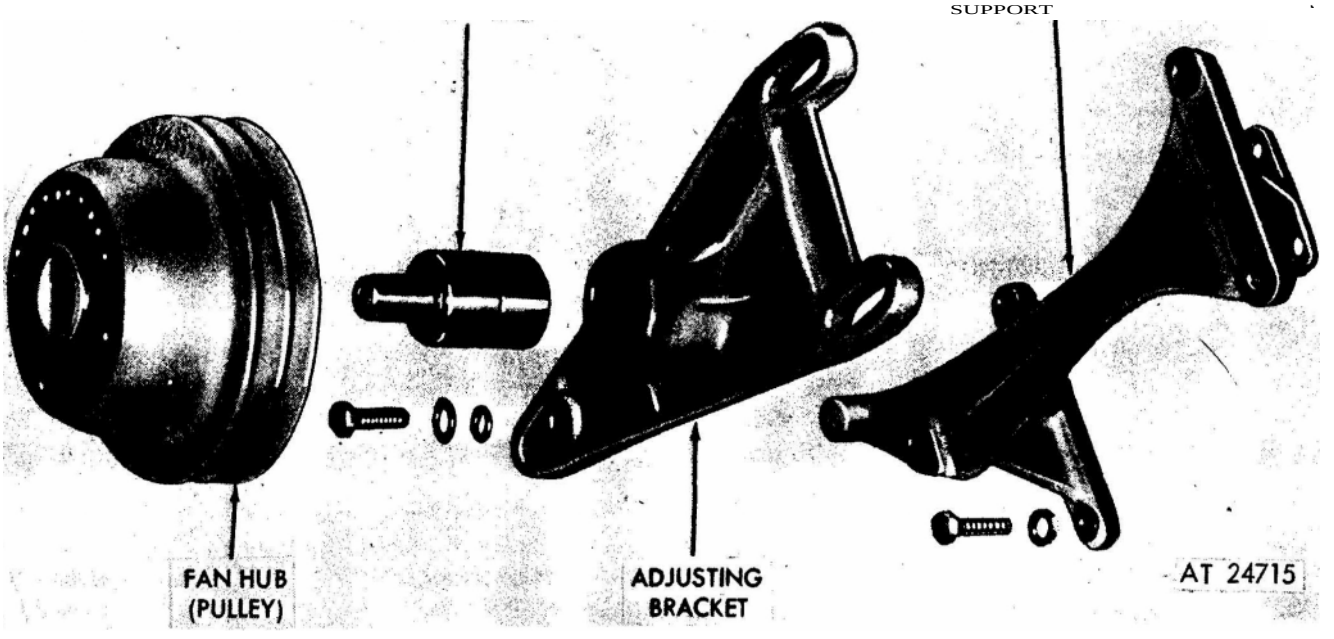


Figure 3. Typical fan hub and adjusting bracket details and relative location of parts (in-line engine)

SPECIFICATIONS-SERVICE TOOLS

Specifications

Standard Bolt and Nut Torque Specifications

Size nut or bolt	Torque (lb-ft)	Size nut or bolt	Torque (lb-ft)	Size nut or bolt	Torque (lb-ft)
1/4 - 20	7-9	7/16 - 20	57-61	3/4 - 10	240-250
1/4 - 28	8-10	1/2 - 13	71-75	3/4 - 16	290-300
5/16 - 18	13-17	1/2 - 20	83-93	7/8 - 9	410420
5/16 - 24	15-19	9/16 - 12	90-100	7/8 - 14	475-485
3/8 - 16	30-35	9/16 - 18	107-117	1 - 8	580-590
3/8 - 24	35-39	5/8 - 11	137-147	1 - 14	585-595
7/16 • 14	46-50	5/8 - 18	168-178		

Exceptions to Standard Bolt and Nut Torque Specifications

Application	Size nut or bolt	Torque (lb-ft)
Water Pump Cover	5/16 -.18	6-7

Service Tools

Tool No.	Tool name
J . 358-1	Holder
J 1930	Remover and Installer
J 4794-01	Puller
J 8329	Plates
J 22091	Seal Installer
J 7092-2	Handle

SECTION 6

EXHAUST SYSTEM

CONTENTS

EXHAUST SYSTEM

Engine is equipped with an air-cooled exhaust manifold. The exhaust manifold is secured to the cylinder head with two clamps and nuts. Two copper asbestos gaskets are used on the studs between the clamps and manifold.

EXHAUST MANIFOLD

The exhaust manifold has *a* circular outlet which is connected to the exhaust pipe with *a* Marmon-type clamp.

Remove Exhaust Manifold

1. Disconnect the exhaust pipe or muffler from the exhaust manifold flange.
2. Loosen, but do not remove, one of the center exhaust manifold nuts. Remove the other nuts, clamps, and copper gaskets.
3. Support the manifold and remove the remaining center nut, clamp, and copper gasket
4. Remove the manifold and gasket from the cylinder head.

Inspection

Remove any loose scale and carbon that may have accumulated on the internal walls of the exhaust manifold. Clean the manifold and check for cracks, especially in the holding lug areas. Clean all traces of gasket material from the cylinder head. Examine the exhaust manifold studs. Replace damaged studs. Apply sealant to the threads and tighten the new studs to 25-40 lb-ft torque.

Install Exhaust Manifold

1. Place a new gasket over the studs and against the cylinder head.
2. Position the exhaust manifold over the studs and hold it against the cylinder head.
3. Install the two end nuts on the studs.
4. Place a copper asbestos gasket over each of the two center studs against the manifold. Place clamps over the manifold on the two center studs.
5. Thread the nuts on the tw center studs. Beginning with one of the center nuts working alternately toward each end of the manifold, tighten the nuts to 30-35 lb-ft torque.
6. Connect the exhaust pipe or muffler to the exhaust manifold flange.

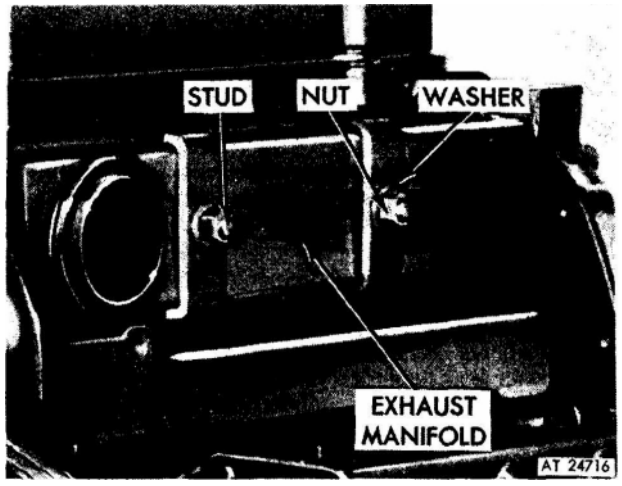


Figure 1. Exhaust manifold with ***marmon*** *flange.*

SECTION 7

ELECTRICAL EQUIPMENT, INSTRUMENTS AND PROTECTIVE SYSTEMS

CONTENTS

ELECTRICAL SYSTEM

The engine is equipped with a 24-volt electrical system.

Detailed information on maintenance and repair of the specific types of electrical equipment used can be found in the service manuals and bulletins issued by the equipment manufacturer. Information regarding equipment manufactured by the Delco-Remy Division of General Motors Corporation may be obtained from their electrical equipment operation and maintenance manuals. The manuals may be obtained from United Motors Service, or from the Technical Literature Section, Delco-Remy, Division of General Motors Corporation, Anderson, Indiana.

In most instances, repairs and overhaul work on electrical equipment should be referred to an authorized repair station of the manufacturer of the equipment. For electrical equipment manufactured by Delco-Remy Division, repair service and parts are available through United Motors Service branches and repair stations.

STARTING MOTOR

The starting motor (fig. 1) has a shift lever and solenoid plunger that are totally enclosed to protect them from road dirt, icing conditions, and road splash.

The starting motor is equipped with a Sprag overrunning clutch drive (figs. 2 and 3). An important feature of the Sprag type drive is that once the solenoid has moved the starter pinion in mesh with the ring gear on the flywheel, it will not disengage during intermittent engine firing, which prevents damage to the pinion and the ring gear teeth. The pinion remains engaged until starting is assured and the solenoid circuit is interrupted.

The solenoid switch, mounted on the starting motor housing, operates the overrunning clutch drive by means of linkage and a shift lever. When the starting switch is engaged, the solenoid is energized, shifting the starting motor pinion in mesh with the engine flywheel ring gear and closing the main contacts within the solenoid. Battery current is then directed to the motor causing the armature to turn. Cranking torque is transmitted by the Sprag clutch from the starting motor armature to the engine flywheel ring gear. To protect the armature from excessive speed as the engine starts, the clutch "overruns", or turns faster than the armature, which permits the pinion to disengage.

Under normal operating conditions, no maintenance will be required on the starting motor between engine overhaul periods.

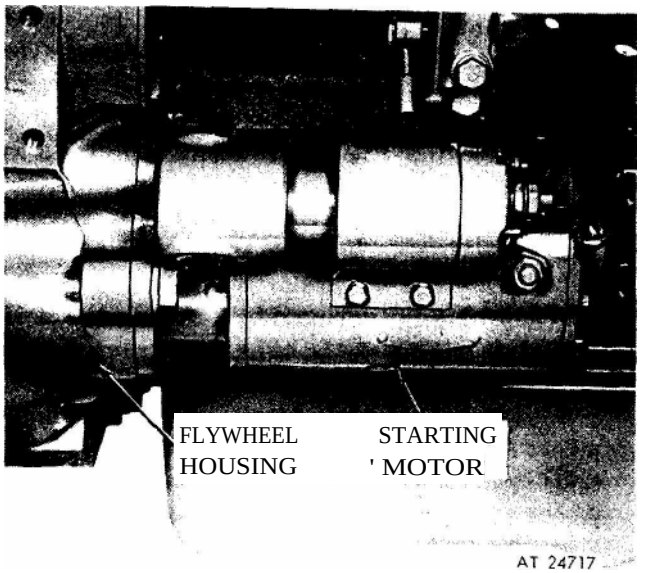


Figure 1. Typical starting motor mounting.

Adjustable Nose Housing

The nose housing on the Sprag clutch type starting motor can be rotated to obtain a number of different solenoid positions with respect to the mounting flange. When repositioning of the solenoid is required on a service replacement starting motor, preceed as follows:

STARTER WITH INTERMEDIATE DUTY CLUTCH

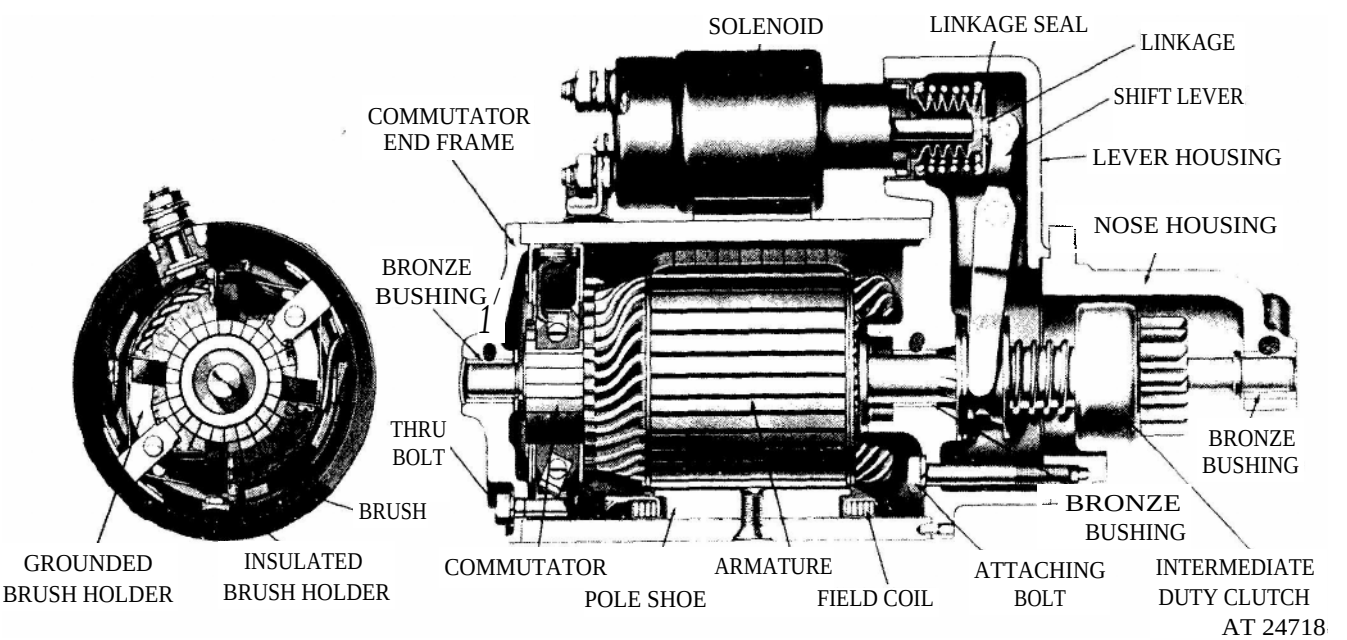


Figure 2. Cross-sectional view of motor with sprag intermediate duty clutch.

7.3 STARTING MOTOR

The lever housing and the commutator end frame are held to the field frame by bolts extending from the end frame to threaded holes in the lever housing. The nose housing is held to the lever housing by internal attaching bolts extending from the lever housing to threaded holes in the nose housing (fig. 2). With this arrangement, it is necessary to partially disassembly the motor to provide access to the nose housing attaching bolts. Relocate the nose housing as follows:

1. Remove the electrical connector and the screws attaching the solenoid assembly to the fide, frame; then, remove the bolts from the commutator end frame.
2. Separate the field frame from the remaining assembly and pull the armature away from the lever housing until the pinion stop rests against the clutch pinion; this will provide access to the nose housing attaching bolts.
3. Remove the nose housing attaching bolts with a box wrench or open end wrench.
4. Turn the nose housing to the required position.

NOTE

The solenoid must never be located below the centerline of the starter or dust, oil, moisture and foreign material Can collect and cause solenoid failures.

5. Reinstall the nose housing attaching bolts and tighten them to 11-15 lb-ft torque.
6. Reassembly the motor.

Lubrication

The starting motor bearings (bushings) are lubricated by oil saturated wicks which project through each bronze bushing (one at each end and one at the center) and contact the armature shaft. Oil can be added to each wick by removing a pipe plug with is accessible on the outside of the motor.

Remove Starting Motor

1. Remove the ground strap or cable from the battery or the cable from the starting motor solenoid. Tape the *end* of the cable to prevent discharging the battery from a direct short.
2. Disconnect all of the wires from the starting motor solenoid terminals. Tag the wires to insure correct reinstallation.
3. Support the motor and remove the three bolts and lock washers which secure it to the flywheel housing. Then, pull the motor forward to remove it from the flywheel housing.

Check the starting motor, if required, in accordance with the Delco-Remy "Cranking Circuit" maintenance handbook.

Install Starting Motor

To install the starting motor, reverse the procedure outlined for removal. Tighten the ⅜"-11 mounting bolts to 137-147 lb-ft torque. Keep all of the electrical connections clean. Connect the starting motor cables and solenoid wiring as tagged. Tighten the 10-32 connections to 16-30 lb-in torque and the ½"-13 connection to 20-25 lb-ft torque.

SECTION 12

SPECIAL EQUIPMENT

CONTENTS

AIR HEATER

The engine is equipped with an air aspirated nozzle type air heater for heating the induction air during cold weather starting and warm-up operation. See figures 1 and 2.

This section contains disassembly, cleaning, inspection and assembly of the air box heater assembly. The heater air pump, spray nozzle assembly, solenoid valve and ignition coil are not to be disassembled and are to be replaced as a complete assembly if it has been determined that they are faulty. It will be necessary to clean and inspect the assemblies for external damage and operation.

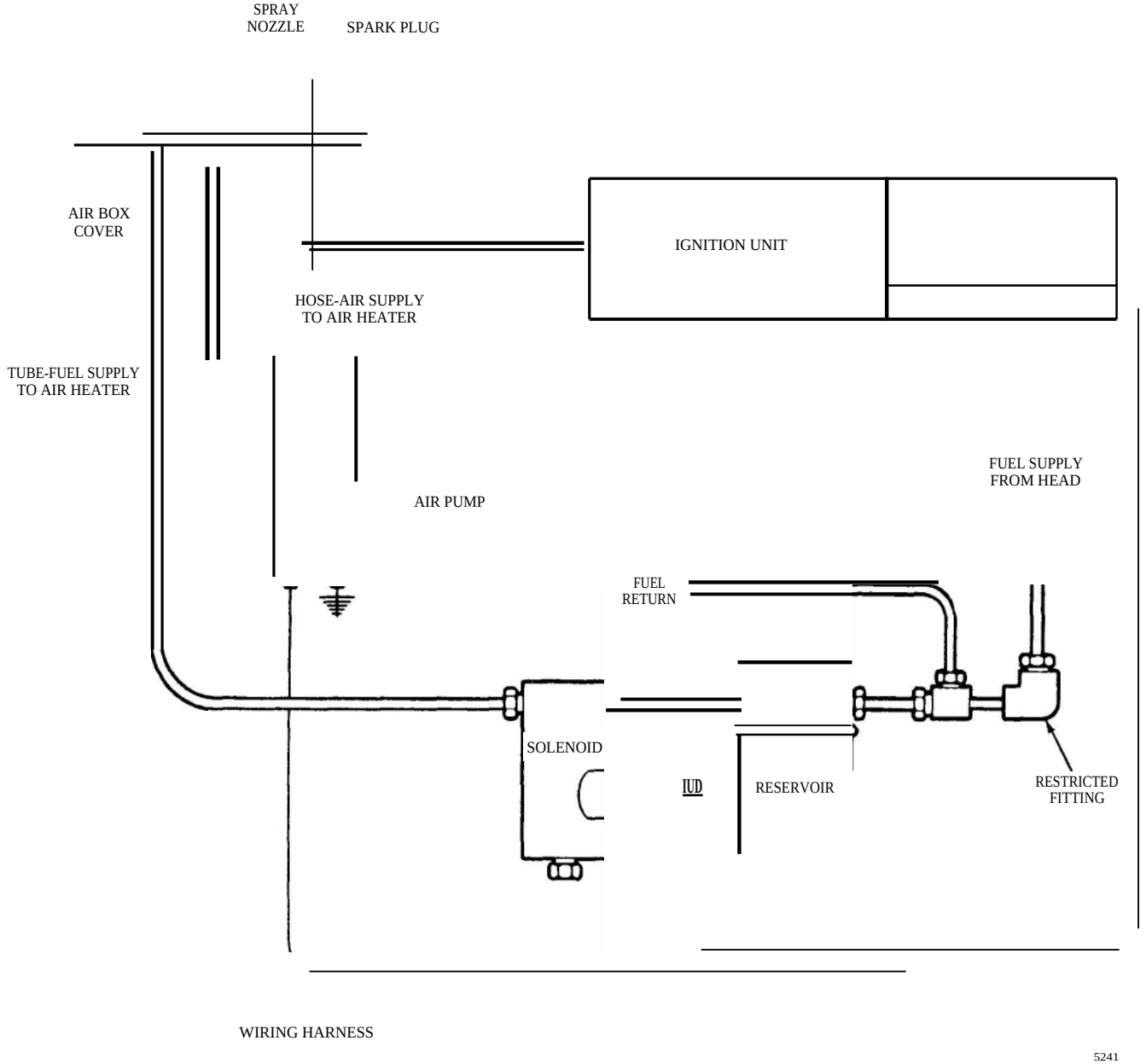


Figure 1. Circuit diagram—Air box - 24 V starting system.

12.6 AIR BOX HEATER

The air heater assembly consists of a cover, spark plug and air aspirated spray nozzle assembly. The air pump delivers compressed air through the nozzle aspirating and spraying fuel into the air box. The fuel vapor is ignited by the spark plug and burns in the air box, heating the air box air before it enters the combustion chamber. The spark plug is energized by the ignition coil.

The air heater solenoid valve is mounted on the same bracket as the fuel reservoir and *is* energized (opened) whenever the air box heater is actuated. The solenoid valve *insures* that fuel *is* delivered only when the system is actuated and stops the flow the instant the air box heater operation *is* discontinued.

The ignition unit assembly consists of a coil and a vibrator. The coil converts low voltage electrical power to the high voltage power required to activate the electrode. The vibrator interrupts the flow of high voltage to the electrode thus producing a series of electrical discharges.

The air pump is a vane type compressor driven by an enclosed electric motor. The pump delivers air through the spray nozzle which aspirates fuel from the reservior and supplies it to the solenoid valve which then, when actuated, supplies fuel thru the spray nozzle. The air pump is energized by a switch located on the vehicle instrument panel.

REMOVE AIR BOX HEATER

It is necessary to remove the fuel pump and governor before removing the air heater cover. Refer to section 2.2 and 2.7.1 in this manual for removal of the pump and governor.

After cleaning all of the exterior dirt from the components of the heater assembly proceed with removal.

1. Disconnect the air supply hose and electrical wires at the air pump.
2. Remove two clamps and lift the air pump from the mounting bracket.
3. Disconnect electrical wires from the ignition unit.
4. Remove two clamps and lift the ignition unit from the mounting bracket.
5. Disconnect the fuel supply and fuel return lines at the reservoir.
6. Disconnect the fuel line and electrical wires at the solenoid.
7. Remove four bracket attaching bolts and washers and remove the bracket with the solenoid and reservoir attached.
8. With the fuel and air lines and the electrical wire disconnected at the air heater cover remove two special screws. Withdraw the air box heater cover and gasket.

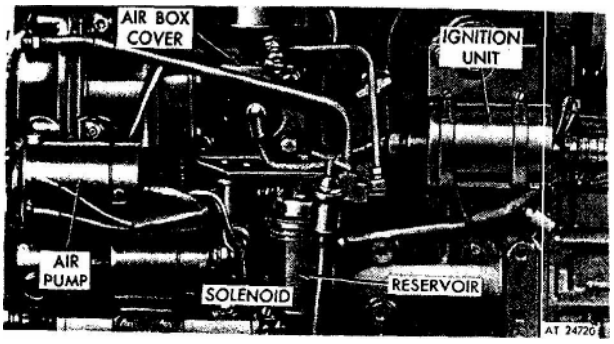


Figure 2. Air box heater system mounting.

CLEANING

AIR BOX HEATER ASSEMBLY

(1) Remove and clean all parts with dry-cleaning solvent or mineral spirits and blow dry with compressed air.

(2) Clean carbon deposits from the elctrode.

SOLENOID VALVE

(I) Plug the fuel inlet and outlet openings in the solenoid. Clean the solenoid assembly using dry-cleaning solvent or mineral spirits.

AIR HEATER IGNITION UNIT

(1) Clean the ignition coil surface with dry-cleaning solvent or mineral spirits.

AIR PUMP ASSEMBLY

(1) Plug the air outlet opening in the pump and clean the pump with dry-cleaning solvent or mineral spirits.

Clean flexible hoses and electrical lines with soap and water.

INSPECTION

AIR BOX HEATER

(1) Inspect the spark plug for cracks, excessive corrosion or other damage. Clean, test or replace spark plug.

(2) Inspect the fuel spray nozzle to insure orifice is not plugged. Replace the nozzle assembly if found to be faulty (damaged or burned).

AIR HEATER SOLENOID VALVE

(1) Inspect the air heater solenoid valve for evidence of broken fittings, dents, or other damage, and replace the solenoid, valve assembly if necessary.

HEATER IGNITION UNIT

(1) Inspect ignition unit for broken or damaged electrical connectors. Replace iginition unit if damaged in any way.

AIR PUMP

(1) Inspect air pump assembly for broken or damaged electrical connectors. Replace air pump if damaged.

TEST and ADJUSTMENT

SPARK PLUG

(1) Using a suitable feeler gage, set the spark plug electrode gap to .023"-.028".

IGNITION UNIT

(1) Connect output of ignition assembly to the spark plug terminal.

(2) Connect the air heater assembly and ignition assembly to a common ground.

(3) Connect a source of 24V DC to input of iginition assembly.

(4) Observe electric arc at spark plug tip. Arc should be steady with a slight crackling noise.

WARNING

High voltages exist when performing this test which could cause injury to personnel. Do not touch ignition assembly, air heater assembly or exposed connectors while test is *in* operation.

CAUTION

Do not apply voltage to ignition assembly without connections specified in steps (1) and (2) above having been made.

SOLENOID ASSEMBLY

(1) Intermittently connect a source of 24 volts direct current to the solenoid and verify valve opening and closing. When valve is stuck open, inspect for obstructions.

AIR PUMP

(1) Remove hose from air pump. Connect a source of 24 volts of direct current to the pump terminals.

(2) Check for air flow.

INSTALL AIR BOX HEATER

1. Using a new gasket position the air box cover assembly on the cylinder block and fasten it with two special flat head screws.
2. Refer to sections 2.2 and 2.7.1 for reassembly of the fuel pump and governor previously removed.
3. Place the bracket with the solenoid and reservoir attached, on the air box cover and fasten with four bolts and washers.
4. Attach the fuel supply and return lines to the reservoir. Also attach fuel line from solenoid to the air box heater cover.
5. Fasten the ignition unit to the bracket on the water hole cover with two clamps. Reconnect the electrical wires.
6. Attach the air pump to the mounting bracket with two clamps.
7. Reconnect the air pump electrical wires and the air supply hose to the air box cover.

SECTION 13

OPERATING INSTRUCTIONS

CONTENTS

ENGINE OPERATING INSTRUCTIONS

PREPARATION FOR STARTING ENGINE FIRST TIME

The operator should read and follow these instructions before attempting to start the engine.

NOTE

When preparing to start a new or overhauled engine or an engine which has been in storage, perform all of the operations listed below. Before a routine start (at each shift), see"Daily Operations" in the "Lubrication and Preventive Maintenance Chart" section 15.1.

Cooling System

Install all of the drain cocks (which were removed for shipping) in the cooling system. Open the cooling system vents, if the unit is so equipped. Remove the filler cap and fill the cooling system with clean, soft water or with a protecting solution of high boiling-point type antifreeze if the engine will be exposed to freezing temperatures. Keep the liquid level to about two inches below the filler neck to allow for fluid expansion.

When using water alone in the cooling system, add a quality rust inhibitor. Close the cooling system vents after filling.

Lubricating System

The lubricating oil film on certain upper parts of new engines, overhauled engines, or engines which have been in storage for a considerable length of time may be inadequate for proper lubrication when the engine is first started. For this reason, it is recommended that the uppper engine parts be prelubricated before starting the engine.

Remove the rocker cover and pour approximately two quarts of lubricating oil (of the same viscosity as that used in the engine crankcase) over the rocker arms and push rods.

Check the oil level in crankcase by means of the oil level dipstick at the side of the crankcase. Remove the dipstick, wipe the lower end with a clean cloth, then insert and remove the dipstick to take the level reading. Keep the oil level to the FULL mark on the dipstick. Use only HEAVY-DUTY lubricating oils, as specified under LUBRICATING OIL SPECIFICATIONS in section 13.3.

Fuel System

Fill the fuel tank with diesel engine fuel as specified under FUEL OIL SPECIFICATIONS in section 13.3. Open the fuel supply valve, if the unit is so equipped.

To ensure prompt starting, fill at least that portion of the fuel system between the pump and the fuel return passage with fuel. The fuel oil filter (between the fuel pump and the injectors) on any engine that has been out of service a considerable length of time, should be primed. To prime a filter, remove the vent plug in the top of the filter cover and pour fuel slowly through the opening until the filter is full.

NOTE

The fuel system of a new engine is filled with fuel before leaving the factory. If the fuel is still present in the system when preparing to start, priming should be unnecessary.

Lubrication Fittings

Lubricate at all pressure fittings and fill all grease cups with all purpose grease. Lubricate at hinge cap oilers, throttle linkage, and any exposed moving parts with engine oil in a hand oiler.

Drive Belts

Adjust all drive belts as recommended under "Lubrication and Preventive Maintenance" in section 15.1

Clutch

Disengage the clutch or clutches, if the unit is so equipped.

Cold Start Procedure

1. Shift transmission into neutral and turn on master switch.
2. Leaving foot throttle in idle position engage starter and heater switches.
3. If after 45 seconds of cranking the engine does not start, depress foot throttle half way and release heater switch. If engine again does not start begin cycling heater "on" for 4-6 seconds and "off" for 2-3 seconds. Continue this cycle until engine starts.

NOTE

The engine should begin firing during the crank and heat period. If no cylinder firing is noted within the first 30 seconds, abort the start and check the air heater for proper operation. Remove the inspection plug above the spark plug and check for flame.

13.1 ENGINE OPERATING INSTRUCTIONS

RUNNING

Oil Pressure

Immediately after starting, observe the oil pressure on the gage. If no pressure is shown after 10 to 15 seconds, stop the engine and check the lubricating system. See TROUBLE SHOOTING CHARTS, section 15.2.

Inspection

With the engine running, check the unit over carefully for any water, fuel oil, or lubricating oil leaks. Tighten line connections where necessary to stop leaks.

Engine Temperature

Under normal operating conditions, the coolant temperature should range between 160°F. and 185°F. with a corresponding oil temperature of 56°F. to 60°F. above the water outlet temperature.

Crankcase

After normal operating temperature has been reached, stop the engine, wait approximately 5 minutes and check the oil level. Replenish to the FULL mark on the oil gage.

NOTE

This is necessary only for the first start after a crankcase refill.

Use only specially compounded Heavy-Duty lubricating oils as specified under LUBRICATING OIL SPECIFICATIONS, in section 13.3.

Cooling System

After the engine has reached operating temperature, remove the radiator or heat exchanger tank cap slowly and check the coolant level. The coolant level should he near the top of the opening. Add sufficient soft water or high boiling-point type antifreeze to bring the coolant to the proper level.

Avoid Unnecessary Engine Idling

Prolonged engine idling will result in the temperature of the *engine* coolant falling below the specified operating range of 60° to 185°F. Low operating temperature causes the development of several conditions detrimental to engine operation and life. Imcomplete combustion of fuel in a cold engine causes crankcase dilution and forms lacquer or gummy deposits on valves, pistons and rings. It also causes rapid accumulation of sludge within the engine.

NOTE

When prolonged engine idling is necessary, maintain at least 800 rpm.

STOPPING

Throttle

Release the load and at the same time decrease the engine speed. Allow the engine to run at half speed or lower with no-load for four or five minutes before closing the throttle and stopping the engine. The emergency shut-down system should never be used to stop the engine except in an emergency. Use of the emergency shut-down can cause oil to be sucked past the oil seals into the blower housing.

Fuel System

If the unit is equipped with a fuel valve, close it. Fill the fuel tank; a full tank minimizes condensation.

Exhaust System

Open the drain or valve, if one is used in the exhaust line or silencer, to drain the condensation.

Cooling System

If there is no antifreeze in the cooling system and freezing temperatures are anticipated, drain the cooling system and leave the drains open.

Crankcase

Check and replenish the oil in the engine crankcase, as required, to bring it to the proper level.

Clean Engine

Clean and check the engine thoroughly to make certain it will be ready for the next run.

Refer to the LUBRICATION AND MAINTENANCE CHART, section 15.1, and perform all of the daily maintenance operations. Also, perform all of the operations required for the number of hours the unit has been in operation. Make any routine adjustments and minor repairs needed to correct difficulties which became apparent to the operator during the last run.

ENGINE OPERATING CONDITIONS

The following charts are included as an aid to trouble shooting. Any variations from the conditions *as* listed *may* be indicative of an abnormal situation demanding correction. Make sure that readings represent true values, and that instruments are accurate, before attempting to make corrections to the engine.

Series 3. 53N Engines (4-Valve Cylinder Head)

	2800 rpm
Lubricating Oil Pressure—psi (Normal)	40-60
Lubricating Oil Pressure—psi (Minimum for Safe Operation)	32
Air Box Pressure—inches mercury (Minimum, with zero exhaust back pressure)	6.1
Air Box Pressure—inches mercury (Minimum, with maximum exhaust back pressue)	9.3
Air Inlet Restriction—inches water (Maximum, Air Cleaner Dirty, Oil Bath or Dry Type)	25.0
Air Inlet Restriction—inches water (Maximum, Air Cleaner Clean) Oil Bath or Dry Type with Precleaner	16.0
Dry Type with no Precleaner	10.0
Crankcase Pressure—inches water (Maximum)	1.0
Exhaust Back Pressure—inches mercury (Maximum) Full Load	4.0
Exhaust Back Pressure—inches mercury (Maximum) No-Load	2.7
Fuel Pressure—psi *(Normal, at cylinder head inlet passage)*	45-70
Fuel Spill No-Load (.070" Rest) gpm-Min.	.6
Fuel Pump Suction, Maximum at Pump Inlet-In. Hg.	
Clean System	6
Dirty System	12
Compression Pressure-480 psi at 600 rpm (590 rpm "N" engines) (Average, new engine at sea level)	
Compression Pressure-430 psi at 600 rpm (540 rpm "N" engines) (Minimum, at sea level)	
Coolant Temperature—Degrees F. (Normal)	160-185
$ Lubricating Oil *Temperature—Degrees* F. (Normal)	200-235 200-235 205-240

$ The lubricating oil temperature range is based on the temperature measurement in the oil pan at the oil pump inlet. When measuring the oil temperature at the cyliner block oil gallery it will be 10° lower than the oil pan temperature.

ENGINE RUN-IN INSTRUCTIONS

Following a complete overhaul or any major repair job involving the installation of piston rings, pistons, cylinder liners, or bearings, the engine should be RUN-IN on a dynamometer prior to release for service. The dynamometer is a device for applying specific loads to an engine. It permits the service man to physically and visually inspect and check the engine while it is operating. It is an excellent method of detecting improper tune-up, misfiring injectors, low compression and other malfunctions, and may save an engine from damage at a later date.

The operating temperature within the engine affects the operating clearances between the various moving parts of the engine and determines to a degree how the parts will wear. Normal coolant temperature (160°-185°F.) should be maintained throughout the RUN-IN.

The rate of water circulation through engine on a dynamometer should be sufficient to avoid having the engine outlet water temperature more than 10°F. higher than the water inlet temperature. Though a 10°F. temperature rise across an engine is recommeded, it has been found that a 15°F. temperature rise maximum can be permitted. Thermostats are used in an engine to control the coolant flow; therefore, be sure they are fully operative or the engine can overheat during the RUN-IN. The overhauled engine should be tested without a thermostat if the dynamometer has a water stand-pipe with a temperature control regulator, such as a Taylor valve or equivalent.

The Basic Engine Run-in Horsepower Schedule shown below is at SAE conditions, dry air density .0705 lb cu. ft., air temperature of 85°F., and 500 ft. elevation.

NOTE

Before starting the RUN-IN or starting up the engine for any reason following an overhaul, it is of extreme importance to observe the instructions on "Preparation for Starting Engine First Time" in section 13.1.

DYNAMOMETER TEST AND RUN-IN PROCEDURES

The Basic Engine

The great number of engine applications make any attempt to establish comparisons for each individual model impractical. For this reason, each model has a basic engine rating for comparison purposes. A basic engine includes only the optional equipment actually required to run the engine. The addition of any other engine driven equipment would result in a brake horsepower figure less than the indicated values shown in the "Basic Run-In Horsepower Schedule" below. The following are included on the basic engine—blower, fuel pump, fresh water pump, and governor. The fan and battery charging generator typify accessories not considered on the basic engine. In situations where other than basic engine equipment is used during the test, proper record of this fact should be made on the test report form. The effects of this additional equipment on engine performance should then be considered when evaluating test results.

Dynamometer

The function of the dynamometer is to absorb and measure the engine output. Its basic components are a frame, engine mounts, the absorption unit, a heat exchanger, and a torque loading and measuring device.

The engine is connected through a universal coupling to the absorption unit. The load on the engine may be varied from zero to maximum by decreasing or increasing the resistance in the unit. The amount of power absorbed in a water brake type dynamometer, as an example, is governed by the volume of fluid within the working system. The fluid offers resistance to a rotating notion. By controlling the volume of water in the absorption unit, the load may be increased or decreased as required. The power absorbed is generally measured in torque (lb-ft) on a suitable scale. This value for a given engine speed will show the horsepower developed in the engine by the following formula:

$$\text{Engine Horsepower} = \frac{\text{Torque} \times \text{RPM}}{5250}$$

Some dynamometers indicate direct horsepower readings. Therefore, the use of the formula is not required when using these units.

13.2.1 ENGINE RUN-IN INSTRUCTIONS

Basic Run-In Horsepower Schedule

RPM	Time			4-valve head
			3-53	
1800	10 Min.		15	
1800	½ Hr.			
2000	½ Hr.			
2200	1/2 Hr.		64	
2200	1/2 Hr.			
2500	1/2 Hr.			
2500	'/2 Hr.			
2800	1/2 Hr.			

Final run-in (within 5 percent of Rated BHP) should be for ½ hour at 2000 rpm for 2-53 engine, 2200 rpm for all 2-Valve cylinder head engines, 2500 rpm for 4-53 turbocharged engines (4-Valve) and 2800 rpm for all other 4-Valve) cylinder head engines.

TEST AND RUN-IN PROCEDURES

During the actual operation, all data taken should be recorded immediately on an Engine Test Report (see sample on page 4).

Instrumentation

Certain instrumentation is necessary so that data required to complete the test report form may be obtained. The following list contains both the minimum amount of instructions and the proper location of the fittings pn the engine so that their readings represent a true evaluation of engine conditions.

a. Oil pressure gage installed in one of the engine main oil galleries.

b. Oil temperature gage installed in the oil pan, or thermometer installed in the dipstick hole in the cylinder block.

c. Adaptor for connecting pressure gage or mercury manometer to engine air box.

d. Water temperature gage installed in thermostat housing.

e. Adaptor for connecting pressure gage or water manometer to crankcase.

f. Adaptor for connecting pressure gage or mercury manometer to exhaust manifold at flange.

g. Adaptor for connecting vacuum gage or water manometer to blower inlet.

h. Adaptor for connecting fuel pressure gage to fuel inlet passage in cylinder block.

i. Adaptors for connecting pressure gage or mercury manometer to turbocharger.

In some cases, gages reading in pounds per square inch are used for determining pressures while standard characteristics are given in inches of mercury or inches of water. It is extremely important that the scale of such *a* gage be of low range and finely divided if accuracy is desired. This is especially true of a gage reading in psi, the reading of which is to be converted to inches of water. The following conversion factors may be helpful.

Inches of water	psi x 27.7"
Inches of mercury	psi x 2.04"

It is very important that the fuel and lubricating oil used for engine testing should conform to the specifications shown in section 13.3.

Run-In and Test

The procedure outlined below will follow the order of the sample "Engine Test Report".

A. PRE-STARTING

1. Fill lubrication system as outlined under "Lubricating System — Preparation for Starting Engine First Time" in section 13.1.
2. Prime the fuel system as outlined under "Fuel System — Preparation for Starting Engine First Time" in section 13.1.
3. A preliminary valve clearance adjustment must be made before the engine is started, see "Valve Clearance Adjustment" in section 14.1.
4. A preliminary injector timing check must be made before starting engine. See "Injector Timing" in section 14.2.
5. Preliminary governor adjustments must be made as outlined in section 14.
6. Preliminary injector rack adjustment -- see section 14.

B. BASIC ENGINE RUN-IN

The operator should be alert at all times to detect any malfunction which may develop. Since the engine has just been reconditioned, this RUN-IN will be a test of the workmanship or the

service man who performed the overhaul. Minor difficulties should be detected and corrected to prevent a major problem from developing.

After performing the preliminary steps, make certain that all the water valves, fuel valves, etc., are open. Also inspect the exhaust system, being sure that it is properly connected to the engine. Always start the engine with minimum dynamometer resistance.

After the engine starts, if a water brake type dynamometer is being used, allow sufficient water, by means of the control loading valves into the dynamometer absorption unit to show a reading of approximately 5 lb-ft on the torque gage (or 10-15 HP on horsepower gage.) This is necessary on some units, to lubricate the absorption unit seals and protect them from damage.

Set the engine throttle at idle speed, check lubricating oil pressure and check all connections to be sure there are no leaks.

Refer to the "Engine Test Report" sample which establishes the sequence of events for test and RUN-IN, and to the "Basic RUN-IN Horsepower Schedule" which indicates the speed (rpm), length of time and the horsepower required for each phase of the test. Also, refer to the "Operating Conditions" in section 13.2 which presents the engine operating characteristics. These characteristics will be a guide for tracing faulty operation or lack of power.

Engine governors **in** most cases must be re-set at the maximum full-load speed designated for the RUN-IN. **If** it is found that the governor cannot be adjusted to this speed, a stock governor should be installed for the period of RUN-IN.

After checking the engine performance at idle, be certain that the engine and dynamometer are operating properly, increase the engine rpm to half speed and apply the load indicated in the "Basic Run-In Horsepower Schedule". The engine should be run at this speed and load for 15 minutes to allow sufficient time for the coolant temperature to reach the normal operating range. Record the length of time, speed, horsepower, coolant temperature and lubricating oil pressure on the "Engine Test Report".

Run the engine at each speed and rating for the length of time indicated in the "Basic Run-In Horsepower Schedule". This is the Basic Run-In. During this time engine performance will improve as new parts begin to "seat in". Record all the required data.

C. BASIC RUN-IN INSPECTION

While the engine is undergoing the Basic Run-In, check each item indicated in Section "C" of the "Engine Test Report." Check for fuel oil or water leaks in the rocker arm compartment.

During the final portion, at full speed and load, of the Basic Run-In, the engine should be inspected for fuel oil, lubricating oil and water leaks.

Upon completion fo the Basic Run-In, and Inspection, the load should be removed from the dynamometer and the engine speed gradually reduced to idle and the engine finally stopped.

D. INSPECTION AFTER BASIC RUN-IN

The preliminary purpose of this inspection is to provide a fine engine tune-up. First the cylinder head and rocker arm shaft bolts should be tightened to the proper torque. Next the appliable tune-up procedure should be completed. See section 14.

E. FINAL RUN-IN

After all tests have been made and the "Engine Test Report" form completed through Section "D", the engine is ready for final test. This portion of the test and RUN-IN procedure will assure the engine owner that his engine has been rebuilt to deliver factory rated performance at the same maximum speed and load which will be experienced in the installation.

If the engine has been rebuilt to deliver factory rated performance at the same maximum speed and load which will be experienced in the installation.

If the engine has been shut-down for one hour or longer, it will be necessary to have a warm up period of 15 minutes at the same speed and load used for warm-up in the Basic RUN-IN. If piston rings, cylinder liners or bearings have been replaced as a result of findings in the Basic RUN-IN, the entire Basic RUN-IN should be repeated as though the RUN-IN and test procedure were started anew. All readings observed during the FINAL RUN-IN should fall within the range specified in the tables under "Operating Conditions" in section 13.2, and should be taken at full load unless otherwise specified. Following is a brief discussion of each condition to be observed. Water temperature reading should be taken during the last portion of the Basic Run-In at full load. It should be recorded and should be within the specified range.

13.2.1 ENGINE RUN-IN INSTRUCTIONS

ENGINE TEST REPORT

Date _____ Unit Number _____

Repair Order Number _____ Model Number _____

A **PRE-STARTING**

1. PRIME LUB. OIL SYSTEM	2. PRIME FUEL SYSTEM	3. ADJUST EXHAUST VALVES	4. TIME INJECTORS	5. ADJ. GOV.	6. ADJUST INJ. RACKS

B **BASIC ENGINE RUN-IN**

TIME AT SPEED	TIME START	TIME STOP	RPM	BHP	WATER TEMP.	LUB. OIL PRESS.

C **BASIC RUN-IN INSPECTION**

1. Check oil at rocker mechanism	
2. Inspect for lubricating oil leaks	
3. Inspect for fuel oil leaks	
4. Inspect for water leaks	
5. Check and tighten all external bolts	
6.	

D **INSPECTION AFTER BASIC RUN-IN**

1. Tighten Cylinder Head & Rocker Shaft Bolts		4. Adjust Governor Gap	
2. Adjust Valves (Hot)		5. Adjust Injector Racks	
3. Time Injectors		6.	

E **FINAL RUN-IN**

TIME START	TIME STOP	TOP RPM NO-LOAD	TOP RPM FULL LOAD	BHP	AIR BOX PRESSURE FULL LOAD	EXHAUST BACK PRESSURE F/L	CRANKCASE PRESSURE F/L

BLOWER INTAKE RES. - F/L	FUEL OIL PRESSURE F/L RET. MAN.	WATER TEMP. FULL LOAD	LUB. OIL TEMP. F/L	LUB. OIL PRESSURE FULL LOAD	LUB. OIL PRESSURE IDLE	IDLE SPEED

F **INSPECTION AFTER FINAL RUN**

1. Inspect Air Box, Pistons, Liners, Rings		6. Replace Lubricating Oil Filter Elements	
2. Inspect Blower		7. Tighten Flywheel Bolts	
3. Check Generator Charging Rate		8. Rust Proof Cooling System	
4. Wash Oil Pan, Check Gasket		9.	
5. Clean Oil Pump Screen, Remove. Cloth		10.	

REMARKS:

Final Run OK'd _____ Dynamometer _____ Date _____

Lubricating oil temperature reading must be taken while the engine is operating at full load and after the engine has been operating long enough for the temperature to stabilize. This temperature should be recorded and should be within the specified range. Lubricating oil pressure should be recorded in psi after being taken at engine speeds indicated in Operating Conditions", section 13.2.

Fuel oil pressure may be taken by removing the 1/4" pipe plug from the fuel inlet passage in the cylinder head and attaching a 0-100 psi gage. Pressure should be recorded and should fall within the specified range. Fuel pressure should be recorded at maximum engine rpm during the Final Run-In.

Air box pressure should be checked while the engine is operating at maximum rpm and load. This check may be made by attaching a suitable gage (0-15 psi) or manometer (15-0-15) to an air box drain or to an air box cover prepared for this purpose. If an air box drain is used as a source for this check, it must be clean. The air box pressure, in inches of mercury, should be recorded.

Crankcase pressure should be checked and recorded while the engine is operating at maximum Run In speed. Either the oil level dipstick hole or one f the 1/4" pipe tapped holes in the crankcase is suitable for attaching a gage or manometer calibrated to read in inches of water. Normally, Crankcase pressure should decrease during the RUN-IN indicating that new rings are beginning to "seat-in".

Air inlet restriction should be measured in inches of water while the engine is operating at maximum RUN-IN speed and should fall within the specified limits. Record the reading on the Engine Test Report. Attach the gage to a fitting installed in the ¼" pipe tapped hole located in the air inlet housing. IF such a hole is not provided, a stock housing should be drilled, tapped and kept on hand for future use. The restriction at this point should be checked at a specific engine speed. Then, the air cleaner and ducting should be removed from the air inlet housing and the engine again operated at the same speed while noting the manometer reading. On turbocharged engines, take the reading on the inlet side of the turbocharger. The difference between the two readings, with the air cleaner and ducting and without the air cleaner and ducting, is the actual restriction caused by the air cleaner and ducting.

Check the normal air intake vacuum at various speeds (at no-load) and compare the results with the "Engine Operating Conditions" in Section 13.2. Record these readings on the Engine Test Report. Check the exhaust back pressure at the exhaust manifold companion flange or within one inch of this location. The check should be made with a mercury manometer through a tube adaptor installed at the tapped hole. If the exhaust manifold does not have a ⅛" pipe tapped hole, such a hole can be incorporated by reworking the exhaust manifold. Then install a fitting for a pressure gage or manometer in this hole. Care should be exercised so that the fitting does not protrude into the stack. The manometer check should produce a reading in inches that is below the Maximum Exhaust Back Pressure for the engine (refer section 13.2).

Turbocharger compressor outlet pressure and turbine inlet pressures are taken at full load and no-load speeds. Figure 1 in Section 13.2 shows the location of the fittings for taking the readings.

Determine the maximum rated horsepower for the engine from the engine name plate, at the full load speed to be used during the FINAL RUN-IN. Apply the load thus determined to the dynamometer. If a hydraulic governor is used, the droop may be adjusted at this time by following the prescribed procedure. The engine should be run at this speed and load for 30 minutes. While making the FINAL RUN-IN, the engine should develop, within 5 percent of the maximum rated horsepower indicated for the speed at which it is operated. If this horsepower is not developed, the cause should be determined and corrections made.

When the above conditons have been met with the engine running, start the Final RUN-IN by adjusting the maximum no-load speed to conform with that specified by conditions in the installation in which the engine will operate. This speed may be either higher or lower than the maximum speed used during the Basic RUN-IN. This will ordinarily require a governor adjustment. All information required in section "E", Final RUN-IN, of the "Engine Test Report" should be determined and filled in. After the prescribed time for the Final RUN-IN has elapsed, the load should be removed from the dynamometer and the engine speed gradually reduced to idle and the engine stopped. The Final RUN-IN is complete.

F. INSPECTION AFTER FINAL RUN-IN

After the Final RUN-IN and before the "Engine Test Report" is completed, a final inspection must be made. This inspection will provide final assurance that the engine and accessories required in the installation are in proper working order. During this inspection, prepare the engine for any brief delay in delivery or installation with may occur. This is accomplished by rust-proofing the fuel system, also a rust inhibitor should be introcuded into the c000ling system (section 15.3).

DIESEL FUEL OIL SPECIFICATIONS

The quality of the fuel oil used for high-speed diesel engine operation is a major factor in satisfactory engine performance and life. The fuel oils selected must be clean, completely distilled, stable, and non-corrosive. Enlist the aid of your supplier in obtaining proper fuel oil. The responsibility for clean fuel lies with the fuel supplier as well *as* with the operator.

DISTILLATION RANGE, CETANE NUMBER, AND SULFUR CONTENT are three of the most important properties in the selection of diesel fuels for optimum combustion and minimum wear. Engine speed, load, and atmospheric temperature influence the selection of the fuels with respect to distillation range and cetane number. THE SULFUR CONTENT OF THE FUEL MUST BE AS LOW AS POSSIBLE, to avoid excessive deposit formation and premature wear.

Diesel fuels are generally marketed according to ASTM DESIGNATION D975 and only distillate fuels No. 1D and 2D are considered satisfactory for Detroit Diesel engines. These fuels should not be confused with the domestic type furnace oils ASTM D396 which have similar properties but are not always satisfactory for engine use due to their varying composition, cetane number, and distillation range.

As a guide to the selection of the proper fuel oil for various applications refer to the Fuel Oil Selection Chart and the ASTM Classification.

ASTM Classification of Diesel Fuel Oils

	No. 1-0	No. 2-D
Flosh Pt. °F Min.	100	125
	0.15	0.35
	Trace	0.10
Viscosity of 100°F: centistokes Min.	1.4	2.0
Max.	2.5	4.3
Sulfur	0.5	0.7
Cetone No; in.		

Engine operation at altitudes above 5000 feet requires use of next lighter class of fuel oil than would normally be used.

During cold weather engine operation, the "cloud point" (the temperature at which wax crystals begin to form in the fuel oil) should be 10°F. below the lowest expected fuel temperature to prevent clogging of the fuel filters by wax crystals.

At temperatures below -20°F. consult an authorized Detroit Diesel Service Outlet, since particular attention must be given the cooling system, lubricating system, fuel system, electrical system, and cold weather starting aids for efficient engine operation.

FUEL OIL SELECTION CHART

Type of Engine Service	Typical Application	General Fuel Classification	Final Boiling Point (Max.)	Cetane Number (Min.)	Sulfur Content (Max.)
Light load and speed with considerable idling.	City Buses	No. 1-D	550°F	45	0.30%
Light load and speed.	Generator sets, Industrial and Automotive Equipment in city and suburban operation.	Winter No. 1-D	550 F	45	0.30%
		Summer No. 1-D	600°F	40	0.50%
Medium load and speed.	Marine Pleasure Craft, Tractors, Industrial equipment.	Winter No. 1-D	600°F	45	0.50%
		Summer No. 2-D*	675°F	40	0.50%
Heavy load and high speed with idling.	Highway Trucks	Winter No. 2-D*	675°F	45	0.50%
		Summer No. 2-D*	675°F	40	0.50%
Heavy load and high speed.	Heavy Duty Off-the-road Equipment, Trucks, Tractors	No. 2-D*	675°F	45	0.50%

"NOTE: For most satisfactory engine life, use only those No. 2-D diesel fuel oils containing 0.50% or less sulfur. Where minimum exhaust smoke is required or where long periods of idling or cold weather conditions below 32°F. are encountered, the more volatile or light distillate fuels are recommended.

BREAK-IN OILS AND ADDITIVES

The use of proprietary blends of supplementary additive or concentrates such as engine oil supplements, break-in oils, tune-up compounds and friction reducing compounds is not recommended in lubricating oils used in Detroit Diesel engines unless given official Detroit Diesel part numbers and made available for use in appropriate service applications.

DiE-S-EL LUBRICATING OIL SPECIFICATIONS

OIL QUALITY

There are hundreds of commercial crankcase oils marketed today. Lubricants marketed for heavy duty diesel service consist of refined crude oil to which has been added additives compounded to meet the desired engine performance levels. Oil additive selection is based on evaluations conducted by the oil supplier; therefore, satisfactory OIL QUALITY is the responsibility of the oil supplier. (The term oil supplier is applicable to refiners, blenders and rebranders of petroleum products, and does not include distributors of such products.) Experience has shown that oil performance in commercial heavy duty diesel service applications varies from brand to brand. Obviously engine manufacturers or users cannot completely evaluate the hundred of commercial oils; therefore, the selection of a suitable lubricant in consultation with a reliable oil supplier, strict observance of his oil change recommendations (used oil sample analysis can be of value), and proper filter maintenance will provide your best assurance of satisfactory oil performance. Detroit Diesel lubricant recommendations are based on general experience with current lubricants of various types and give consideration to the commercial lubricants presently available.

RECOMMENDATION

MIL-L-2104B Lubricants

Detroit Diesel *engines* have *given* optimum performance and experienced the longest service life with the MIL-L-2104B, SAE-30 oils evaluated by Detroit Diesel, MIL-L-2104B oils have superseded the older MIL-L-2104A and Supplement 1 oils. MIL-L-2104B, SAE-30 oils should be used during run-in prior to initial oil drain and are recommended for continued use thereafter. Contact a reliable oil supplier and obtain his assurance that his product has been tested and given good performance in Detroit Diesel engines. You may wish to request the oil supplier to show the performance results of his product in Detroit Diesel engines. An SAE-30 oil of MIL-L-2104B performance level is recommended for year-round use. The use of lower viscosity oils or multigrade products will usually result in less than nominal engine life.

MIL-L-45199 (Series 3) Lubricants

The use of Low Ash Series 3 oils (sulfated ash less than 1.85 percent by weight — A.S.T.M. designation D-874) may be necessary if the continued use of high sulfur fuel is unavoidable. Low ash Series 3 oils are premium priced products and may be desired by the user in preference to MIL-L-2104B oils. Consult a reliable oil supplier, obtain assurance that his products have been tested in Detroit Diesel engines, and select the best performer for optimum engine life. Low ash Series 3 oils do NOT have to meet any specific miliary low temperature performance requirements; therefore, they may NOT perform as well as MIL-L-2104B lubricant in cold climates. The older high ash Series 3 oils should NOT be used in Detroit Diesel engines as they tend to deposit heavy ash on valve faces and head inserts resulting in channelling, guttering, and short engine life.

Supplement 1 Lubricating Oils

Supplement 1 lubricating oils have been superseded by MIL-L-2104B lubricants and S-1 oils are gradually becoming unavailable. However, where *a* history of satisfactory performance of a specific S-1 oil has been experienced, it can still be used.

MIL-L-2104A Lubricating Oils

This military specification is obsolete.

Multigrade Lubricating Oils

Multigrade oils are NOT recommended. The use of an SAE-30 grade is desirable for year-round use when cold starting can be accomplished. Multigrade oils should be considered only as the "last resort" to facilitate starting when prolonged exposure to temperatures below freezing is unavoidable and adequate starting aids are unavailable. Experience clearly indicates that multigrade oils are NOT comparable to SAE-30 lubricants for heavy duty diesel service. Cylinder liner scuffing, liner port and ring groove deposit levels are all greater using multigrade lubricants. This results in shortened engine life.

COLD WEATH E R OPERATION

Cold weather starting will be facilitated when immersion type electrical coolant heaters can be used. Other practical considerations, such as the use of batteries, cables and connectors of adequate size, generators of alternators of ample capacity, proper setting of voltage regulators, ether starting aids, oil and coolant heater systems, and proper fuel selection will accomplish starting with the use of SAE-30 oil. For complete cold weather starting information, consult an Authorized Detroit Diesel Service Outlet.

OIL CHANGES

It is recommended that new engines be started with 100 hour oil change periods. For highway vehicles this corresponds to approximately 3,000 miles, and for "city-service" vehicles approximately 1,000-

2,000 miles. The drain interval may then be gradually increased, or decreased with experience on a specific lubricant while also considering the recommendations of the oil supplier (analysis of the drained oil can be helpful here) until the most practical oil change period for the particular service has been established. Solvents should not be used as flushing oils in running engines. Dilution of the fresh refill oil supply can occur which may be detrimental.

OIL FILTRATION

Heavy sludge deposits found on the oil filter elements at the time of an oil change must be taken as an indication that the detergency of the oil has been exhausted. When this occurs, the oil drain interval should be shortened. Since abrasive dust, metal particles and carbon material accumulate in the lubricating oil during engine operation, the oil filter ements must be replaced each time the oil is changed.

NOTE

The manufacturer's warranty applicable to Detroit Diesel engines provides in part that the provisions of such warranty shall not apply to any engine unit which has been subject to misuse, negligence or accident. Accordingly, malfunctions attributable to neglect or failure to follow the manufacturer's lubricating recommendations indicated above may not be within the coverage of the warranty.

SECTION 14
ENGINE TUNE-UP

CONTENTS

ENGINE TUNE-UP PROCEDURES

There is no scheduled interval for performing an engine tune-up. As long as the engine performance is satisfactory, no tune-up should be needed. Minor adjustments in the valve and injector operating mechanisms, governor, etc., should only be required periodically to compensate for normal wear on parts.

The mechanical engine governors is identified by a name plate attached to the governor housing. The letters D.W.-L.S. stamped on the name plate denote a double weight limiting speed governor. Normally, when performing a tune-up on an engine in service, it is only necessary to check the various adjustments for a possible change in the settings. However, if the cylinder head, governor, of injectors have been replaced or overhauled, then certain preliminary adjustments are required before the engine is started.

The preliminary adjustments consist of the first four items in the tune-up sequence. The procedures are the same except that the valve clearance is greater for a cold engine: To tune-up an engine completely, all of the adjustments are made by following the applicable tune-up sequence given below after the engine has reached the normal operating temperature. Since the adjustments are normally made while the engine is stopped, it may be necessary to run the engine between adjustments to maintain normal operating temperature.

Tune-up Sequence for Mechanical Governor

1. Adjust the exhaust valve clearance.
2. Time the fuel injectors.
3. Adjust the governor gap.
4. Position the injector rack control levers.
5. Adjust the maximum no-load speed.
6. Adjust the idle speed.
7. Adjust the buffer screw.
8. Adjust the throttle booster spring (variable speed governor only).

EXHAUST VALVE CLEARANCE ADJUSTMENT

The correct exhaust valve clearance at normal engine operating temperature is important for smooth, efficient operation of the engine. Insufficient valve clearance can result in loss of compression, misfiring cylinders, and eventually burned valve seats and valve seat inserts. Excessive valve clearance will result in noisy operation, especially in the low speed range.

Whenever the cylinder head is overhauled, the exhaust valves are reconditioned or replaced, or the valve operating mechanism is replaced or disturbed in any way, the valve clearance must first be adjusted to the cold setting to allow for normal expansion of the engine parts during the engine warm-up period. This will ensure a valve setting which is close enough to the specified clearance to prevent damage to the valves when the engine is started. All of the exhaust valves may be adjusted, in firing order sequence, during one full revolution of the crankshaft.

Exhaust Valve Clearance Adjustment—Four valve Cylinder Head (Cold Engine)

1. Clean the loose dirt from the exterior of the engine and remove the valve rocker cover(s).

2. Place the speed control lever in the idle speed position. If a stop lever is provided, secure it in the no-fuel position.

3. Rotate the crankshaft until the injector follower is fully depressed on the cylinder to be adjusted.

NOTE

If a wrench is used on the crankshaft bolt, do not turn the engine in a left-hand direction of rotation or the bolt will be loosened.

4. Loosen the push rod lock nut.

5. Place a .027" feeler gage, J 9708, between the end of one valve stem and the rocker arm bridge (fig. 2). Adjust the push rod to obtain a smooth pull on the feeler gage.

6. Remove the feeler gage. Hold the push rod with a 5 / 16" wrench and tighten the lock nut with a ½" wrench.

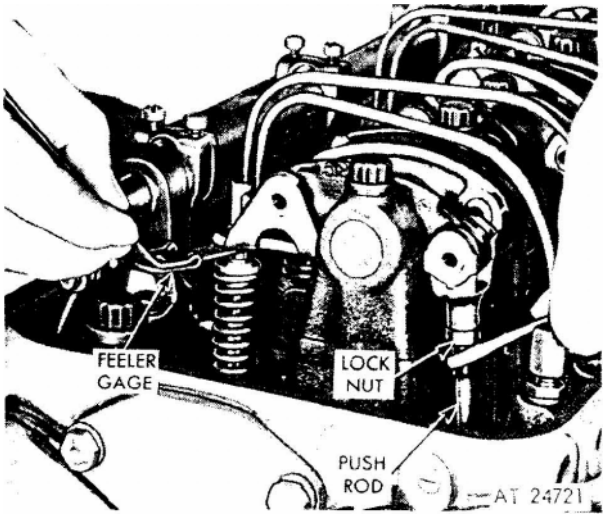


Figure 1. Adjusting valve clearance (four-valve cylinder head).

7. Recheck the clearance. At this time, if the adjustment is correct, the .025" gage will pass freely between the end of one valve stem and the rocker arm bridge, and the .027" gage will not pass through. Readjust the push rod, if necessary.

Exhaust Valve Clearance Adjustment—Four Valve Cylinder Head (Hot Engine)

Maintaining normal engine operating temperature is particularly important when making the final valve clearance adjustment. If the engine is allowed to cool off before setting any of the valves, the clearance, when running at full load, may become insufficient.

With the engine at normal operating temperature (160° F.), recheck the exhaust valve clearance with gage J 9708. At this time, if the valve clearance is correct, the .023" gage should pass freely between the end of one valve stem and the rocker arm bridge and the .025" feeler gage should not. Readjust the push rod. if necessary-. Use new gaskets when installing the valve rocker cover.

FUEL INJECTOR TIMING

To time a fuel injector properly, the injector follower must be adjusted to a definite height in relation to the injector body. All of the injectors can be timed, in firing order sequence, during one full revolution of the crankshaft.

! *Timing fuel injector.*

Time Fuel Injector

1. Clean the loose dirt from the exterior of the engine and remove the valve rocker cover(s).
2. Place the speed control lever in the idle speed position. If a stop lever is provided, secure it in the no-fuel position.
3. Rotate the crankshaft, manually or with the starting motor, until the exhaust valves are fully depressed on the particular cylinder to be timed.

CAUTION

If a wrench is used on the crankshaft bolt at the front of the engine, do not turn the crankshaft in a left-hand direction of rotation or the bolt will be loosened.

4. Place the small end of the injector timing gage (see table below for correct timing age) in the hole provided in the top of the injector body, with the flat of the gage toward the injector follower as shown in figure 1.

Injector	Timeing dimension	Tool number
35 (Reefer Car)	1.508	J 8909
35	1.484	J 1242
40	1.484	J 1242
N40	1.460	J 1853
N45	1.460	J 1853
N50	1.460	J 1853
M65	1.460	J 1853

5. Loosen the push rod lock nut.
6. Turn the push rod and adjust the injector rocker arm until the extended part of the gage will just pass over the top of the injector follower
7. Hold the push rod and tighten the lock nut. Check the adjustment and readjust, if necessary.
8. Time the remaining injectors as outlined above.
9. Use new gaskets when installing the valve rocker cover(s).

LIMITING SPEED MECHANICAL GOVERNOR AND INJECTOR RACK CONTROL ADJUSTMENT (IN-LINE ENGINE)

After timing the fuel injectors and adjusting the exhaust valves, adjust an engine with a limiting speed mechanical governor as follows:

NOTE

Loosen the load limit lever for the load limiting device, if the engine is so equipped, before proceeding with the governor adjustment.

Adjust Governor Gap

With the engine at operating temperature, the governor gap may be adjusted as follows: Ordinarily, adjustment is required when the governor has been repaired or replaced.

1. Remove the high speed spring retainer cover.
2. Back out the buffer screw until it extends 5/8" beyond the governor housing.

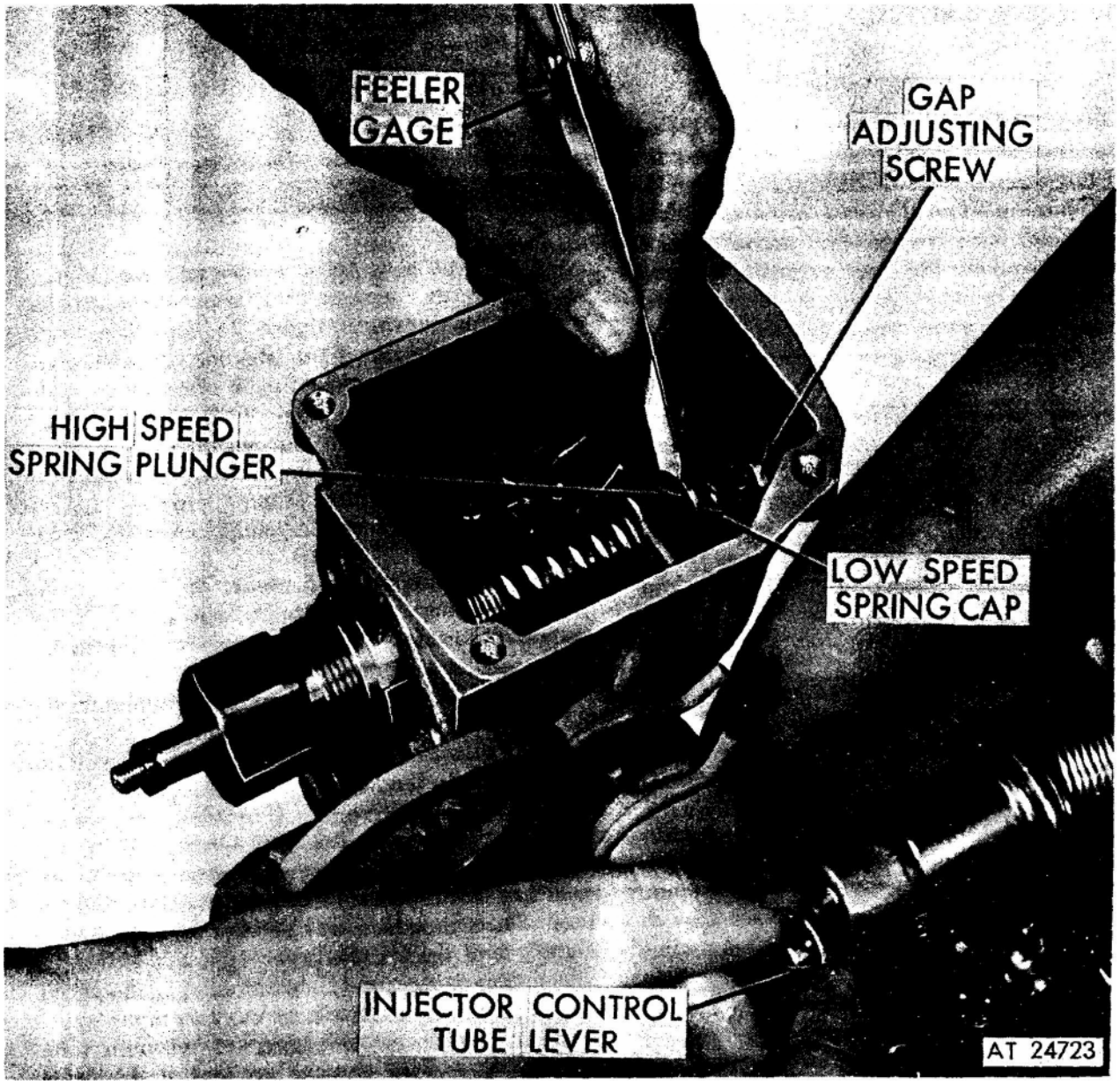


Figure 1. Adjusting governor gap—tool J 3172.

14.3.1 LIMITING SPEED GOVERNOR ADJUSTMENT

3. Remove the valve rocker cover.

4. Start the engine and adjust the idle speed screw to obtain an idle of 500 to 600 rpm (fig. 5).

NOTE

The normal idle speed is 500 to 600 rpm, but may vary with special engine applications.

5. Shut the engine down and remove the governor cover.

6. Start the engine and control the speed manually by operating the injector control tube lever. Engine speed should be between 800 and 1000 rpm.

CAUTION

Do not overspeed the engine.

7. Check the gap between the low speed spring cap and the high speed spring plunger with a.0015" feeler gage. If the gap setting is incorrect, reset the gap adjusting screw (fig. 1). If the setting is correct, the .0015" movement can be seen by placing a few drops of oil into the governor gap and pressing a screw driver against the gap adjusting screw. Movement of the cap toward the plunger will force the oil from the gap in the form of a small bead.

8. Hold the gap adjusting screw and tighten the lock nut.

9. Recheck the gap and readjust if necessary.

10. Install the governor cover. The governor cover should be placed on the housing with the pin of the speed control lever projecting into the slot of the differential lever.

11. Install the screws and lockwashers finger tight. Pull the cover away from the engine and tighten the screws. This step will properly locate the cover on the governor housing.

Position Injector Rack Control Levers

Properly positioned injector rack control levers with the engine at full load will result in the following:
Speed control lever at the maximum speed position.
Governor low speed gap closed.
High speed spring plunger on the seat in the governor control housing.
Injector fuel control racks in the full-fuel position.
Adjust the rear injector rack control lever (fig. 2) first to establish a guide for adjusting the remaining injector rack control levers.

1. Refer to figure 2 and disconnect any linkage attached to the speed control lever.

2. Loosen all inner and outer injector rack adjusting screws. Be sure all injector rack control levers are free on the injector control tube.

Figure 2. Positioning the rear injector rack control

3. Move the speed control lever to the full fuel position as shown in figure 2. Turn the inner adjusting screw down on the rear injector rack control lever until a step up in effort to turn the screw driver is noted. This will place the rear injector rack in the full-fuel position. Turn down the outer adjusting screw until it bottoms lightly on the injector control tube. Then alternately tighten both the inner and outer adjusting screw until they are tight.

The above step should result in placing the governor linkage and control tube assembly in the same positions that they will attain while the engine is running at full load.

4. To be sure of proper rack adjustment, the following check should be performed.

Hold the speed control lever in the full-fuel position. Press down on the injector rack with a screw driver or finger tips causing the rack to rotate and release the rack. The setting is sufficiently tight if the injector rack returns to its original position. If the rack does not return to its original position, it is too loose. To correct, back off the outer adjusting screw slightly and tighten the inner adjusting screw.

The setting is too tight if, when moving the speed control lever from the idle to the maximum speed position, the injector rack becomes tight before the speed control lever reaches the end of its travel (stop under the governor cover). This will result in a step LID in effort to move the speed control lever to

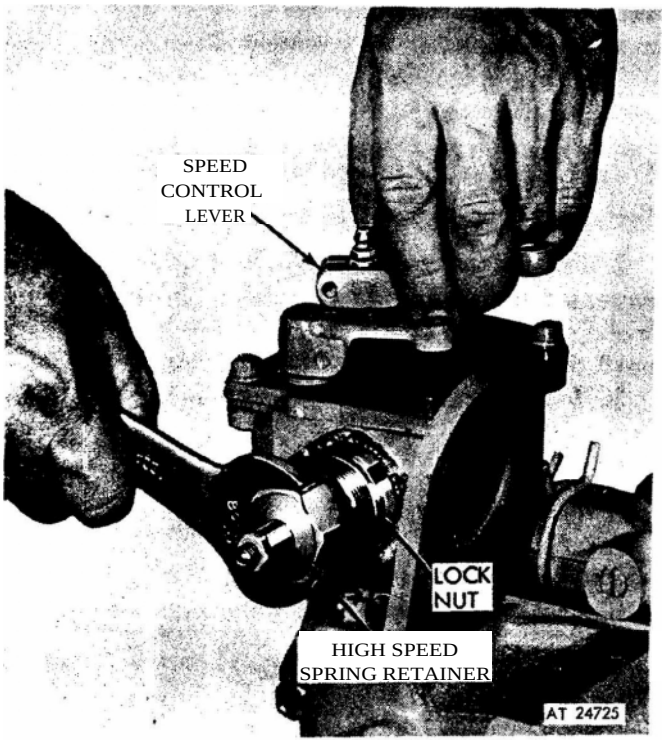


Figure 3. Adjusting maximum no-load engine speed

its maximum speed position and a deflection in the fuel rod (fuel rod deflection can be seen at the bend). If the rack is too tight, back off the inner adjusting screw slightly and tighten the outer adjusting screw.

5. Manually hold the rear injector rack control lever in the full-fuel position. Turn down the inner adjusting screw on the injector rack control lever of the adjacent injector until the injector rack has moved into the full-fuel position and the inner adjusting screw is bottomed on the injector control tube. Turn the outer adjusting screw down until it bottoms lightly on the injector control tube. Then, alternately tighten both the inner and outer adjusting screws until they are tight.

6. Recheck the rear injector rack to be sure that it has remained snug on the ball end of the injector rack control lever while adjusting the adjacent injector. If the rack of the rear injector has become loose, back off slightly the inner adjusting screw on the adjacent injector rack control lever. Tighten the outer adjusting screw. When the settings are correct, the racks of both injectors must be snug on the ball end of their respective rack control levers.

7. Position the remaining injector rack control levers as outlined in steps 5 and 6.

Adjust Maximum No-Load Engine Speed

All governors are properly adjusted before leaving the factory. However, if the governor has been reconditioned or replaced, and to ensure the engine speed will not exceed the recommended no-load speed as given on the unit name plate, the maximum no-load speed may be set as follows:

Adjust Maximum No-Load Engine Speed

TYPE **B GOVERNOR SPRINGS** (fig. **4):**

1. Start the engine and, after it reaches normal operating temperature, remove the load from the engine.

2. Place the engine speed control lever in the full-fuel position and note the engine speed.

3. Stop the engine and, if necessary, adjust the no-load speed as follows:

a. Remove the high speed spring retainer, high speed spring. and plunger assembly (fig. 4).

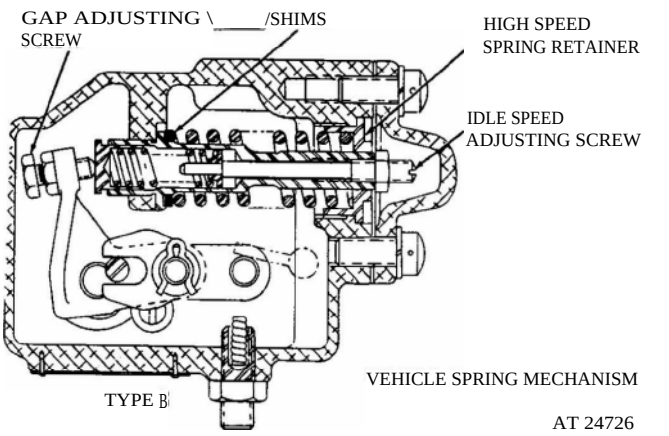


Figure 4. Governor spring assemblies.

CAUTION

To prevent the low speed spring and cap from dropping into the governor, be careful not to jar the assembly while it is being removed.

b. Remove the high speed spring from the high speed plunger and add or remove shims as required to establish the desired engine no-load speed.

NOTE

For each .010" in shim added, the engine speed will be increased approximately 10 rpm.

c. Replace the high speed spring on the high speed plunger and assembly the spring assembly into the governor housing. Install the spring retainer in the governor housing and tighten it securely.

d. Start the engine and recheck the engine no-load speed. Repeat steps a, b and c as is necessary to establish the no-load speed.

14.3.1 LIMITING SPEED GOVERNOR ADJUSTMENT

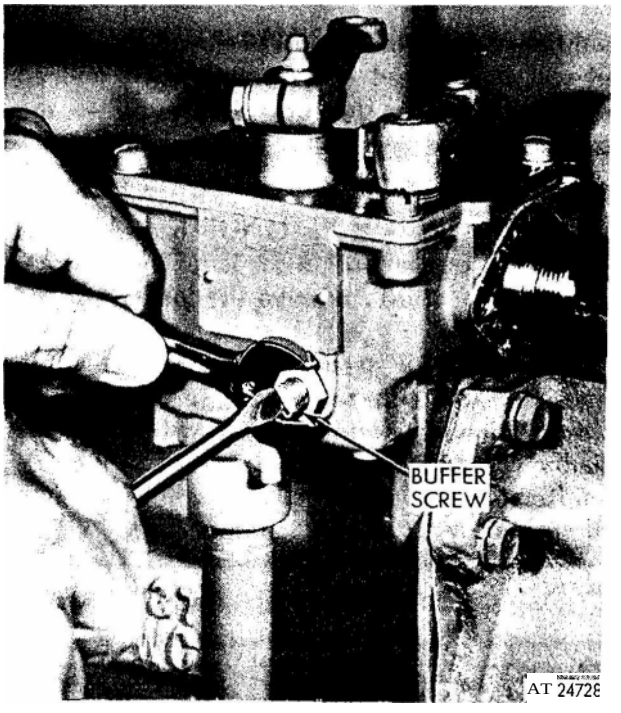


Figure 5. Adjusting engine idle speed.

Adjust Idle Speed

With the maximum no-load speed properly adjusted, the idle speed may be adjusted as follows:

1. With the engine running at normal operating temperature and with the buffer screw backed out to avoid contact with the differential lever, turn the idle speed adjusting screw, (fig. 5), until the engine idles at the recommended idle speed.

The recommeded idle speed is 500 rpm but may vary with special engine applications.

2. Hold the idle speed adjusting screw and tighten the lock nut.
3. Install the high speed spring cover.

Adjust Buffer Screw

With the idle speed properly set, adjust the buffer screw as follows:

1. With the engine running at normal operating temperature, turn the buffer screw in (fig. 6) so that it contacts the differential lever as lightly as possible and still eleminates the engine roll.

NOTE

Do not increase the engine idle speed more than 15 rpm with the buffer screw.

2. Recheck the maximum no-load speed. If it has increased more than 25 rpm from the maximum speed attained in step 1, back off the buffer screw until the incresase is less than 25 rpm.
3. Hold the buffer screw and tighten the lock nut.

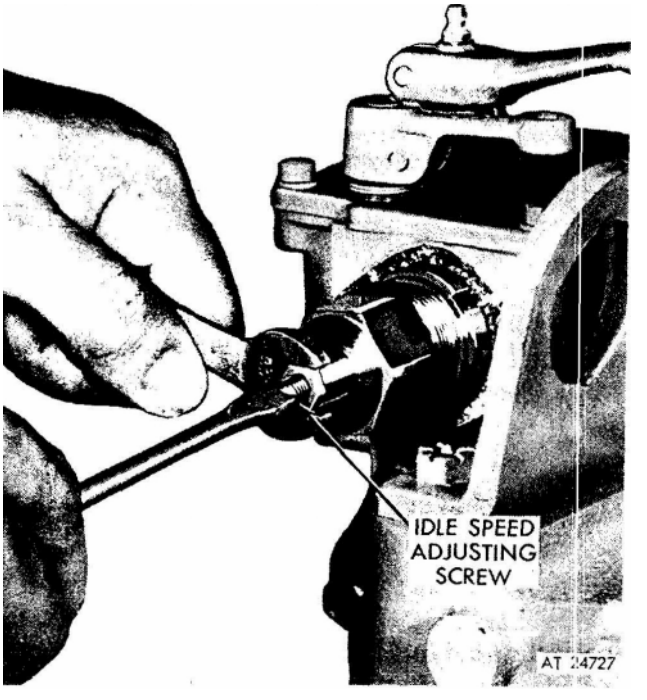


Figure 6. Adjusting the buffer screw.

SECTION 15
PREVENTIVE MAINTENANCE-- IROUBLE SHOOTING—STORAGE

CONTENTS

I TEM 1

Check the oil level daily before starting the engine. Add oil, if necessary, to bring it to the proper level on the dipstick.

Select the proper grade of oil in accordance with the instructions given in the "Lubricating Oil Specifications" in section 13.3.

It is recommended that new engines be started with 100 hour oil change periods. For highway vehicles, this corresponds to approximately 3,000 miles, and for city-service vehicles approximately 1,000-2,000 miles. The drain interval may then be gradually increased, or decreased, following the recommendations. of an independent oil analysis laboratory, or oil supplier (based upon the oil sample analysis) until the most practical oil change period has been established.

I TEM 2

Install new engine oil filter elements and gaskets each time the engine oil is changed. Check for oil leaks after starting the engine.

ITEM 3

Check the coolant level daily and maintain it near the top of the radiator upper tank.

Clean the cooling system every 30,000 miles, using a good radiator cleaning compound in accordance with the instructions on the compound container. After cleaning, rinse the cooling system thoroughly with fresh water; then, fill the system with soft water, adding a good grade of rust inhibitor or a high boiling point type antifreeze. With the use of a proper antifreeze or rust inhibitor, this interval may be lengthened until, normally, this cleaning is done only in the spring or fall. The length of this interval will, however, depend upon an inspection for rust or other deposits on the internal walls of the cooling system. When a thorough cleaning of the cooling system is required, it should be reverse flushed.

I TEM 4

Inspect all of the cooling system hoses at least once every 15,000 miles for signs of deterioration. Replace the hoses if necessary.

I TEM 5

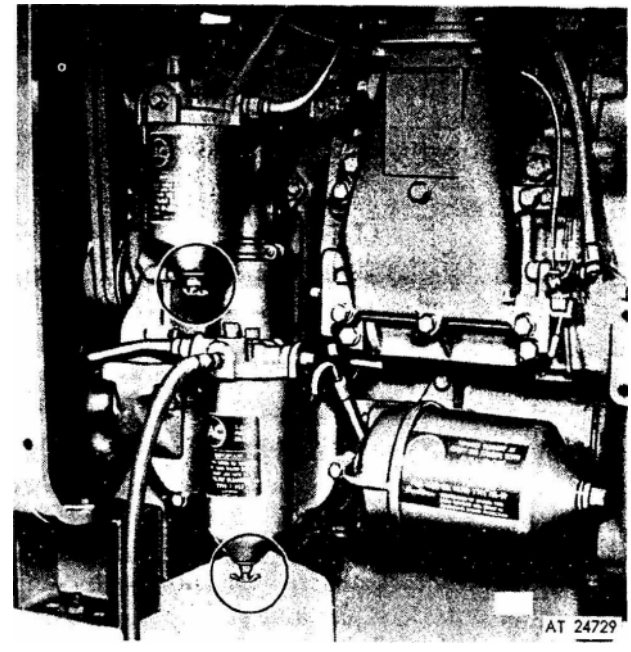
Inspect the exterior of the radiator core every 30,000 miles and, if necessary, clean it with a quality *grease* solvent such as Oleum and compressed air. It may be necessary to clean the radiator more frequently if the engine *is* being operated in dusty or dirty areas.

I TEM 8

Keep the fuel tank filled to minimize condensation. Select the proper grade of fuel in accordance with the "Diesel Fuel Oil Specifications" in section 13.3. Open the drain at the bottom of the fuel tank every 15,000 miles to drain off any water or sediment.

I TEM 9

Drain approximately one-fourth pint of fuel to remove sediment and water from the strainer and the filter daily by opening the drain cock in the bottom of each shell. Install new elements every 9,000 miles or when plugging is indicated. Refer to the fuel system Section for instructions on replacing elements.

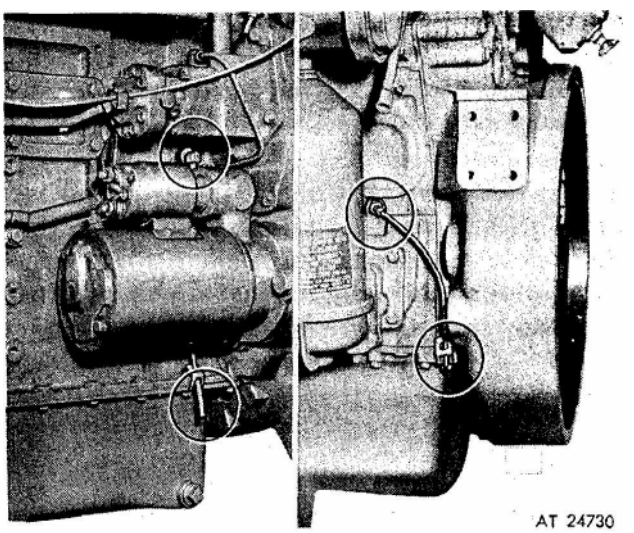


Item 9

A method of determining when elements are plugged to the extent that they should be changed is based on the fuel pressure at the cylinder head fuel inlet manifold and the inlet restriction at the fuel pump. In a clean system, the maximum pump inlet restriction must not exceed 6 inches of mercury. At normal operating speeds (1800-2800 rpm) the fuel pressure is 45 -to 70 psi. Change the fuel filter elements whenever the inlet restriction (suction) at the fuel pump reaches 12 inches of mercury at normal operating speeds (1800-2800 rpm) and whenever the fuel pressure at the inlet manifold falls to 45 psi.

ITEM 11

With the engine running, check for flow of air from the air box drain tubes every 30,000 miles. If the tubes are clogged, remove, clean, and reinstall the tubes. The air box drain tubes should be cleaned periodically even though a clogged condition is not apparent. If the engine is equipped with an air box drain check valve, replace the valve every 15,000 miles.



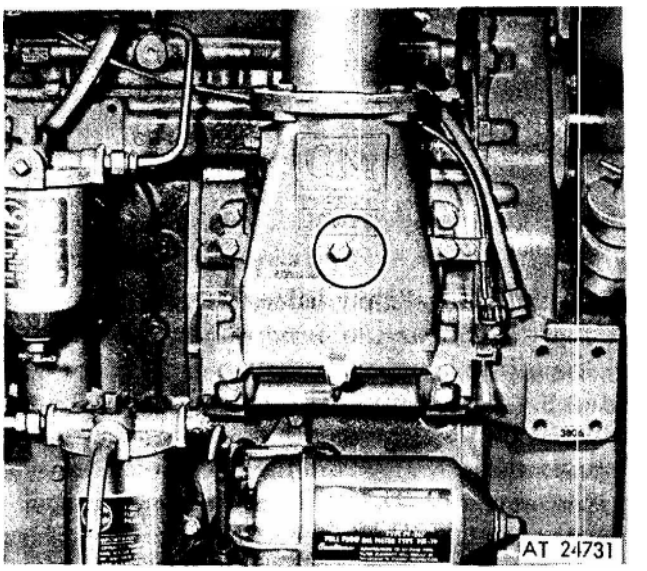
Item II

ITEM 13

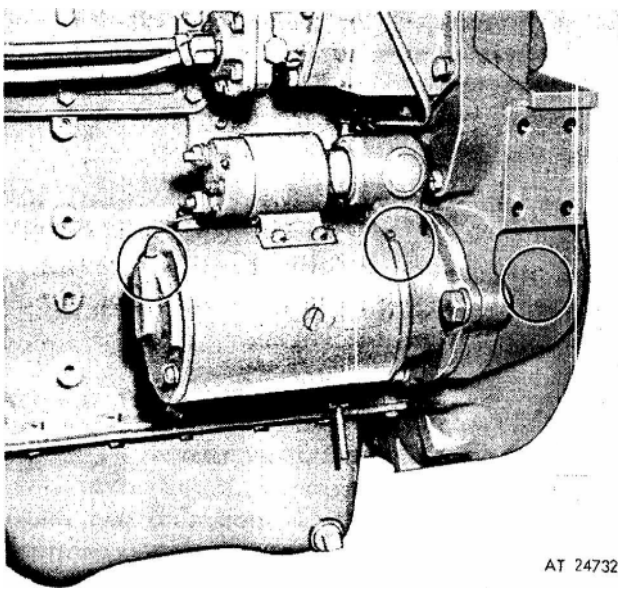
Inspect the blower screen and gasket assembly every 30,000 miles and, if necessary, clean the screen in fuel oil and dry it with compressed air. Reinstall the screen and gasket assembly with the *screen* side of the assembly toward the blower.

ITEM 14

The electrical starting motor is lubricated at the time of original assembly. Oil can be added to the oil wicks, which project through each bushing and contact the armature shaft, by removing the pipe plugs on the outside of the motor. The wicks should be lubricated whenever the starting motor is taken off the engine or disassembled. The Sprag overrunning clutch drive mechanism should be lubricated with a few drops of light engine oil whenever the starting motor is overhauled.



Item 13



Item 14

ITEM 18

Lubricate the throttle control mechanism every 6,000 miles with an all purpose grease. At temperatures above +30°F., use a No. 2 grade grease. Use a No. 1 grade grease below this temperature. Lubricate all other control mechanisms as required with engine oil.

ITEM 19

There is no scheduled interval for performing ar engine tune-up. As long as the engine performance is satisfactory, no tune-up should be needed. Minor adjustments in the valve and injector operating

mechanisms, governor, etc., should only be required periodically to compensate for normal wear on parts.

ITEM 20

New drive belts will stretch after the first few hours of operation. Therefore, retighten new fan drive, pump drive, after 30 miles and again after 240 miles of operation. Thereafter, check the tension of the drive belts every 6,000 miles and adjust, if necessary. Too tight a belt is destructive to the bearings of the driven part; a loose belt will slip.

CAUTION

Replace all belts in *a* set when one is worn. Single belts of similar size should not be used as a substitute for a matched belt set, premature belt wear can result because of belt length variation. All belts in a matched belt set are within .032" of their specified center distances.

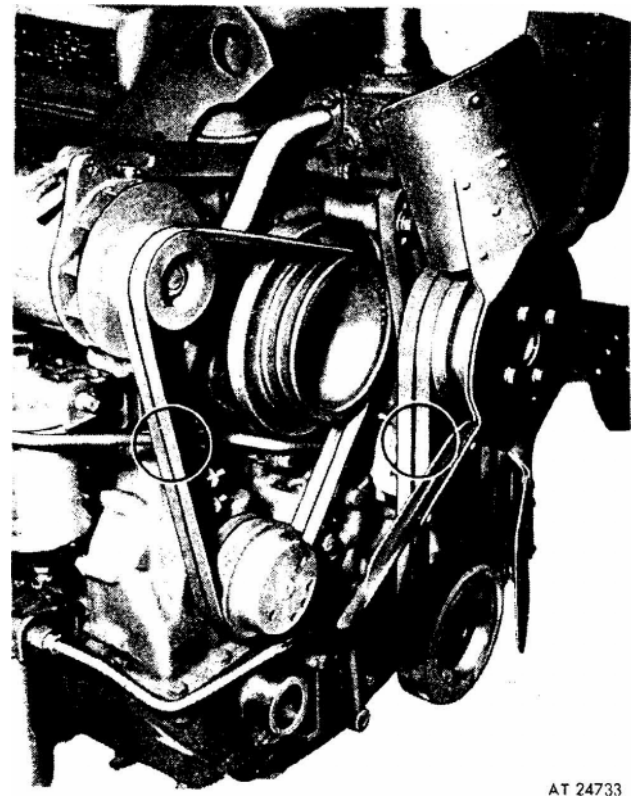
NOTE

When installing or adjusting an accessory drive belt(s), be sure the bolt at the accessory adjusting pivot point is properly tightened, as well as the bolt in the adjusting slot.

Adjust the belt tension so that *a* firm push with the thumb, at a point midway between two pulleys, will depress the belt 1/2" to 3/4". If a belt tension gage such as BT-33-73F or equivalent is available, adjust the belt tension as outlined in the following chart.

Belt Tension Chart (lbs. belt)

Model	Fan drive		Generator drive		
	2 or 3 belts	Single belt	Two 3/8" or 1/2" belts	one 1/2" belt	One wide belt
3, 3-53	40-50		40-50	50-70	40-50
All	For 3-point or triangular drive use a tension of 90-120.				



Item 20

TROUBLE SHOOTING

Certain abnormal conditions which sometimes interfere with satisfactory engine operation, together with methods of determining cause of such conditions, are covered on the following pages.

Satisfactory engine operation depends primarily on:

1. The presence of an adequate supply of air compressed to a sufficiently high compression pressure.
2. The injection of the proper amount of fuel at the right time.

Lack of power, uneven running, excessive vibration, stalling at idle speed, and hard starting may be caused by either low compression, faulty injection in one or more cylinders, or lack of sufficient air. Since proper compression, fuel injection and the proper amount of air are important to good engine preformance, detailed procedures for their investigation are given *as* follows:

Locating a Misfiring Cylinder

1. Start the engine and run it at part load until it reaches normal operating temperature.
2. Stop the engine and remove the valve rocker cover. Discard the gasket.
3. Check the valve clearance.
4. Hold an injector follower down with a screwdriver, to prevent operation of the injector.' If the cylinder has been misfiring, there will not be any 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 injector follower is held down. This is similar to short-circuiting a spark ping in a gasoline engine.
5. If the cylinder is firing properly, repeat the procedure on the other cylinders until the faulty one has been located.
6. Provided the injector operating mechanism of the faulty cylinder is functioning satisfactorily, remove the fuel injector and install a new one by performing the removal and installation procedure outlined in section 2.1.1.

If installation of a new injector does not eliminate misfiring, check the compression pressures.

Checking Compression Pressure

1. Start the engine and run at it approximately one-half rated load until normal operating temperature is reached.
2. With the engine stopped, remove the fuel pipes from the injector in cylinder No. 1 and the fuel connectors.

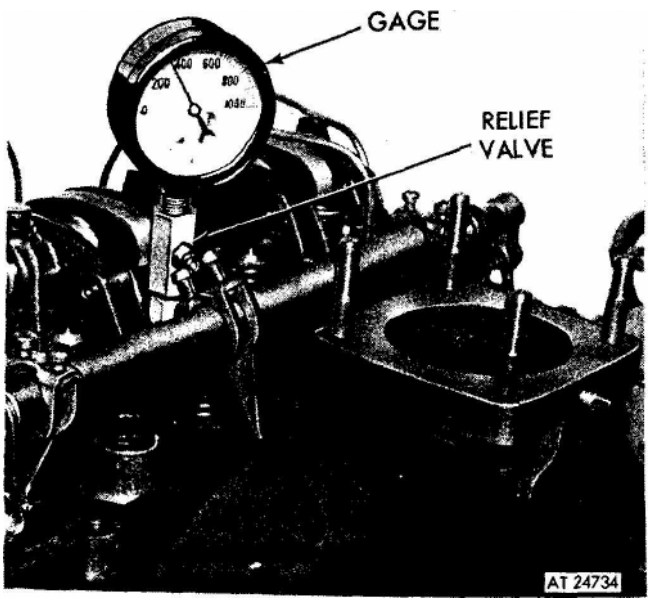


Figure 1. Checking compression pressure.

3. Remove the injector and install the adaptor and pressure *gage* from Diagnosis Kit J 9531-01 (fig. 1).
4. Use a spare fuel pipe and fabricate a jumper connection between the fuel inlet and return passage to permit fuel to flow directly to the return passage.
5. Start the engine and run it at 600 rpm. Observe and record the compression pressure indicated on the gage. Do not crank the engine with the starting motor to check the compression pressure.

Compression pressure is affected by altitude as follows:

Minimum compression pressure, psi "N" engine	Altitude, feet above sea level
540	0
500	2,500
465	5,000
430	7,500
395	10,000

6. Perform Steps 2 through 5 on each cylinder. The compression pressure in any one cylinder should not be less then 430 psi (540 psi for "N" engine) at 600 rpm. In addition, the variation in compression pressures between cylinders of the engine must not exceed 25 psi at 600 rpm. *For example:*

If the compression pressure readings were as shown

in the following table, it would be evident that No. 3 cylinder should be examined and the cause of the low compression pressure be determined and corrected.

Cylinder	Gage reading*
1	525 psi
2	520 psi
3	485 psi
4	515 psi

*The above pressures are for an engine operating at an altitude of near sea level.

Note that all of the cylinder pressures are above the low limit for satisfactory operation of the engine. Nevertheless, the No. 3 cylinder conpression pressure indicates that something unusual has occurrred and "that *a* localized pressure leak has developed.

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, remove the air box cover and inspect them by pressing on the compression rings with a blunt tool. A broken or stuck compression ring will not have a "spring like" action.

B. Compression pressure may be leaking past the cylinder head gasket, valve seats, injector tubes, or through a hole in the piston.

Engine Out of Fuel

The problem in restarting the engine after it is run out of fuel stems from the fact that after the fuel is exhausted from the fuel tank, fuel is then pumped from the primary fuel strainer and sometimes partially removed from the secondary fuel filter before the fuel supply becomes insufficient to sustain engine firing. Consequently, these components must be refilled with fuel and the fuel pipes rid of air in order for the system to provide adequate fuel for the injectors.

When an engine is run out of fuel inadvertently, there is a definite procedure to follow for restarting the engine. The procedure is outlined below:

1. Fill the fuel tank with the recommended grade of fuel oil. If only partial filling of the tank is possible, add a minimum of ten gallons of fuel.

2. Remove the fuel strainer shell and element from the strainer cover and fill the shell with fuel oil. Install the shell and element.

3. Remove and fill the fuel filter shell and element with fuel oil as in Step 2.

4. Start the engine. Check the filter and strainer for leaks.

NOTE

In some instances, it may be necessary to remove a valve rocker cover and loosen a fuel pipe nut in order to bleed trapped air from the fuel system. Be sure the fuel pipe is retightened securely before replacing the rocker cover.

Primer J 5956 may be used to prime the entire fuel system. Remove the filler plug in the fuel filter cover and install the prim er. Prime the system. Remove the primer and install the filler plug.

Fuel Flow Test

1. Disconnect the fuel return tube and hold the open end in a suitable container.

2. Start and run the engine at approximately 1200 rpm and measure the fuel flow from the return tube for one minute. At least .6 gallons of fuel should flow from the return tube per minute.

3. Be sure all tube connections between the fuel supply and the pump are tight so no air will be drawn into the fuel system; then, immerse the end of the fuel return tube into the fuel in the container. Air bubbles rising to the surface of the fuel will indicate a leak on the suction side of the pump.

Crankcase Pressure

The crankcase pressure indicates the amount of air that has passed 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 carnkcase is needed to prevent the entrance of dust. A loss of engine lubricating oil through the breather tube, crankcase ventilator, or dipstick hole in the cylinder block is indicative of excessive crankcase pressure. The maximum crankcase pressure is shown in the following chart:

Crankcase Pressure
(*max.* in *inches of* water)

Engine	Speed ((rpm)				
	1800	2000	2200	2500 *	2800
3-53	.5		.5	.9	1.0

* Engines with four valve cylinder head.

The causes of high crankcase pressure [nay 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 with the manometer in the engine diagnosis test kit J 9531-01. The manometer should be connected to the oil level dipstick opening in the cylinder block. Check the readings obtained at various engine speeds with the specifications in the chart.

Exhaust Back Pressure

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. The maximum exhaust back pressure (no-load) is shown in the following chart.

Exhaust Back Pressure
(max, in inches of mercury)

Engine	Speed (rpm)				
	1800	2000	2200	2500 *	2800
3-53	1.3		2.1	2.7	2.7

* **Engines** with four valve cylinder head.

Causes of high exhaust back 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 exhuast back pressure, measured in inches of mercury, may be checked with the manometer in the engine diagnosis test kit, J 9531-01. The manometer or pressure gage is connected to the exhaust manifold, by removing the 1/2" pipe plug which is provided for that purpose. If there is no opening provided, one can be made by drilling an 11 / 32" hole in the exhaust manifold companion flange and tapping *a* ⅛" pipe thread.

Check the readings obtained at various speeds (no load) with the specifications in the Exhaust Back Pressure Chart.

Air Box Pressure

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 inlet restriction, damaged blower rotors, an air leak from the air box, such as leaking end plate gaskets, a clogged blower air inlet screen.

Air Box Pressure
(min. in. inches of Mercury)

Engine	Max. exhaust back pressure (full load) Speed (rpm				
	1800	2000	2200	2500	2800
3-53	5.5		8.6	8.0	9.3
(Zero exhaust back pressure)					
3-53	3.8	—	6.2	4.8	6.1

*Engines with four valve cylinder head.

Lack of power or black or grey exhaust smoke are also indications of low air box pressure.

To check the air box pressure connect a manometer to the air box drain tube. Check the readings obtained at various speeds with the specifications in the chart.

Air Inlet Restriction

Excessive restriction of the air inlet 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 inlet restriction.

The air inlet restriction may be checked with a water manometer connected to a fitting in the air intake ducting located 2" above the air inlet housing. When practicability prevents the insertion of *a* fitting at this point, the manometer may be connected to the engine air inlet housing. The restriction at this point should be checked at a specific engine speed. Then, the air cleaner and ducting should be removed from the air inlet housing and the engine again operated at the same speed while noting the manometer reading. The difference between the two readings, with the air cleaner and ducting and without the air cleaner and dueling, is the actual restriction caused by the air cleaner and ducting.

Check the normal air intake vacuum at various speeds (at no-load) and compare the results with the following chart:

Air Intake Restrictions
(in inches of water)

Engine	Speed (rpm)				
	1800	2000	2200	2500 *	2800 *
Max. with dirty air cleaner (oil bath or dry)					
3-33	13.4		18.8	23.0	25.0
Max. witl clean air cleaner (oil bath or dry) with precelaner					
3-53	9.5		12.0	14.0	16.0
Max. with clean air cleaner (dry) no precleaner					

* Engines with four valve cylinder head.

PROPER USE OF MANOMETER

The U-tube manometer is a primary measuring device indicating pressure or vacuum by the difference in the height of two columns of fluid.

Connect the manometer to the source of pressure, vacuum, or differential pressure. When the pressure is imposed, add the number of inches one column of fluid travels up to the amount the other column travels down to obtain the pressure (or vacuum) reading.

The height of a column of mercury is read differently than that of a column of water. Mercury does not wet the inside surface; therefore, the top of the column has a convex meniscus (shape). Water wets the surface and therefore has a concave meniscus. A mercury column is read by sighting horizontally between the top of the convex mercury surface (fig. 2) and the scale. A water manometer is read by sighting horizontally between the bottom of the concave water surface and the scale.

Should one column of fluid travel further than the other column, due to minor variations in the inside diameter of the tube or to the pressure imposed, the accuracy of the reading obtained is not impaired.

The Manometer reading may be converted into other units of measurement by use of the pressure conversion chart.

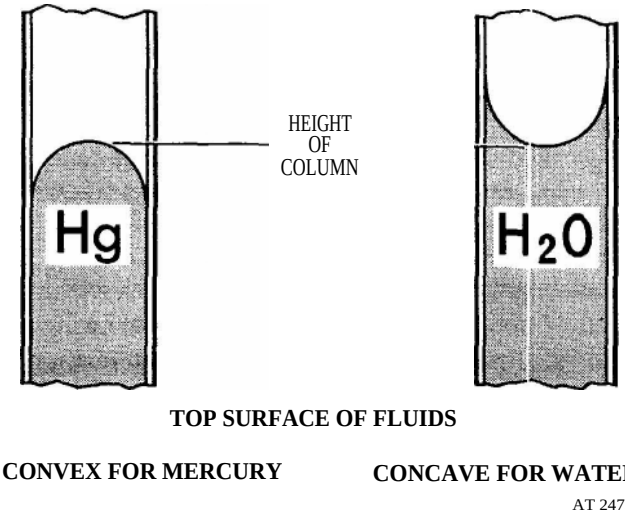


Figure 2. Comparison of column height for mercury and water manometers.

Pressure Conversion Chart

1" water	0735" mercury
1" water	0361 psi
1" mercury =	.491 psi
1" mercury	13.6" water
1 psi	= 27.7" water
1 psi	2.036" mercury

Chart 1

EXHAUST SMOKE ANALYSIS

CHECKS SHOULD BE MADE WITH WATER OUTLET TEMPERATURE AT 160°F. MINIMUM

BLACK OR GRAY SMOKE

Probable Causes

1. INCOMPLETELY BURNED FUEL
2. EXCESSIVE FUEL OR IRREGULAR FUEL DISTRIBUTION
3. IMPROPER GRADE OF FUEL

BLUE SMOKE

Probable Causes

4. LUBRICATION OIL NOT BURNED IN CYLINDER (BLOWN THROUGH CYLINDER DURING SCAVENGING PERIOD)

WHITE SMOKE

Probable Cause

5. MISFIRING CYLINDERS

SUGGESTED REMEDY

1. High exhaust back pressure or restricted air inlet causes insufficient air for combustion and will result in incompletely burned fuel.

   High exhaust back pressure is caused by faulty exhaust piping or muffler obstruction and is measured at exhaust manifold outlet with a manometer. Parts causing high exhaust back pressure should be replaced.

   Restricted air inlet to the engine cylinders is caused by clogged cylinder liner ports, air cleaner, blower to air inlet screen. These items should be cleaned. Check emergency stop to see that it *is* completely open and readjust if necessary.

2. Check for improperly timed injectors and improperly positioned injector rack control levers, Time the fuel injectors *as* outlined in "Fuel Injector Timing" and perform the appropriate governor tune-up to correct this condition.

   Replace faulty injectors if this condition still persists after timing the injectors and performing an engine tune-up.

   Lugging of the engine will cause incomplete combustion and should be avoided.

3. Check for the use of an improper grade of fuel. Consult the "Fuel Oil Specifications" for the correct fuel to use.

4. Check for internal lubricating oil leaks; refer to "High Lubricating Oil Consumption" chart.

5. Check for faulty injectors and replace as necessary.

   Check for low compression; refer to "Hard Starting" chart.

   The use of low cetane fuel will cause this condition and can be corrected by consulting and following the **"Fuel Oil Specifications".**

Chart 2

HARD STARTING

Probable Causes

ENGINE WILL NOT ROTATE

Check For

1. LOW BATTERY, LOOSE STARTER CONNECTIONS OR FAULTY STARTER
2. DEFECTIVE STARTING MOTOR SWITCH
3. INTERNAL SEIZURE

LOW CRANKING SPEED

Check For

4. IMPROPER LUBRICATING OIL VISCOSITY
5. LOW BATTERY OUTPUT
6. LOOSE STARTER CONNECTIONS OR FAULTY STARTER

NO FUEL

Check For

7. AIR LEAKS, FLOW OBSTRUCTIONS, FAULTY FUEL PUMP, FAULTY INSTALLATION
8. INJECTOR RACKS NOT IN FULL-FUEL POSITION

LOW COMPRESSION

Check For

9. EXHAUST VALVES STICKING OR BURNED
10. COMPRESSION RINGS WORN OR BROKEN
11. CYLINDER HEAD GASKET LEAKING
12. IMPROPER VALVE CLEARANCE ADJUSTMENT
13. BLOWER NOT FUNCTIONING

INOPERATIVE STARTING AID AT LOW AMBIENT TEMP.

Check For

14. IMPROPER OPERATION OF FLUID STARTING AID

Chart **2 (Cont'd.)**

HARD STARTING (Cont'd.)

SUGGESTED REMEDY

1. Refer to *Items* 2 and 3 and perform operations listed.

2. Replace starting motor switch.

3. Hand crank engine at least one complete **revolution. If engine** cannot be rotated through a complete revolution, internal damage is indicated and the engine must be disassembled to ascertain the cause.

4. Use the proper lubricating oil viscosity grade as recommended in the "Lubricating Oil Specifications".

5. Recharge the battery if a light load test indicates low or no voltage. Replace the battery if it is damaged or will not hold *a* charge.

   Properly connect the leads after replacing the terminals that are damaged or corroded.

   At low ambient temperatures, the use of a starting aid will facilitate keeping the battery fully charged by reducing the cranking time.

6. Tighten starter connections. Inspect starter commutator and brushes for wear. Replace brushes if badly worn and overhaul the starting motor if commutator is damaged.

7. To check for air leaks, flow obstruction, faulty fuel pump, or faulty installation, consult the "No Fuel or Insufficient Fuel" chart.

8. Inspect for binding governor to injector linkage that will prevent the governor from positioning the injector racks into the Full-Fuel position. Remove any bind found and readjust governor and injector controls if necessary.

9. The cylinder head must be removed and overhauled to correct this condition.

10. Remove the air box covers and inspect the compression rings through the ports in the cylinder liners. Overhaul the cylinder assemblies if the rings are badly worn or broken.

11. To check for compression gasket leakage, remove the coolant filler cap and operate the engine. A steady flow of gases from coolant filler indicates either the cylinder head gasket(s) are damaged or the cylinder head(s) are cracked. Remove the cylinder head and replace gaskets.

12. Check exhaust valve clearance and adjust to correct clearance.

13. Inspect blower drive shaft and drive coupling. Replace damaged parts.

14. Operate the starting aid according to the instructions under "Cold Weather Starting Aids".

Chart 3

ABNORMAL ENGINE OPERATION

Probable Causes

UNEVEN RUNNING OR FREQUENT STALLING

Check For

1. LOW COOLANT TEMPERATURE
2. INSUFFICIENT FUEL
3. FAULTY INJECTORS
13. LOW COMPRESSION PRESSURES
5. GOVERNOR INSTABILITY (HUNTING)

LACK OF POWER

Check For

6. IMPROPER ENGINE ADJUSTMENTS (TUNE-UP) AND GEAR TRAIN TIMING
7. INSUFFICIENT FUEL
8. INSUFFICIENT AIR
9. ENGINE APPLICATION
10. HIGH RETURN FUEL TEMPERATURE
11. HIGH AMBIENT AIR TEMPERATURE
12. HIGH ALTITUDE OPERATION

DETONATION

Check For

14. OIL PICKED UP BY AIR STEAM
15. LOW COOLANT TEMPERATURE
16. FAULTY INJECTORS

SUGGESTED REMEDY

1. Watch engine cooling temperature gage and if the temperature does not reach 160°F to 185°F while engine is operating, consult the "Abnormal Engine Coolant Temperature" chart.
2. Check engine fuel spill back and if return is less than .6 gallon per minute consult the "No Fuel or Insufficient Fuel" char.
3. Check injector timing and the position of

Chart **3 (Cont'd.)**

ABNORMAL ENGINE OPERATION (Cont'd.)

SUGGESTED REMEDY

the injector racks. If the engine was not tuned correctly, perform an engine tune-up. Erratic engine operation may also be caused by leaking injector spray tips. Replace the faulty injectors.

4. Check the compression pressures within the cylinders and consult the "Hard Starting" chart if compression pressures are low.

5. Engine hunting may be caused by governor-to-injector operating linkage binding or by faulty adjustments when performing the engine tune-up. These items may be corrected by performing the appropriate engine tune-up procedure as outlined for the governor.

6. The engine should be tuned whenever performance is not satisfactory.

   Check the engine gear train timing. An improperly timed gear train will result in a loss of power due to the valves and injectors' being actuated at the wrong time in the engine's operating cycle

7. Check engine fuel spill back and if the return is less than that specified for the particular engine *(see* Section 13.2) consult the "No Fuel or Insufficient Fuel" chart.

8. Check for damaged or clogged air cleaners and clean, repair or replace damaged parts.

   Remove the air box covers and inspect the cylinder liner ports. If the ports are over 50% plugged, clean them.

   When it is determined that the engine is not getting an adequate supply of air into the cylinders, resulting in poor combustion, check for damaged or dirty air cleaners, inadequate air supply to the engine compartment, cylinder liner ports over 50% plugged, blower air intake obstructed, or high exhaust back pressure. The faulty parts should be cleaned, repaired or replaced.

   Check the compression pressures; if found low, consult the "Hard Starting" chart.

9. Incorrect operation of the unit may result in excessive loads on the engine. Operate the unit according to approved procedures.

10. Refer to Item 13 on the "No Fuel or Insufficient Fuel" chart.

11. Check the ambient air temperature. A power decrease of .15 to .5 horsepower per cylinder, depending upon injector size, for each 10°F. temperature rise above 90°F. will occur. Relocate the engine air intake to provide a cooler source of air.

12. Engines lose horsepower with increases in altitude. The percentage of power loss is governed by the altitude at which the unit is operating.

13. Check oil bath air cleaners to *see* that they have been filled to the proper level with the same viscosity lubricating oil that is used in the engine.

    Clean the air box and drain tubes to prevent accumulations that may be picked up by the air stream and enter the engine's cylinders.

    Inspect the blower oil seals by removing the air inlet housing and watching through the blower inlet for oil radiating away from the blower rotor shaft oil seals while the engine is running. If oil is passing through the seals, overhaul the blower.

    Check for a defective blower-to-cylinder block gasket or seal rings. Replace the gasket or seal rings if necessary. If the blower has been removed, install a new gasket or seal rings.

14. Refer to Item 1 of this chart.

15. Check injector timing and the position of each injector rack. If the engine was not tuned-up correctly, perform an engine tune-up. If the engine *is* correctly tuned, the erratic operation may be caused by an injector check valve leaking, spray tip holes enlarged, or a broken spray tip. Replace all injectors found faulty.

Chart 4

NO FUEL OR INSUFFICIENT FUEL

Probable Causes

AIR LEAKS

Check For

1. LOW FUEL SUPPLY
2. LOOSE CONNECTIONS OR CRACKED LINES BETWEEN FUEL PUMP AND TANK OR SUCTION LINE IN TANK
3. DAMAGED FUEL OIL STRAINER GASKET
4. FAULTY INJECTOR TIP ASSEMBLY

FLOW OBSTRUCTION

Check For

5. FUEL STRAINER OR LINES RESTRICTED
6. TEMPERATURE LESS THAN 10°F. ABOVE POUR POINT OF FUEL

FAULTY FUEL PUMP

Check For

7. RELIEF VALVE NOT SEATING
8. WORN GEARS OR PUMP BODY
9. FUEL PUMP NOT ROTATING

FAULTY INSTALLATION

Check For

10. DIAMETER OF FUEL SUCTION LINES TOO SMALL
11. RESTRICTED FITTING MISSING FROM RETURN LINE
12. INOPERATIVE FUEL INTAKE LINE CHECK VALVE
13. HIGH FUEL RETURN TEMPERATURE

Chart **4 (Cont'd.)**

NO FUEL OR INSUFFICIENT FUEL (Cont'd.)

SUGGESTED REMEDY

1. The fuel tank should be filled above the level of the engine suction tube.
2. Perform a "Fuel Flow Test" and if air is present, tighten loose connections and replace cracked lines.
3. Perform a "Fuel Flow Test" and if air is present replace the fuel strainer gasket when changing the strainer element.
4. Perform a "Fuel Flow Test" and **if air is** present, with all fuel lines and connections assembled correctly, check for and replace faulty injectors.
5. Perform a "Fuel Flow Test" and replace the fuel strainer and filter elements, also fuel lines as necessary.
6. Consult "Fuel Oil Specifications" and use the fuel oil recommended.
7. Perform a "Fuel Flow Test" and, if inadequate, clean and inspect the valve seat assembly.
8. Replace the gear and shaft assembly or the pump body.
9. Check the condition of the fuel pump drive and blower drive and replace the defective parts.
10. Replace with larger tank-to-engine fuel lines.
11. Install a restricted fitting in the return line.
12. See that the check valve is installed in the line correctly; the arrow should be on top of the valve assembly or pointing upward. Reposition the valve if necessary. If the valve is inoperative, replace it with a new valve assembly.
13. Check the engine fuel spill back temperature. The return fuel temperature must be less than 150°F. or a loss in horsepower will occur. This condition may be corrected by installing larger fuel lines, or relocating the fuel tank to a cooler position.

Chart 5

HIGH LUBRICATING OIL CONSUMPTION

Probable Causes

EXTERNAL LEAKS

Check For

1. OIL LINES OR CONNECTIONS LEAKING
2. GASKET OR OIL SEAL LEAKS
3. HIGH CRANKCASE PRESSURE
4. EXCESSIVE OIL IN AIR BOX

INTERNAL LEAKS

Check For

5. BLOWER OIL SEAL LEAKING
6. OIL COOLER CORE LEAKING

OIL CONTROL AT CYLINDER

Check For

7. OIL CONTROL RINGS WORN, BROKEN OR IMPROPERLY INSTALLED
8. PISTON PIN RETAINER LOOSE
9. SCORED LINERS, PISTONS, OR OIL RINGS
10. PISTON AND ROD ALIGNMENT
11. EXCESSIVE INSTALLATION ANGLE
12. EXCESSIVE OIL IN CRANKCASE

SUGGESTED REMEDY

1. Tighten or replace defective parts.
2. Replace defective gaskets or oil seals.
3. See the "Excessive Crankcase Pressure" chart.
4. See the "Abnormal Engine Operation" chart.
5. Remove the air inlet housing and inspect the blower end plates while engine is operating. If oil is seen on end plate radiating away from oil seal, overhaul the blower.
6. Inspect the engine coolant for lubricating Oil contamination; if contaminated, inspect the oil cooler core and replace if necessary. Then use a good grade of cooling system cleaner to remove oil from cooling system.
7. Replace the oil control rings on the piston.
8. Replace the piston pin retainer and defective parts.
9. Remove and replace the defective parts.
10. Check crankshaft thrust washers for wear. Replace all worn and defective parts.
11. Decrease the installation angle.
12. Fill the crankcase to the proper level only.

Chart 6

EXCESSIVE CRANKCASE PRESSURE

Probable Causes

CYLINDER BLOW-BY

Check For

1. CYLINDER HEAD GASKET LEAKING
2. PISTON OR LINER DAMAGED
3. PISTON RINGS WORN OR BROKEN

BREATHER RESTRICTION

Check For

4. OBSTRUCTION OR DAMAGE TO BREATHER

AIR FROM BLOWER OR AIR BOX

Check For

5. DAMAGED BLOWER-TO-BLOCK GASKET
6. CYLINDER BLOCK END PLATE GASKET LEAKING

EXCESSIVE EXHAUST BACK PRESSURE

Check For

7. EXCESSIVE MUFFLER RESISTANCE
8. FAULTY EXHAUST PIPING

SUGGESTED REMEDY

1. Check compression pressure and even if only one cylinder has low compression remove the cylinder head and replace the cylinder head gaskets.
2. Inspect the piston and liner and replace damaged parts.
3. Install new piston rings.
4. Clean and repair or replace the breather assembly.
5. Replace the blower-to-block gasket.
6. Replace the end plate gaskets.
7. Check the exhaust back pressure and repair or replace the muffler if an obstruction is found.
8. Check the exhaust back pressure and install larger piping if it is determined that the piping is too small, too long or has too many bends.

Chart 7

LOW OIL PRESSURE

CHECK SHOULD BE MADE WITH WATER OUTLET TEMPERATURE AT 160°F, MINIMUM

Probable Causes

LUBRICATING OIL

Check For

1. SUCTION LOSS
2. LUBRICATING OIL VISCOSITY

POOR CIRCULATION

Check For

3. COOLER CLOGGED
4. COOLER BY-PASS VALVE NOT FUNCTIONING PROPERLY
5. PRESSURE REGULATOR VALVE NOT FUNCTIONING PROPERLY
6. EXCESSIVE WEAR ON CRANKSHAFT BEARINGS
7. GALLERY, CRANKSHAFT OR CAMSHAFT PLUGS MISSING

PRESSURE GAGE

Check For

8. FAULTY GAGE
9. GAGE LINE OBSTRUCTED
10. GAGE ORIFICE PLUGGED
3. ELECTRICAL INSTRUMENT PANEL SENDING UNITS FAULTY

OIL PUMP

Check For

11. INTAKE SCREEN PARTIALLY CLOGGED
4. RELIEF VALVE FAULTY
14. AIR LEAK IN PUMP SUCTION
15 PUMP WORN OR DAMAGED
16. FLANGE LEAK - PRESSURE SIDE

Chart 7 (Cont'd.)

LOW OIL PRESSURE (Cont'd.)

SUGGESTED REMEDY

1. Check the oil level and bring it to the proper level on the dipstick or correct the installation angle.
2. Wrong viscosity of lubricating oil being used; consult "Lubricating Oil Specifications".

   Check for fuel leaks at injector seal ring and fuel pipe connections. Leaks at these points will cause lubricating oil dilution.
3. A plugged oil cooler is indicated by excessively high lubricating oil temperature. Remove and clean the oil cooler core.
4. Remove by-pass valve and clean the valve and valve seat and inspect the valve spring. Replace the defective parts.
5. Remove pressure regulator valve, clean valve and valve seat and inspect the valve spring. Replace the defective parts.
6. Change the bearings. Consult the "Lubricating Oil Specifications" for proper grade of oil to use and change the oil filters.
7. Replace any missing plugs.
8. Check the oil pressure with a reliable gage and replace the gage if found faulty.
9. Remove and clean the gage line; replace it if necessary.
10. Remove and clean the gage orifice.
11. Repair or replace defective electrical equipment.
12. Remove and clean the oil pan and oil intake screen; consult the "Lubricating Oil Specifications" for the proper grade of oil to use and change the oil filters.
13. Remove and inspect the valve, valve bore and spring, replace faulty parts.
14. Disassemble piping and install new gaskets.
15. Remove the pump, clean and replace defective parts.
16. Remove the flange and replace the gasket.

Chart 8

ABNORMAL ENGINE COOLANT OPERATING TEMPERATURES

Probable Causes

ABOVE NORMAL		BELOW NORMAL	
Check For		Check For	
1. INSUFFICIENT HEAT TRANSFER		3. IMPROPER CIRCULATION	
2. POOR CIRCULATION		4. EXCESSIVE LEAKAGE AT THERMOSTAT SEAL	

SUGGESTED REMEDY

1. The cooling system should be cleaned with a good cooling system cleaner and thoroughly flushed to remove scale deposits.

   The exterior of the radiator core should be cleaned to open plugged passages permitting normal air flow.

   Loose fan belts should b e adjusted to proper tension to prevent slippage.

   Check for improper size radiator or inadequate shrouding.

   Repair or adjust inoperative shutters.

   Repair or replace inoperative temperature-controlled fan.

2. Check coolant level and fill to filler neck if coolant is low.

   Inspect for collapsed or disintegrated hoses. Replace all faulty hoses.

   Thermostat(s) may be inoperative. Remove, inspect and test thermostat; replace if found faulty,

   Check the water pump for a loose or damaged impeller.

   Check the flow of water through the radiator. A clogged radiator will cause an inadequate supply of water on the suction side of the pump. Clean the radiator core.

   Remove the radiator cap and operate the engine, checking for combustion gases in cooling system. The cylinder head must be removed and inspected for cracks and head gaskets replaced if combustion gases are entering cooling system.

   Check for air leak on suction side of the fresh water pump. Replace the defective parts.

3. The thermostat may not be closing. Remove, inspect, and test thermostat. Install new thermostat if necessary.

   Check for an improperly installed heater.

4. Excessive leakage of coolant past the thermostat seal(s) is a cause of continued low coolant operating temperature. When this occurs replace the thermostat seal(s).

STORAGE

PREPARING ENGINE UNITS FOR STORAGE

When an engine unit is to be stored or removed from operation, special precautions should be taken to protect the interior and exterior of the engine, transmission and other parts from rust, corrosion, and gumming in the fuel system. The parts requiring attention and the recommeded preparations are given below.

An engine unit should be processed for storage as soon as possible after removal from operation. If an engine unit is not processed for storage as soon as possible after removal from operation. If an engine unit is not processed at the earliest possible opportunity and corrosion starts on the exposed metal surfaces, it will then be necessary to carefully and thoroughly remove the corrosion before applying a rust inhibitor.

Engine units should be stored in a building which is dry and may be heated during the winter months. Moisture absorbing chemicals are available commercially for use when excessive dampness prevails in storage areas.

TEMPORARY STORAGE (30 days or less)

Protect engine unit for a temporary period of time as outlined below:

1. Drain the engine crankcase.
2. Fill the crankcase to the proper level with the recommended viscosity and grade of oil.
3. Fill the fuel tank with the recommended fuel oil. Operate the engine for two minutes at 1200 rpm and no load.

NOTE

Do not drain the fuel system or the crankcase after this run.

4. If freezing weather is expected during the storage period, add a high boiling point type antifreeze solution in accordance with the manufacturer's recommendations. Drain the raw water system and leave the drain cocks open.
5. Clean entire exterior of the engine with fuel oil and dry it with air.
6. Seal all the engine openings. The material used for this purpose must be waterproof, vapor-proof and possess sufficient physical strength to resist puncture and damage from the expansion of entrapped air.

Engines prepared in this manner can be put into service in a short time by simply removing the seals at the engine openings, checking the engine coolant, fuel oil, lubricating oil.

EXTENDED STORAGE (30 days or more)

When an engine unit is to be removed from operation for an extended period of time, prepare the unit as follows:

1. Drain and thoroughly flush the cooling system with clean, soft water.
2. Refill the cooling system with clean, soft water.
3. Add a rust inhibitor to the cooling system (refer to "Corrosion Inhibitor" in section 5.)
4. Remove, check and recondition the injectors where necessary to make sure they will be ready to operate when the engine is again placed in service.
5. Reinstall the injectors in the engine, time the injectors, and adjust the valve clearance.
6. Circulate the coolant through the entire system by operating the engine until normal operating temperature is reached (160°F. to 185°F.)
7. Stop the engine.
8. Remove the plug and completely drain the engine crankcase. Install new lubricating oil filter elements and gaskets.
9. Fill the crankcase to the proper level with the recommended viscosity and grade of oil.
10. Drain the engine fuel tank.
11. Refill the fuel tank with enough Valvoline Oil Company ‘‘Tectyl 502-C" rust preventive compound, or its equivalent, to enable the engine to operate 15 minutes.
12. Drain the fuel filter and strainer. Remove the retaining bolts, shells and elements. Discard the used elements and gaskets. Wash the shells in clean fuel oil and insert new elements. Fill the cavity between the element and shell about two-thirds full of the same rust preventive compound as used in the fuel tank and reinstall the shell.
13. Start and run the engine at 600 rpm for 5 minutes so that the clean oil can coat all of the internal parts of the engine.

15.3 STORAGE

NOTE

The performance of this step is not necessary on torque converter units.

14. Remove the valve rocker cover(s) from the engine and spray a thin film of Valvoline Oil Company "Tectyl 502-C" rust preventive compound, or its equivalent, on the injector operating mechanism, on the top of the cylinder head and on the underside of the valve rocker cover(s). This compound is soluble in the engine lubricating oil. Reinstall the valve rocker cover(s).

15. Apply a "non-friction" rust preventive compound, similar to Valvoline Oil Company "Tectyl No. 812", to the flywheel and all exposed parts.

CAUTION

Do not apply oil, grease or any wax base compound to the flywheel. The cast iron will absorb these substances which can "sweat" out during operation and cause the clutch to slip.

16. Drain the engine cooling system.

17. Inc oil may be drained from the engine crankcase if so desired.

18. If the oil is drained, reinstall and tighten the drain plug.

19. Insert heavy paper strips between the pulleys and belts to prevent sticking.

20 Seal all of the openings in the unit, including the exhaust outlet, with moisture resistant tape. Use cardboard, plywood or metal covers where practical.

21. Clean and dry the exterior painted surfaces of the engine. Spray the surfaces with a suitable liquid automobile body wax, a synthetic resin varnish or a rust preventive compound.

22. Cover the engine with a good weather-resistant tarpaulin or other cover if it must be stored outdoors. A clear plastic cover is recommended for indoor storage. Stored engines should be inspected periodically. If there are any indications of rust or corrosion, corrective steps must be taken to prevent damage to the engine parts. Perform a complete inspection at the end of one year and apply additional treatment as required.

PROCEDURE FOR RESTORING TO SERVICE ENGINE UNITS WHICH HAVE BEEN IN EXTENDED STORAGE

1. Remove the valve rocker cover.

Pour at least one-half gallon of the proper engine lubricating oil over the injector operating mechanism.

2. Reinstall the valve rocker cover.

3. Remove all covers and tape from the openings of the engine, fuel tank, and electrical equipment. Do Not Overlook The Exhaust Outlet!

4. Wash the exterior of the engine with fuel oil to remove the rust preventive. REMOVE THE RUST PREVENTIVE FROM THE FLYWHEEL.

5. Remove the paper strips from between the pulleys and belts.

6. Check the crankcase oil level. Fill the crankcase to the proper level with the HEAVY-DUTY lubricating oil recommended under "LUBRICATING OIL SPECIFICATIONS" in Section 13.3.

7. Fill the fuel tank with fuel specified under "DIESEL FUEL OIL SPECIFICATIONS" in Section 13.3.

8. Close all of the drain cocks and fill the engine cooling system with clean soft water and a rust inhibitor. If the engine is to be exposed to freezing temperatures, fill the cooling system with a high boiling point type antifreeze solutior.

*General Information Section.

ALPHABETICAL INDEX

* General Information Section.

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