SERIES 53

SERVICE MANUAL

DETROIT DIESEL ENGINES

DETROIT DIESEL ALLISON
DIVISION OF GENERAL MOTORS CORPORATION
DETROIT, MICHIGAN, 48228

Form 6SE201 (Rev. 9/73)
Printed in U.S.A.

IMPORTANT SAFETY NOTICE

Proper service and repair is important to the safe, reliable operation of all motor vehicles. The service procedures recommended by Detroit Diesel Allison and described in this service manual are effective methods for performing service operations. Some of these service operations require the use of tools specially designed for the purpose. The special tools should be used when and as recommended.

It is important to note that some warnings against the use of specific service methods that can damage the vehicle or render it unsafe are stated in this service manual. It is also important to understand these warnings are not exhaustive. Detroit Diesel Allison could not possibly know, evaluate and advise the service trade of all conceivable ways in which service might be done or of the possible hazardous consequences of each way. Consequently, Detroit Diesel Allison has not undertaken any such broad evaluation. Accordingly, anyone who uses a service procedure or tool which is not recommended by Detroit Diesel Allison must first satisfy himself thoroughly that neither his safety nor vehicle safety will be jeopardized by the service method he selects.

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March, 1973

SCOPE AND USE OF THE MANUAL

This manual covers the basic Series 53 Diesel Engines built by the Detroit Diesel Allison 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. Basic maintenance and overhaul procedures are common to all Series 53 engines and therefore apply to all engine models.

The manual is divided into numbered sections. The first section covers the engine (less major assemblies). 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 sub-assembly 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 also numbered consecutively, beginning with a new Figure 1 at the start of each sub-section.

Information regarding a general subject, such as the lubrication system, can best be located by using the Table of Contents. Opposite each subject in the Table of Contents is a section number which registers with a tab printed on the first page of each section throughout the manual. Information on a specific sub-assembly or accessory can then be found by consulting the list of contents on the first page of the 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

Genuine Detroit Diesel "Factory Engineered" replacement parts are available from authorized Detroit Diesel Service Outlets conveniently located within the United States, in Canada from the distribution organization of Diesel Division, General Motors of Canada Limited, and abroad through the sales and service outlets of General Motors Overseas Operations Divisions.

CLEARANCES AND TORQUE SPECIFICATIONS

Clearances of new parts and wear limits on used parts are listed in tabular form at the end of each 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 various specifications apply. This also applies to references within the text of the manual. The column entitled "Limits" lists the amount of wear or increase in clearance which can be tolerated in used engine parts and still assure satisfactory performance. It should be emphasized that the figures given as "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 at the end of each section.

PRINCIPLES OF OPERATION

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

In the diesel 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 heat 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 Fig. 1. 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 is provided to force air into the cylinders for expelling the 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 Fig. 1 (scavenging).

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 Fig. 1 (compression).

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. 1 (power). The intense heat generated during the high compression of the air ignites the fine fuel spray immediately. The 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 half way down, allowing the burned gases to escape into the exhaust manifold as shown in Fig. 1 (exhaust). Shortly thereafter, the downward moving piston uncovers the inlet ports and the cylinder is again swept with clean scavenging air. 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".

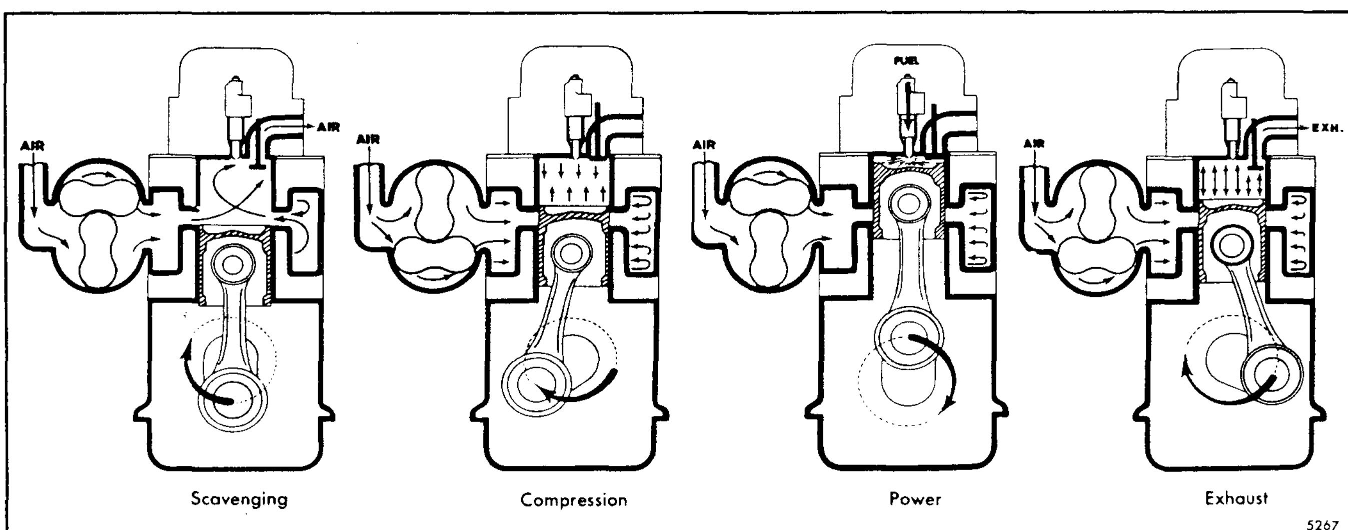


Fig. 1 - The Two Stroke Cycle

GENERAL DESCRIPTION

The two-cycle diesel engines covered in this manual have the same bore and stroke and many of the major working parts such as injectors, pistons, connecting rods, cylinder liners and other parts are interchangeable.

The In-line engines, including the inclined marine models, include standard accessories such as the blower, water pump, governor and fuel pump, which, on some models, may be located on either side of the engine regardless of the direction the crankshaft rotates. Further flexibility in meeting installation requirements is achieved with the cylinder head which can be installed to accommodate the exhaust manifold on either side of the engine.

The V-type engines use many In-line engine parts, including the 3-53 and 4-53 cylinder heads. The blower is mounted on top of the engine between the two banks of cylinders and is driven by the gear train. The governor is mounted on the rear end of the 6V-53 blower and on the front end of the 8V-53 blower.

The meaning of each digit in the model numbering system is shown in Figs. 2 and 3. The letter L or R indicates left or right-hand engine rotation as viewed from the front of the engine. The letter A, B, C or D designates the blower and exhaust manifold location on the In-line engines as viewed from the rear of the engine while the letter A or C designates the location of the oil cooler and starter on the V-type engines.

Each engine is equipped with an oil cooler (not required on certain two-cylinder models), full-flow oil filter, fuel oil strainer and fuel oil filter, an air cleaner or silencer, governor, heat exchanger and raw water pump or fan and radiator, and a starting motor.

Full pressure lubrication is supplied to all main, connecting rod and camshaft bearings and to other moving parts. A rotor-type pump on In-line or 6V engines or a gear-type pump on 8V engines draws oil from the oil pan through a screen and delivers it to the oil filter. From the filter, the oil flows to the oil cooler and then enters a longitudinal oil gallery in the cylinder block where the supply divides. Part of the oil goes to the camshaft bearings and up through the rocker arm assemblies; the remainder of the oil goes to the main bearings and connecting rod bearings via the drilled oil passages in the crankshaft.

Coolant is circulated through the engine by a centrifugal-type water pump. Heat is removed from the coolant, which circulates in a closed system, by the heat exchanger or radiator. Control of the engine temperature is accomplished by thermostat(s) which regulate the flow of the coolant within the cooling system.

Fuel is drawn from the supply tank through the fuel strainer by a gear-type fuel pump. It is then forced through a filter and into the fuel inlet manifold in the cylinder head(s) and to the injectors. Excess fuel is returned to the supply tank through the fuel outlet manifold and connecting lines. Since the fuel is constantly circulating through the injectors, it serves to cool the injectors and to carry off any air in the fuel system.

Air for scavenging and combustion is supplied by a blower which pumps air into the engine cylinders via the air box and cylinder liner ports. All air entering the blower first passes through an air cleaner or silencer.

Engine starting is provided by either a hydraulic or electric starting system. The electric starting motor is energized by a storage battery. A battery-charging generator, with a suitable voltage regulator, serves to keep the battery charged.

Engine speed is regulated by a mechanical or hydraulic type engine governor, depending upon the engine application.

5 0 4 3 — 5 1 0 1

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

APPLICATION DESIGNATION

5042-5100	MARINE
5043-5100	FAN TO F/W—INDUSTRIAL
5044-5100	POWER-BASE
5045-5100	GENERATOR
5047-5100	FAN TO F/W—VEHICLE

DESIGN VARIATION

5043-5000	"N" ENGINE
5043-5100	2 VALVE HEAD
5043-5200	4 VALVE HEAD
5042-2302	TURBOCHARGER

STARTER—BLOWER ARRANGEMENT

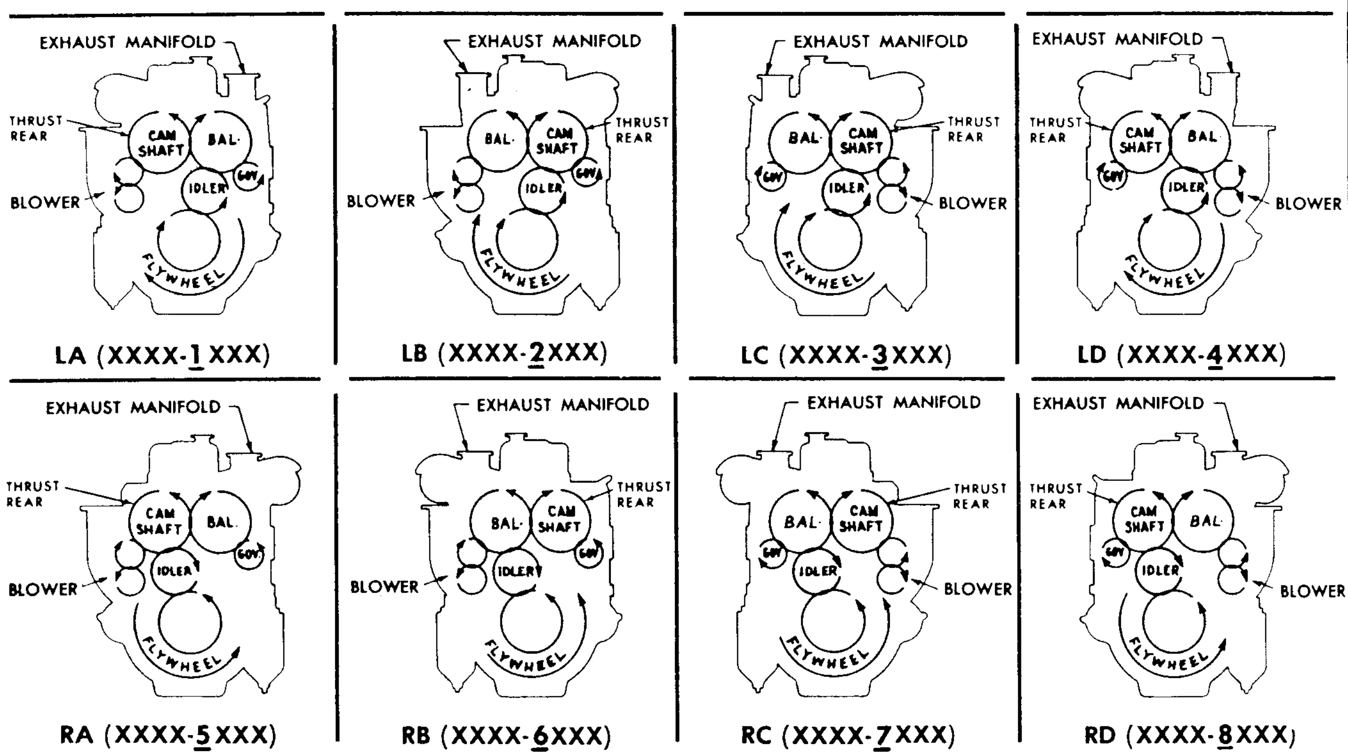
Odd number in last digit designates starter opposite blower.

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

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

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

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



ALL ABOVE VIEWS FROM REAR (FLYWHEEL) END OF ENGINE

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Fig. 2 - In-line Engine Model Description, Rotation, and Accessory Arrangements

5 0 6 3 — 5 2 0 0

SERIES 53	NUMBER OF CYLINDERS	APPLICATION DESIGNATION	BASIC ENGINE ARRANGEMENT * (see below)	DESIGN VARIATION	SPECIFIC MODEL NUMBER

APPLICATION DESIGNATION

5062-3000 MARINE
5063-5200 FAN to F/W-INDUSTRIAL
5064-5200 POWER-BASE
5065-5200 GENERATOR
5067-5040 FAN to F/W VEHICLE
5082-5000 MARINE
5083-5000 FAN to F/W INDUSTRIAL
5087-5040 FAN to F/W VEHICLE

DESIGN VARIATION

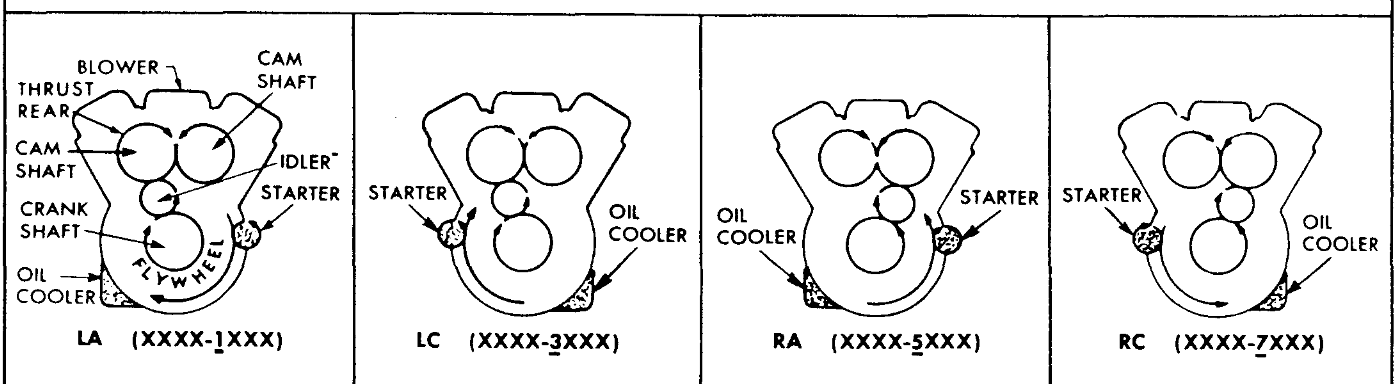
5062-3000 "N" ENGINE
5063-5200 4 VALVE HEAD

*** BASIC ENGINE ARRANGEMENTS**

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

Type: A and C designates location of starter and oil cooler as viewed from the flywheel end of the engine.

Cylinder Bank: Left and right cylinder banks are determined from the flywheel end of the engine.



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ALL ABOVE VIEWS FROM REAR FLYWHEEL END OF ENGINE

Fig. 3 · 6 and 8V Engine Model Description, Rotation and Accessory Arrangement

GENERAL SPECIFICATIONS

	2-53	3-53	4-53	6V-53	8V-53N
Type	2 Cycle	2 Cycle	2 Cycle	2 Cycle	2 Cycle
Number of Cylinders	2	3	4	6	8
Bore	3.875 in.	3.875 in.	3.875 in.	3.875 in.	3.875 in.
Stroke	4.5 in.	4.5 in.	4.5 in.	4.5 in.	4.5 in.
Compression Ratio (Nominal) (Standard Engines).	17 to 1	17 to 1	17 to 1	17 to 1	–
Compression Ratio (Nominal) ("N" Engines) . .	–	21 to 1	21 to 1	21 to 1	21 to 1
Total Displacement - Cubic Inches	106	159	212	318	424
Number of Main Bearings	3	4	5	4	5

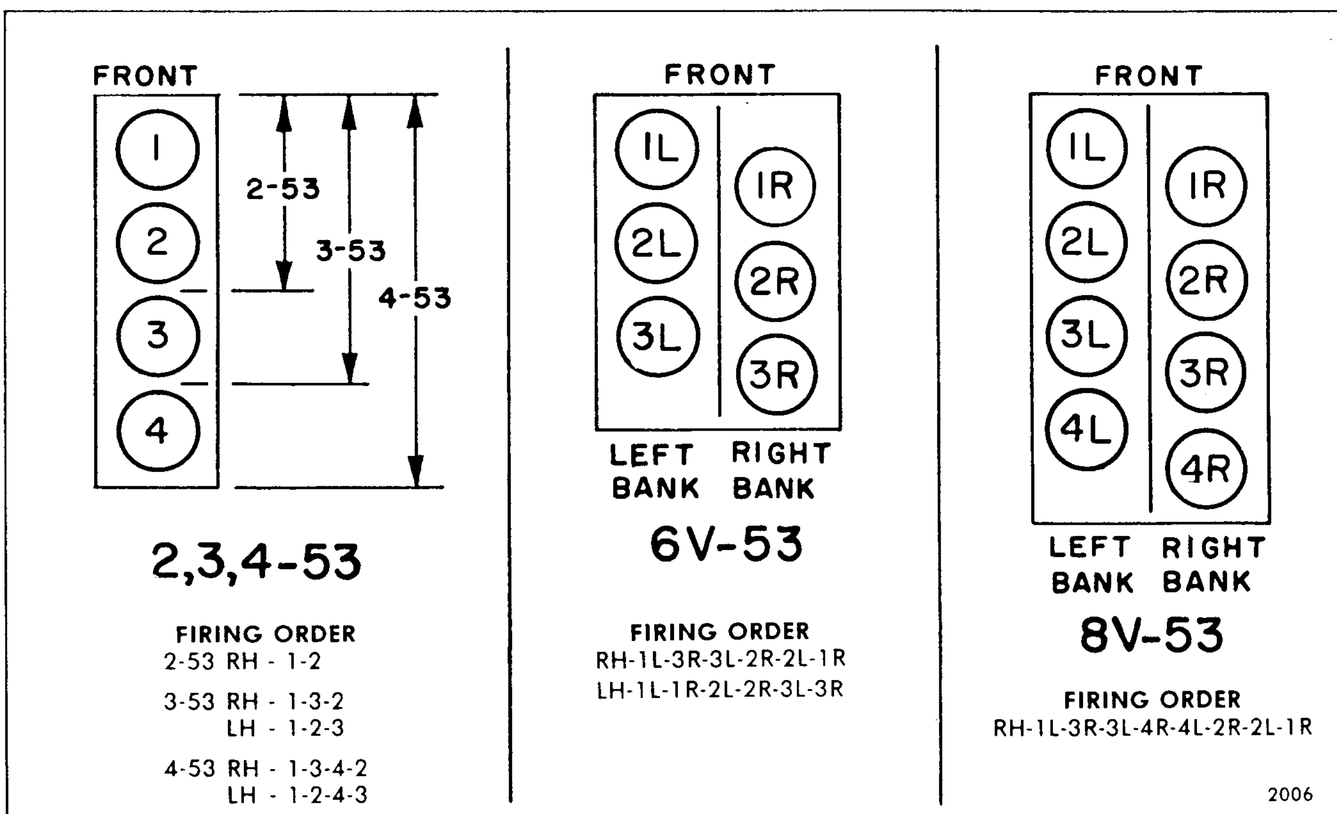


Fig. 4 - Cylinder Designation and Firing Order

ENGINE MODEL, SERIAL NUMBER AND OPTION PLATE

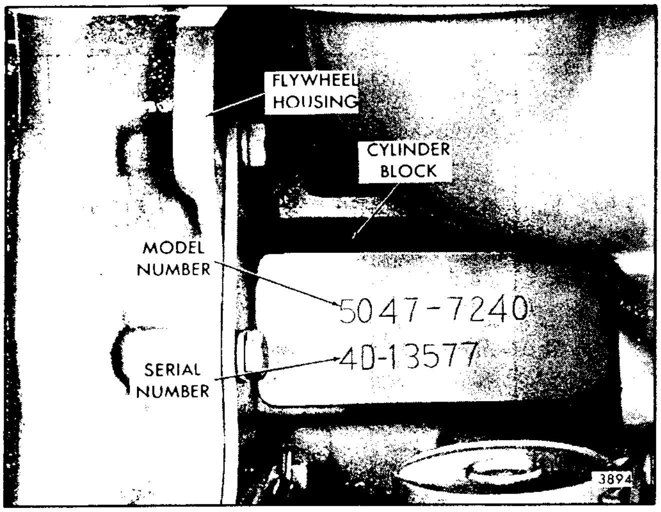


Fig. 5 - Typical Model and Serial Numbers as Stamped on Cylinder Block (In-Line Engine)

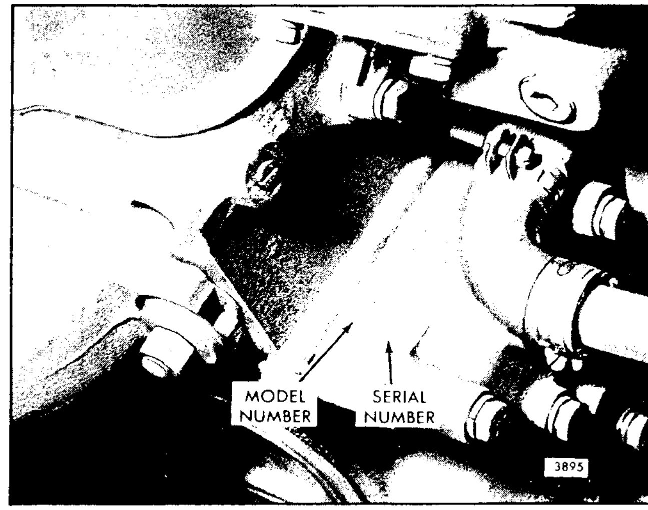


Fig. 6 - Typical Model and Serial Numbers as Stamped on Cylinder Block (6 and 8V Engines)

On the In-line engines, the model number and serial number are stamped on the right-hand side of the cylinder block in the upper rear corner (Fig. 5). The model number and serial number on the V-type engines are located on the top right-hand front corner of the cylinder block, as viewed from the rear of the engine (Fig. 6).

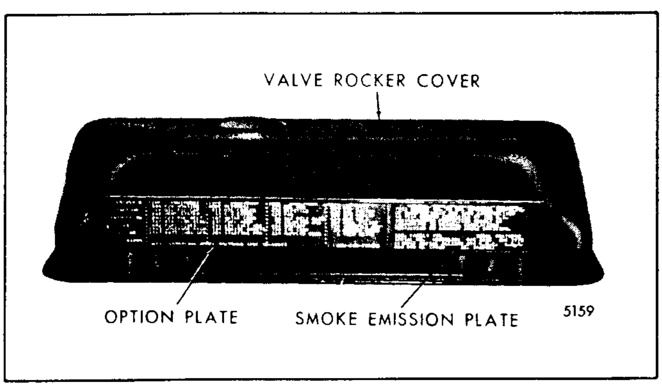


Fig. 7 - Option Plate

An option plate, attached to the valve rocker cover, is also stamped with the engine serial number and model number and, in addition, lists any optional equipment used on the engine (Fig. 7). Where required, a smoke emission certification plate is installed next to the option plate.

With any order for parts, the engine model number and serial number must be given. In addition, if a type number is shown on the option plate covering the equipment required, this number should also be included on the parts order.

All groups of parts used on a unit are standard for the engine model unless otherwise listed on the option plate.

Power take-off assemblies, torque converters, marine gears, etc. may also carry name plates. The information on these name plates is also useful when ordering replacement parts for these assemblies.

GENERAL PROCEDURES

In many cases, a serviceman is justified in replacing parts with new material rather than attempting repair. However, there are times when 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, thereby saving the expense of a new part. Exchange assemblies such as injectors, fuel pumps, water pumps and blowers are also desirable service items.

Various factors such as the type of operation of the engine, 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 sub-assemblies 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, coolant and fuel. On engines cooled by a heat exchanger, the fresh water system and raw water system must both be drained. Lubricating oil should also be drained from any transmission attached to the engine.

To perform a major overhaul or other extensive repairs, the complete engine assembly, after removal from the engine base and drive mechanism, should be mounted on an engine overhaul stand; then the various sub-assemblies should be removed from the engine. 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 removing any of the sub-assemblies from the engine (but after removal of the electrical equipment), the exterior of the engine should be thoroughly cleaned. Then, after each sub-assembly is removed and disassembled, the individual parts should be cleaned. Thorough cleaning of each part is absolutely necessary before it can be satisfactorily inspected. Various items of equipment needed for general cleaning are listed below.

The cleaning procedure used for all ordinary cast iron parts is outlined under *Clean Cylinder Block* in Section 1.1; 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 sub-assemblies.

Solvent Tank Cleaning

A tank of sufficient size to accommodate the largest part that will require cleaning (usually the cylinder block) should be provided and provisions made for heating the cleaning solution to 180 °F.-200 °F.

Fill the tank with a commercial heavy-duty solvent which is heated to the above temperature. Lower large parts directly into the tank with a hoist. Place small parts in a wire mesh basket and lower them into the tank. Immerse the parts long enough to loosen all of the grease and dirt.

Rinsing Bath

Provide another tank of similar size containing hot water for rinsing the parts.

Drying

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

Rust Preventive

If parts are not to be used immediately after cleaning, dip them in a suitable rust preventive compound. The rust preventive compound should be removed 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 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/or 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 be 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 be 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 be removed as far as possible from the assembly area.

Particular attention should be paid to storing of parts and sub-assemblies, after removal and cleaning and prior to assembly, in such a place or manner as to keep them clean. If there is any doubt as to the cleanliness of such parts, they should be 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.

WORK SAFELY

A serviceman can be severely injured if caught in the pulleys, belts or fan of an engine that is accidentally started. To avoid such a misfortune, take these precautions before starting to work on an engine:

Disconnect the battery from the starting system by removing one or both of the battery cables. With the electrical circuit disrupted, accidental contact with the starter button will not produce an engine start.

Make sure the mechanism provided at the governor for stopping the engine is in the stop position. This will mean the governor is in the no-fuel position. The possibility of the engine firing by accidentally turning the fan or, in the case of vehicle application, by being bumped by another vehicle is minimized.

Some Safety Precautions To Observe When Working On The Engine

1. Consider the hazards of the job and wear protective gear such as safety glasses, safety shoes, hard hat, etc. to provide adequate protection.

2. When lifting an engine, make sure the lifting device is fastened securely. Be sure the item to be lifted does not exceed the capacity of the lifting device.

3. Always use caution when using power tools.

4. When using compressed air to clean a component, such as flushing a radiator or cleaning an air cleaner element, use a safe amount of air. Recommendations regarding the use of air are indicated throughout the manual. Too much air can rupture or in some other way damage a component and create a hazardous situation that can lead to personal injury.

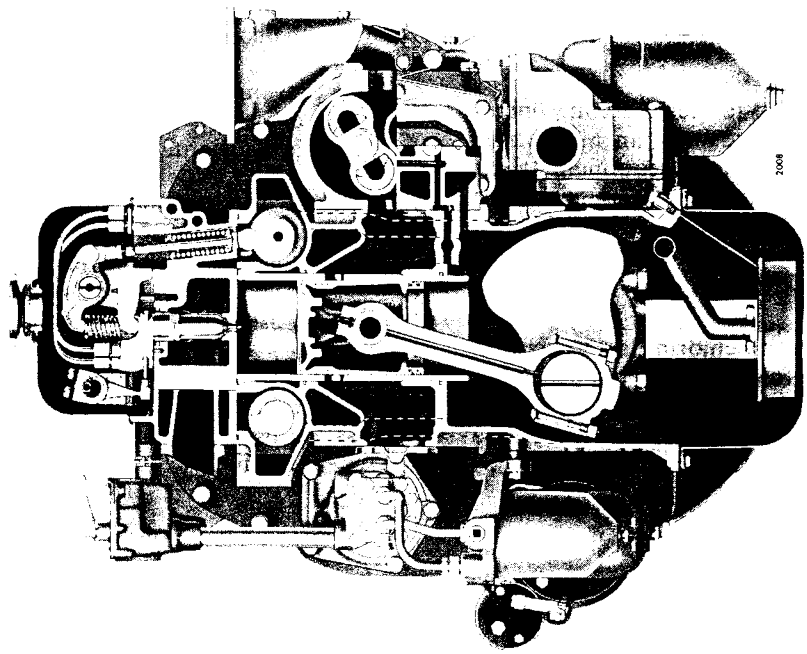
5. Avoid the use of carbon tetrachloride as a cleaning agent because of the harmful vapors that it releases. Use perchlorethylene or trichlorethylene. However, while less toxic than other chlorinated solvents, use these cleaning agents with caution. Be sure the work area is adequately ventilated and use protective gloves, goggles or face shield, and apron.

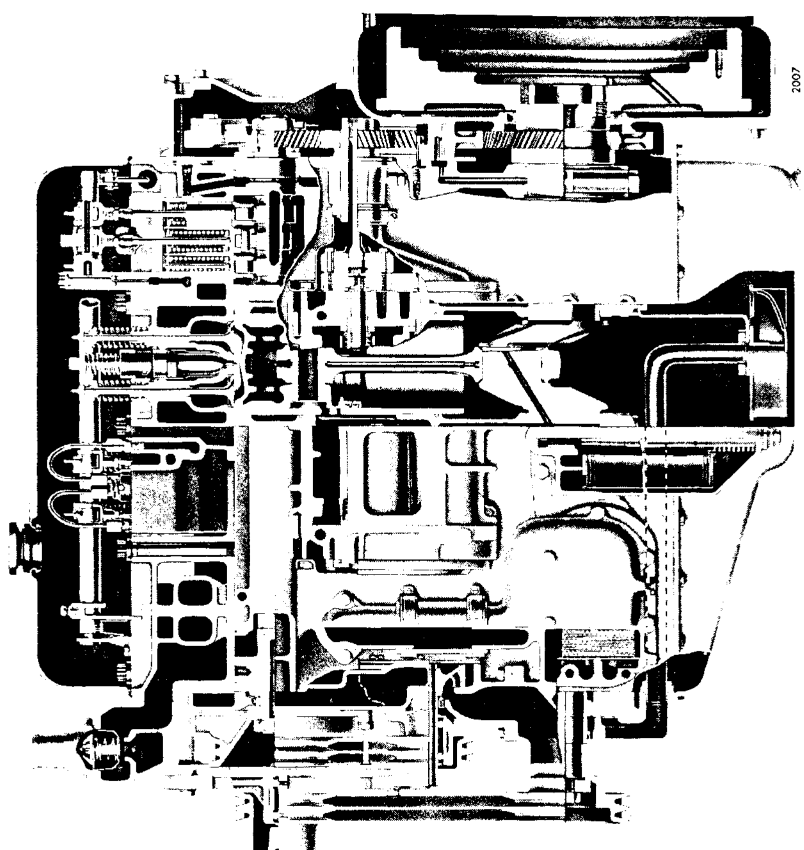
Exercise caution against burns when using oxalic acid to clean the cooling passages of the engine.

6. Use caution when welding on or near the fuel tank. Possible explosion could result if heat build-up inside the tank is sufficient.

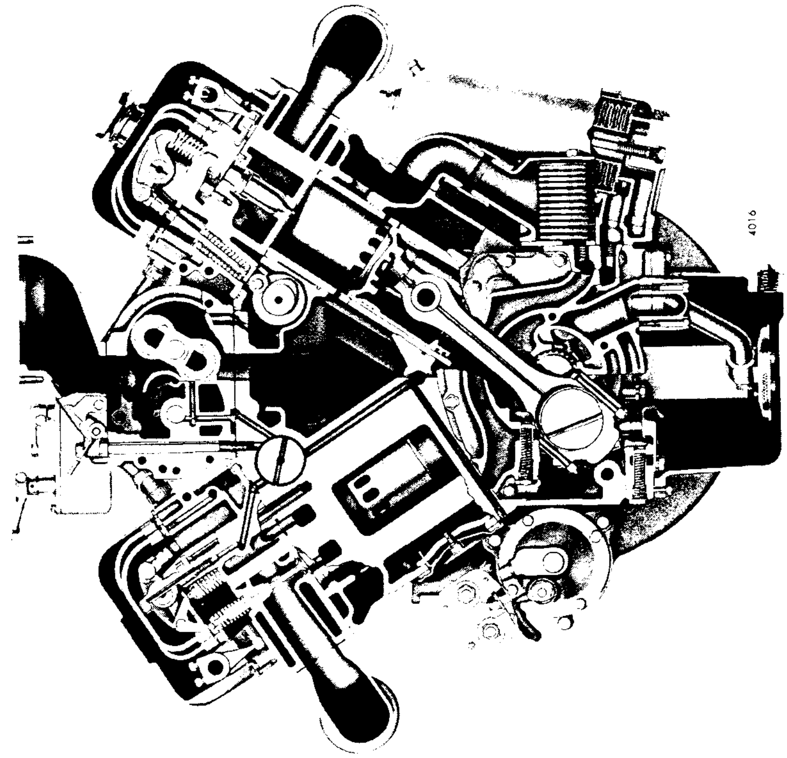
7. Avoid excessive injection of ether into the engine during start attempts. Follow the instructions on the container or by the manufacturer of the starting aid.

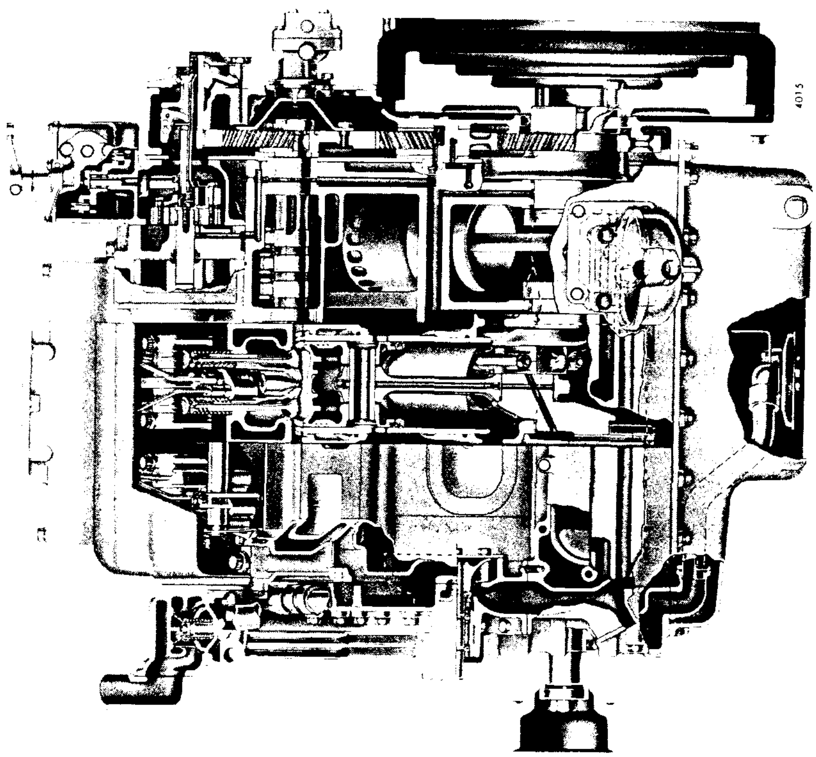
8. When working on an engine that is running, accidental contact with the hot exhaust manifold can cause severe burns. Remain alert to the location of the rotating fan, pulleys and belts. Avoid making contact across the two terminals of a battery which can result in severe arcing.



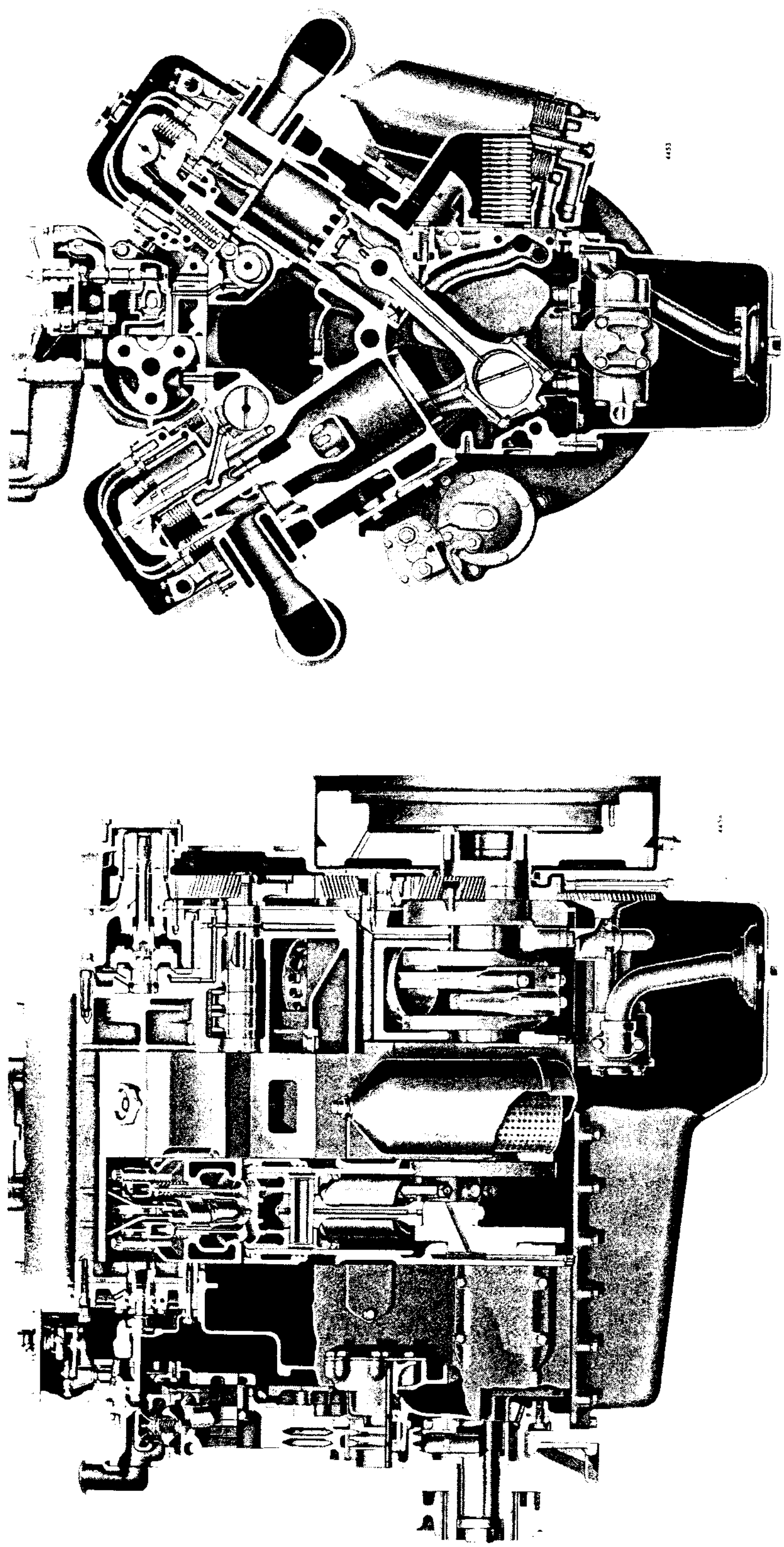


Cross Sections of a Typical In-Line Engine

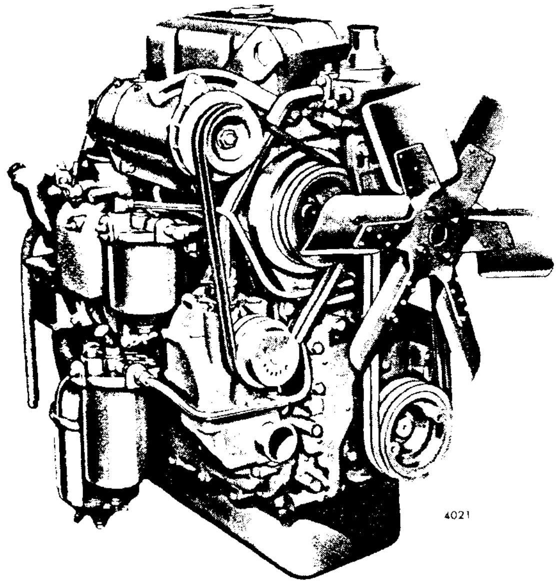




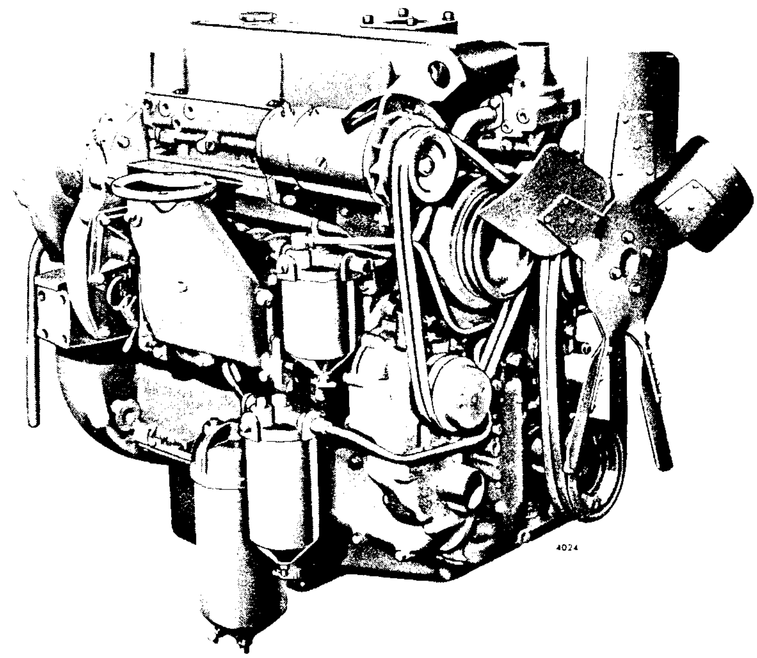
Cross Sections of a 6V-53 Engine



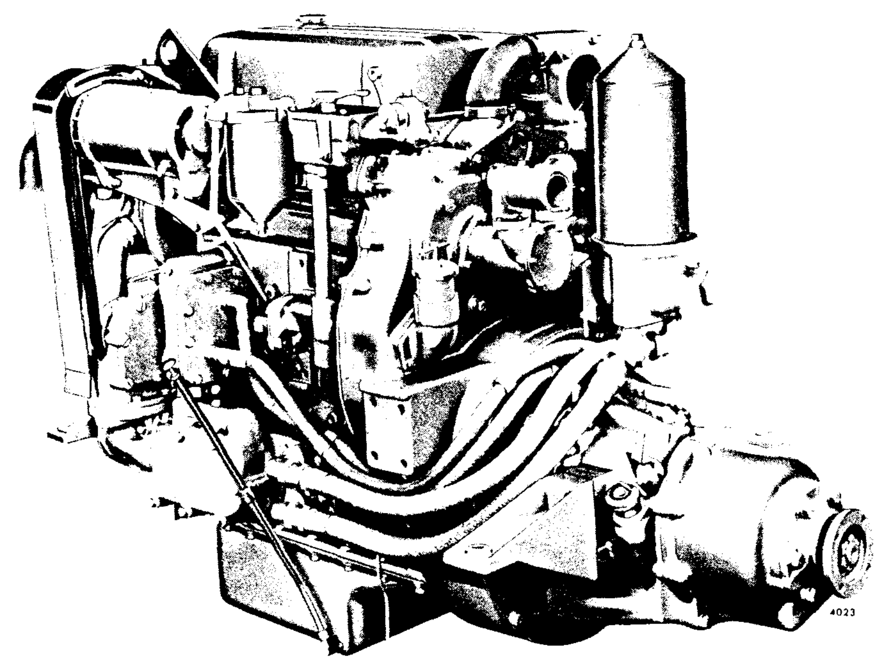
Cross Sections of an 8V-53 Engine



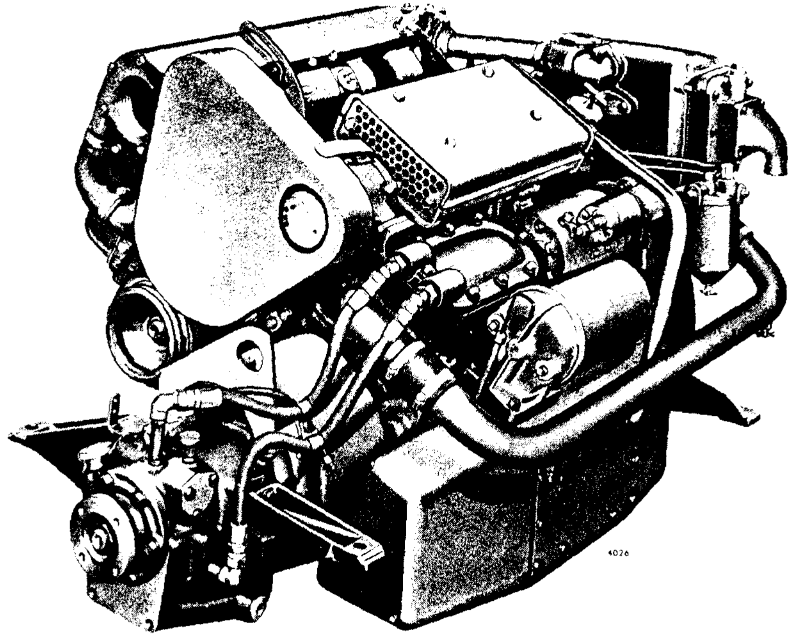
Typical Fan-to-Flywheel Unit (2-53)



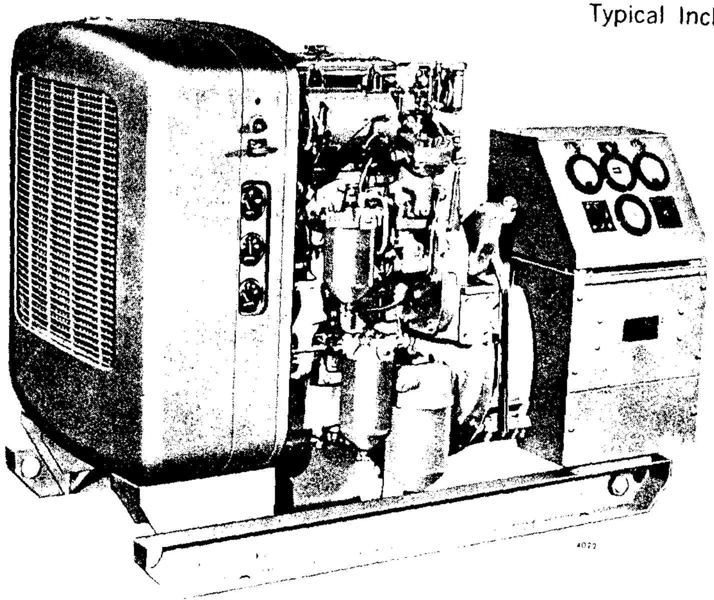
Typical Fan-to-Flywheel Unit (4-53)



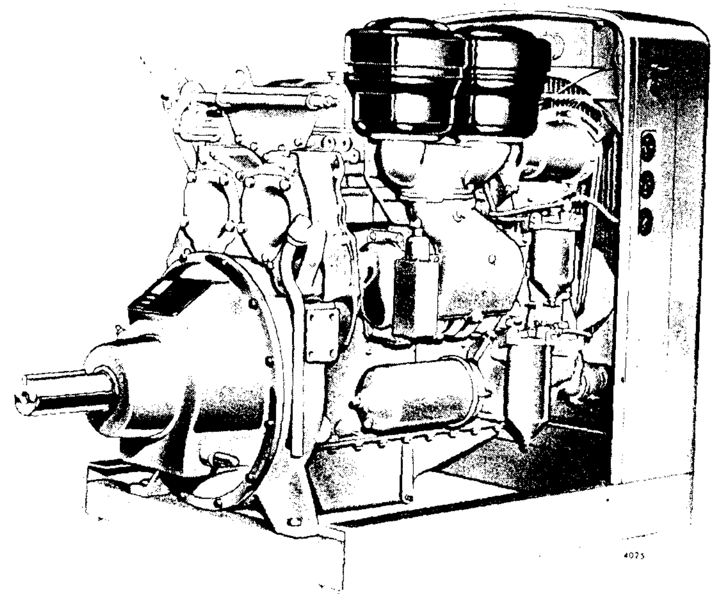
Typical Marine Propulsion Unit (3-53)



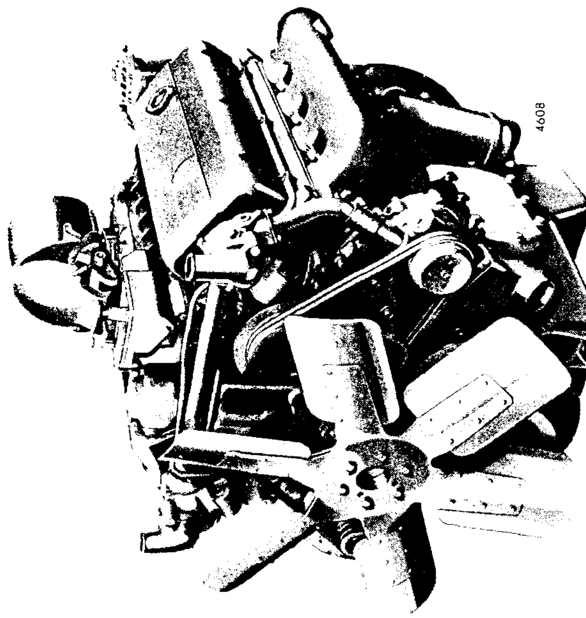
Typical Inclined Marine Propulsion Unit



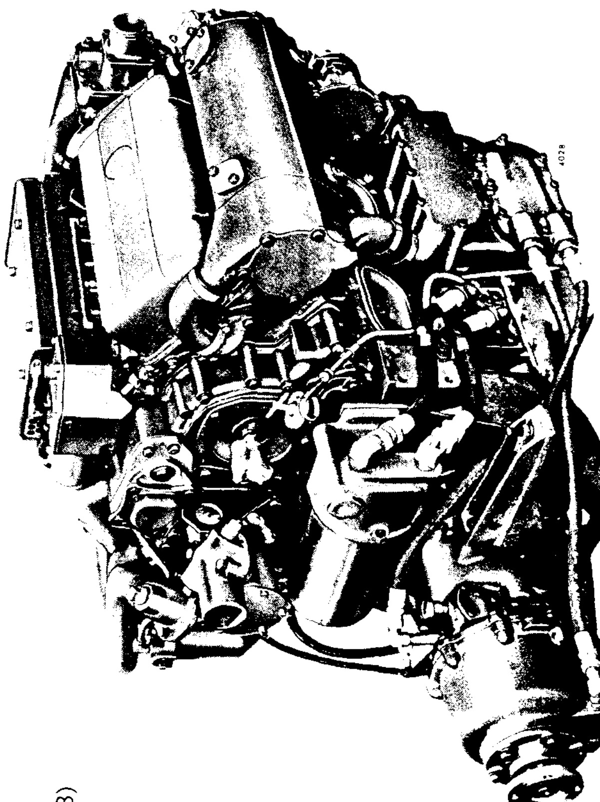
Typical Power Generator Unit



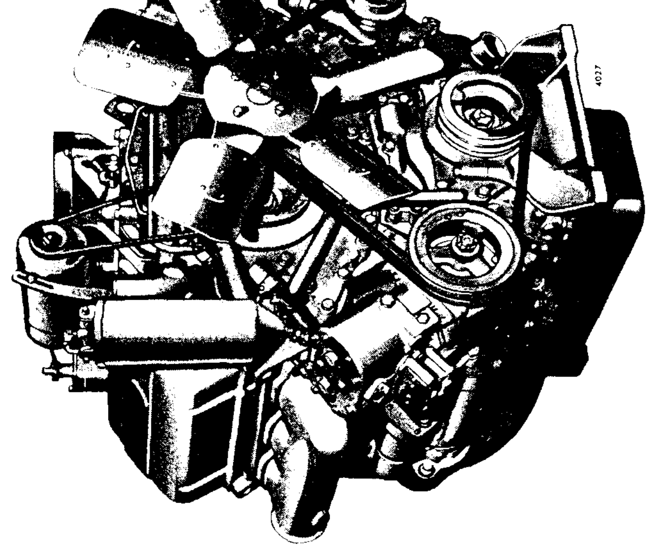
Typical Industrial Power Take-Off Unit



Typical Vehicle Unit (8V-53)



Typical Marine Propulsion Unit (6V-53)



Typical Fan-to-Flywheel Unit (6V-53)

SECTION 1

ENGINE (less major assemblies)

CONTENTS

CYLINDER BLOCK

The cylinder block (Figs. 1 and 2) serves as the main structural part of the engine. Transverse webs provide rigidity and strength and ensure alignment of the block bores and bearings under load. Cylinder blocks for the two, three and four cylinder In-Line engines are identical in design and dimensions except for length.

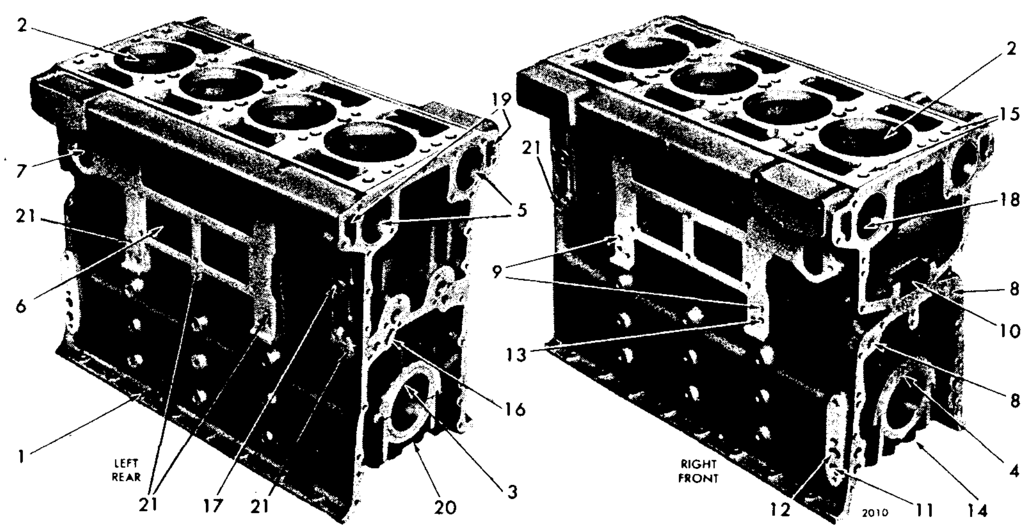
The block is bored to receive replaceable wet-type cylinder liners. On the In-Line and 6V cast iron cylinder blocks, a water jacket surrounds the upper half of each cylinder liner. On the 6V aluminum and the 8V cast iron cylinder blocks, a water jacket also surrounds the lower half of each cylinder liner. The water jacket and air box are sealed off by a seal ring compressed between the liner and a groove in the block (Figs. 3, 4 and 5).

An air box surrounding the lower half of the cylinder liners conducts the air from the blower to the air inlet ports in the cylinder liners. An opening in the side of the block opposite the blower on the In-Line engines and air box openings in both sides of the block on the V-type engines provide access to the air box and permit inspection of the pistons and compression rings through the air inlet ports in the cylinder liners.

The camshaft and balance shaft bores are located on opposite sides near the top of the In-Line engine block. On the V-type engine, the camshaft bores are located on the inner side of each cylinder bank near the top of the block.

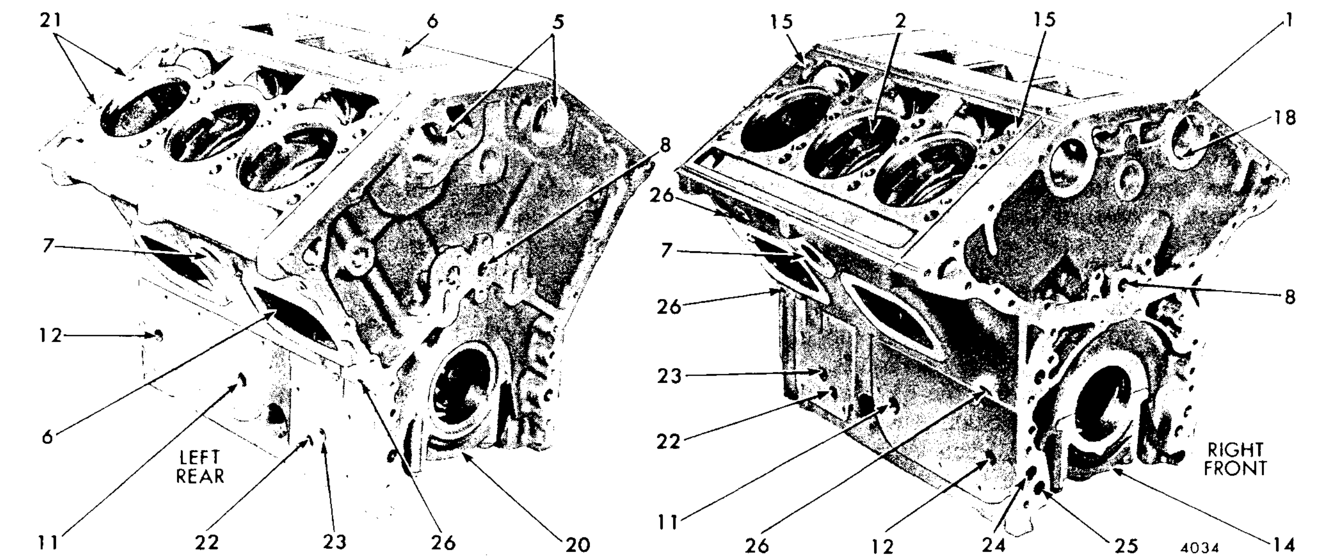
The upper halves of the main bearing supports are cast integral with the block. The main bearing bores are line-bored with the bearing caps in place to ensure longitudinal alignment. Drilled passages in the block carry the lubricating oil to all moving parts of the engine, eliminating the need for external piping.

The top surface of the In-Line block and each cylinder bank of the V-block is grooved to accommodate a block-to-head oil seal ring. Also, each water or oil hole is counterbored to provide for individual seal rings (Fig. 6). In addition, the V-type engine block is grooved around the air inlet opening, between the cylinder banks, to accommodate a blower-to-block seal ring.



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 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)
21. Oil Pressure Take-Off Opening

Fig. 1 - Cylinder Block (Four Cylinder Block Shown)



1. Cylinder Block
2. Bore for Cylinder Liner
5. Camshaft Bore
6. Air Box
7. Water Passage from Oil Cooler to Block
8. Oil Gallery (Main)
11. Oil Passage to Oil Cooler
12. Oil Passage from Oil Cooler
14. Cap--Main Bearing (Front)
15. Oil Passage to Cylinder Head
18. Oil Gallery to Camshaft
20. Cap--Main Bearing (Rear)
21. Water Passage to Cylinder Head
22. Oil Passage to Filter from Pump
23. Oil Passage from Filter to Oil Cooler
24. Oil Passage to Main Gallery via Front Cover
25. Oil Passage from Oil Pump to Filter
26. Oil Pressure Take-Off Opening

Fig. 2 - Cylinder Block (6V Cast Iron Cylinder Block Shown)

Each cylinder liner is retained in the block by a flange at its upper end, which seats in the counterbore in the block bore. An individual compression gasket is used at each cylinder.

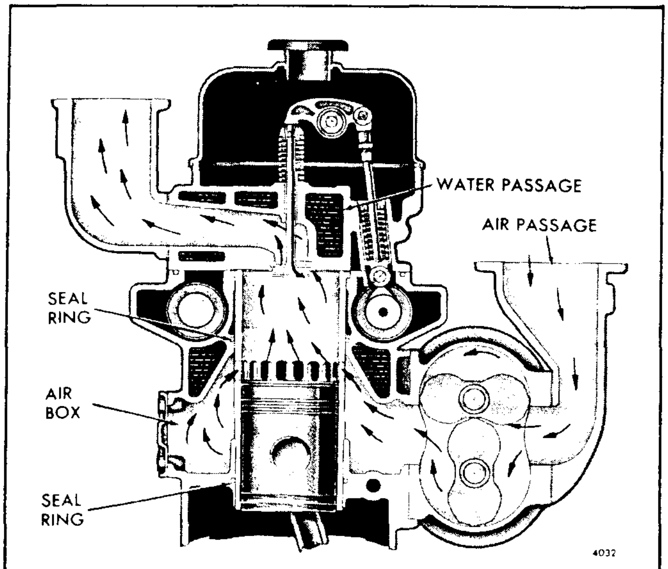


Fig. 3 - Air and Water Passages in In-Line Cylinder Block

When the cylinder head is installed, the gaskets and seal rings compress sufficiently to form a tight metal-to-metal contact between the head and the block.

The In-Line cylinder blocks were revised at the idler gear hub mounting pads, to increase the rigidity of the flywheel housing, by increasing two of the three 5/16 " - 18 bolt holes of each mounting pad to 3/8 " - 16 bolt holes (Fig. 7). The 3/8 " - 16 bolt holes were incorporated in engines beginning with serial numbers 2D-903, 3D-011 and 4D-103. Revised end plates, end plate-to-block gaskets and flywheel housing are required with the change in bolt sizes. Only the revised cylinder blocks are available for service.

The In-Line cylinder blocks have also 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. 8). Cylinder blocks with the vertical oil passages

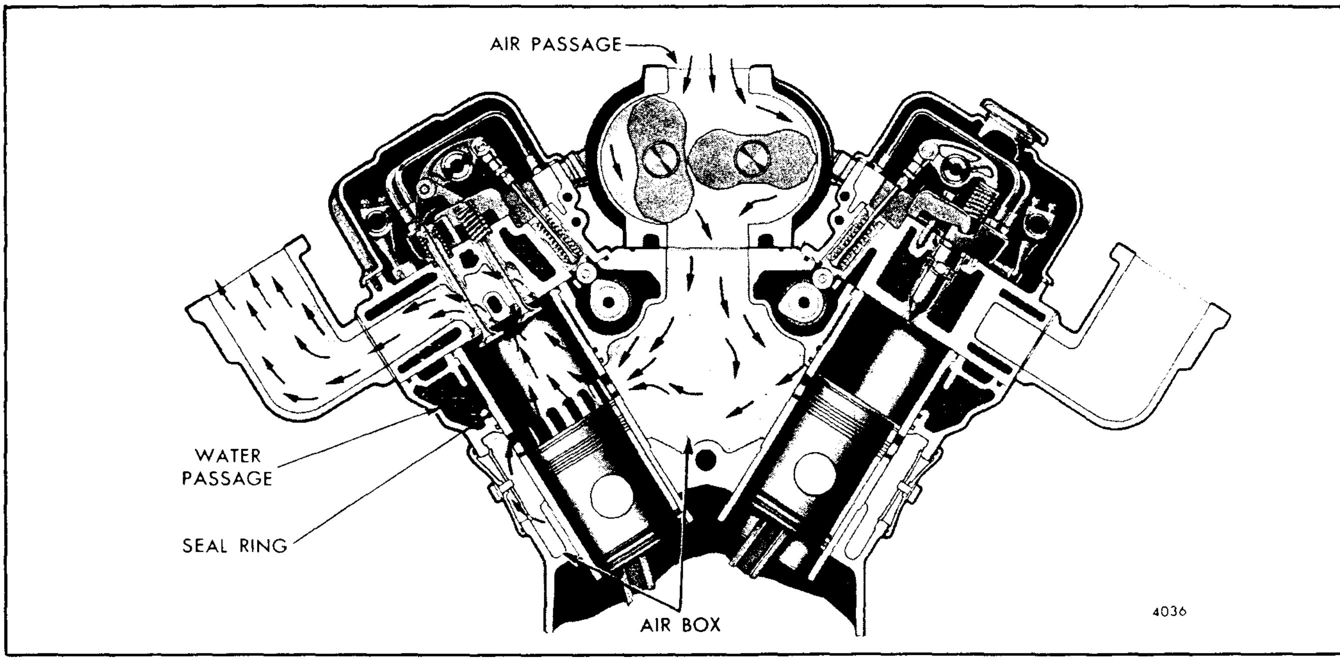


Fig. 4 - Air and Water Passages in 6V Cast Iron Cylinder Block

were used in engines beginning with serial numbers 2D-4010, 3D-117 and 4D-348.

The 8V cylinder block has been revised, effective with engine serial number 8D-2304, to provide improved scavenging and crankcase breathing by the addition of oil drains at the front corners of the cylinder block. The current 8V service cylinder block now incorporates an oil drain at each corner of the block.

New service replacement cylinder block assemblies include the main bearing caps, bolts and washers and the camshaft bearings (bushings). The dowels and the necessary plugs are also included.

Since the cylinder block is the main structural part of the engine, the various sub-assemblies must be removed from the cylinder block when an engine is overhauled.

The hydraulically operated overhaul stand (Fig. 9) 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 end or the oil pan side up.

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 turbocharger, if used.

6. Remove the blower on In-Line engines.

7. Disconnect the exhaust piping and remove the exhaust manifold(s).

8. Disconnect the throttle controls.

9. Disconnect and remove the starting motor, battery-charging generator and other electrical equipment.

10. Remove the air compressor, if used.

11. Remove the radiator and fan guard or the heat exchanger and other related cooling system parts.

12. Remove the air box drain tubes and fittings.

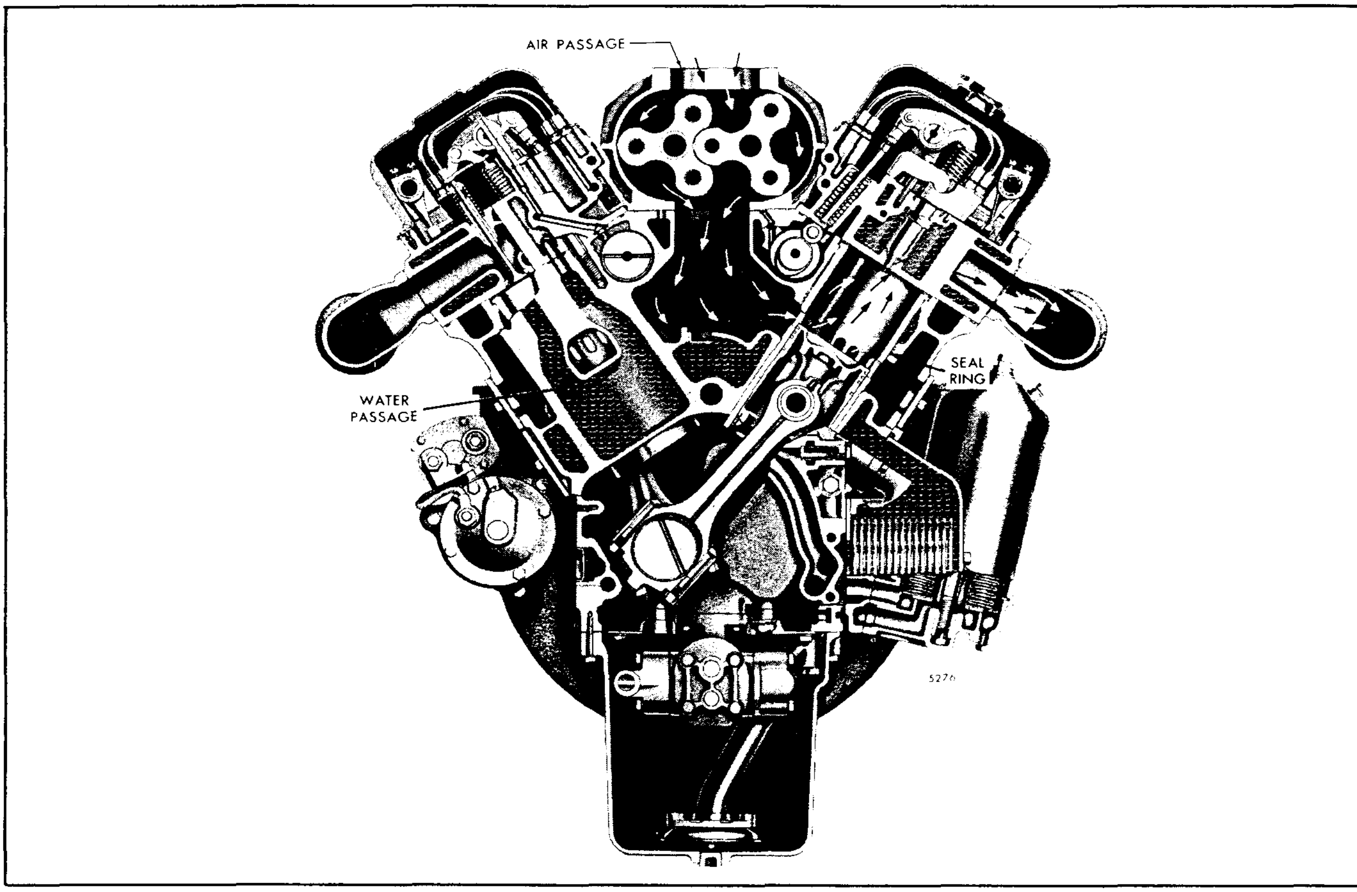


Fig. 5 - Air and Water Passages in 8V Cylinder Block

13. Remove the air box covers.

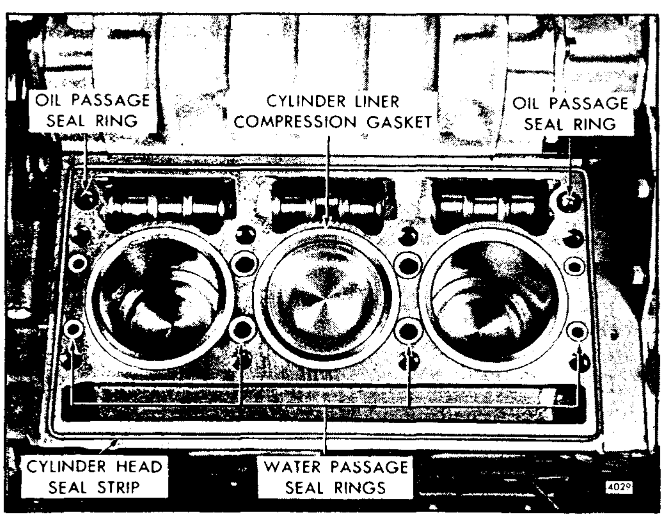


Fig. 6 - Cylinder Head Gaskets and Seals in Place on Cylinder Block

14. Disconnect any other lubricating oil lines, fuel lines or electrical connections.

15. Separate the engine from the transmission or other driven mechanism.

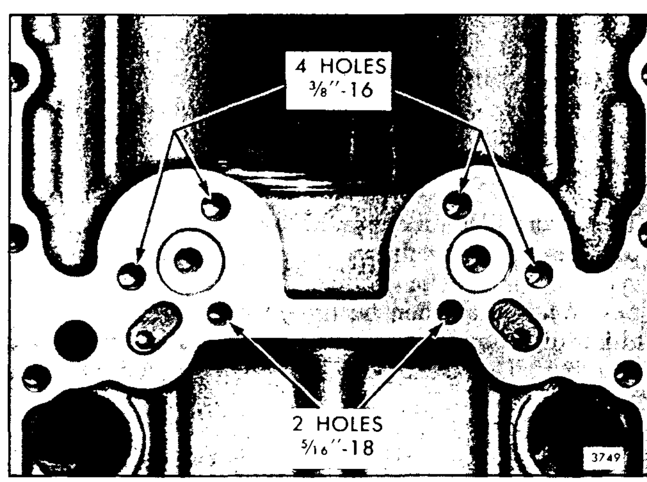


Fig. 7 - Location of the Four 3/8-16 Bolt Holes in Rear of Cylinder Block

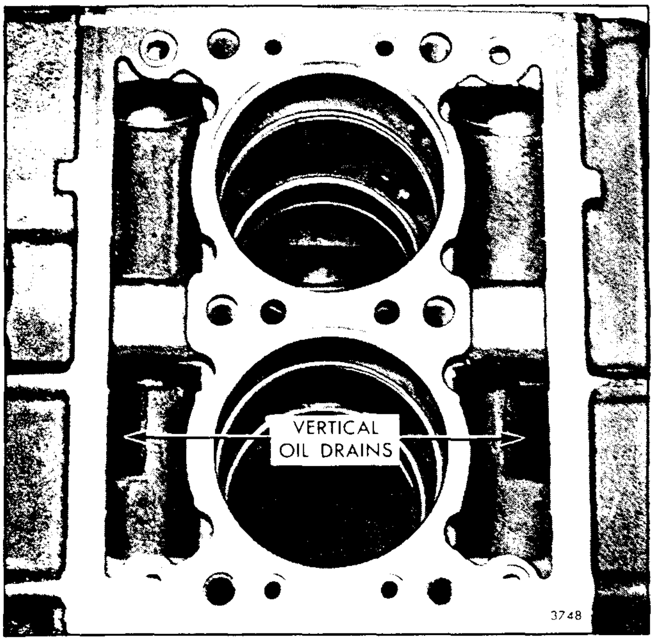


Fig. 8 - Vertical Oil Passages in Top of Cylinder Block

16. Remove the engine mounting bolts.

17. Use a chain hoist and suitable sling attached to the engine lifting brackets to lift the engine.

CAUTION: Do not lift a V-type engine by the webs in the air inlet opening at the top of the cylinder block.

18. Place the side of the cylinder block against the adaptor plate on the overhaul stand (Fig. 9). Use adaptor plate J 7622 (In-Line engine), J 8683 (6V engine) or J 21966 (8V engine) with overhaul stand J 6837-01.

19. 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.

20. With the engine mounted on the overhaul stand, remove all of the remaining sub-assemblies and parts from the cylinder block.

The procedure for removing each sub-assembly from

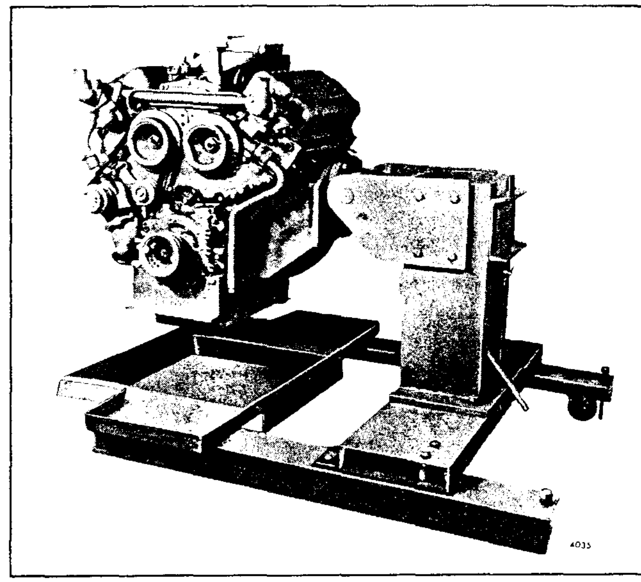


Fig. 9 - Engine Mounted on Overhaul Stand

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 must be thoroughly cleaned and inspected.

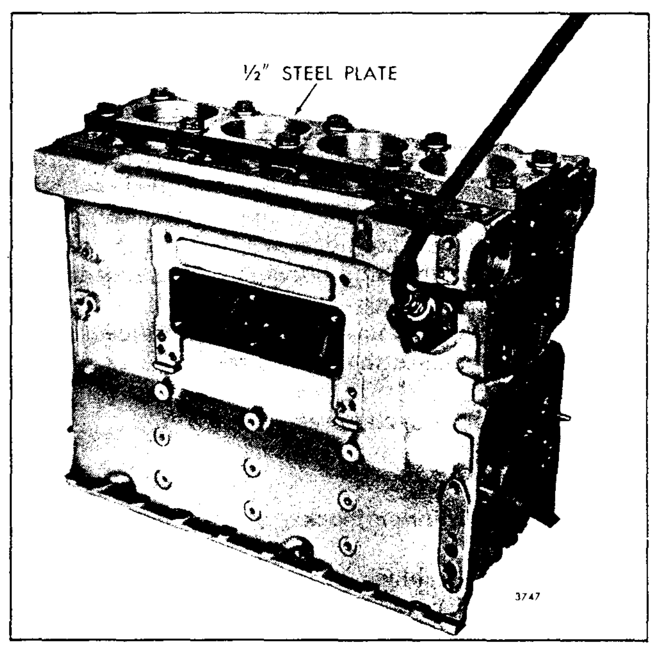


Fig. 10 - Cylinder Block Prepared for Pressure Test

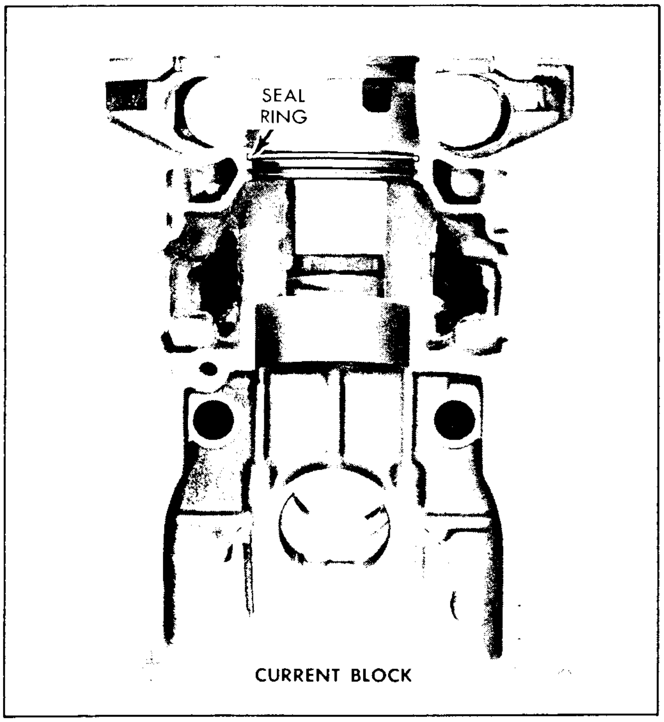


Fig. 11 - Location of Block Bore Seal Ring Groove

Clean Cylinder Block

1. Remove all of the plugs (except cup plugs) and scrape all old gasket material from the block.

2. Clean the block with live steam. Make sure the oil galleries, air box floor and air box drain openings are thoroughly cleaned. On former engines, jets machined in the camshaft and balance shaft bores (In-Line engines) and the camshaft bushing bores (6V engines) permit oil to be sprayed on the cam followers. Make sure they are not plugged. A .020 " wire may be used to clean the jets. Jets are not machined in the camshaft and balance shaft bushing bores in the current In-Line and 6V cylinder blocks. 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, 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 of 1/2 " stock to cover each cylinder bank of the block (Fig. 10). The plate(s) will adequately seal the top surface of the block when used with cylinder liner compression gaskets and water hole

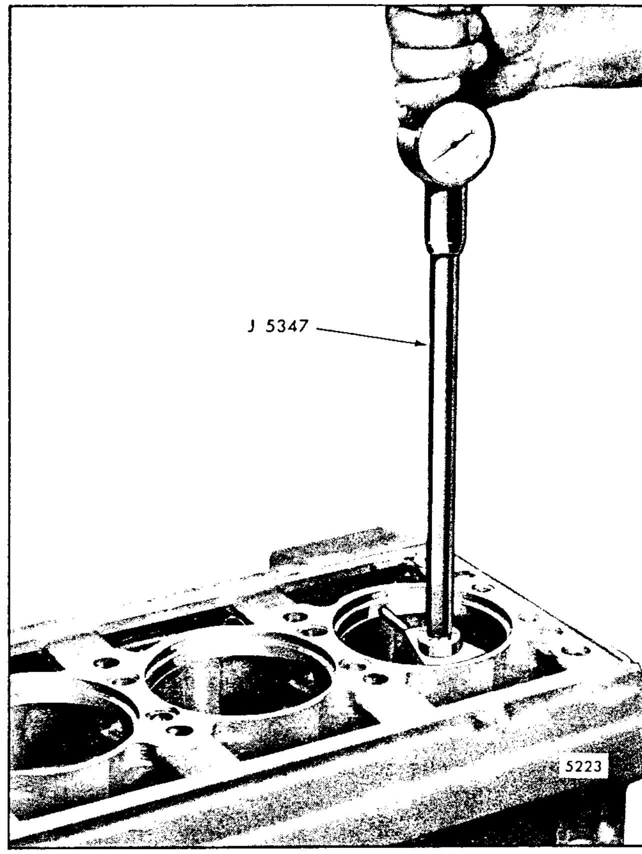


Fig. 12 - Checking Cylinder Block Bore with Tool J 5347

seal rings. It will also be necessary to use water hole cover plates and 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.

1. 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 current 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

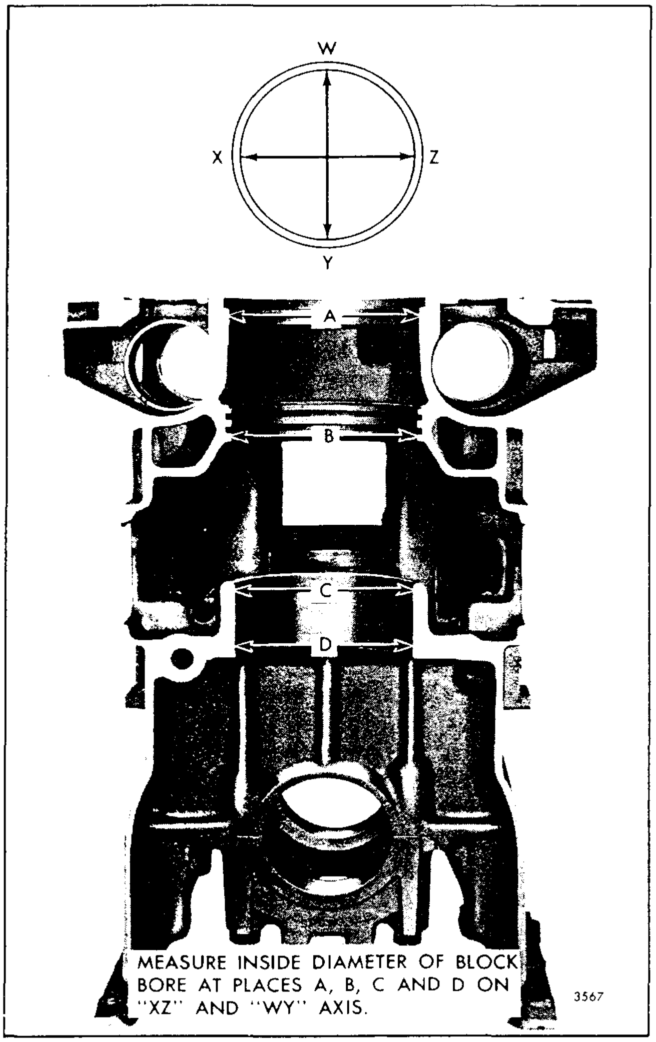


Fig. 13 - Block Bore Measurement Diagram

type shortening or permanent type antifreeze 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. Secure the plate(s) on the top of the block with 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 cylinder block for twenty minutes in a tank of water heated to 180 ° - 200 ° F.

7. Attach an air line to the water hole cover plate and apply 60 psi air pressure to the water jackets and observe the water in the tank for bubbles which will

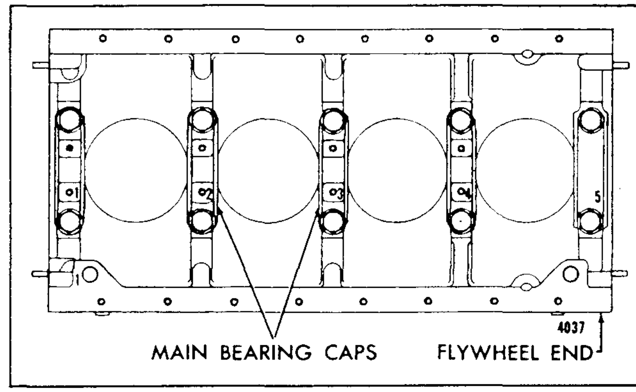


Fig. 14 - Typical Cylinder Block Markings

indicate cracks or leaks. A cracked cylinder block must be replaced by a new block.

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 water tank is unavailable, or when it is desired to check the block for cracks without removing the engine from the equipment which it powers. However, it is necessary to remove the cylinder head(s), blower, oil cooler, air box covers and oil pan.

1. 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 plate(s) and water hole covers as outlined in Method "A".

3. Apply 60 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 which may exist.

4. At the end of this test period, examine the cylinder bores, air box, oil passages, crankcase and exterior of the block for presence of the water and antifreeze mixture which will indicate the presence of cracks. A cracked cylinder block must be replaced by a new block.

5. After the pressure test is completed, remove the

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.

1. Check the block bores as follows:

a. Make sure the seal ring grooves (Fig. 11) 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 current block. The single groove formerly below the air inlet ports has been eliminated. However, a cylinder liner seal ring is required in the upper groove only. The lower groove (on the current block) 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 the entire bore of each cylinder with cylinder bore gage J 5347 (Fig. 12) which has a dial indicator calibrated in .0001 " increments. Use dial bore gage setting tool J 23059 to preset the cylinder bore gage to zero. Measure each block bore at the positions indicated in Fig. 13, on axis 90 ° apart. If the diameter does not exceed 4.5235 " at position "A", 4.4900 " at position "B" (and a sealing problem hasn't occured), or 4.3595 " at position "C" and "D", then the block may be reused. Also, the taper and out of round must not exceed .0015 ".

2. 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 .005 " (2-53 engine), .006 " (3-53 or 6V engine) or .007 " (4-53 or 8V engine) longitudinally.

3. Make sure the cylinder liner counterbores in the block are clean and free of dirt. Then check the depth. The depth must be .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 be over .001 " difference between any two adjacent cylinder counterbores, when measured along the cylinder longitudinal centerline of the cylinder block.

4. Check the main bearing bores as follows:

a. Check the bore diameters with the main bearing caps in their original positions. Lubricate the bolt threads and bolt head contact areas with a small quantity of International Compound No. 2, or equivalent. Then install and tighten the bolts to the specified torque. When making this check, do not install the main bearing cap stabilizers. The specified bore diameter is 3.251 " to 3.252 " (In-Line engine) or 3.751 " to 3.752 " (V-type engine). If the bores do not fall within these limits, the cylinder block must be rejected.

CAUTION: Main bearing cap bolts are especially designed for this purpose and must not be replaced by ordinary bolts. Effective with engine serial numbers 6D-27030 and 8D-1155, a new hexagon head bolt and hardened steel washer are being used in place of the former 12-point flange type main bearing cap bolt.

NOTE: Bearing caps are numbered to correspond with their respective positions in the cylinder block. It is imperative that the bearing caps are reinstalled in their original positions to maintain the main bearing bore alignment. The number of the front main bearing cap is also stamped on the face of the oil pan mounting flange of the cylinder block, adjacent to its permanent location in the engine as established at the time of manufacture. The No. 1 main bearing cap is always located at the end opposite the flywheel end of the cylinder block (Fig. 14).

b. Finished and unfinished main bearing caps are available for replacing broken or damaged caps. When fitting a *finished* replacement bearing cap, it may be necessary to try several caps before one will be found to provide the correct bore diameter and bore alignment. If a replacement bearing cap is installed, be sure to stamp the correct bearing position number on the cap.

NOTE: Use the unfinished bearing caps for the front and intermediate bearing positions. The finished bearing caps, machined for the crankshaft thrust washers, are to be used in the rear bearing position.

c. Main bearing bores are line-bored with the bearing caps in place and thus are in longitudinal alignment. Bearing bores may be considered properly aligned with one another if the crankshaft can be rotated freely by hand after new bearing shells have been installed and lubricated and the bearing caps have been secured in place and the bolts tightened to the specified torque. If a main bearing bore is more than .001 " out of alignment, the block must be line-bored or scrapped. Misalignment may be caused by a broken crankshaft, excessive heat or other damage.

d. If the main bearing bores are not in alignment or a replacement bearing cap is used, the block must be line-bored. Install the bearing caps in their original positions (without the bearing cap stabilizers) and tighten the bolts to the specified torque (Section 1.0). Line-bore the block, but do not remove more than .001 " stock. After boring, all bores must be within the specified limits of 3.251 " to 3.252 " (In-Line block) or 3.751 " to 3.752 " (V-type block).

5. Replace loose or damaged dowel pins. The dowels at the ends of the cylinder block must extend .680 " from the cylinder block face.

The dowels used to retain the crankshaft thrust washers in the cylinder block and on the rear main bearing cap must extend .107 " to .117 " from the surface of the block or bearing cap.

6. 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 tapped holes with a tap or install helical thread inserts.

7. After inspection, if the cylinder block is not to be 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 it in a polar type rust preventive such as Valvoline Oil Company's "Tectyl 502-C", or equivalent. Castings free of grease or oil will rust when exposed to the atmosphere.

Assemble and Install Engine

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

NOTE: Before a reconditioned or new service replacement cylinder block is used, steam clean it to remove the rust preventive and blow out the oil galleries with compressed air.

1. Mount the block on the overhaul stand.

2. If a new service replacement block is used, stamp the engine serial number and model number on the upper rear corner of the In-Line block or the top right-hand corner of the V-type block. Also stamp the position numbers on the main bearing caps (Fig. 14) and the position of the No. 1 bearing on the oil pan mounting flange of the block.

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

4. Clean and inspect all of the engine parts and sub-assemblies and, using new parts as required, install them on the cylinder block by reversing the sequence of disassembly. The procedures for inspecting and installing the various parts and sub-assemblies are outlined in the following sections of this manual.

5. Use a chain hoist and suitable sling to transfer the engine to a dynamometer test stand.

6. Install the air box covers and tighten the bolts. On In-Line engines, tighten the bolts to 12-16 lb-ft torque. On 6V engines when 1/4 " thick air box cover clamps are used, tighten the bolts to 8-10 lb-ft torque and when 3/8 " thick clamps are used, tighten the bolts to 10-15 lb-ft torque. On 8V engines, tighten the bolts to 13-17 lb-ft torque.

7. Complete the engine build-up by installing all remaining accessories, fuel lines, electrical connections, controls etc.

8. Operate the engine on a dynamometer, following the RUN-IN procedure outlined in Section 13.2.1.

9. Reinstall the engine in the equipment which it powers.

CYLINDER BLOCK END PLATES

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 must be removed and subsequently reinstalled.

Inspection

When the end plate is removed, it is essential that all of the old gasket material be removed from both surfaces of the end plate and the end plate 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 make sure it is flat. Check the plug nuts in the end plate 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, replace the end plate or plug nuts.

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.

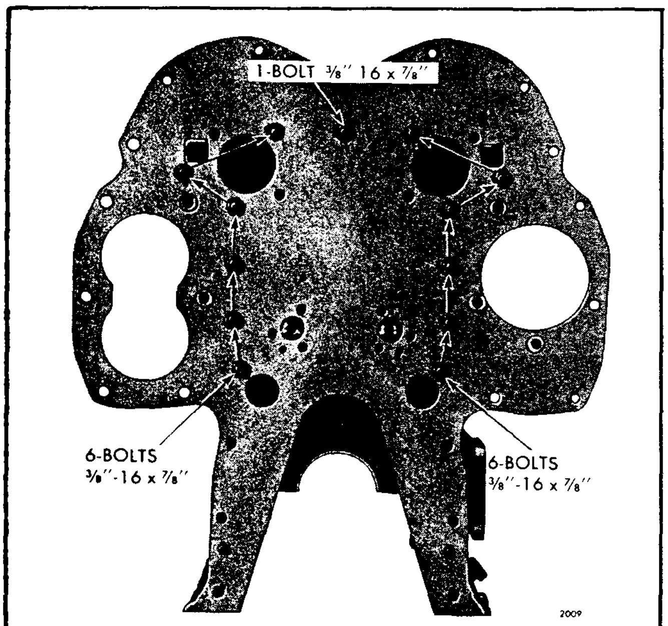


Fig. 1 - Cylinder Block Rear End Plate Mounting (In-Line Engine)

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.

On an 8V engine, a cylinder block to end plate (center) gasket is also used. Affix this gasket to the block over the idler gear hub mounting bolt holes.

> **NOTE:** Remove the perforated sections from the current end plate gasket before installing the gasket on an engine built prior to 6D-6211.

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 of the plug nuts at the top of the end plate on the In-line engine, or the two plug nuts in the side of the end plate on the V-type engine, should always face the forward end of the cylinder block.

3. On In-line engines, refer to Fig. 1 and install the

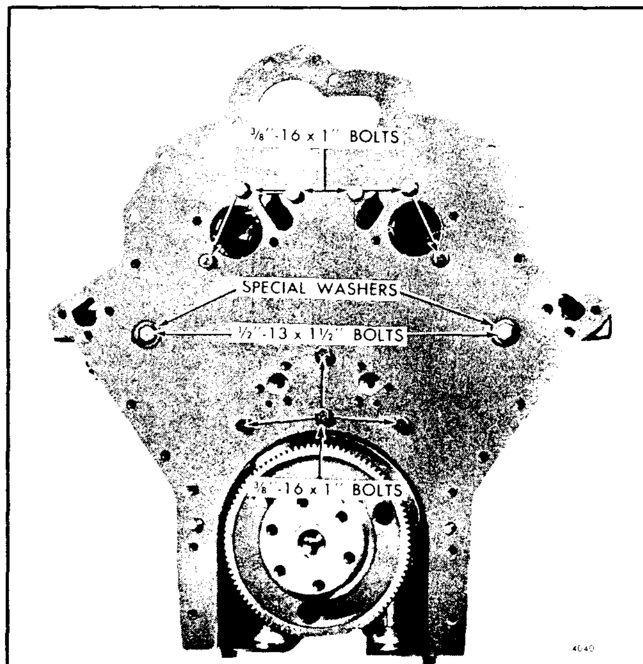


Fig. 2 - Cylinder Block Rear End Plate Mounting (V-Type Engine)

3/8 ″-16 x 7/8 ″ bolts with lock washers. Tighten the bolts to 30-35 lb-ft torque.

NOTE: On In-line engines built prior to engine serial numbers 2D-903, 3D-011 and 4D-103, the top center end plate attaching bolt was 3/8 ″-16 x 3/4 ″. Do not use a longer bolt at this location on engines built prior to the above engine serial numbers.

4. On a V-type engine, refer to Fig. 2 for the location and install the 3/8 ″-16 x 1 ″ bolts with lock washers. Also install the two special washers and two 1/2 ″-13 x 1-1/2 ″ bolts as shown when the fuel pump is driven off the camshaft, or one special washer and bolt when the fuel pump is driven by the accessory gear. Tighten the 3/8 ″-16 bolts to 30-35 lb-ft torque and the 1/2 ″-13 bolts to 71-75 lb-ft torque.

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 air box drain tubes mounted on the sides of the cylinder block.

One drain tube is used on an In-line engine (Fig. 1) and two drain tubes are used on the 6V engines (Fig. 2) at the rear end of the cylinder block.

The 8V marine engines, effective with engine 8D-425, have one short and one long drain tube installed at the right front corner and one drain tube at each rear corner of the cylinder block. Effective with engine 8D-2304, marine engines have an oil drain tube at each corner of the cylinder block.

The 8V vehicle engines effective with 8D-425 have one short and one long drain tube installed at the right front corner and one drain tube at each rear corner of the cylinder block (Fig. 3). Industrial engines effective with 8D-435 have a short and a long drain tube installed at the right front corner and the left rear corner, as well as one drain tube at the left front corner and right rear corner; since they may operate

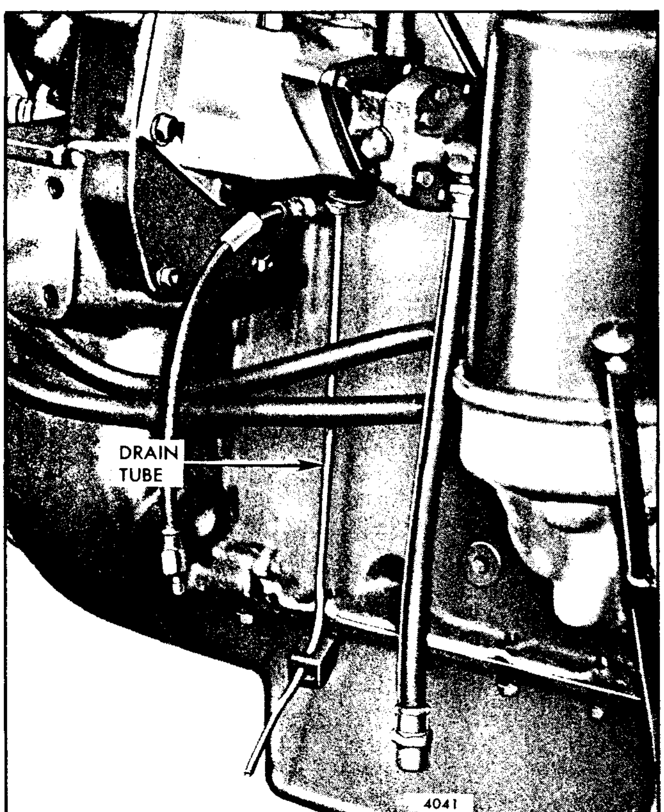


Fig. 1 - Air Box Drain Tube Mounting (In-Line Engines)

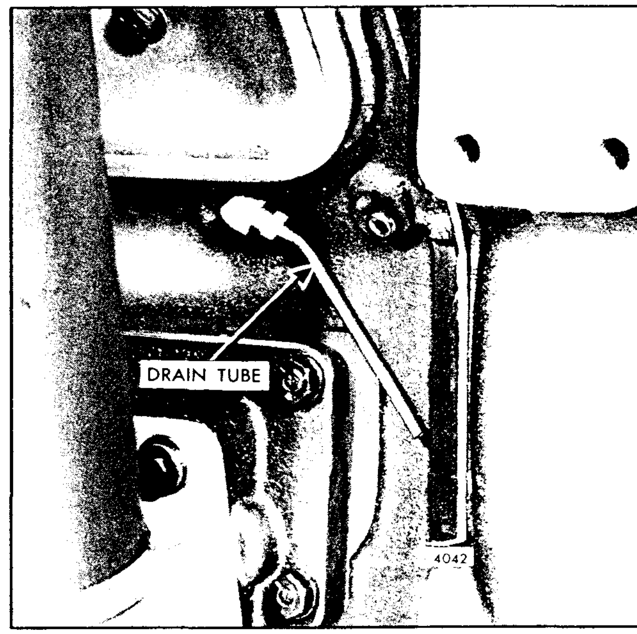


Fig. 2 - Air Box Drain Tube Mounting (6V Engine)

inclined in either direction. It is recommended that the additional drain tubes and fittings be installed on engines built prior to 8D-425.

Inspection

During engine operation, a periodic check is recommended for air flow from the air box drain tubes. A partially plugged air box drain tube may allow air to escape and still cause liquid accumulation within the air box. This liquid accumulation can be seen by removing the cylinder block air box covers.

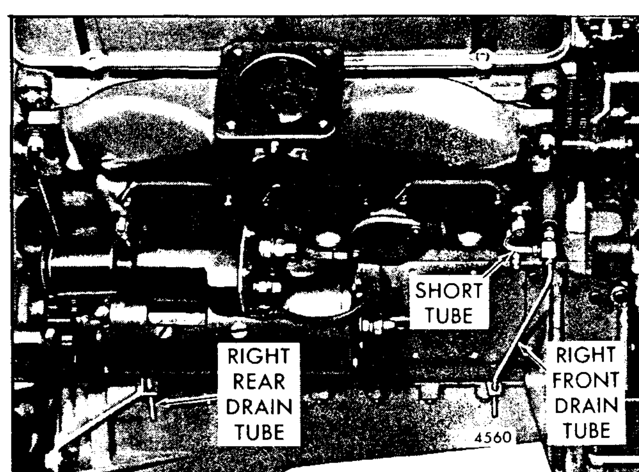


Fig. 3 - Air Box Drain Tube Mounting (8V Engine)

Remove the accumulation with rags or blow out with compressed air. If there is any sign of liquid accumulation or if there is no air flow from the air box drain tubes, remove the tubes and connectors and clean them thoroughly.

CYLINDER HEAD

The cylinder head (Fig. 1) is a one-piece casting. It may be removed from the engine as an assembly containing the 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 a camshaft through cam followers and push rods.

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 very close limits and their freedom from

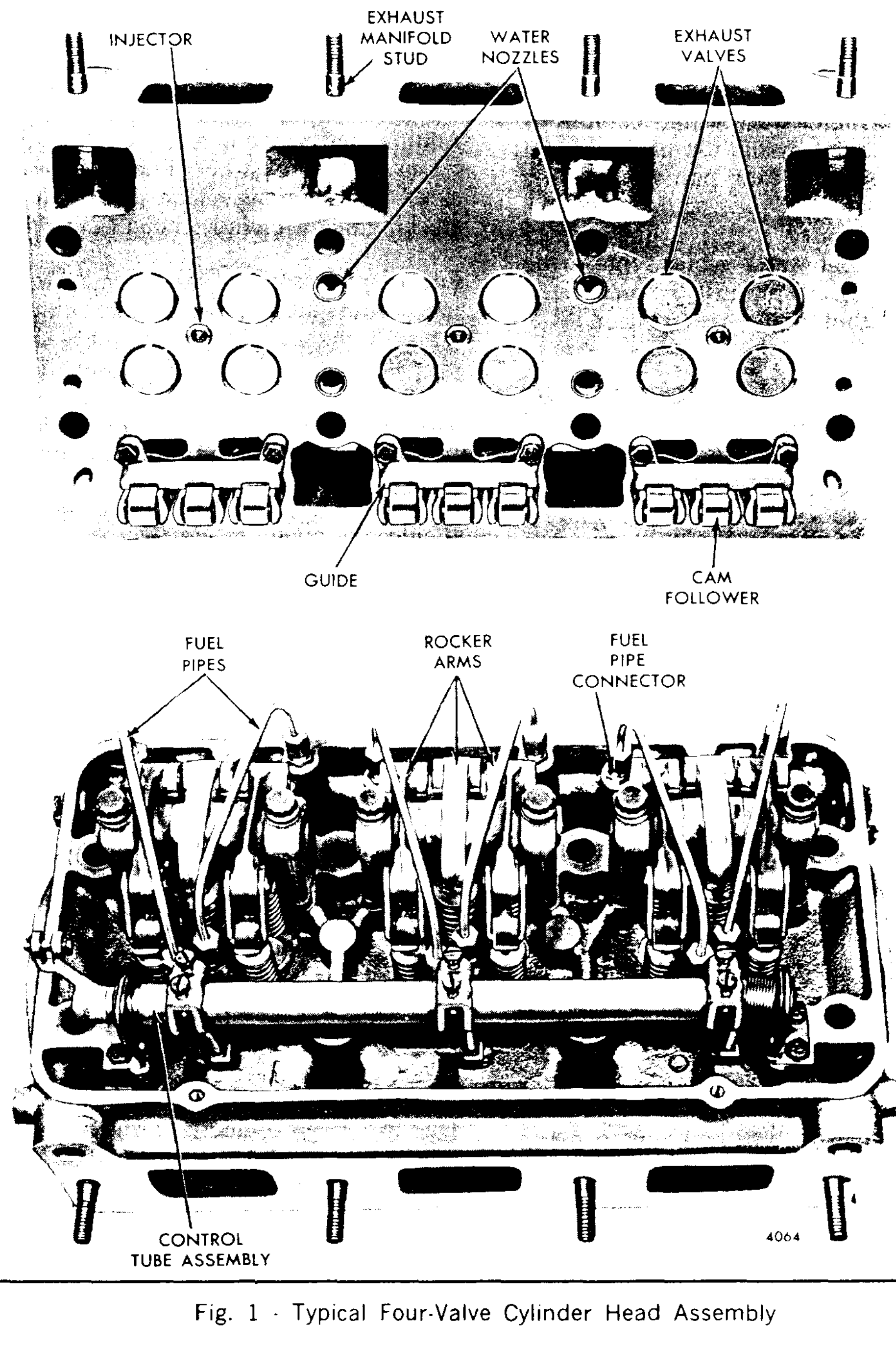


Fig. 1 - Typical Four-Valve Cylinder Head Assembly

warpage, under ordinary conditions, reduces valve reconditioning to a minimum.

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.

The coolant flow pattern is such on two-valve cylinder heads that nozzles are not required.

To seal compression between the cylinder head and the cylinder liner, 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. Reconditioning the exhaust valves and valve seats.
6. Replacing the injector tubes.
7. Installing new cylinder head gaskets.
8. Removing and installing a camshaft.

Cylinder Head Maintenance

Engine temperatures should be maintained between 160° and 185°F. and the cooling system should be inspected daily and kept full at all times.

Unsuitable water in the cooling system may result in lime and scale formation which prevent proper cooling. The 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, a reliable non-corrosive scale remover should be used to remove the deposits from the cooling system of the engine, since a similar condition will exist in the cylinder block and other components of the engine. Refer to Section 13.3 for engine coolant recommendations.

Adding cold water to a hot engine may result in head cracks. Water must be added slowly to a hot engine to avoid rapid cooling which will result in distortion and cracking of the cylinder head (and cylinder block).

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. Refer to Section 2.1.4.

The development of cracks in the cylinder head may be caused by abnormal operating conditions or through neglect of certain maintenance items. If this type of failure should occur, a careful inspection should be made to determine the cause so that a recurrence of the failure will be prevented.

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 head cracks are:

1. Excess fuel in the cylinders due to leaking injectors.
2. Oil pull-over due to an overfilled air cleaner sump, or improper viscosity oil in the air cleaner.
3. Neglected cylinder block air box drains which allow accumulated oil to be drawn into the cylinders.

Remove Cylinder Head

Due to various optional and accessory equipment used on the different engine models, only the general steps for removal of the cylinder head are covered. If the engine is equipped with special accessories that affect cylinder head removal, note the position of each before disconnecting or removing them to assure the correct reinstallation.

1. Disconnect the exhaust piping at the exhaust manifold.

2. Drain the cooling system.

3. Remove the air cleaner(s) or air silencer.

4. Disconnect the fuel lines at the cylinder head.

5. Remove the thermostat housing and the thermostat as an assembly.

6. Clean and 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, remove the fuel pipes and injectors at this time. Refer to Sections 2.1 or 2.1.1 for removal of the injectors.

11. Remove the cylinder head bolts. Then, lift the cylinder head off of the cylinder block, with lifter tool J 22062-01 (Fig. 2).

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 2" thick wood blocks.

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

Disassemble Cylinder Head

If a cylinder head is 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.

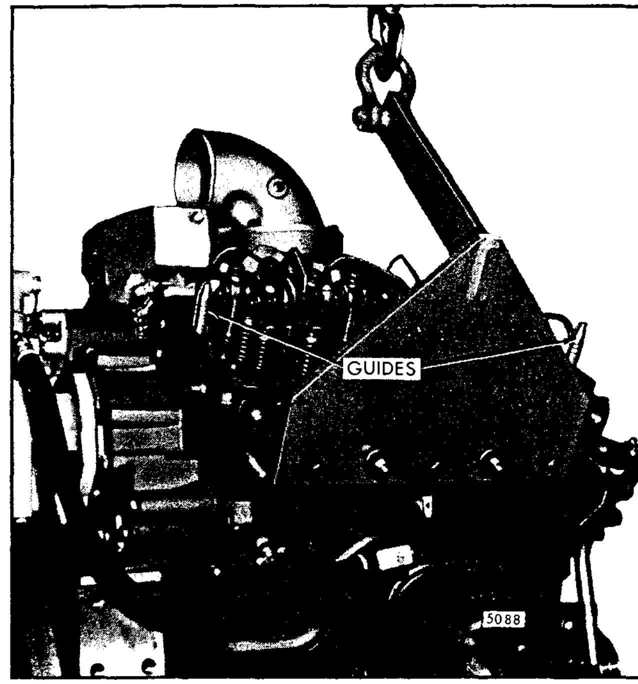


Fig. 2 - Lifting Cylinder Head Assembly Off Cylinder Block with Tool J 22062-01

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

Clean Cylinder Head

After the cylinder head has been stripped of all the component parts and all of the plugs (except cup plugs) have been removed, steam clean the head thoroughly.

Thoroughly clean a new 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 the 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 1/8" brass rod to brush J 8152. After cleaning, dry the cylinder head with compressed air.

Inspect Cylinder Head

1. Check the cylinder head for leaks as follows:

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

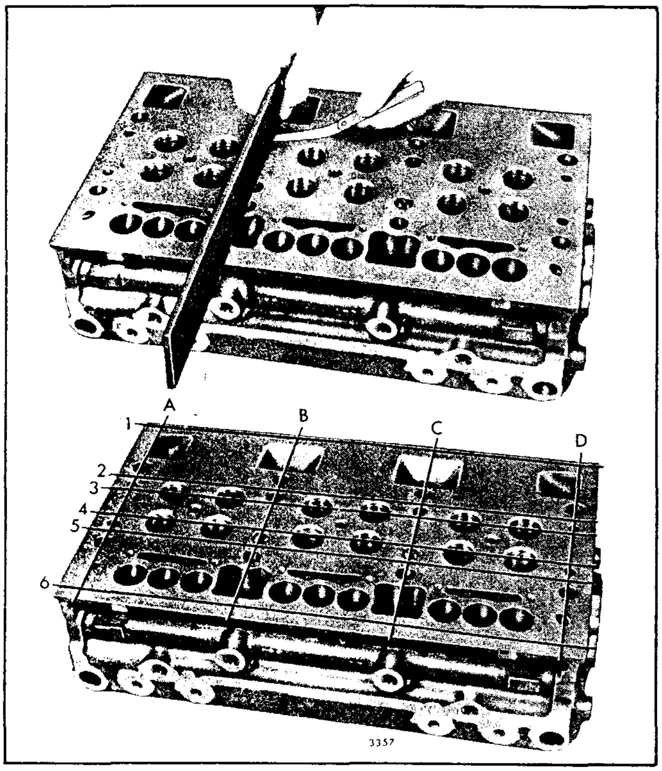


Fig. 3 - Checking Bottom Face of Cylinder Head for Warpage

b. Install dummy or scrap injectors to ensure seating of the injector tubes. Dummy injectors may be made from old injector nuts and bodies - the injector spray tips are not necessary. Tighten the injector clamp bolts 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. Remove the cylinder head from the tank and dry it with compressed air.

e. If inspection revealed cracks, replace the cylinder head.

f. Replace any leaking injector tubes as outlined in Section 2.1.4.

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.

2. Check the bottom (fire deck) of the cylinder head for flatness as follows:

a. Use an accurate straightedge and feeler gage J 3172 to check for transverse warpage at each end and between all of the cylinders. Also, check for longitudinal warpage in six places as shown in Fig. 3. Maximum allowable warpage is given in the following chart:

Engine	Maximum Longitudinal Warpage	Maximum Transverse Warpage
2-53	.004"	.004"
3-53 & 6V-53	.005"	.004"
4-53 & 8V-53	.006"	.004"

b. 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.

c. If the cylinder head is to be refaced, remove the injector tubes prior to machining. Not over .020" of metal should be removed from the fire deck of the cylinder head. The distance from the top to the bottom (fire deck) of the cylinder head must not be less than 4.376", as shown in (Fig. 4). Stamp the amount of stock removed on the face of the fire deck near the outer edge of the head, in an area not used as a sealing surface.

d. After a cylinder head has been refaced and new injector tubes have been installed as outlined in Section 2.1.4, pressure check the cylinder head as outlined in Step 1.

3. Inspect the cam follower bores in the cylinder head for scoring or wear. Light score marks may be cleaned

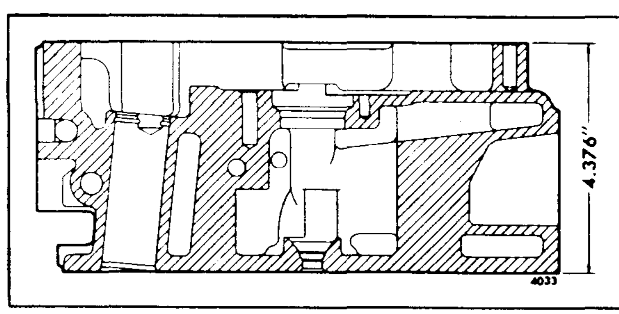


Fig. 4 - Minimum Distance Between Top and Bottom Faces of Cylinder Head

up with crocus cloth wet with fuel oil. If the bores are excessively scored or worn so that the cam follower-to-head clearance exceeds .006", replace the cylinder head.

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

5. Check the water nozzles in a four-valve cylinder head to be sure they are not loose. Water nozzles are used only in the passages between the cylinders. If necessary, install or replace the water nozzles as follows:

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 5/8" diameter drill. Break the edges of the holes slightly.

b. 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 in place with the outlet holes positioned as shown in Fig. 5. The angle between the outlet holes in the nozzle is 90°. Press the nozzles from flush to 1/32" below the bottom surface of the cylinder head.

6. Inspect the parts removed from the cylinder head before they are reinstalled in the old head or transferred to a new cylinder head.

Assemble Cylinder Head

New service cylinder heads include valve guides, valve seat inserts, water nozzles, injector tubes 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 the excess with a clean, lint-free cloth so that the sealant will not be washed into the fuel system and result in damage to the injectors.

When a new cylinder head is to be used, remove the parts listed below from the old head and install them in the new head. If the old cylinder head is to be reused, install the parts in the old head prior to assembling the head on the cylinder block.

1. Exhaust manifold studs.

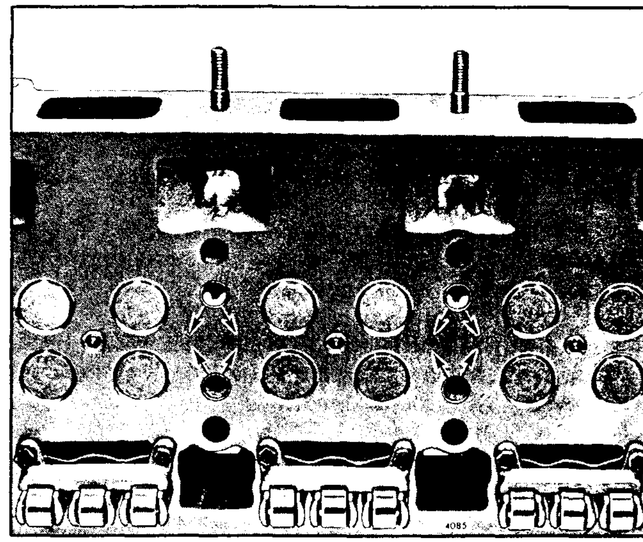


Fig. 5 - Correct Installation of Water Nozzles in Four-Valve Cylinder Head

2. Exhaust valves and springs (Section 1.2.2).

3. Install the fuel injectors at this time or after installing the cylinder head (Sections 2.1 or 2.1.1).

4. Cam followers, cam follower guides, push rod assemblies, rocker arm shafts and rocker arms; do not tighten the rocker arm bracket bolts at this time (Section 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

Perform the following inspections just prior to installing the cylinder head on the engine.

1. Check the cylinder liner flange height 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 into the 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. 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. Place a new compression gasket on each cylinder liner.

b. 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 in the cylinder block near the outer edge of the area covered by the cylinder head.

NOTE: Used water seals, oil seals and compression gaskets should *never* be used.

2. To install the cylinder head on the engine without disturbing the gaskets and seals, use guide stud set J 9665. Install the guide studs in the end cylinder block bolt holes (Fig. 2).

3. Make a final visual check of all of 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.

4. Wipe the bottom of the cylinder head clean; then, lower the head on the block.

5. Lubricate the threads and the underside of each cylinder head bolt with a small quantity of International Compound No. 2, or equivalent. Then, install the bolts. On the In-line engines equipped with both six and twelve point cylinder head bolts, the twelve point bolts must be installed on the camshaft side of the head to eliminate possible interference between the governor control link and the cylinder head bolt.

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

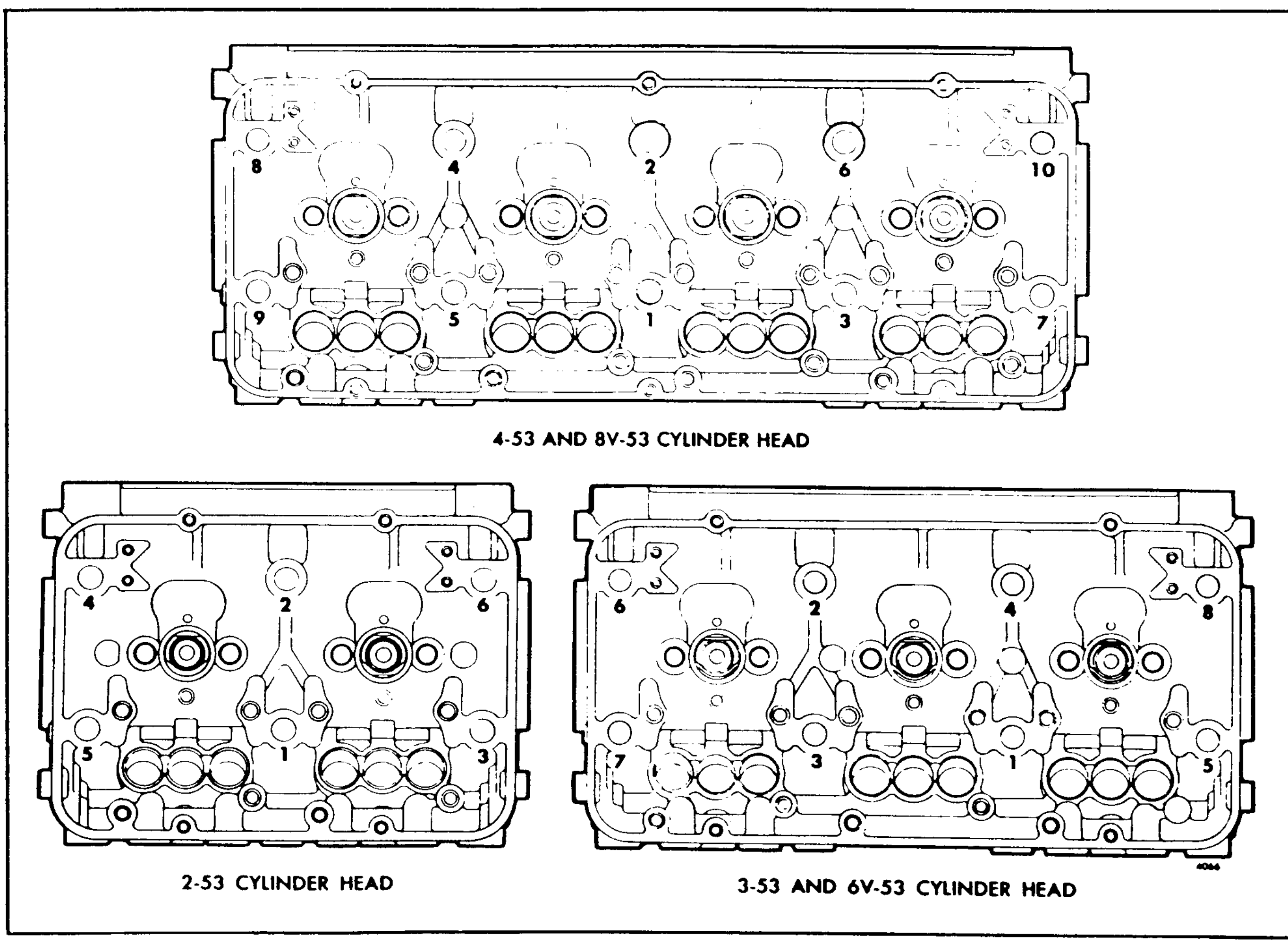


Fig. 6 - Sequence for Tightening Cylinder Head Bolts

6. The cylinder head must be gradually and uniformly drawn down against the gaskets and seals to ensure a good seal between the cylinder head and the block. Therefore, it is vitally important that the cylinder head be installed with the utmost care.

7. 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 Fig. 6. Under no circumstances should the torque exceed the specified limits, otherwise the bolts may become stretched beyond their elastic limits.

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

9. If the injectors were not previously installed, refer to Section 2.1 or 2.1.1 and install them at this time.

10. Tighten the rocker arm bracket bolts to 50-55 lb-ft torque.

CAUTION: There is a possibility of damaging the exhaust valves if the exhaust valve bridge is not resting on the ends of the exhaust valves when tightening the rocker arm bracket bolts. Therefore, note the position of the exhaust valve bridge before, during and after tightening the bolts.

11. Align the fuel pipes and connect them to the injectors and the fuel connectors. Use socket J 8932-01 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 ends of the fuel pipes and result in leaks. Lubricating oil diluted by fuel oil can cause serious damage to the engine bearings.

12. Set the injector control tube assembly in place on the cylinder head and tighten the bolts, finger tight only. When positioning the injector control tube, be sure that the ball end of each injector rack control lever engages the slot in the corresponding injector control rack. With one end of the control tube return spring hooked around an injector rack control lever and the other end hooked around a control tube bracket, tighten the bracket bolts to 10-12 lb-ft torque.

13. After tightening the bolts, revolve the 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.

14. Install the fuel rod and the fuel rod cover (if used).

15. Remove the covers from the drain holes in the head.

16. Install the exhaust manifold and connect the exhaust piping.

17. Install the thermostat housing and the thermostat.

18. Install the air cleaners.

19. Connect the fuel lines.

20. Fill the cooling system and check for leaks.

21. With the throttle in the OFF position, crank the engine over to be sure that all of the parts function freely.

22. Before starting the engine, perform an engine tune-up as outlined in Section 14.

23. Refer to Section 13.1 and start the engine. After starting the engine, check all fuel line connections to ensure that no fuel oil leaks into the cylinder head compartment to dilute the lubricating oil.

24. After the engine has been warmed up (to at least 160°F.), recheck the torque on the cylinder head bolts.

25. Recheck the exhaust valve clearance and the injector timing after the engine reaches normal operating temperature.

26. Examine all fuel oil, lubricating oil and water connections for possible leaks. Tighten the connections, if necessary.

27. Install the valve rocker cover, using a new gasket.

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 rocker arm assemblies pivots on a 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).

Each cam follower operates in a bore in the cylinder head. 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 coil spring, located inside of 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 removal of the cylinder head are:

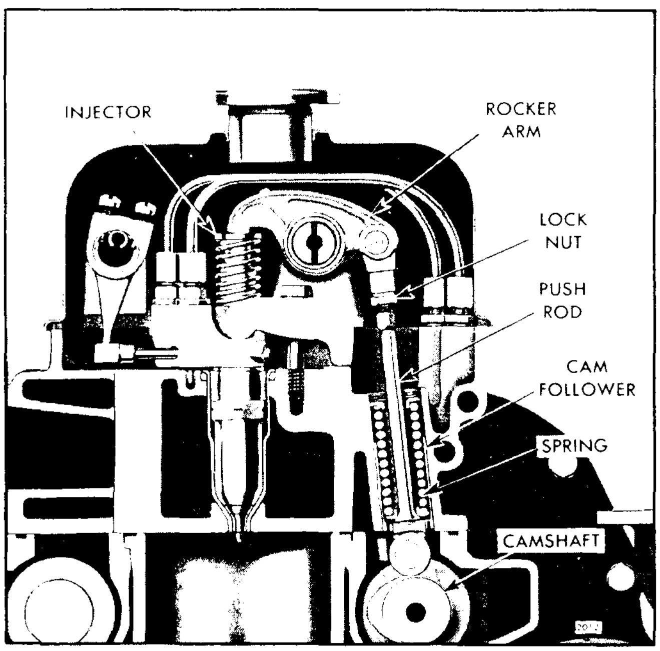


Fig. 1 - Injector Operating Mechanism (In-Line Engine Shown)

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.

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

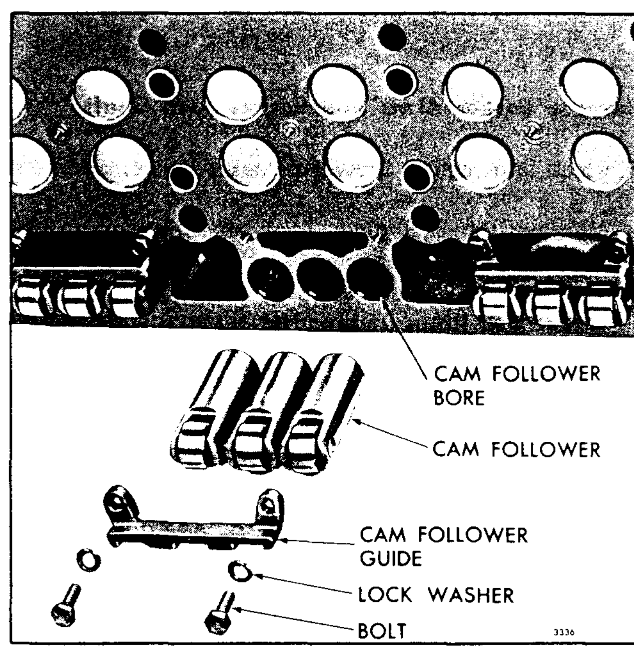


Fig. 2 - Cam Follower and Guide Location

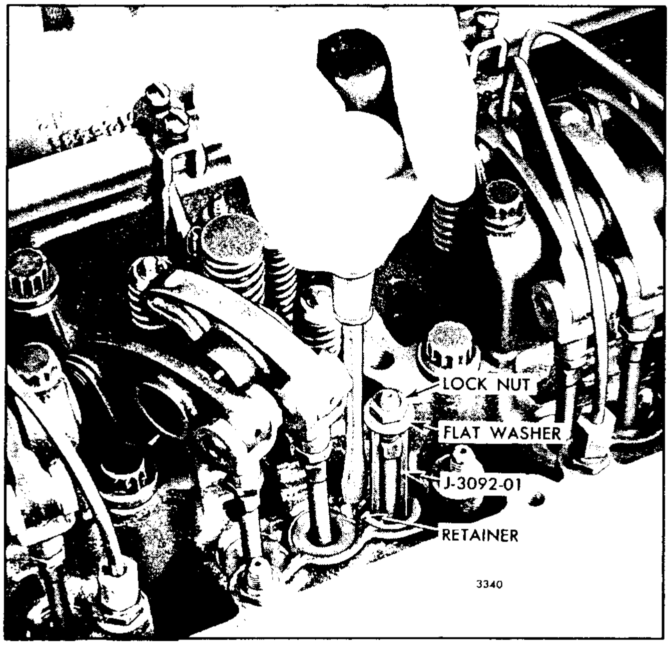


Fig. 3 · Removing Push Rod from Upper Side of Cylinder Head with Tool J 3092-01

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 directed against the cam follower rollers.

Remove Rocker Arms and Rocker Arm Shaft

1. Clean and remove the valve rocker cover.

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

> **CAUTION:** Immediately after removing the fuel pipes, cover each injector opening with a shipping cap to prevent dirt or other foreign matter from entering the injector.

3. Bar the engine over in the direction of engine rotation or crank the engine with the starting motor to bring the push rod ends -- the outer ends -- of the injector and valve rocker arms in line horizontally.

> **CAUTION:** Left-hand turning engines should not be barred in the direction of rotation by use of a wrench on the crankshaft bolt, to avoid the possibility of loosening the bolt.

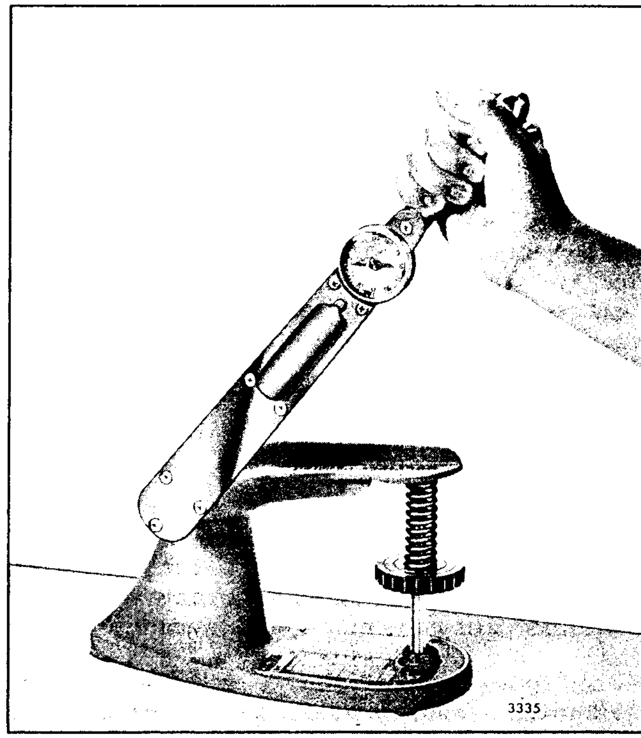


Fig. 4 · Testing Push Rod Spring

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

5. 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.

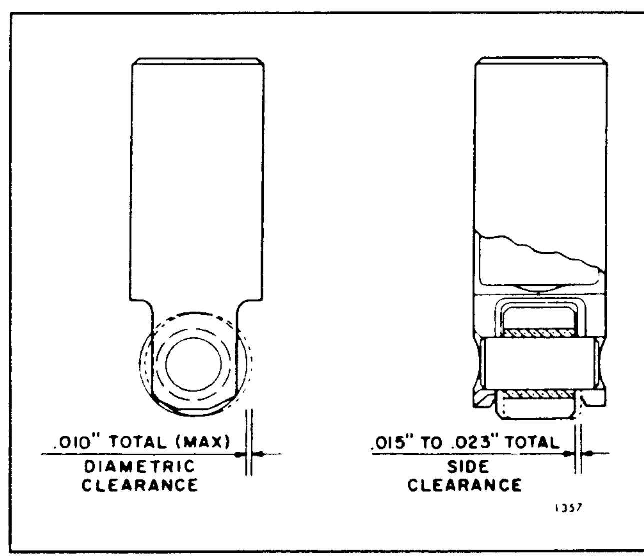


Fig. 5 · Cam Roller Wear and Clearance Diagram

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 of the 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 (four valve cylinder heads).

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

With the cylinder head removed from the engine, remove the cam followers as follows:

1. 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.

2. Pull the cam followers from the bottom of the cylinder head.

3. Remove the fuel pipes from the injector and the fuel connectors.

4. Loosen the lock nuts at the upper end of the push rods and unscrew the push rods from the rocker arm clevises.

5. Pull the push rod and spring assemblies from the bottom of the cylinder head.

6. 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.

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 Fig. 3.

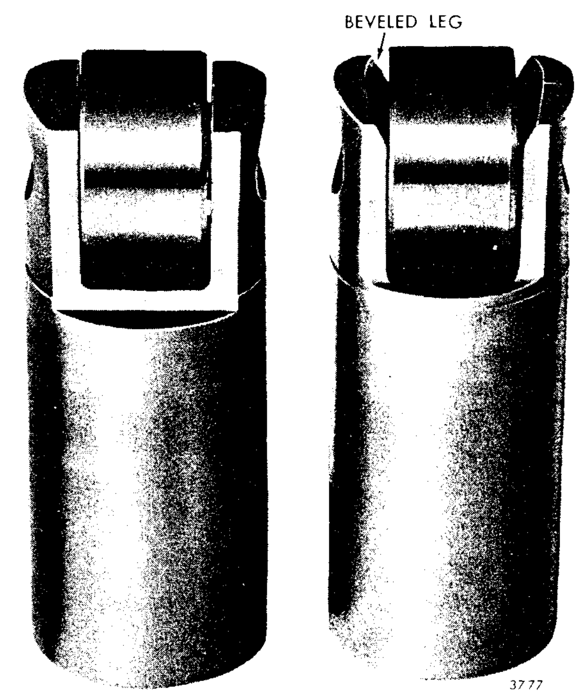


Fig. 6 - Former and Current Cam Followers

1. Clean and remove the valve rocker cover.

2. Remove the fuel pipes 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, a 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 Fig. 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.

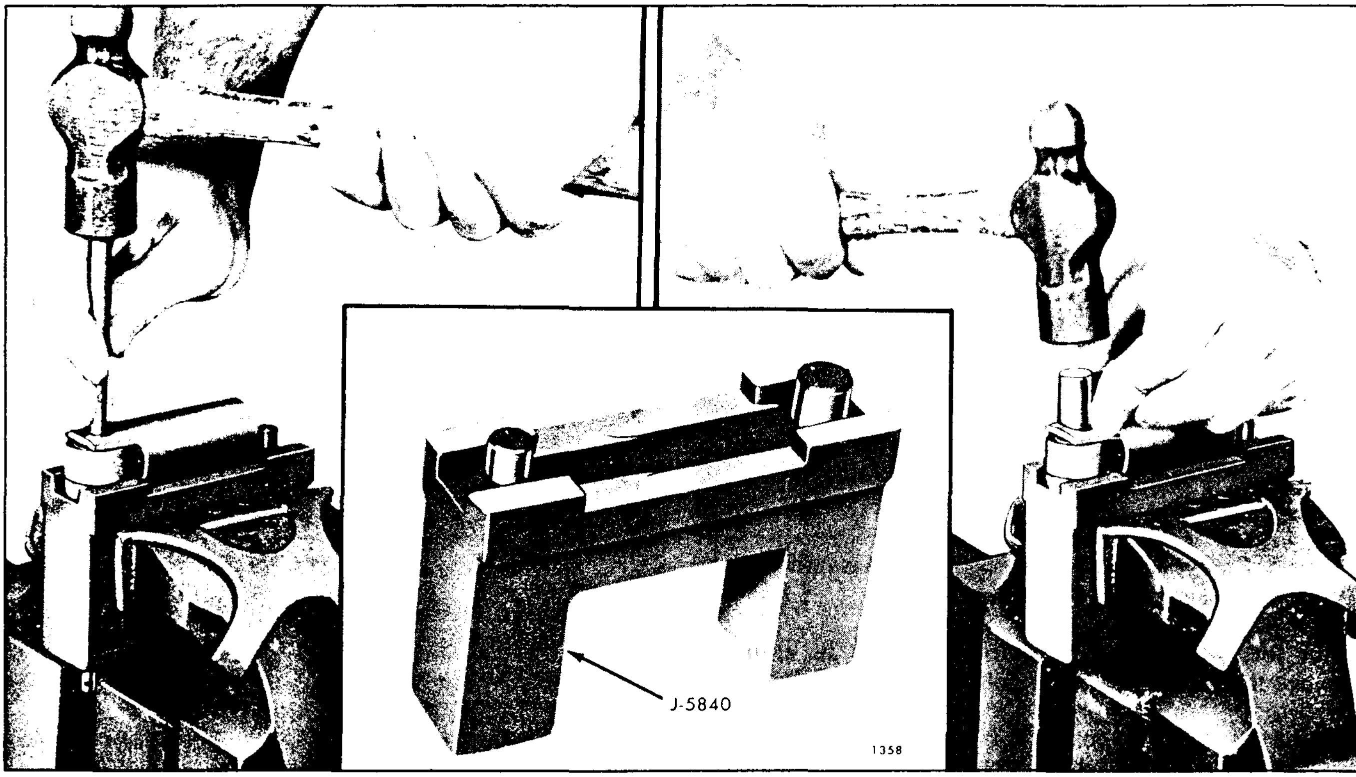


Fig. 7 - Removing or Installing Cam Follower Roller and Pin with Tool J 5840

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 inspected 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 are removed, wash them with lubricating oil or Cindol 1705 and wipe dry. *Do not use fuel oil.* Fuel oil working its way in between the roller and bushing may cause scoring on the initial engine start-up since fuel oil does not provide adequate lubrication. Wash only the cam follower associated parts 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 roller on the camshaft lobe at all times. Check the push rod spring load whenever the cam followers and related parts are removed for inspection.

The current push rod spring is made from .192 " diameter wire and was first used only in the injector cam follower position, effective with engines 2D-13453, 3D-3792, 4D-5323 and 6D-1077.

Effective with engines 2D-14188, 3D-6128, 4D-8549 and 6D-2709, the new spring is also used in the exhaust valve cam follower position. The former push rod spring was made from .177 " diameter wire.

Use spring tester J 9666 and an accurate torque wrench to check the push rod spring load (Fig. 4). Replace the current type spring when a load of less than 250 pounds will compress it to a length of 2-9/64 ". Replace the former type spring when a load of less than 172 pounds will compress it to a length of 2-1/8 ".

It is recommended that if one former type push rod spring requires replacement, all of the former type springs in either the injector or valve cam follower positions be replaced by the current type spring. A new design upper spring seat is required with the use of the current push rod spring.

Examine the cam follower bores in the cylinder head

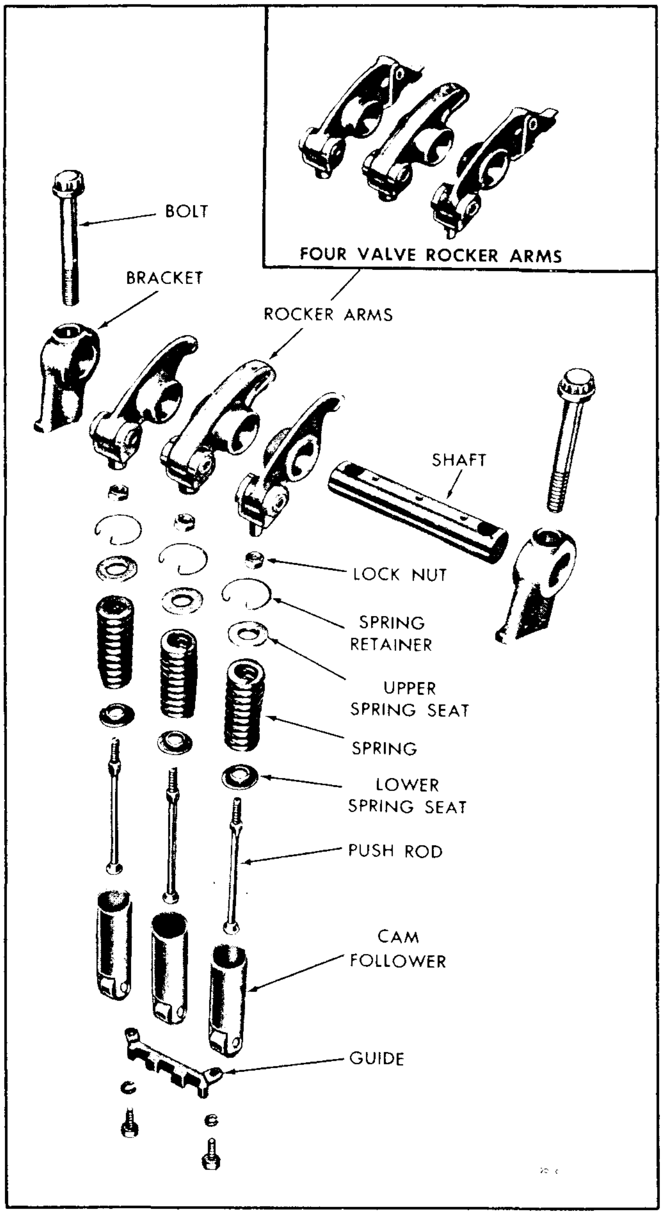


Fig. 8 - Valve and Injector Operating Mechanism Details and Relative Location of Parts

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. If replacement of a cam follower is necessary, use the correct type service cam follower to be assured that the cam roller will receive the proper lubrication.

The cam follower roller must turn smoothly and freely

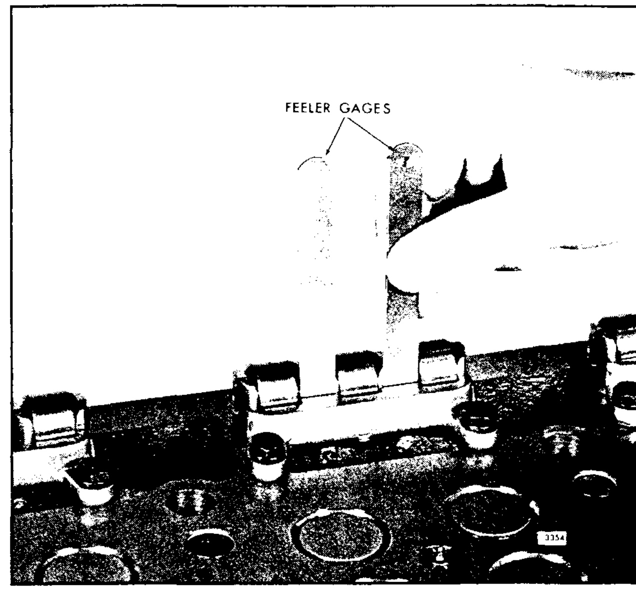


Fig. 9 - Checking the Clearance Between the Cam Follower Guide and Cam Follower Legs

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 camshaft.

Measure the total clearance between the roller bushing and pin, crosswise of the pin, as shown in Fig. 5 and, if the bushing is worn to the extent that more than

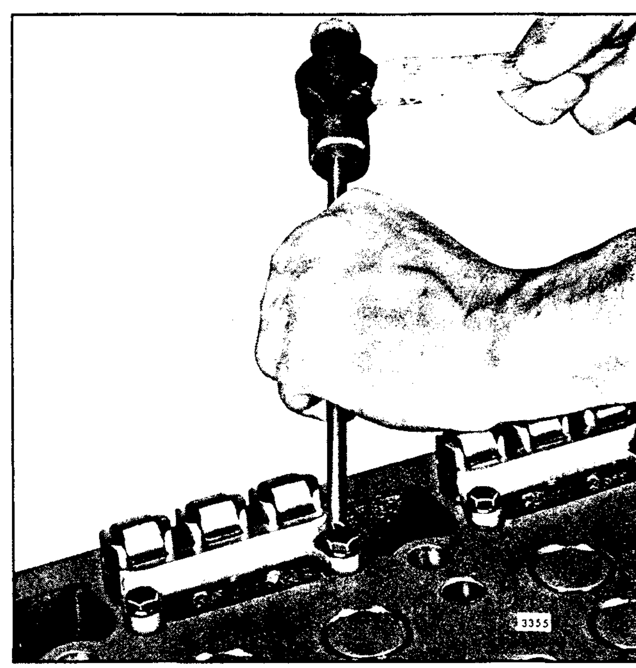


Fig. 10 - Adjusting Cam Follower Guide

.010 " diametric clearance exists, replace the cam follower assembly or install a new cam roller and pin, which are serviced as a set. Be sure the follower legs are beveled (Fig. 6) and check the total side clearance between the roller and follower; this clearance must not be less than .015 " nor more than .023 ".

Oversize roller and pin sets are available for service when required. However, DO NOT attempt to bore out the legs of a standard cam follower for an oversize roller and pin set. This cannot be over emphasized because of the extremely close manufacturing tolerances.

> **NOTE:** Cam follower assemblies with the letter "S" stamped on the end of the roller, pin and on one leg of the cam follower body are equipped with oversize roller and pin sets.

Remove and Install Cam Follower Roller and Pin

1. Clamp fixture J 5840 securely in a vise as shown in Fig. 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. Drive the pin from the roller with a suitable drift. 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. Before installing the new roller and pin kit, remove the preservative by washing the parts with clean lubricating oil or Cindol 1705. *Do not use fuel oil.*

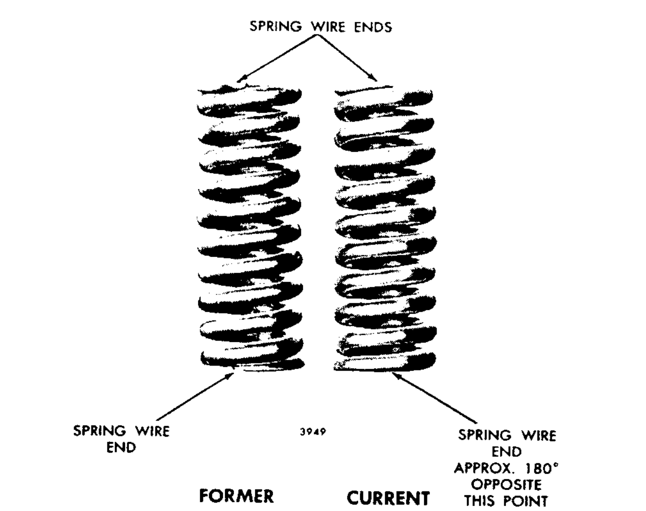


Fig. 11 - Push Rod Spring Identification

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

5. 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.

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. If the engine being assembled was equipped with plain lower spring seats, replace them with serrated spring seats (Fig. 8).

2. Place the push rod springs (Fig. 11) on the push rods.

3. Install the proper upper spring seat on each push rod. The cup shaped spring seat used with the current type push rod spring may also be used with the former spring.

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 cam follower bore from the bottom of the cylinder head.

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 clean 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 the roller bushings. Rotate the cam follower roller during the soaking period to aid in purging any air from the bushing-roller area. The heated Cindol 1705 results in better penetration as it is less viscous than engine oil and flows more easily between the pin and roller bushing surfaces. After the cam follower is removed from the Cindol 1705, the cooling action of any trapped air in the pin and bushing area tends to pull the oil into the cavity.

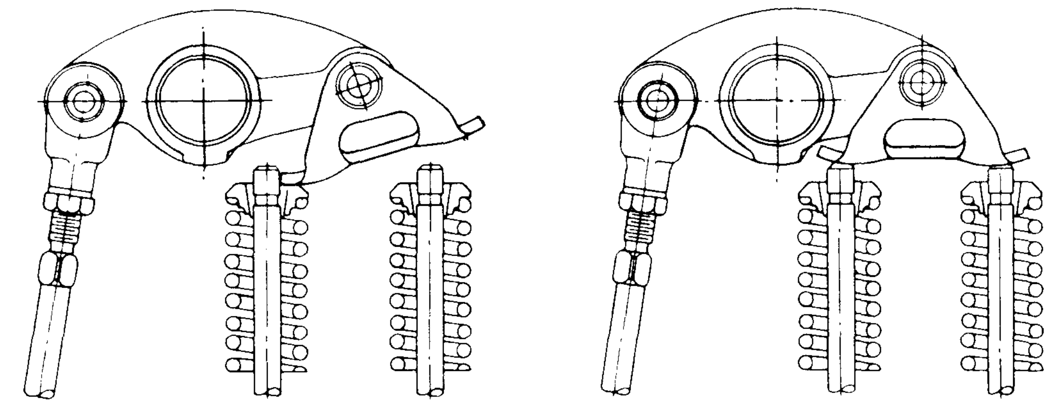


Fig. 12 - Relationship Between Exhaust Valve Bridge and Valve Stems

NOTE: 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.

IMPORTANT: When installing a new cam follower assembly, wash it with clean lubricating oil or Cindol 1705 to remove the preservative.

7. Note the oil hole in the bottom of the cam follower. With this oil hole pointing away from the exhaust 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. 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.

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

1. Lubricate the cam follower as stated in Step 6 under *Install Cam Follower and Push Rod Assembly (Cylinder Head Removed from Engine).*

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. If the engine being assembled was equipped with plain lower spring seats, replace them with serrated spring seats.

4. Place the push rod springs (Fig. 11) on the push rods.

5. Install the proper upper spring seat on each push rod. The cup shaped spring seat used with the current type push rod spring may also be used with the former spring.

6. Set the push rod, lower spring seat, spring and upper spring seat down in the cam follower.

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. Partially collapse the retainer and install it in the cylinder head groove.

8. Remove the nut, flat washer and tool 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: 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 valve bridges are not resting on the ends of the 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.

> **CAUTION:** Do not bend the fuel pipes and do not exceed the specified torque. Excessive tightening 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 Section 14.1 and 14.2 before starting the engine.

7. Start the engine and check for leaks in the fuel, cooling and lubrication systems.

8. Tune-up the engine, as outlined in Section 14, after the engine reaches normal operating temperature.

EXHAUST VALVES

Either two or four exhaust valves are provided for each cylinder, depending upon the engine model (Fig. 1). The valve heads are heat treated and ground to the proper seat angle and diameter. The valve stems are ground to size and hardened at the end which contacts the rocker arm or the exhaust valve bridge.

The exhaust valve stems are contained within exhaust valve guides which are pressed into the cylinder head. Exhaust valve seat inserts, pressed into the cylinder head, permit accurate seating of the exhaust valves under varying conditions of temperature and materially prolong the life of the cylinder head. The exhaust valves and exhaust valve seat inserts 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. The valves are cooled by the flow of air from the blower past the valves each time the air inlet ports are uncovered.

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 the correct valve clearance (Section 14.1) must be maintained.

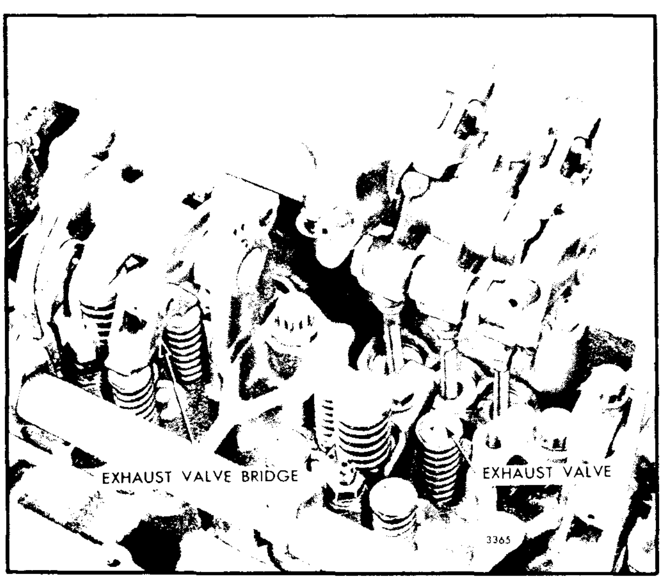


Fig. 1 - Location of Exhaust Valves

Proper maintenance and operation of the engine is important to long valve life. Engine operating temperatures should be maintained between 160 °F. and 185 °F. 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 sludge.

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, 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 should be changed periodically to avoid 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 antifreeze (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 be accurately adjusted and checked 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.

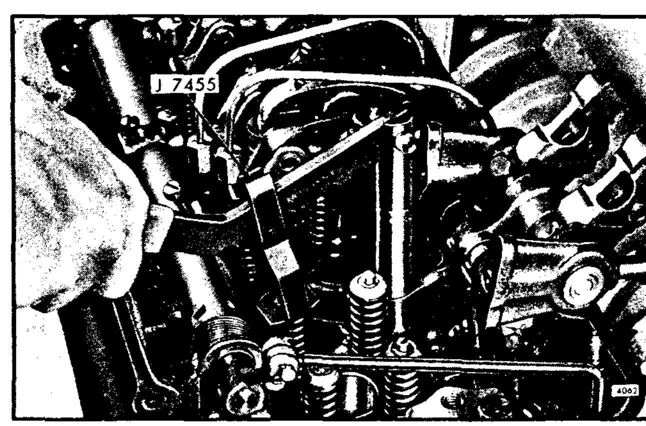


Fig. 2 - Removing Valve Spring

The cylinder head must first be removed before the exhaust valves, valve seat inserts or valve guides can be removed for replacement or reconditioning. However, the valve springs may be replaced without removing the cylinder head.

Remove Exhaust Valve Spring (Cylinder Head Installed)

An exhaust valve spring may be removed, without removing the cylinder head from the engine, as follows:

1. Clean and 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 pipes from the injector and the fuel connectors.

> **CAUTION:** Immediately after removing the fuel pipes, cover each injector opening with a shipping cap to prevent dirt or other foreign matter from entering the injector.

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

5. Remove the cylinder block air box cover so that the

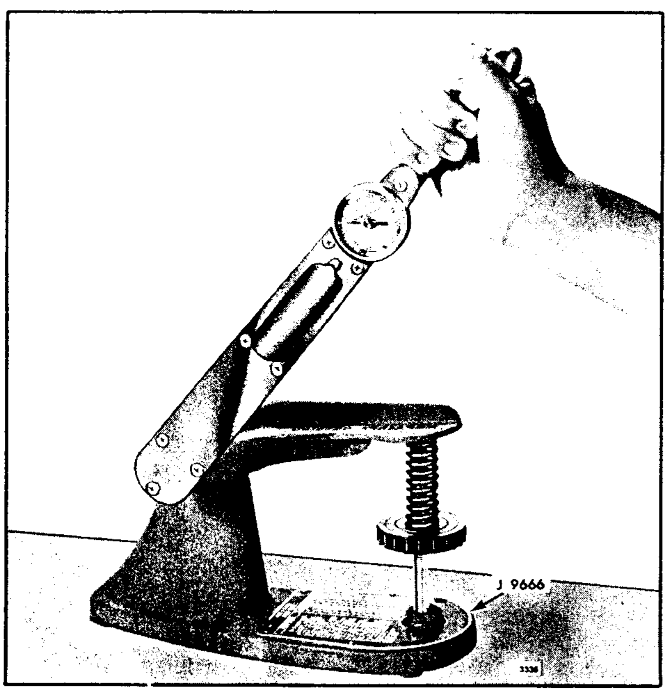


Fig. 3 - Testing Valve Spring

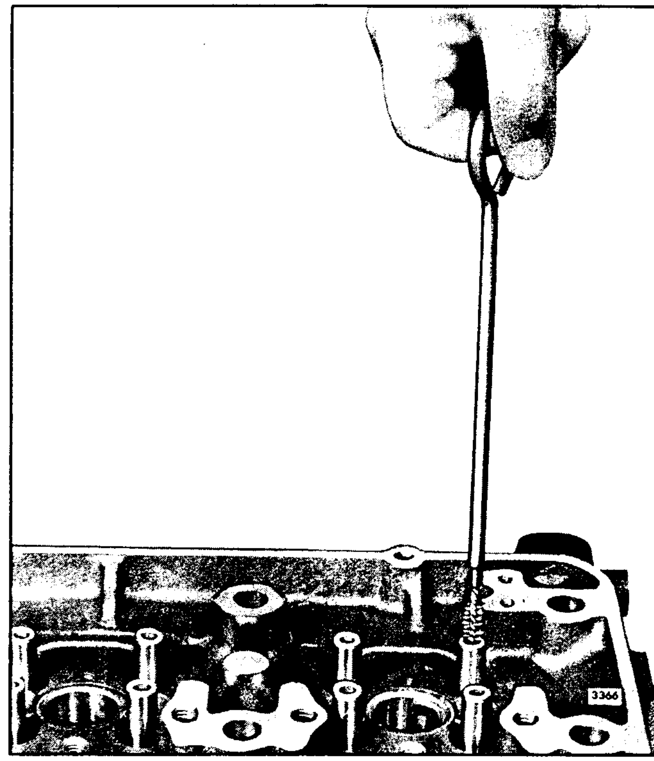


Fig. 4 - Cleaning Valve Guide

piston travel may be observed, then turn the crankshaft until the piston is at the top of its stroke.

6. Thread the spring compressor tool into one of the rocker arm support 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.

Remove Exhaust Valves and Valve Springs (Cylinder Head Removed)

With the cylinder head removed from the engine, remove the exhaust valves and springs as follows:

1. Support the cylinder head on 2 " thick wood blocks to keep the cam followers clear of the bench.

2. Disconnect and remove the fuel pipes from the injectors and the fuel connectors.

> **CAUTION:** Immediately after removing the fuel pipes, cover each injector opening with a shipping cap to prevent dirt or other foreign matter from entering the injector.

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 valves. Remove the exhaust valve springs as outlined in Steps 6 and 7 above.

6. Turn the cylinder head over, using care to keep the valves from falling out of the head. If the valves are to be reused, number each valve to facilitate re-installation in the same position. Then withdraw the valves from the cylinder head.

7. Remove the cam followers and push rod assemblies as outlined in Section 1.2.1 under *Remove Cam Follower and Push Rod Assembly (Cylinder Head Removed from Engine).*

Inspection

Clean the springs with fuel oil, dry them with compressed air and inspect them. Replace a pitted or fractured spring.

Check the springs with spring tester J 9666 and an accurate torque wrench. Replace a spring if a load of less than 33 pounds will compress a two valve cylinder head spring to 2.31 inches, or a load of less than 25 pounds will compress a four valve cylinder head spring to 1.93 inches. The difference in the load between a pair of four valve cylinder head springs must not exceed 6 pounds or the valve bridge will be unbalanced.

To eliminate exhaust valve spring surge, a new valve spring is used in the 6V-53 vehicle engines where the maximum speed rating has been increased from 2600 rpm to 2800 rpm. It is also used in the 6V-53 non-turbocharged engines. The change is effective with approximate engine serial number 6D-82217.

The new spring can be used only in engines built after engine serial number 6D-60776 that employ the present low lift camshaft, or older engines which have these camshafts installed.

> **NOTE:** The low lift camshaft which provides a maximum valve cam lobe lift of .276 " is stamped V7L at both ends.

> **CAUTION:** The use of the new spring with the former high-lift camshaft (.327 " valve cam lobe lift, stamped V7 or V at both ends) will cause the valve springs to bottom out, resulting in bent push rods and possible engine damage.

The new exhaust valve spring has a wire diameter of .148 "; the former exhaust valve spring has a wire diameter of .135 ".

For service replacement, change the new spring when a load of less than 25 lbs. will compress it to 1.93 " (installed length).

The new and former valve springs are interchangeable in an engine rated below 2800 rpm using a low-lift (V7L) camshaft. However, on any given valve bridge, it is recommended that both springs be the same.

When a former spring is replaced in an engine rated at 2800 rpm with a low lift (V7L) camshaft, all of the springs must be replaced with the new spring.

Inspect the valve spring seats and caps for wear. If worn, replace with new parts.

Carbon on the face of a valve indicates blow-by due to a faulty seat. Black carbon deposits extending from the valve seats to the valve guides may result from cold operation due to light loads or the use of too light a grade of fuel. Rusty brown valve heads with carbon deposits forming narrow collars near the valve guides is evidence of high operating temperatures. High operating temperatures are normally due to overloads, inadequate cooling, or improper timing which results in carbonization of the lubricating oil.

Clean the carbon from the valve stems and wash the valves with fuel oil. The valve stems must be free from scratches or scuff marks and the valve faces must be free from ridges, cracks or pitting. If necessary, reface the valves or install new valves. If the valve heads are warped, replace the valves.

If there is evidence of engine oil running down the exhaust valve stem into the exhaust chamber, creating a high oil consumption condition because of excessive idling and resultant low engine exhaust back pressure, replace the valve guide oil seals or, if not previously used, install valve guide oil seals.

Clean the inside diameter of the valve guides with brush J 5437 (two valve head) or brush J 7793 (four valve head) as shown in Fig. 4. This brush will remove all gum and carbon deposits from the valve guides.

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 .006 " (two valve head) or .005 " (four valve head), replace the valve guides.

The current valve guides, which are not machined for use with oil seals, have a 45 ° chamfer at the upper end. They replace the former 15 ° chamfer valve guides for service.

Remove Exhaust Valve Guide

1. Support the cylinder head, bottom side up, on 3 ″ thick wood blocks.

2. Drive the valve guide out of the cylinder head with valve guide remover J 6569 (two valve head) or J 7775 (four valve head) as shown in Fig. 5.

Install Exhaust Valve Guide

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

1. Insert the internally threaded end of the valve guide in the proper valve guide installing tool (refer to the *Valve Guide Installing Tool* 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 press the installing tool gently to start the guide in place (Fig. 6). Then press the guide in until the tool contacts the cylinder head (the bottom of the counterbore in the four valve cylinder head).

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

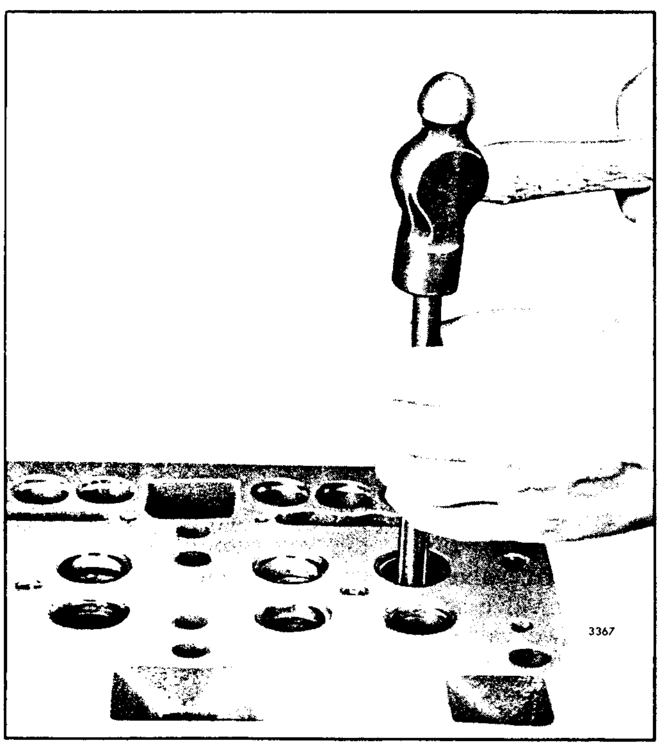


Fig. 5 - Removing Valve Guide

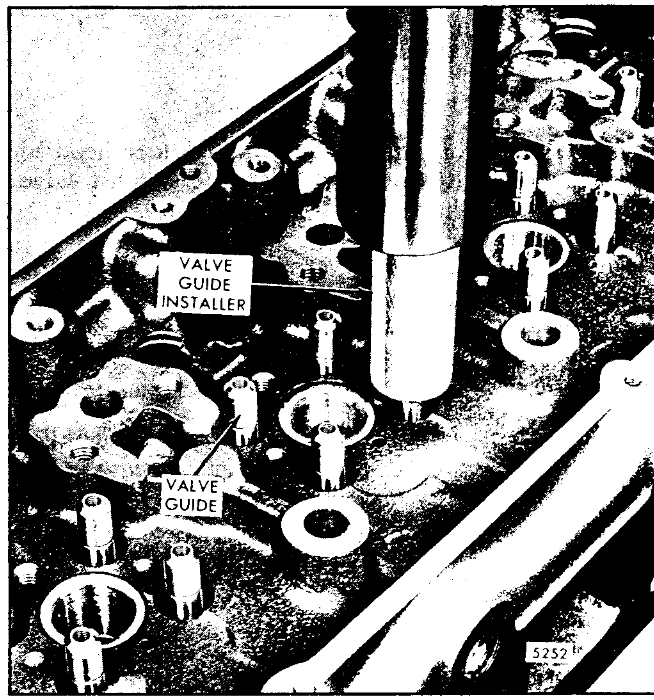


Fig. 6 - Installing Valve Guide

Tool No.	Cyl. Head	Valve Guide	Distance of Guide Below Top of Head
J 7560	2 Valve	15° Chamfer	.010"-.040"
J 7832	4 Valve	15° Chamfer	.010"-.040"
J 9756	2 Valve	45° Chamfer	.010"-.040"
J 9729	4 Valve	45° Chamfer	.010"-.040"
J 9730	4 Valve	*	.190"-.220"

*Machined for use with valve guide oil seal.

Valve Guide Installing Tools

Inspect Exhaust Valve Seat Insert

Inspect the exhaust valve seat inserts for excessive wear, pitting or cracking.

Remove Exhaust Valve Seat Insert

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

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

2. Place the collet of tool J 6974 (two valve head) or

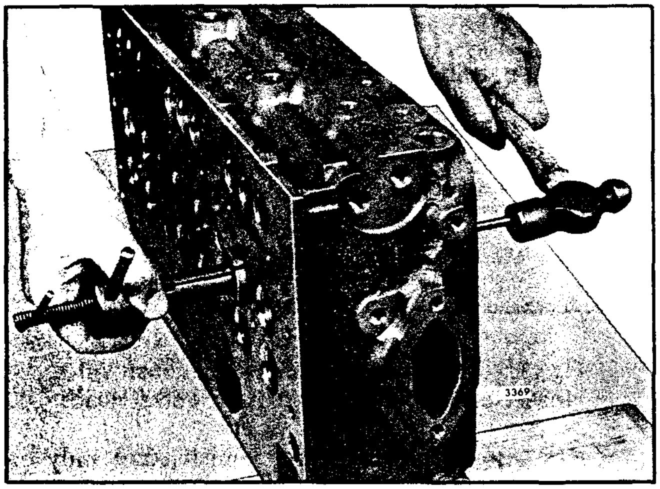


Fig. 7 - Removing Valve Seat Insert

J 7774 (four valve head) inside the valve insert so that 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. Turn the T handle to 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.

Install Exhaust Valve Seat Insert

1. Clean the valve seat insert counterbores in the head with trichloroethylene or other suitable 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 in a two valve head have a diameter of 1.439 " to 1.440" and a depth of .294 " to .306 ". The counterbores in a four valve head have a diameter of 1.159 " to 1.160 " and a depth of .294 " to .306 " on former engines and a depth of .300 " to .312 " on current engines.

NOTE: Valve seat inserts which are .010 "

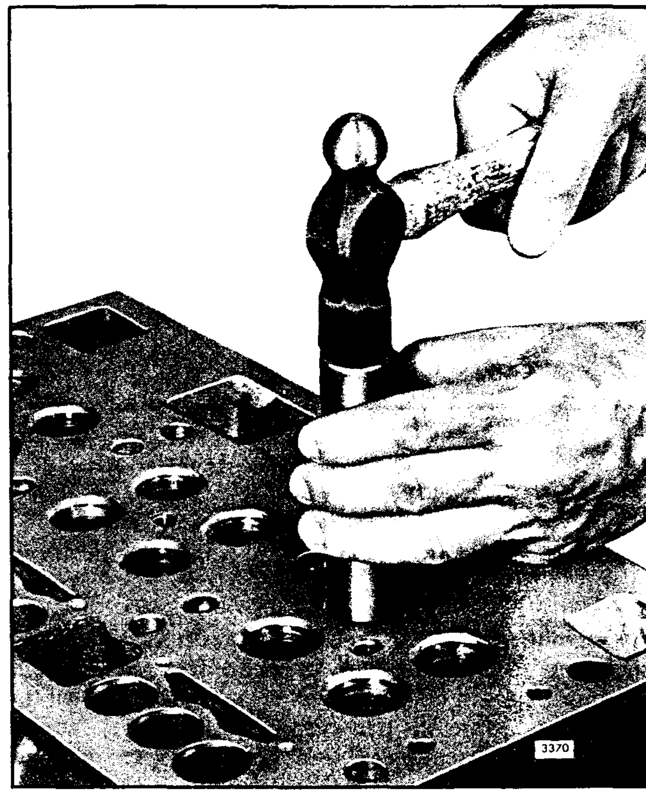


Fig. 8 - Installing Valve Seat Insert

oversize on the outside diameter are available, if required.

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 a bench and place an insert in the counterbore--valve seat side up. This must be done quickly while the cylinder head is still hot and the insert is cold (room temperature). If the temperature of the two parts is allowed to become nearly the same, installation may become difficult and damage to the parts may result.

5. Drive the insert in place with installer J 6976 (two valve head) or J 7790 (four valve head) as shown in Fig. 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.

Recondition Exhaust Valve and Valve Seat Insert

An exhaust valve which is to be reused may be refaced, if necessary (Fig. 9). To provide sufficient valve strength and spring tension, the edge of the

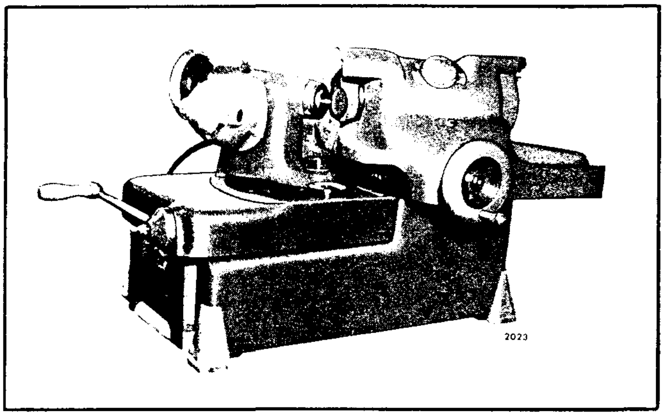


Fig. 9 - Refacing Exhaust Valve

valve at the valve head must not be less than 1/32 " in thickness and must still be within the specifications shown in Figs. 11 and 12 after refacing.

Before either a new or used valve is installed, examine the valve seat in the cylinder head for proper valve seating. 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. The proper angle for the seating face of both the valve and valve seat insert is 30 °.

When a new valve seat insert is installed or an old insert refaced, the work must be done with a grinding wheel (Fig. 10).

The eccentric grinding method for reconditioning valve seat inserts is recommended. This method

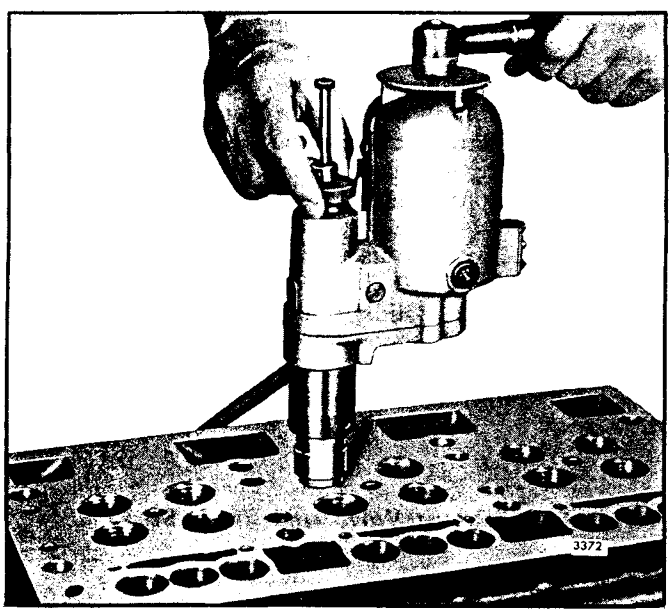


Fig. 10 - Grinding Valve Seat Insert

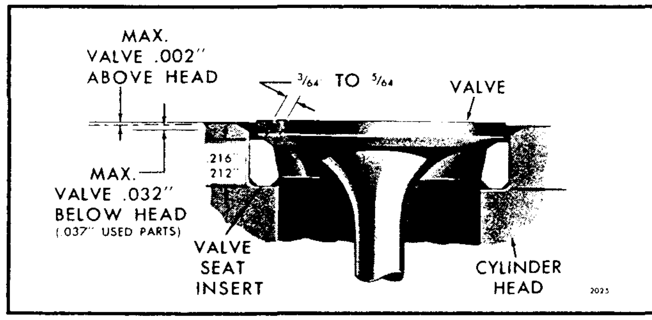


Fig. 11 - Relationship Between Exhaust Valve, Insert and Cylinder Head (Two Valve Head)

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 seat inserts for a two valve cylinder head, use the following tools:

1. Grinder J 8165-1
2. Dial Gage J 8165-2
3. Pilot J 7659-1
4. Grinding Wheel (15 °) J 7924-1
5. Grinding Wheel (30 °) J 7924-2
6. Grinding Wheel (60 °) J 7924-3

To grind the valve seat inserts for a four valve cylinder head, use the following tools:

1. Grinder J 8165-1
2. Dial Gage J 8165-2
3. Pilot J 7792-1
4. Grinding Wheel (15 °) J 7792-2
5. Grinding Wheel (30 °) J 7792-3
6. Grinding Wheel (60 °) 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 with a 15 ° wheel to narrow the width of the seat from 3/64 " to 5/64 "

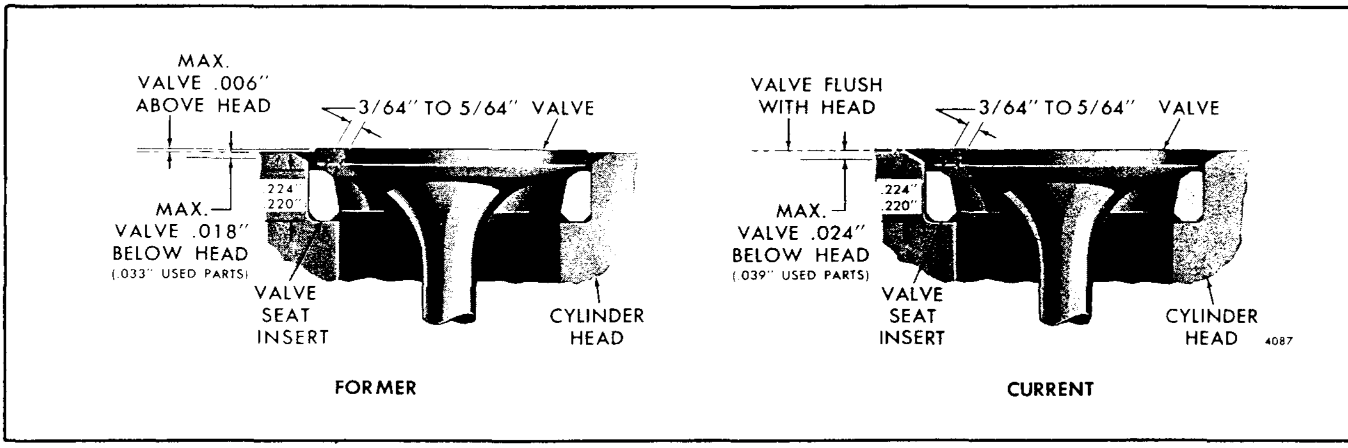


Fig. 12 - Relationship Between Exhaust Valve, Insert and Cylinder Head (Four Valve Head)

(Figs. 11 and 12). The 30° face of the insert may be adjusted relative to the center of the valve face with the 15° and 60° grinding wheels.

CAUTION: Do not permit the grinding wheel to contact the cylinder head when grinding the insert. If necessary, replace the insert.

The maximum amount that the exhaust valve should protrude beyond the cylinder head (when the valve is in the closed position), and still maintain the proper piston-to-valve clearance, is shown in Figs. 11 and 12. 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 specified limits, replace the valve seat insert.

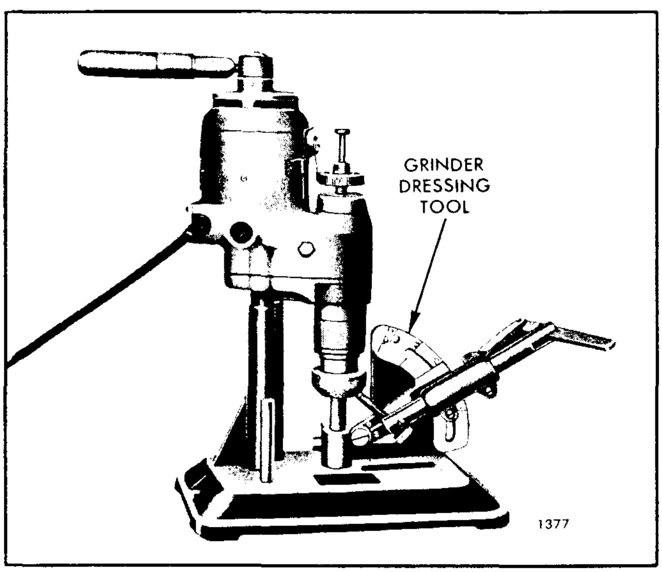


Fig. 13 - Grinding Wheel Dressing Tool of Set J 8165

When occasion requires, the grinding wheel may be dressed to maintain the desired seat angle with the dressing tool provided with the grinder set (Fig. 13).

After 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 Fig. 14 and rotate it to determine the concentricity of each valve seat insert relative to the valve guide. If the runout exceeds .002", check for a bent valve guide before regrinding the insert.

4. After the valve seat insert has been ground, determine the position of the contact area between the valve and the valve seat insert as follows:

a. Apply a light coat of Prussian Blue or similar paste to the valve seat insert.

b. Lower the stem of the valve in the valve guide and "bounce" the valve on the seat. *Do not rotate the valve.* This procedure will show 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.

Install Exhaust Valves and Springs

When installing exhaust valves, check to see that the valves are within the specifications shown in Figs. 11 and 12. Also, do not use "N" pistons with former four valve cylinder head assemblies unless the valves are flush with the cylinder head. If the valves are not flush, it may be necessary to regrind the valve seats so that

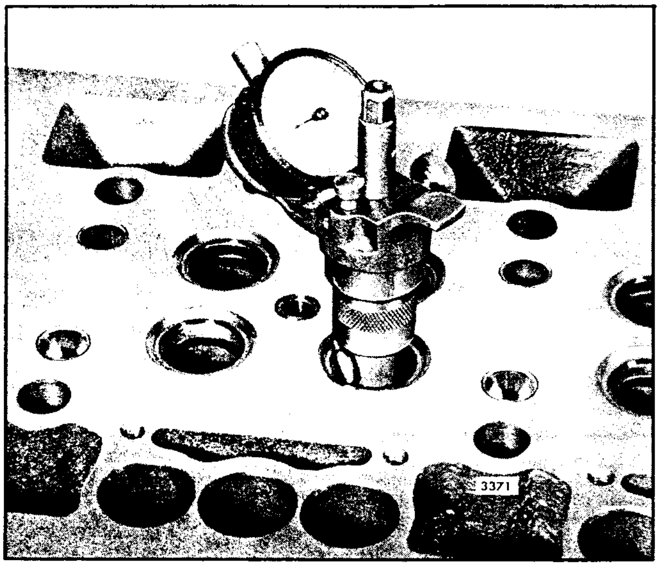


Fig. 14 - Checking Relative Concentricity of Valve Seat Insert with Relation to Valve Guide

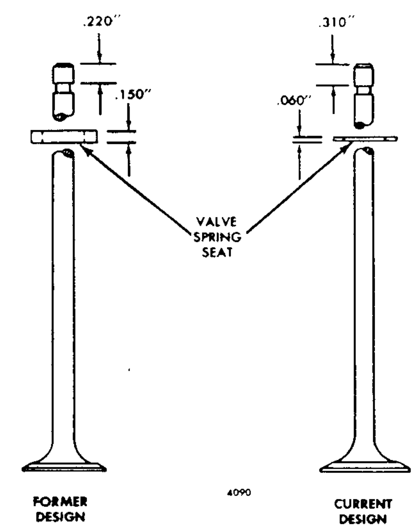


Fig. 15 - Former and Current Design Exhaust Valves (Four Valve Head)

the valves will be flush with the bottom surface of the cylinder head.

> **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 " in current design cylinder heads or 1-5/64 " in former design heads.

Be sure and install the correct parts in the four valve cylinder head. Current design cylinder heads are equipped with the thin valve spring seats (.060 ") and current design exhaust valves (Fig. 15). To facilitate replacement of a four valve head on an engine using the former exhaust valves, the proper quantity of the thick spring seats (.150 ") must be used.

Service cylinder heads are of the current design. The current thin valve spring seats (.060 ") are included with each cylinder head as a shipped loose item.

1. Lubricate the valve stems with sulphurized oil (E.P. type) and slide the valves all the way into the guides.

> **IMPORTANT:** If reconditioned valves are used, install them in the same relative location from which they were removed.

2. Hold the valves in place temporarily with a strip of masking tape. Then, 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 spring seats.

4. Install the valve guide oil seals, if used, on the valve guides as follows:

   a. Place the plastic seal installation cap on the end of the valve stem. If the cap extends more than 1/16 " below the groove on the valve stem, remove the cap and cut off the excess length.

   b. Lubricate the installation cap and start the seal carefully over the valve stem. Push the seal down slowly until it rests on top of the valve guide.

   c. Remove the installation cap.

5. Install the valve springs and valve spring caps.

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

7. 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. Tap the end of the valve stem lightly with a plastic hammer to seat the valve locks.

> **NOTE:** If valve guide oil seals are used, compress the valve spring only enough to permit installation of the valve locks. Compressing the spring too far may result in damage to the oil seal.

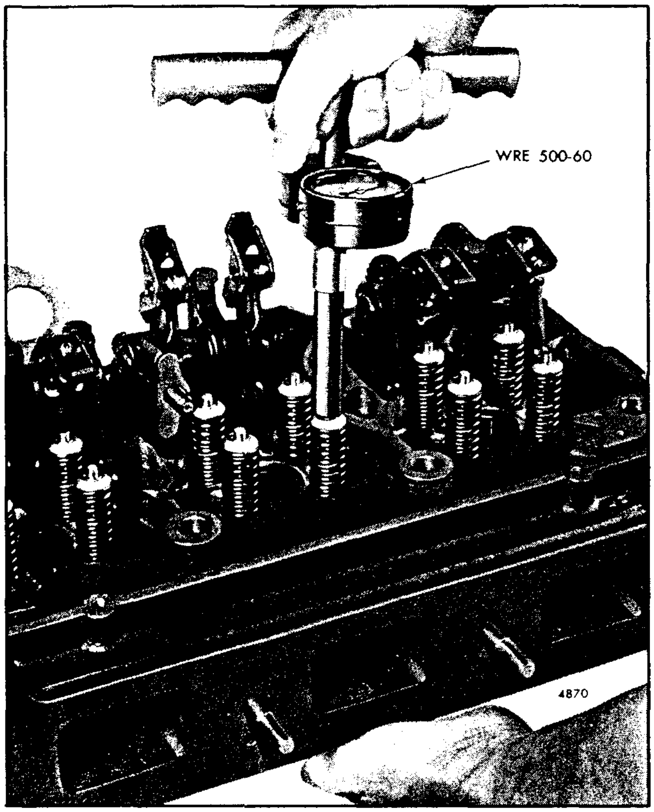


Fig. 16 - Checking Valve Opening Pressure with Gage WRE-500-60

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

9. Check the position of the exhaust valve (Fig. 11).

10. With the exhaust valves installed in the cylinder head, use spring checking gage WRE -500-60 and note the gage reading the moment the exhaust valve starts to open (Fig. 16). The minimum pressure required to start to open the exhaust valve must not be less than 33 pounds for a two valve cylinder head or 25 pounds for a four valve cylinder head.

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

12. Install the cylinder head. Refer to *Pre-Installation Inspection* and *Install Cylinder Head* in Section 1.2.

13. Perform a complete engine tune-up.

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. The top of the cylinder head is sealed against oil leakage by a gasket located in the flanged edge of the cover.

An option plate is inserted in a retainer (Fig. 1) attached to the cover on each In-Line engine and to one of the covers on a V-type engine.

The valve rocker cover assembly on certain engines may include a breather assembly or an oil filler, depending upon the engine application.

Remove and Install Valve Rocker Cover

Clean the cover before removing it fron. 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 rocker cover.

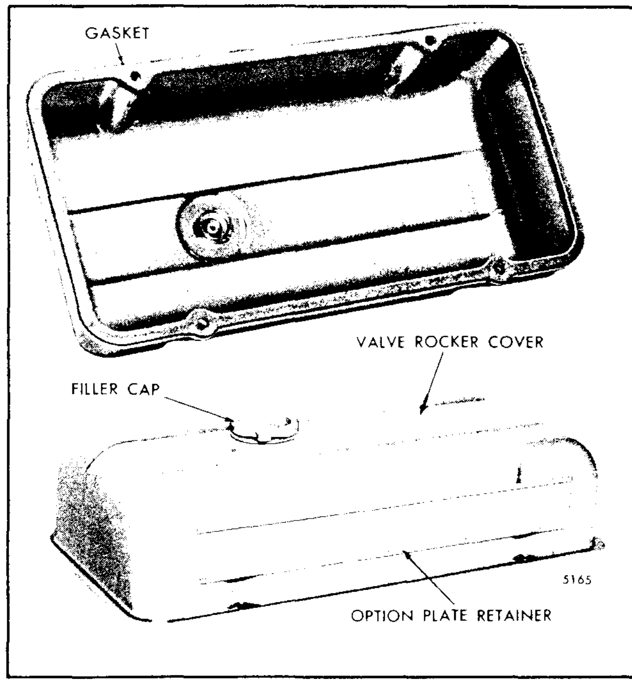


Fig. 1 - Typical Valve Rocker Cover Assembly

CRANKSHAFT

The crankshaft (Figs. 1 and 2) for the Series 53 engine is a one-piece steel forging, heat-treated to ensure strength and durability. All main and connecting rod bearing journal and oil seal surfaces are induction hardened.

Complete static and dynamic balance of the crankshaft has been achieved by counterweights incorporated in the crankshaft.

The crankshaft end thrust is controlled by thrust washers located at the rear main bearing cap of the engine. Full pressure lubrication to all connecting rod and main bearings is provided by drilled passages within the crankshaft and cylinder block.

On certain 4-53 and 6V-53 engines, a crankshaft with splines at the front end is used. These engines use a splined crankshaft pulley and pulley mounting components.

On In-Line and 6V engines, six tapped holes are provided in the rear end of the crankshaft for attaching the flywheel.

On the 8V engine, two dowels are provided in the rear end of the crankshaft for locating the flywheel and six tapped holes are provided for attaching the flywheel. One hole is unequally spaced so that the flywheel can be attached in only one position.

In-line engine main bearing journals are 3 " in diameter and the connecting rod journals are 2-1/2 " in diameter. On the V-type engine the main bearing journals are 3-1/2 " in diameter and the connecting rod journals are 2-3/4 " in diameter.

Effective with 8V engine serial number 8D-149, the 2.878 " diameter position at the front of the crankshaft serves as a journal for the outboard bearing (bushing type). A spacer (sleeve) is used on the 2.5000 " diameter position to provide a replaceable contact surface for the front oil seal which is located in the outboard bearing support assembly. Prior to engine 8D-149, the 2.878 " diameter position served as a contact surface for the front oil seal assembled in the front cover.

Remove Crankshaft

When removal of the crankshaft becomes necessary, first remove the transmission, then proceed as follows:

1. Clean the exterior of the engine.

2. Drain the cooling system.

3. Drain the engine crankcase.

4. Remove all engine to base attaching bolts; then with a chain hoist and sling attached to the lifter brackets

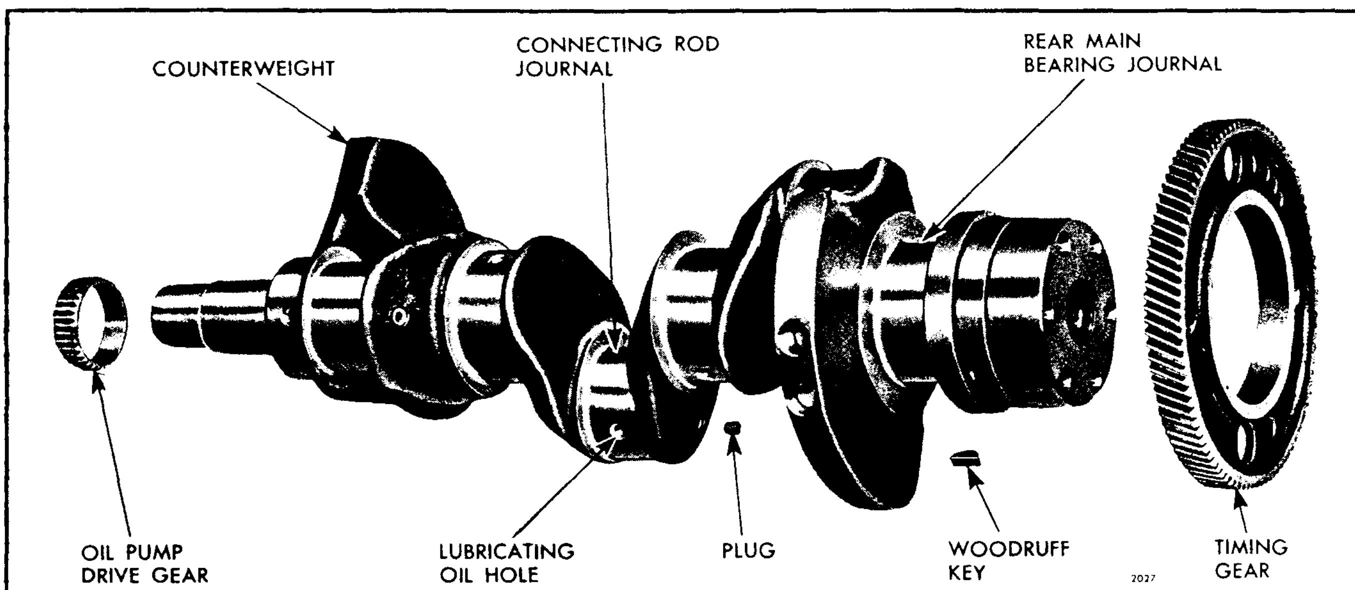


Fig. 1 · Crankshaft Details and Relative Location of Parts (Three Cylinder In-Line Engine Crankshaft Shown)

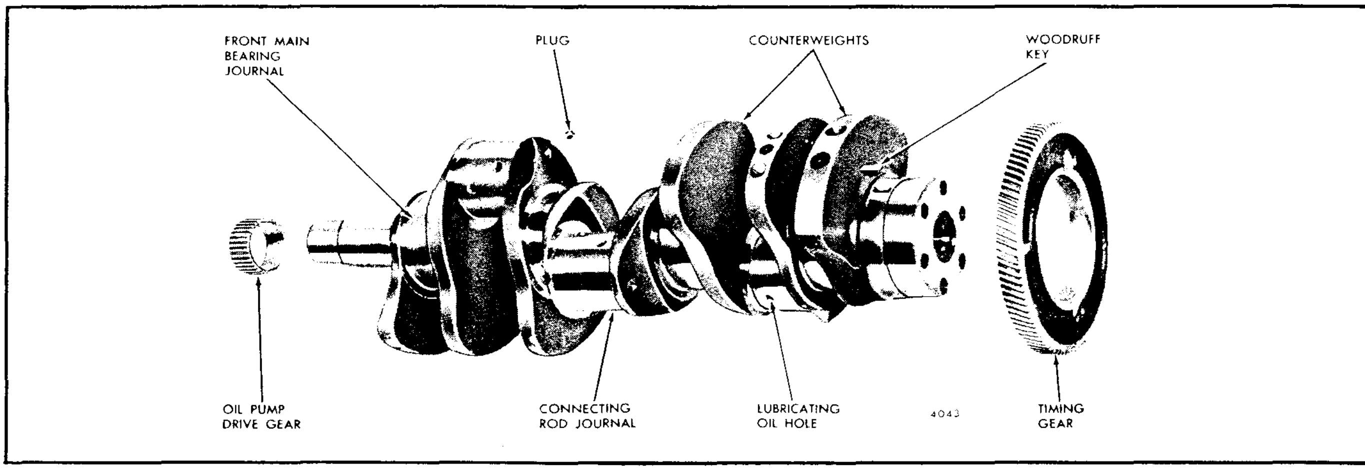


Fig. 2 - Crankshaft Details and Relative Location of Parts (6V-53 Engine Crankshaft Shown)

at each end of the engine, remove the engine from its base.

5. Remove all of the 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.

CAUTION: Be absolutely sure the engine is securely attached 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 used.

12. Remove the engine lower front cover and oil pump assembly.

13. Remove the cylinder head(s).

14. On the V-type engines, remove the main bearing cap stabilizers.

15. 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 the timing gear (Fig. 3).

20. Refer to Section 1.7.5 for removal of the crankshaft timing gear and Section 4.1 for the procedure covering removal of the oil pump drive gear.

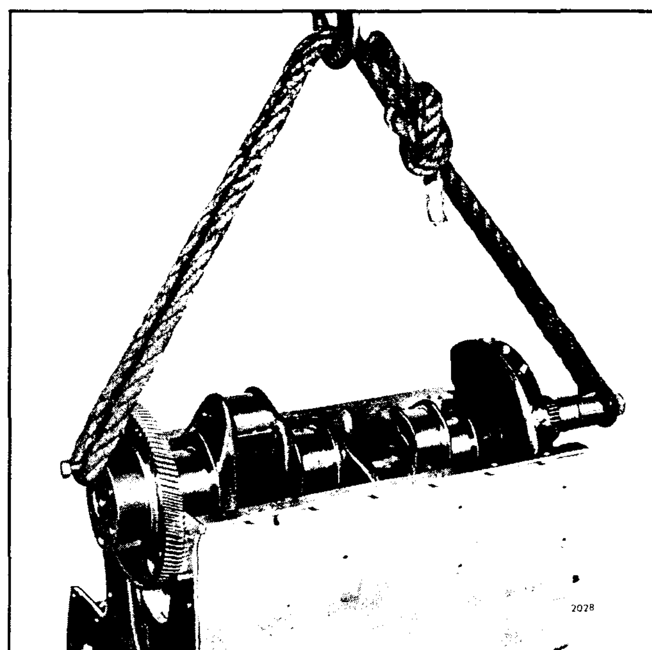


Fig. 3 - Lifting or Lowering Crankshaft from/into Cylinder Block

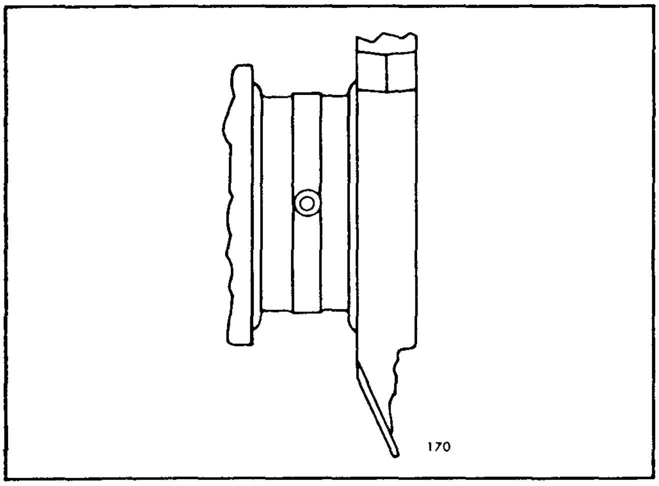


Fig. 4 - Typical Ridging of Crankshaft

Inspection

After the crankshaft has been removed, clean and inspect it thoroughly before reinstalling it in the engine.

Remove the plugs and clean out the oil passages thoroughly with a stiff wire brush. Clean the crankshaft with fuel oil and dry it with compressed air. Then, reinstall the plugs.

Inspect the keyways for evidence of cracks or wear. Replace the crankshaft, if necessary.

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

Used crankshafts will sometimes show a certain amount of ridging caused by the groove in the upper main bearing shell or lower connecting rod bearing shell (Fig. 4). Ridges exceeding .0002 " must be removed. If the ridges are not removed, localized high unit pressures on new bearing shells will result during engine operation.

The ridges may be removed by working crocus cloth, wet with fuel oil, around the circumference of the crankshaft journal. If the ridges are greater than .0005 ", first use 120 grit emery cloth to clean up the ridge, 240 grit emery cloth for finishing, and wet crocus cloth for polishing. Use of a piece of rawhide or other suitable rope wrapped around the emery cloth or crocus cloth and drawn back and forth will minimize the possibility of an out-of-round condition developing (keep the strands of rawhide apart to avoid bind). If rawhide or rope is not used, the crankshaft should be rotated at intervals. If the ridges are greater than .001 ", the crankshaft may have to be reground.

Carefully inspect the front and rear end of the crankshaft in the area of the oil seal contact surface for evidence of a rough or grooved condition. Any imperfections of the oil seal contact surface will result in oil leakage at this point.

Slight ridges on the crankshaft oil seal contact surfaces may be cleaned up with emery cloth and crocus cloth in the same manner as detailed for the crankshaft journals. 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.

Check the crankshaft thrust surfaces for excessive wear or grooving. If only slightly worn, the surfaces may be dressed with a stone. Otherwise, it will be necessary to regrind the thrust surfaces.

Check the oil pump drive gear and the crankshaft timing gear for worn or chipped teeth. Replace the gears, if necessary.

On an 8V engine, check the crankshaft dowel extension. The dowels should not extend more than 1/2 " from the crankshaft.

Inspect the crankshaft for cracks as outlined under *Inspection for Cracks*.

Crankshaft Measurements

Support the crankshaft on its front and rear journals on V-blocks or in a lathe and check the alignment at the adjacent intermediate main journals with a dial indicator.

On 2, 3 and 4 cylinder in-line and 6V-53 crankshafts, the maximum runout on the intermediate journals must not exceed .002 " total indicator reading.

On an 8V-53 crankshaft, the maximum runout at the No. 2 and 4 journals must not exceed .002 "; the maximum runout at No. 3 journal must not exceed .004 " and the maximum runout on the outboard journal must not exceed .001 ".

On the 6V and 8V-53 crankshafts, when the runout on the adjacent journals is in opposite directions, the sum must not exceed .003 " total indicator reading. When the runout on the adjacent journals is in the same direction, the difference must not exceed .003 " total indicator reading. When high spots of runout on the adjacent journals are at right angles to each other, the sum must not exceed .004 " total indicator reading, or .002 " on each journal. If the runout limit is greater than given above, the crankshaft must be replaced.

Measure all of the main and connecting rod bearing

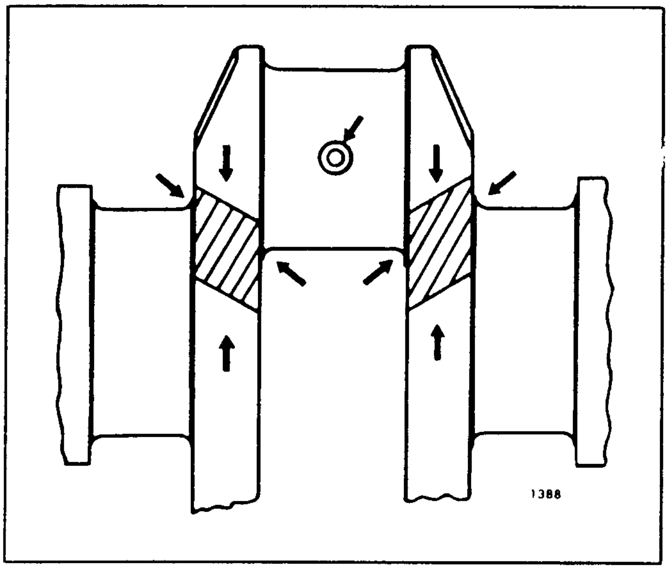


Fig. 5 - Critical Crankshaft Loading Zones

journals. Measure the journals at several places on the circumference so that taper, out-of-round and bearing clearances can be determined. If the crankshaft is worn so that the maximum connecting rod journal-to-bearing shell clearance (with new shells) exceeds .0045 " (In-line engine) or .0041 " (V-type engine), or the main bearing journal-to-bearing shell clearance (with new shells) exceeds .0040 " (In-line and V type engines), the crankshaft must be reground. Also, if the journal taper or out-of-round is greater than .003 ", the crankshaft must be reground. Measurements of the crankshaft should be accurate to the nearest .002 ".

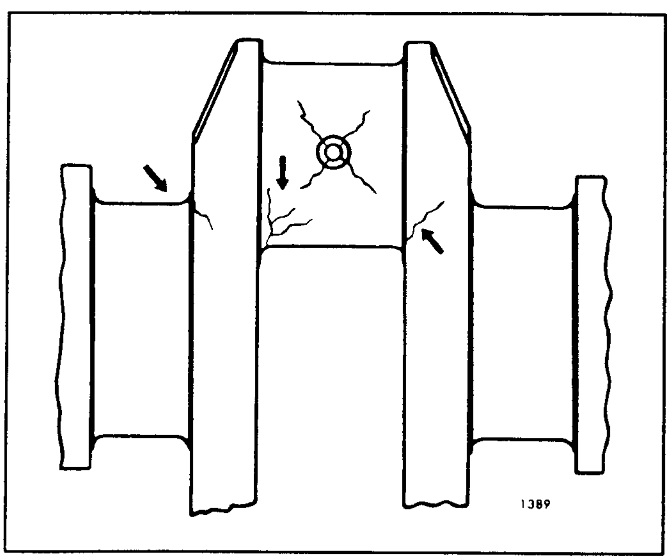


Fig. 6 - Crankshaft Fatigue Cracks

Inspection for Cracks

Carefully check the crankshaft 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. Several methods of determining the presence of minute cracks not visible to the eye are outlined below.

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

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".

Fluorescent 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 is dried. A developing powder is then applied which helps to draw the penetrant out of the flaws by

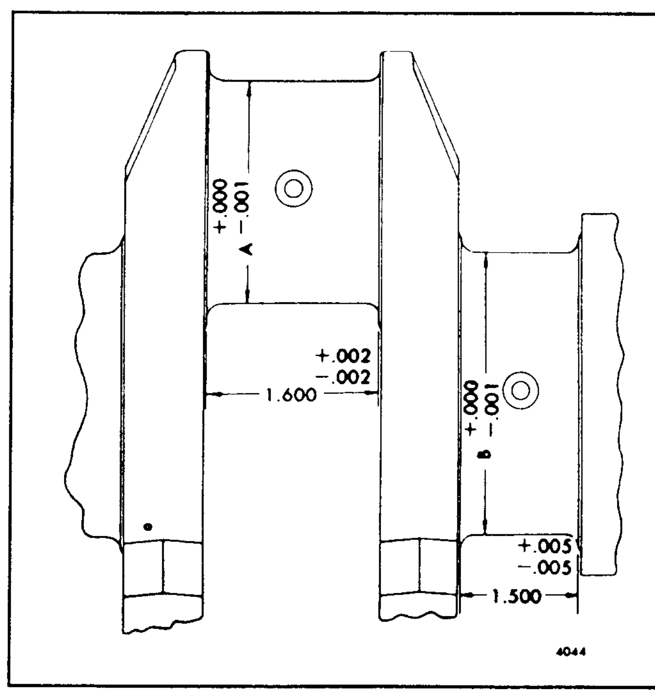


Fig. 7 - Dimensions of Crankshaft Journals - In-line Engine

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 the 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. 5).

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 the piston is divided between the adjacent bearings. An abnormal bending stress in the crankshaft, particularly in the crank fillet, may be a result of misalignment of the main bearing bores, improperly fitted bearings, 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 bearings, 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.

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 Fig. 5.

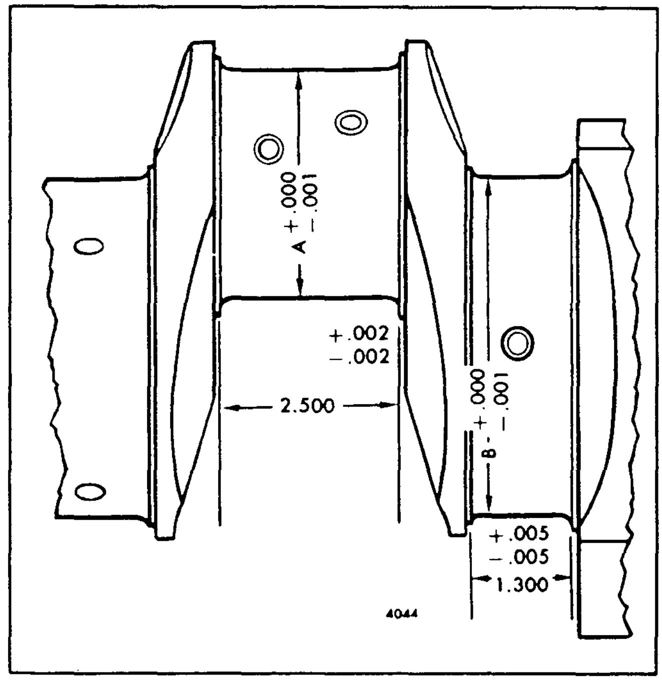


Fig. 8 - Dimensions of Crankshaft Journals - V-Type Engine

Torsional stresses may produce a fracture in either the connecting rod journal or the crank cheek. Connecting rod journal failures are usually at the fillet at 45° to the axis of the shaft.

A loose, damaged or defective vibration damper, a loose flywheel or 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 of the indications

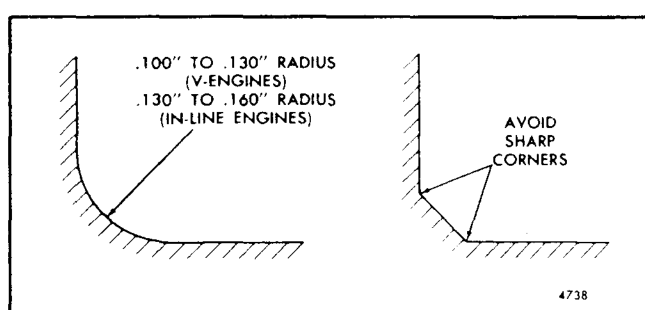


Fig. 9 - Crankshaft Journal Fillets

found during 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 the axis of the shaft) starting from either the critical fillet locations or the connecting rod journal holes as shown in Fig. 6. Replace the crankshaft when cracks of this nature are found.

Crankshaft Grinding

In addition to the standard size 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 wear on crankshafts on which regrinding is unnecessary.

If the crankshaft is to be reground, proceed as follows:

1. Compare the crankshaft journal measurements taken during inspection with the dimensions in Table 1 and Figs. 7 or 8 and determine the size to which the journals are to be reground.

Measurement of the crankshaft journals, and comparison of these measurements to the diameters required for various undersize bearings shown in Figs. 7 or 8 and Table 1, will determine the size to which the crankshaft journals must be reground.

2. If one or more main or connecting rod journals require grinding, then grind all of the main journals or all of the connecting rod journals to the same required size.

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"
V-Engines		
Standard	2.750"	3.500"
.002" Undersize	2.750"	3.500"
.010" Undersize	2.740"	3.490"
.020" Undersize	2.730"	3.480"
.030" Undersize	2.720"	3.470"

TABLE 1

3. All journal fillets on the In-line crankshafts must have a .130 " to .160 " radius and on the 6V and 8V crankshafts, a .100 " to .130 " radius between the crank cheek and the journal, and must not have any sharp grind marks (Fig. 9). The fillet must blend smoothly into the journal and the crank cheek, and must be free of scratches. The radius may be checked with a fillet gage.

4. Care must be taken to avoid localized heating which often produces grinding cracks. Cool the crankshaft while grinding, using coolant generously. Do not crowd the grinding wheel into the work.

5. Polish the ground surfaces to an 8-12 R.M.S. finish. The reground journals will be subject to excessive wear unless polished smooth.

6. If the thrust surfaces of the crankshaft are worn or grooved excessively, they must be reground and polished. Care must be taken to leave a .130 " to .160 " radius on the In-line crankshaft and .100 " to .130 " radius on the 6V and 8V engines between each thrust surface and the bearing journal (Fig. 9).

7. Stone the edge of all oil holes in the journal surfaces smooth to provide a radius of approximately 3/32 ".

8. After grinding has been completed, inspect the crankshaft by the magnetic particle method to determine whether cracks have originated due to the grinding operation.

9. Demagnetize the crankshaft.

10. Remove the plugs and clean the crankshaft and oil passages thoroughly with fuel oil. Dry the shaft with compressed air and reinstall the plugs.

Install Crankshaft

If a new crankshaft is to be installed, steam clean it to

Nominal Size	Thrust Washer Thickness	
	Min.	Max.
Standard	.1190"	.1220"
.005" Oversize	.1255"	.1270"
.010" Oversize	.1300"	.1320"

TABLE 2

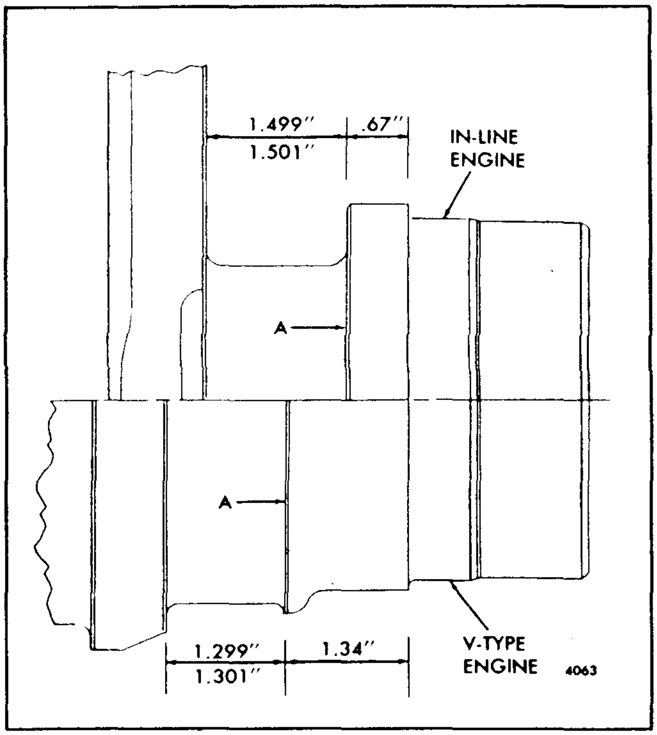


Fig. 10 - Standard Dimensions at Rear Main Bearing Thrust Washers--In-Line and V-Type Engines

remove the rust preventive, blow out the oil passages with compressed air and install the plugs. Then, install the crankshaft as follows:

NOTE: When a new or reground crankshaft is installed, **ALL** new main and connecting rod (upper and lower) bearing shells and new thrust washers must also be installed.

1. Assemble the crankshaft timing gear (Section 1.7.5) and the oil pump drive gear (Section 4.1) on the crankshaft.

2. Install the upper *grooved* bearing shells in the block. If the old bearing shells are to be used again, install them in the same locations from which they were removed.

3. Apply clean engine oil to all crankshaft journals and install the crankshaft in place so that the timing marks on the crankshaft timing gear and the idler gear match. Refer to Section 1.7.1 for the correct method of timing the gear train.

4. Install the upper halves of the crankshaft thrust washers on each side of the rear main bearing support and the doweled lower halves on each side of the rear main bearing cap. *The grooved side of the thrust washers must face toward the crankshaft thrust surfaces.*

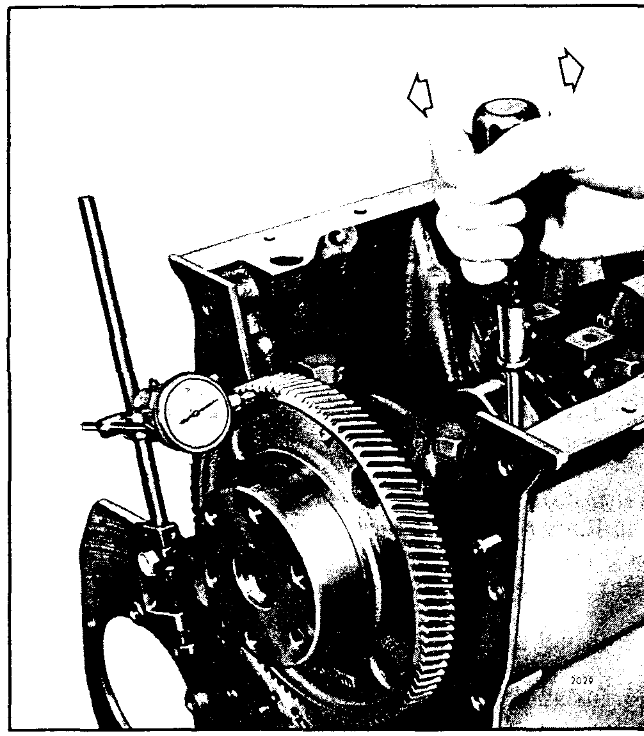


Fig. 11 - Checking Crankshaft End Play

NOTE: If the crankshaft thrust surfaces were reground, it may be necessary to install oversize thrust washers on one or both sides of the rear main journal. Refer to Fig. 10 and Table 2.

5. Install the lower bearing shells (no oil grooves) in the bearing caps. If the old bearing shells are to be used again, install them in the same bearing caps from which they were removed. Lubricate the bolt threads and bolt head contact surfaces with a small quantity of International Compound No. 2, or equivalent. Install the bearing caps and draw the bolts up snug. Then, rap the caps sharply with a soft hammer to seat them properly.

6. Draw the bearing cap bolts uniformly tight, starting with the center cap and working alternately toward both ends of the block, to 120-130 lb-ft torque. On a V-type engine, tighten the stabilizer to cylinder block bolts to 46-50 lb-ft torque. Rotate the crankshaft to make sure 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.

7. Check the crankshaft end play by moving the crankshaft toward the gage (Fig. 11) with a pry bar. Keep a constant pressure on the pry bar and set the dial indicator to zero. Then, remove and insert the pry

bar on the other side of the bearing cap. Force the crankshaft in the opposite direction and note the amount of end play on the dial. The end play should be .004 " to .011 " with new parts or a maximum of .018 " with used parts. Insufficient end play 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.

8. Install the cylinder liner, piston and connecting rod assemblies (Section 1.6.3).

9. Install the cylinder head(s) (refer to Section 1.2).

10. Install the flywheel housing (Section 1.5), then install the flywheel.

11. Install the crankshaft lower engine front cover and the lubricating oil pump assembly on In-line and 6V engines or the engine front cover and outboard bearing support on 8V engines (Section 1.3.5).

12. Install the engine front support, if used.

13. Install the crankshaft pulley (Section 1.3.7).

14. Install the oil pump inlet pipe and screen on In-line and 6V engines; on the 8V engine, install the lubricating oil pump, inlet pipe and screen assembly (Section 4.1).

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

16. 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.

17. Install all of the accessories that were removed.

18. 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.

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

20. After replacing the main or connecting rod bearings or installing a new crankshaft, operate the engine as outlined in the run-in schedule, Section 13.2.1.

CRANKSHAFT OIL SEALS

An oil seal is used at each end of the crankshaft to prevent the lubricating oil from escaping from the crankcase. The seals also provide protection against the entrance of dirt, dust, mud or oil from the external portion of the engine (Figs. 1 and 2).

The front oil seal is pressed into the lower front cover on In-line and 6V engines. The seal is pressed into the front cover on early 8V engines; effective with engine 8D-149, the seal is pressed into the outboard bearing support.

A single-lip oil seal is used at the rear end of the crankshaft of most industrial engines. A double-lip oil seal is used in all applications where oil is on both sides of the seal; the lips of the seal face in opposite directions. The rear oil seal is pressed into the flywheel housing.

Remove Crankshaft Oil Seals

1. Remove the engine front cover, outboard bearing or the flywheel housing and remove the oil seals as follows:

2. Support the forward face of the front cover, or the outboard bearing support, on two wood blocks next to the oil seal bore. Then press or drive the oil seal out of the front cover or the outboard bearing support. Discard the oil seal.

3. Support the forward face of the flywheel housing on In-line or 6V engines and the rear face of the flywheel housing on 8V engines on two wood blocks next to the oil seal bore. Then press or drive the oil seal out of the housing. Discard the oil seal.

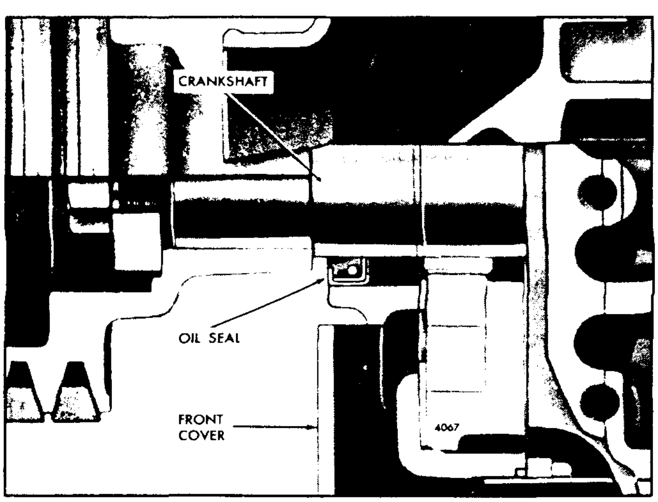


Fig. 1 - Crankshaft Front Oil Seal

4. Clean the oil seal bore in the front cover, outboard bearing support or flywheel housing thoroughly before installing a new oil seal.

When necessary, the crankshaft oil seals may be removed without removing the front cover, outboard bearing support 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.

Inspection

Oil leaks indicate worn or damaged oil seals. Oil seals may become worn or damaged due to improper installation, excessive main bearing clearances, excessive flywheel housing bore runout, or grooved sealing surfaces on the crankshaft. To prevent a repetition of any oil seal leaks, these conditions must be checked and corrected.

Inspect the front and rear end of the crankshaft and the crankshaft front end oil seal sleeve (8V engines) for wear due to the rubbing action of the oil seal or dirt build-up.

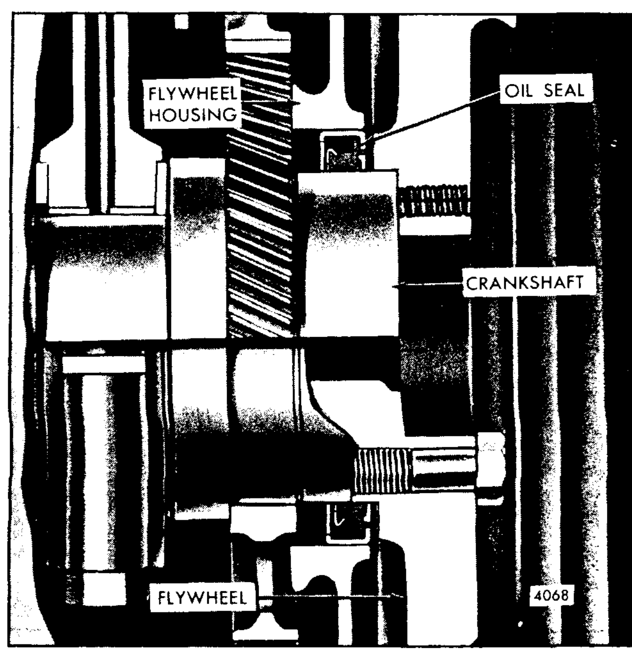


Fig. 2 - Crankshaft Rear Oil Seal (In-Line and 6V Engines)

Inspect the rear end of the crankshaft at the flywheel connection for signs of fretting.

The rear seal area of the crankshaft must be clean and smooth to prevent damaging the seal lip when a new oil seal is installed. Slight ridges may be removed from the crankshaft as outlined under *Inspection* in Section 1.3.

On In-line or 6V engines, if the crankshaft cannot be cleaned up satisfactorily, the oil seal may be pressed into the flywheel housing or the front cover 1/8" from its original position.

On 8V engines, if the crankshaft rear oil seal surface is grooved excessively, an oil seal spacer (Fig. 4) may be installed between the counterbore in the flywheel housing and the oil seal. The spacer changes the relative position of the seal and establishes a new contact surface. However, the spacer cannot be used with a double-lip seal since the grooves worn in the crankshaft are too close together to permit repositioning of the seal.

If excessive wear or grooving is present, install an oil seal sleeve (Figs. 3, 4 and 5) which provides a replaceable wear surface for the lip-type oil seal. An oversize seal will be required with use of the sleeve.

Install the rear oil seal sleeve (Figs. 3 and 4) as follows:

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

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

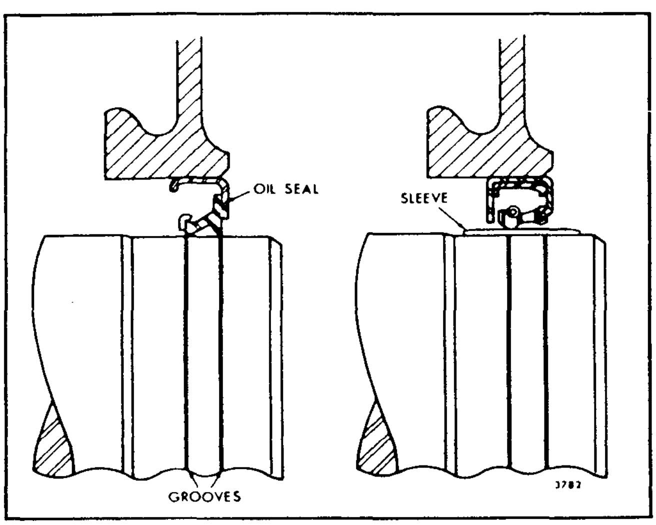


Fig. 3 - Use of Rear Oil Seal Sleeve on Grooved Crankshaft (In-line and 6V Engines)

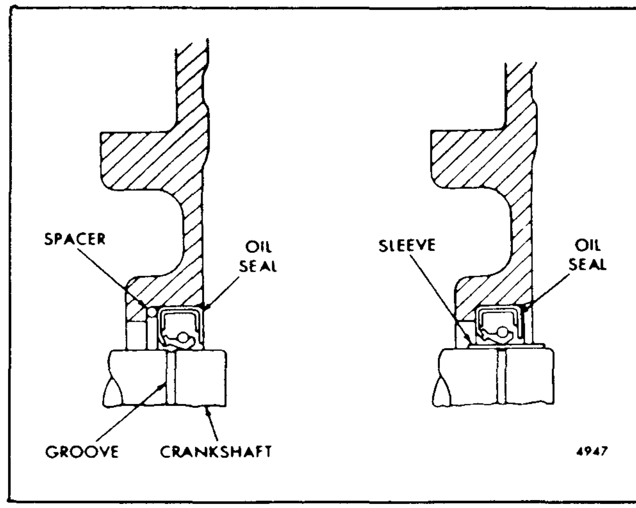


Fig. 4 - Use of Rear Oil Seal Spacer or Sleeve on Grooved Crankshaft (8V Engines)

3. Drive the sleeve squarely on the shaft with crankshaft rear oil seal sleeve installer J 21277 (in-line or 6V engines) or installer J 4194 (8V engines).

4. Wipe off any excess sealant.

Install the front oil seal sleeve (Fig. 5) as follows:

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

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

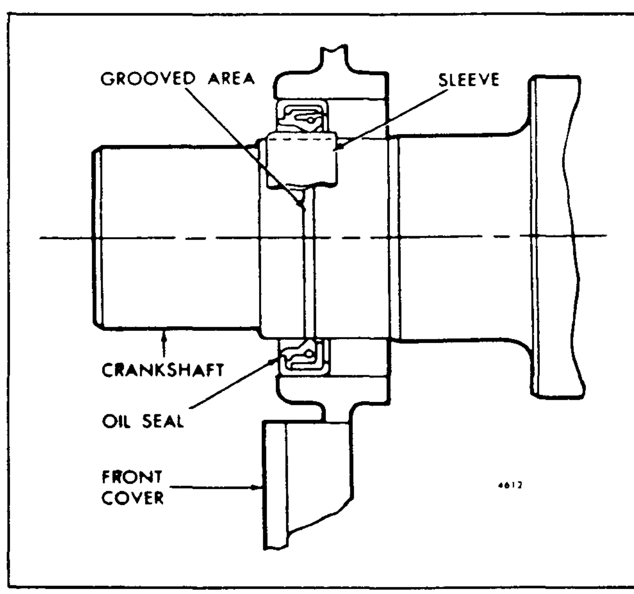


Fig. 5 - Use of Front Oil Seal Sleeve on Grooved Crankshaft (In-line or V Engines)

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

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

5. Wipe off any excess sealant.

To remove a worn sleeve, peen the sleeve until it stretches sufficiently so that it can be slipped off of the shaft.

Oil Seals

Current oil seals are made of an oil resistant synthetic rubber which is pre-lubricated with a special lubricant. Do not remove this lubricant. Keep the sealing lip clean and free from scratches. In addition, a plastic coating which acts as a sealant has been applied to the outer surface of the casing. Do not remove this coating.

Install Crankshaft Front Oil Seal

1. If the outside diameter of the seal is not pre-coated with sealant, apply a non-hardening sealant to the periphery of the metal casing.

2. Apply grease or vegetable shortening to the sealing lip; then, position the seal in the cover or outboard bearing support with the lip of the seal pointing toward the inner face of the cover or bearing support.

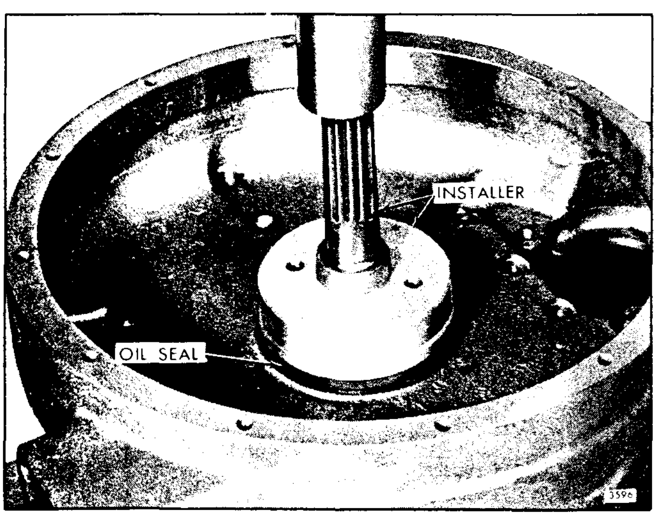


Fig. 6 - Installing Oil Seal in Flywheel Housing

3. Place the cover or outboard bearing support in an arbor press (inner face down).

4. On In-line and 6V engines, use installer J 9783 to press the oil seal into the cover until the seal is flush with the outside face of the cover. On early 8V engines, use installer J 21992. Effective with engine 8D-149, press the oil seal into the outboard bearing support with installer J 22153.

5. Remove all excess sealant.

6. Install the engine front cover or the outboard bearing support.

Install Crankshaft Rear Oil Seal

1. Support the inner face of the flywheel housing in an arbor press.

2. If the seal is not pre-coated, apply a non-hardening sealant to the periphery of the metal casing.

3. If not previously lubricated, apply grease or vegetable shortening to the lip of the oil seal; then, position the seal in the flywheel housing bore with the lip of the seal pointing toward the inner face of the housing.

4. On In-Line and 6V 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. 6).

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 9479-2 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. On 8V engines, use installer J 9727 and handle J 3154-1 to press the oil seal in the flywheel housing bore until it seats in the bottom of the counterbore. If the flywheel housing was not removed from the engine, place the oil seal expander J 22425 against the end of the crankshaft. Then, with the lip of the seal pointed toward the engine, slide the seal over the tool and on the crankshaft. Remove the seal expander and drive the seal in place with installer J 9727 and handle J 3154-1.

6. Remove all excess sealant from the housing and the seal.

CAUTION: If the oil seal is of the type which incorporates a brass retainer in the inner diameter of the seal, be sure the retainer is in place in the seal before installing the flywheel housing on the engine. If the retainer is left out, it will cause excessive oil leakage.

7. Install the flywheel housing as outlined in Section 1.5.

CRANKSHAFT MAIN BEARINGS

The main bearing shells are precision made and are replaceable without machining. They consist of an upper shell seated in each cylinder block main bearing support and a lower shell seated in each 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.

On In-line and early V-type engines, a 7/16" 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.

On 6V marine engines effective with 6D-11074 and all other 6V engines effective with 6D-17960 and all 8V engines effective with engine 8D-4611, an upper main bearing shell which has six 1/4" holes and one 7/16" hole (Fig. 3) is used. The additional holes in the upper main bearing shells improves piston cooling by allowing more oil, under pressure, to flow to the drilled passage in the crankshaft.

NOTE: On the 8V engines, a new high capacity oil pump is used in combination with the seven hole bearing shells.

The single hole and the seven hole upper main bearings are not interchangeable. If the seven hole upper main bearing shells are used on an early engine, the current lower engine front cover (Section 1.3.5), lubricating oil distribution system (Section 4.1) and revised cast iron oil pan (Section 4.7) must be used together. The single hole and seven hole upper main bearing shells must never be mixed in an engine.

The lower main bearing shells have no oil grooves; therefore, the upper and lower bearing shells are not interchangeable.

The tangs on the lower bearing shells are off-center while the tangs on the upper bearing shells are

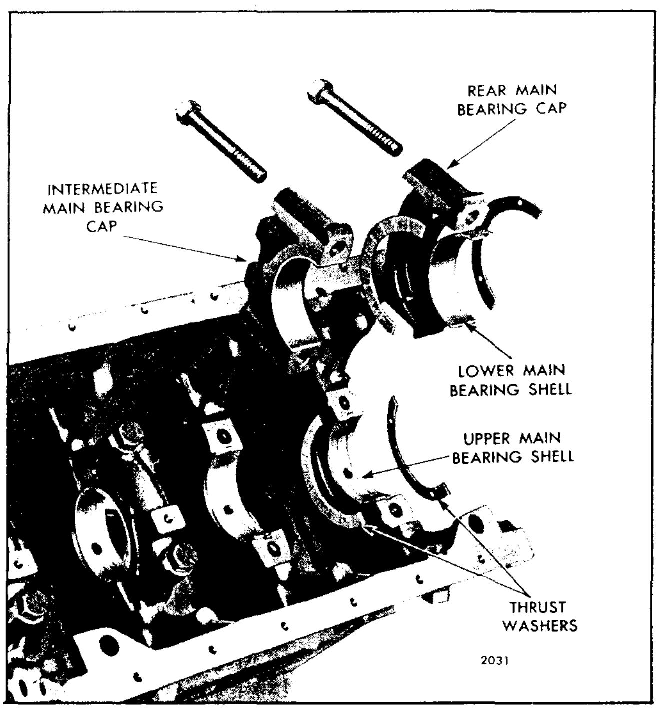


Fig. 1 - Main Bearing Shells, Bearing Caps and Crankshaft Thrust Washers -- In-Line Engines

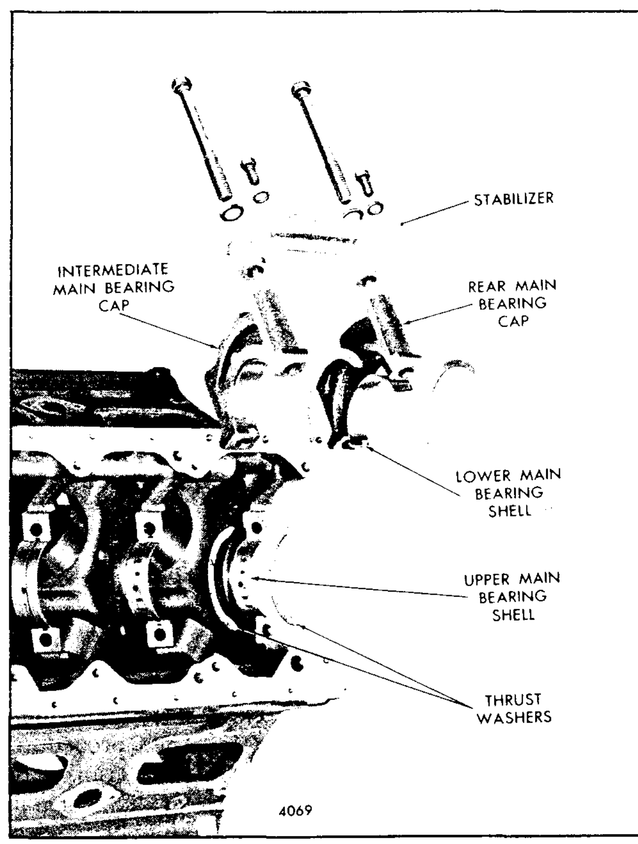


Fig. 2 - Main Bearing Shells, Bearing Caps and Crankshaft Thrust Washers -- V-Type Engines

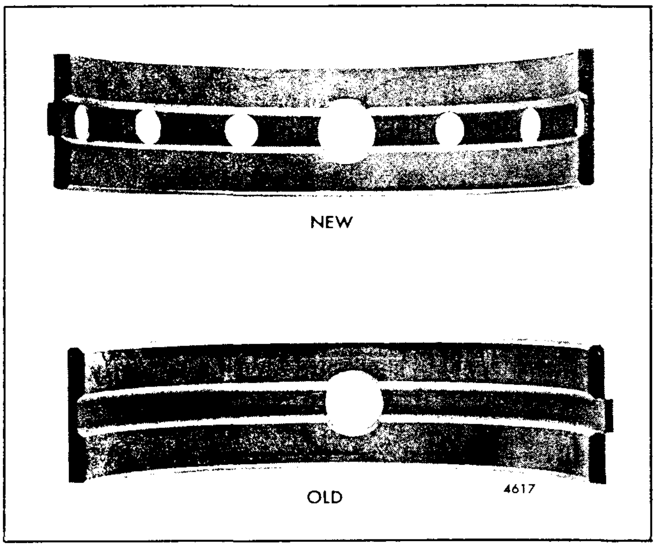


Fig. 3 - Old and New Upper Main Bearing Shells (V-Type Engines)

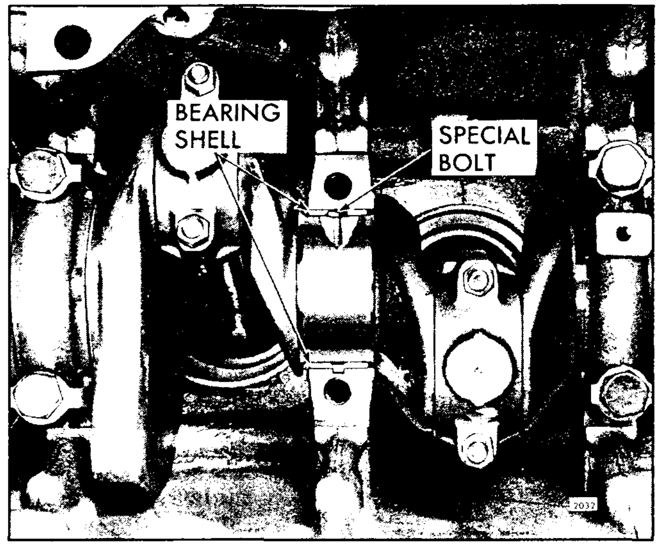


Fig. 4 - Removing Main Bearing Upper Shell (Except Rear Main) - Crankshaft in Place

centered to aid in the correct installation of the main bearing shells.

Crankshaft thrust washers (Figs. 1 and 2) absorb the crankshaft thrust. The lower halves of the two-piece washers are doweled to the bearing cap, the upper halves are not doweled.

Main bearing trouble is ordinarily indicated by low or no oil pressure and, in extreme cases, may cause the flywheel to wobble. All of the main bearing load is carried on the lower bearings; therefore, wear will occur on the lower shells first. The condition of the lower main bearing shells may be observed by removing the main bearing caps.

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.

Remove Main Bearing Shells (Crankshaft in Place)

All crankshaft main bearing journals, except the rear, are drilled for an oil passage. The procedure, therefore, for removing the shells with the crankshaft in place is somewhat different on the drilled journals than on the one at the rear which is not drilled. Remove the main bearing shells as follows:

1. Drain and remove the oil pan to expose the main bearing caps.

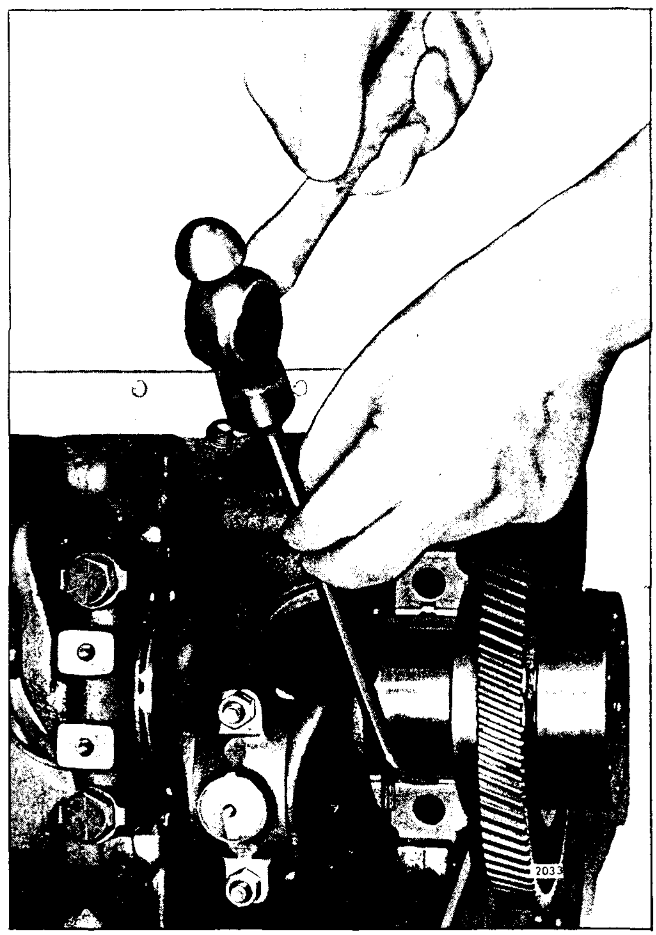


Fig. 5 - Removing Rear Main Bearing Upper Shell - Crankshaft in Place

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

3. Remove one main bearing cap at a time and inspect the bearing shells as outlined under *Inspection*. Complete replacement of the bearing shells and reinstallation of the bearing cap before removing another bearing cap

a. To remove all except the rear main bearing shell, insert a 1/4" x 3/4" bolt, with a 1/2" diameter and 1/16" thick head (made from a standard bolt), into the crankshaft journal oil hole, then revolve the shaft to the 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 (Fig. 4).

b. The lower halves of the crankshaft thrust washers will be removed along with the rear main bearing cap. Remove the upper halves of the washers by pushing on the ends of the washers with a small rod, thus forcing them around and out of the main bearing support.

c. Remove the rear main bearing upper shell by driving on the edge of the bearing shell with a small curved rod (Fig. 5) and revolving the crankshaft at the same time, thus rolling the shell from its position.

Inspection

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.

Check the oil filter elements and replace them if necessary. Also, check the oil by-pass valve to make sure it is operating freely.

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. The lower bearing shells, which carry the load, will normally show signs of distress before the upper shells do.

Inspect the backs of the bearing shells for bright spots which indicate they have been moving in the caps or the cylinder block. If such spots are present, discard the bearing shells.

Measure the thickness of the bearing shells at point "C", 90° from the parting line, as shown in Fig. 7. Tool J 4757, placed between the shell and a micrometer as illustrated in Fig. 8, will give an accurate measurement. The bearing shell thickness will be the total thickness of the steel ball and the bearing shell, less the diameter of the ball. This is the only practical method for measuring the 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 of the shells must be replaced.

Check the clearance between the main bearings and the crankshaft journals. This clearance (Section 1.0) may be determined with the crankshaft in place by means of a soft plastic measuring strip which is squeezed between the journal and the bearing, 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 on the main bearing cap bolts. If the clearance between any crankshaft main bearing journal and its bearing shells exceed .006", all of the bearing shells must be discarded and replaced with new shells.

The two bearing shells do not form a true circle when not installed. Measure the inside diameter with the bearing shells installed in the cylinder block and the caps bolted in place (crankshaft removed). The two halves of the shells have a squeeze fit in the main bearing bore, 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 must be replaced.

Before installing new replacement bearings, it is very important to thoroughly inspect the crankshaft journals. Very often, after prolonged engine operation, a ridge is formed on the crankshaft journals in line with the journal oil holes. If this ridge is not removed before new bearings are installed, then, during engine operation, localized high unit pressures in the center area of the bearing 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 be inspected for scoring, over-heating or wear without removing the crankshaft. However, to measure the diameter of the journals, the crankshaft must be removed. Refer to *Crankshaft Inspection* in Section 1.3.

Do not replace one main bearing shell alone. If one bearing shell requires replacement, install both new

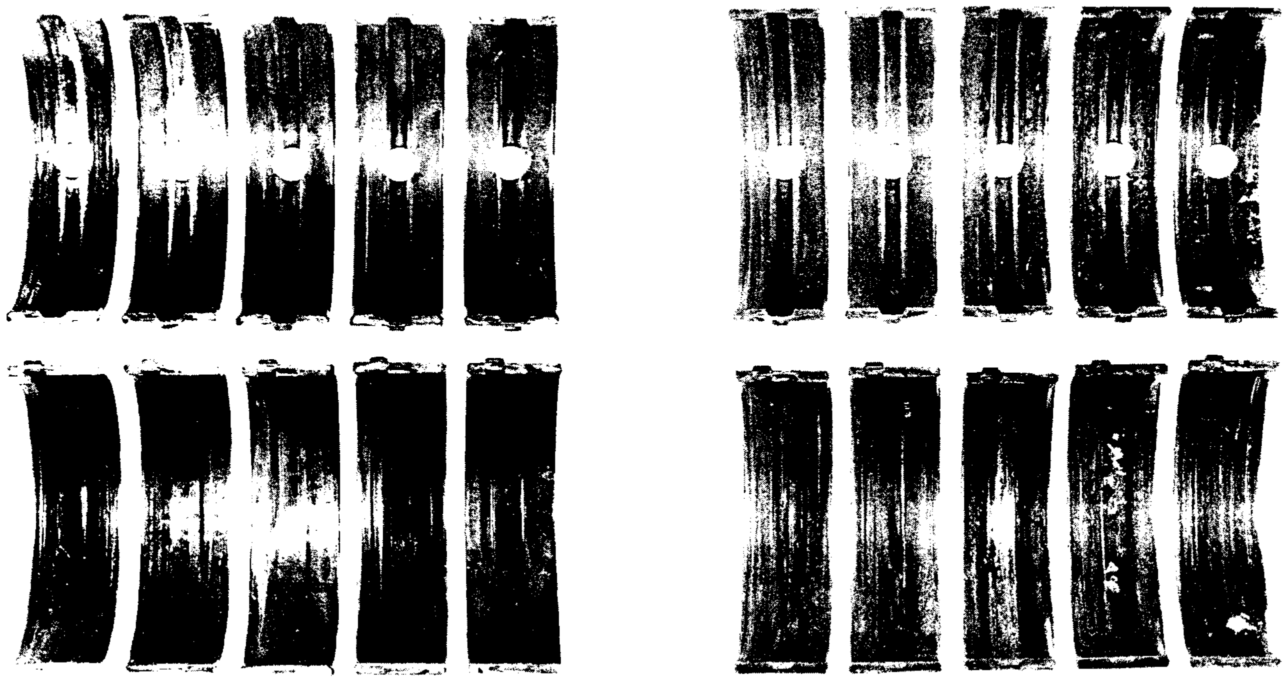


Fig. 6 - Comparison of Main Bearing Shells

upper and lower shells. Also, if a new or reground crankshaft is used, install all new bearing shells.

Bearing shells are availble in .010", .020" and .030" undersize for service with crankshafts which have been ground to a smaller journal diameter.

Bearings 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.

Table 1 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.

Excessive crankshaft end play due to an improper flywheel or improper clutch adjustment can contribute to excessive wear or scoring of the crankshaft thrust washers.

Measure the crankshaft end play as outlined under *Install Crankshaft* in Section 1.3. With new parts, the end play must be within .004" to .011". The maximum allowable end play with used parts is .018". Replace the thrust washers if necessary.

Inspect the crankshaft thrust surfaces and, if necessary, recondition the thrust surfaces as outlined under *Crankshaft Grinding* in Section 1.3. If, after "dressing up" or grinding the crankshaft, new standard size thrust washers do not hold the end play within the specified limits, then oversize thrust washers must be used. If one of the thrust surfaces of the crankshaft is worn or ground considerably more than the other, it may be necessary to install thrust washers of different thickness on either side of the main bearing to properly center the crankshaft main journal on the bearing. The oversize thrust washers are listed in Table 2.

Install Main Bearing Shells (Crankshaft in Place)

Make sure all of the parts are clean. Apply clean engine oil to each crankshaft journal and install the main bearing shells by reversing the sequence of operations given for removal.

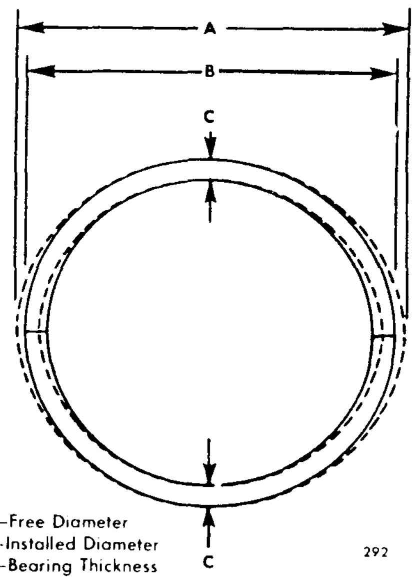


Fig. 7 - Inside Diameter of Main Bearing Shell at Parting Line and 90 Degrees to Parting Line

CAUTION: Do not mix one hole and seven hole upper main bearing shells in a V-type engine. If the current seven hole bearing shells are installed in an early engine, the current oil pump must be included, otherwise low oil pressure will result.

The upper and lower main bearing shells are not alike; the upper shell is grooved and drilled for lubrication -- the lower shell is not. Be sure to install the grooved and drilled shells in the cylinder block and the plain shells in the bearing caps, otherwise the oil flow to the upper end of the connecting rods will be blocked off. Used bearing shells must be reinstalled on the same journal from which they were removed.

1. When installing the upper main bearing shells with the crankshaft in place, start the plain end of the shell around the crankshaft journal so that, when the shell is in place, the tang will fit into the groove in the bearing support.

2. Assemble the crankshaft thrust washers before installing the main bearing cap. Clean both halves of the thrust washer carefully and remove any burrs from the washer seats -- the slightest particle of dirt may decrease the clearance between the washers and the crankshaft beyond limits. Slide the upper halves of the thrust washers into place in their grooves (Fig. 9), then assemble the lower halves over the dowel pins in the bearing cap.

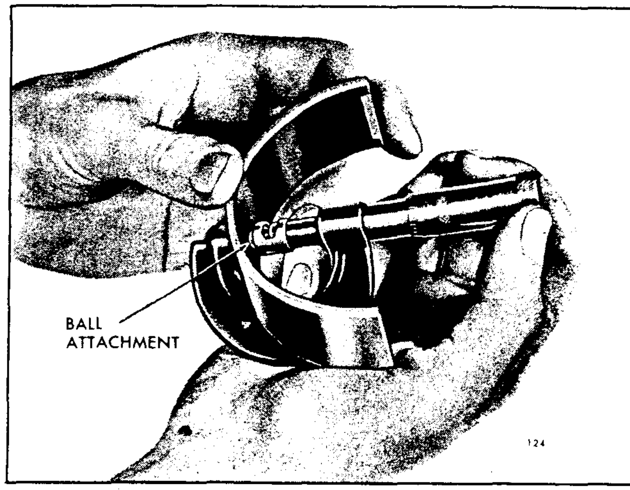


Fig. 8 - Measuring Thickness of Main Bearing Shell

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"
	V-Type Engines	
Standard	.1240"	3.499"-3.500"
.002" Undersize	.1250"	3.497"-3.498"
.010" Undersize	.1290"	*3.489"-3.490"
.020" Undersize	.1340"	*3.479"-3.480"
.030" Undersize	.1390"	*3.469"-3.470"

Table 1

Nominal Size	Washer Thickness
Standard	.1190"/.1220"
.005" Oversize	.1255"/.1270"
.010" Oversize	.1300"/.1320"

TABLE 2

NOTE: The main bearing caps are bored in position and marked 1, 2, 3, etc. They must be replaced in their original positions with the marked side of the caps facing the same side of

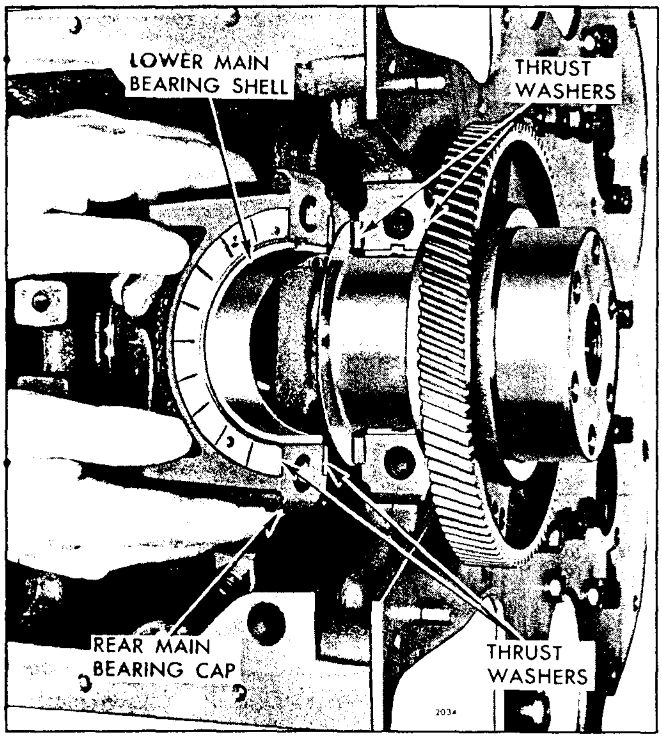


Fig. 9 - Crankshaft Thrust Washer Mounting

the cylinder block that carries the engine serial number.

3. With the lower bearing shells installed in the bearing caps, install the caps on an In-line engine, or caps and stabilizers on a V-type engine, 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, rap the caps sharply with a soft hammer to seat them properly and draw the bearing cap bolts uniformly tight, starting with the center cap and working alternately towards both ends of the block, to 120-130 lb-ft torque. On a V-type engine, tighten the stabilizer to cylinder block 7/16"-14 bolts to 46-50 lb-ft torque.

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.

4. Check the crankshaft end play as outlined under *Install Crankshaft* in Section 1.3.

5. Install the lubricating oil pump intake pipe assembly.

6. Use a new gasket and install the oil pan.

7. Fill the crankcase to the proper level (indicated on the dipstick) with heavy-duty lubricating oil of the viscosity recommended (see *Lubricating Oil Specifications* in Section 13.3).

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)

In-Line and 6V Engines

The engine lower front cover is mounted against the cylinder block at the lower front end of the engine (Figs. 1 and 2). 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. The clean-out openings in the periphery of the current cover incorporate tapped holes and 1/2 ″-14 threaded plugs.

On all In-line and 6V engines effective with engine serial numbers 2D-13569 (except 2D-13592, 13597, 13622 and 13626), 3D-4295 (except 3D-4373), 4D-6027 and 6D-3858 (6D-3246, model 5063-5200), the oil pressure regulator valve is located on the right-hand side of the engine front cover, as viewed from the front of the engine. Prior to the above engine serial numbers, the oil pressure regulator valve was located on the left-hand side of the front cover just below the oil cooler by-pass valve.

Current 6V engines include a regulator valve with a non-replaceable stop swaged in the valve. When it becomes necessary to replace the regulator valve or plug in an early engine, both must be replaced together. Also, when the valve and plug in either side of the engine lower front cover needs to be replaced, the valve and plug in both sides of the cover must be replaced.

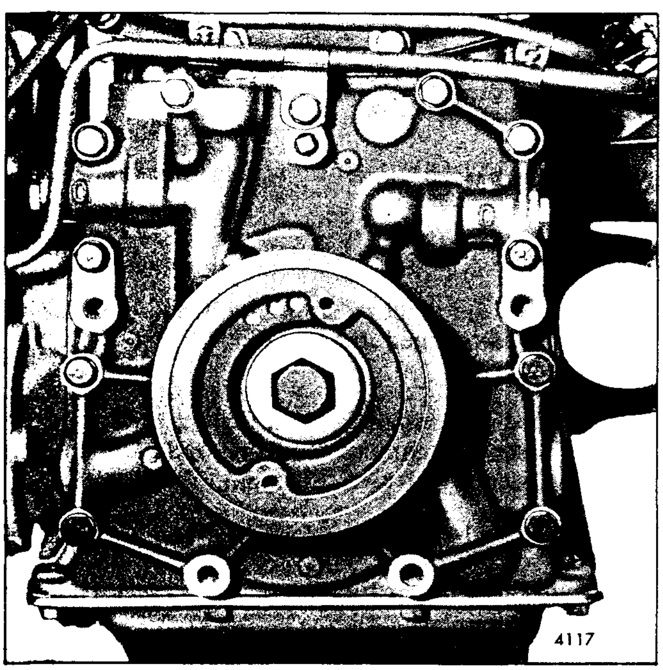


Fig. 1 - Engine Front Cover Mounting (Lower) -- In-Line Engine

Remove Engine Front Cover

1. Drain the oil and remove the oil pan.

2. Remove the crankshaft pulley as outlined in Section 1.3.7.

3. Remove the two bolts and lock washers that secure the lubricating oil pump inlet tube flange or elbow to the engine front cover.

4. Remove the bolts and lock washers that secure the engine front cover to the cylinder block.

5. Strike the cover with a soft hammer to free it from the dowels. Pull the cover straight off the end of the crankshaft.

6. Remove the cover gasket.

7. 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.

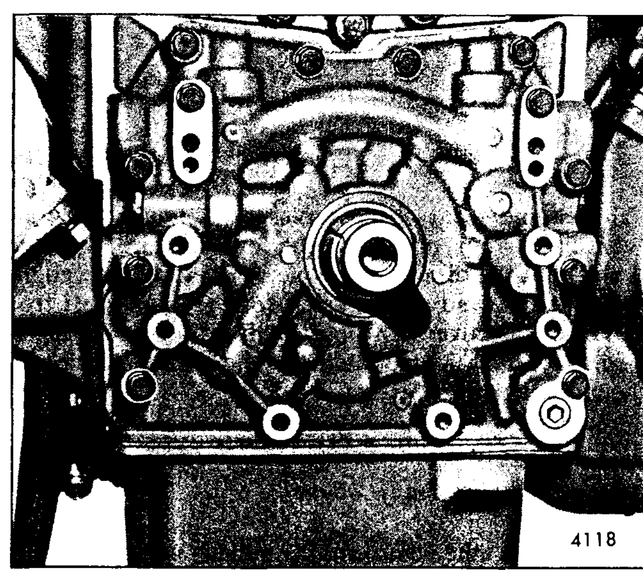


Fig. 2 - Engine Front Cover Mounting (Lower) -- 6V-Engine

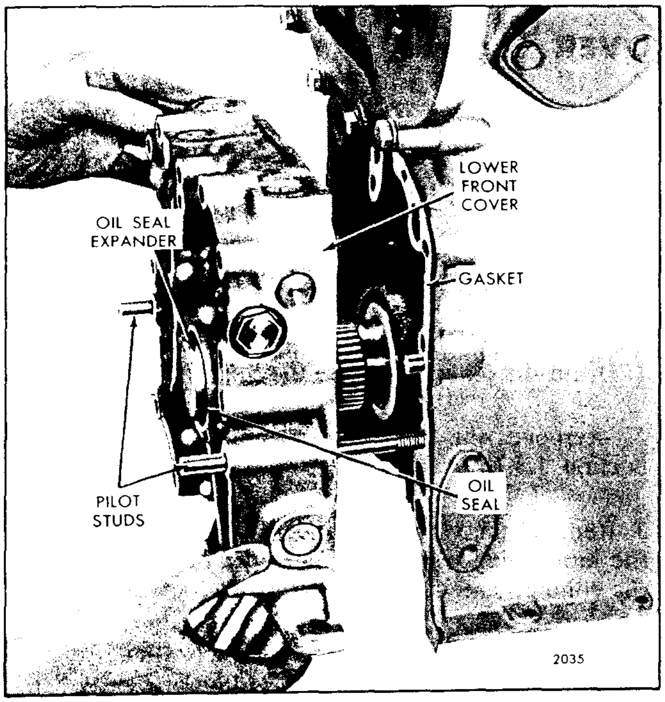


Fig. 3 - Installing Lower Engine Front Cover -- In-Line Engine

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 3/8 ″-16 pilot studs approximately 8 ″ long into two diametrically opposite bolt holes in the cylinder block to guide the cover in place (Fig. 3).

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 Fig. 3. 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 Figs. 1 and 2 and install the 3/8 ″-16 bolts and lock washers. Tighten the bolts to 30-35 lb-ft torque.

7. Affix a new seal ring on the end of the lubricating oil pump inlet tube next to the flange on an In-line engine, or a new gasket to the elbow on a 6V-engine. 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 install and 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.

ENGINE FRONT COVER

8V Engine

The engine front cover serves as a housing for the camshaft front oil seals, the oil pressure regulator valve and the oil cooler by-pass valve. Prior to engine 8D-149, it served as a housing for the crankshaft front oil seal. Effective with engine 8D-149, the crankshaft front oil seal is mounted in the outboard bearing support assembly (Section 1.3.5.1).

Remove Engine Front Cover

1. Remove the crankshaft pulley as outlined in Section 1.3.7.

2. Remove the pulleys from the front ends of the camshafts as outlined in Section 1.7.

3. Remove the engine front cover, including the engine front trunnion and/or outboard bearing support assembly, if used, (Section 1.3.5.1).

4. Remove and discard the cover gaskets.

5. Remove and discard the oil seals.

6. Check the oil pressure regulator and oil cooler by-pass valves as outlined in Section 4.1.1.

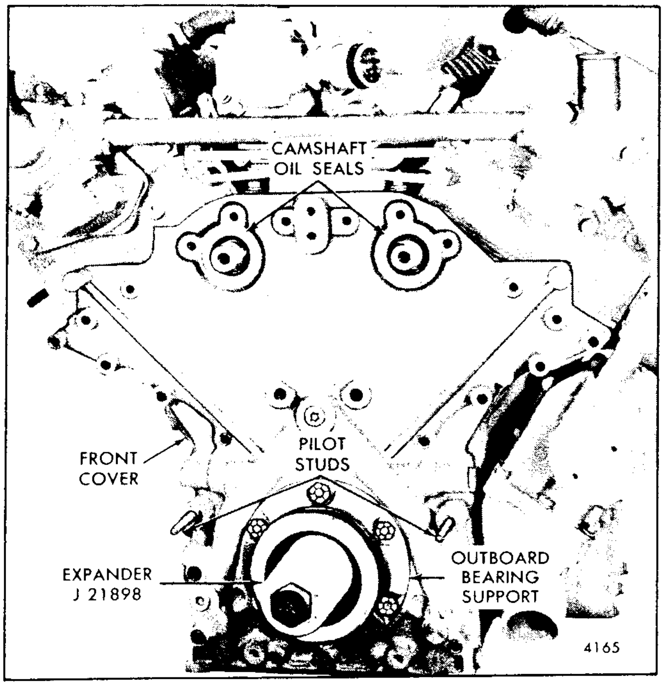


Fig. 4 - Installing Engine Front Cover - 8V-Engine

Install Engine Front Cover

CURRENT ENGINES (effective with 8D-149):

1. Install the camshaft oil seals, if removed, with installer J 21899.

2. Affix new front cover gaskets to the cylinder block.

3. Install two pilot studs (Fig. 4) into diametrically opposite bolt holes in the cylinder block to guide the engine front cover in place.

4. Slide the front cover over the pilot studs.

5. Remove the pilot studs and install the front cover attaching bolts and lock washers. Tighten the bolts to 30-35 lb-ft torque.

6. Install the outboard bearing support on the engine front cover as follows:

   a. Install oil seal expander J 21898 (Fig. 4) over the end of the crankshaft. Then apply a light coat of cup grease to the lip of the oil seal and install the outboard bearing support over the oil seal expander and against the engine front cover. Remove the seal expander.

   b. Install the six attaching bolts. Hold the outboard bearing support in a downward position with light hand pressure when tightening the bolts. First snug all the bolts, then tighten them to 75-85 lb-ft torque.

   c. Check the outboard bearing-to-crankshaft clearance with a feeler gage. The clearance must not be less than .0035 " or more than .008 " with the bearing support in the downward position.

   d. Install the front trunnion, if used.

7. Install the crankshaft front sleeve, if used.

8. Install the crankshaft pulley as outlined in Section 1.3.7.

9. Install the camshaft pulleys as outlined in Section 1.7.

FORMER ENGINES (prior to 8D-149):

1. Install the camshaft oil seals, if removed, with installer J 21899.

2. Install the crankshaft front oil seal as outlined in Section 1.3.2.

3. Affix new front cover gaskets to the cylinder block.

4. Install the oil seal expander J 21898 over the end of the crankshaft.

5. Install two pilot studs into diametrically opposite bolt holes in the cylinder block.

6. Apply a light coat of cup grease to the lip of the oil seal and guide the front cover over the pilot studs and against the cylinder block.

7. Install the front cover attaching bolts and lock washers and tighten the bolts to 30-35 lb-ft torque.

8. Remove the oil seal expander and the pilot studs.

9. Install the crankshaft front sleeve, if used.

10. Install the crankshaft pulley as outlined in Section 1.3.7.

11. Install the camshaft pulleys as outlined in Section 1.7.

CRANKSHAFT OUTBOARD BEARING SUPPORT

8V Engines

The crankshaft outboard bearing support (Fig. 1) houses the crankshaft front outboard bearing (bushing) and the crankshaft front oil seal. The support is a one-piece casting which bolts directly to the engine front cover, providing easy access for removing and installing the oil seal and bearing. A seal ring is used between the bearing support and the engine front cover.

The bearing is pressure lubricated by oil from an internal oil passage in the crankshaft.

The bearing support must be removed when replacement of the bearing or crankshaft oil seal is required.

Remove Outboard Bearing Support

1. Remove the crankshaft pulley (Section 1.3.7).

2. Remove the front trunnion (Fig. 1), if used.

3. Remove the six attaching bolts and detach the bearing support from the engine front cover.

4. Remove and discard the seal ring.

Inspection

Oil leaks are indications of worn or damaged seals.

Inspect the oil seal sleeve for wear due to the rubbing

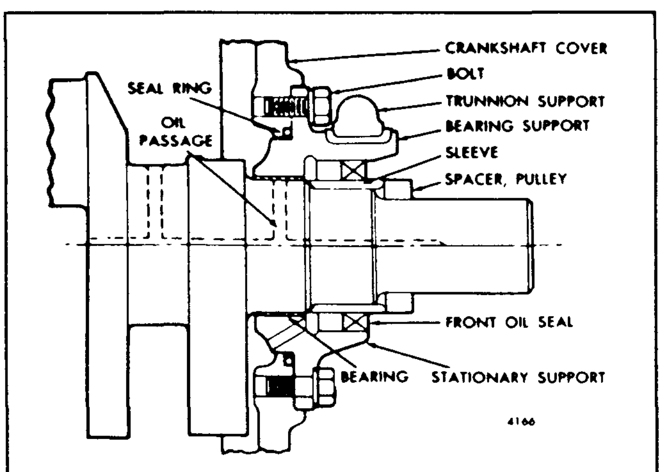


Fig. 1 - Outboard Bearing Support Assembly

action of the oil seal or dirt build-up. The sleeve must be smooth and clean, otherwise the oil seal lip will be damaged when a new seal is installed.

The oil seal sleeve may be smoothed up with emery cloth and polished with crocus cloth wet with fuel oil. Clean up the circumference of the sleeve without disturbing the concentricity.

Excessive wear or grooving in the crankshaft oil seal sleeve may require the use of a new sleeve (refer to Section 1.3.2).

Inspect the bearing for scoring or excessive wear. The crankshaft to bearing clearance with new parts is .0035 " to .0071 " and a maximum of .0080 " with used parts. The crankshaft journal diameter (new) is 2.8770 " to 2.8780 ".

Install Outboard Bearing Support

1. If the bearing was removed, position a new bearing in the support, with the split line in the bearing toward the bottom of the support (Fig. 2), and press it in until it is flush with the rear face of the support.

NOTE: The top of the bearing support is

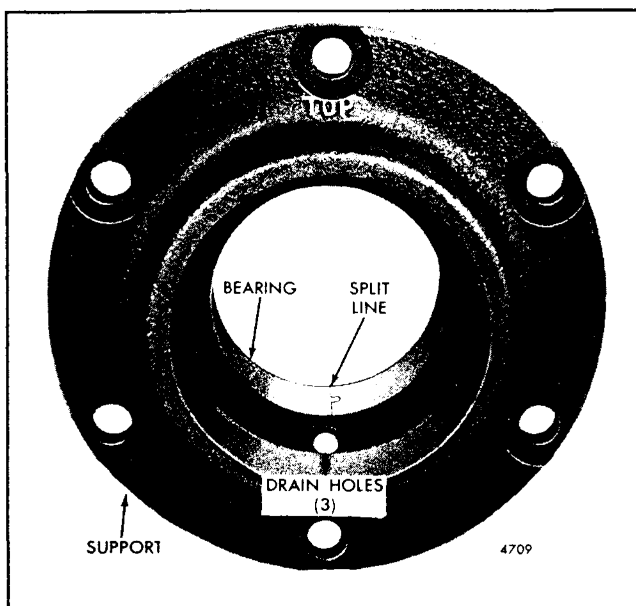


Fig. 2 - Location of Bearing in Support

identified by the word "TOP" cast in the front face of the support.

2. Install a new oil seal as outlined in Section 1.3.2.

3. Install a new seal ring on the bearing support.

4. Install the bearing support assembly on the engine front cover as outlined in Section 1.3.5.

5. Install the trunnion support.

6. Install the crankshaft pulley (Section 1.3.7).

CRANKSHAFT VIBRATION DAMPER

On certain 8V engines, a viscous type vibration damper is mounted on the front end of the crankshaft to reduce crankshaft stresses to a safe value (Fig. 1). The vibration damper is bolted to a hub which is retained on the front end of the crankshaft.

A viscous type vibration damper consists of an inertia mass (flywheel) enclosed in a fluid-tight outer case but separated therefrom by a thin wall of viscous liquid not responsive to temperature changes. Any movement of the inertia mass, therefore, is resisted by the friction of the fluid, which tends to dampen excessive torsional vibrations in the crankshaft.

The vibration damper must be removed whenever the crankshaft, crankshaft front oil seal or crankshaft front cover is removed.

Remove Vibration Damper

1. Remove the crankshaft pulley retaining bolt and washer.

2. Remove the crankshaft pulley. If required, use a suitable puller to remove the pulley.

3. Reinstall the pulley retaining bolt in the end of the crankshaft.

4. Attach puller J 4558 to the vibration damper hub, as shown in Fig. 2, with two long bolts threaded into the two 3/8" -24 tapped holes provided in the hub. Pull the damper and hub assembly, together with the outer cone, until the outer cone is loose on the crankshaft.

5. Remove the puller from the damper hub and pull the outer cone off of the crankshaft.

CAUTION: Pounding with a hammer or prying with other tools must not be resorted to when removing a viscous type damper from the crankshaft. Dents in the damper outer case may render the damper ineffective. *The damper cannot be repaired.*

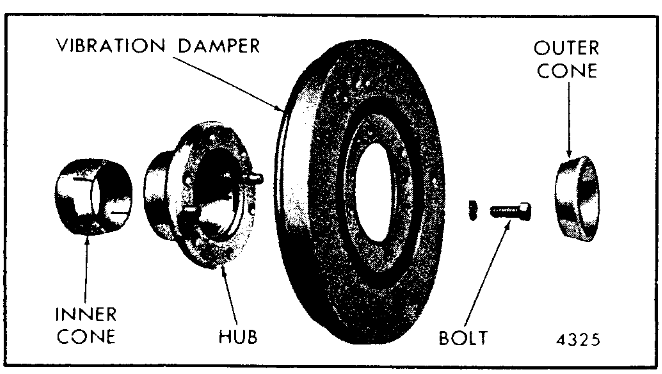


Fig. 1 - Vibration Damper Details and Relative Location of Parts

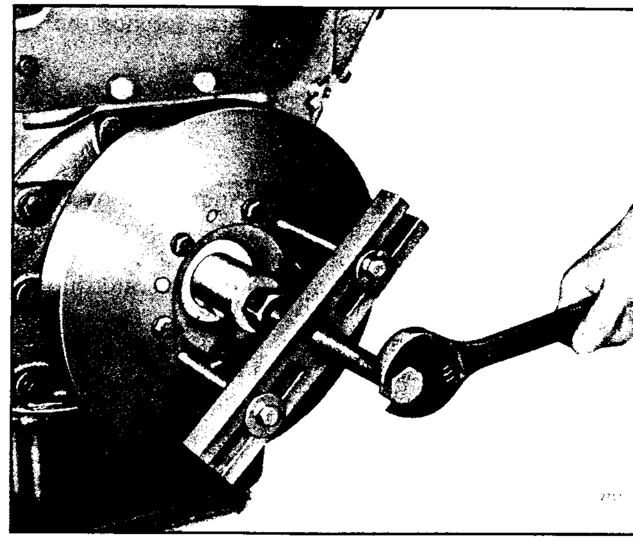


Fig. 2 - Removing Vibration Damper Outer Cone

6. Slide the vibration damper and damper hub as an assembly off of the end of the crankshaft by hand.

7. If necessary, remove the vibration damper inner cone from the crankshaft.

Inspection

Inspect the damper for dents, nicks or bulges in the outer casing. Any indications of the above are sufficient cause for rejection. Due to the close clearances between the damper internal flywheel and the outer casing, dents may render the damper ineffective. Bulges or splits indicate the fluid has ignited and expansion of the resultant gases bulged or forced the casing open at its crimped edges.

Regardless of condition, a viscous type damper must be replaced at the time of normal periodic major engine overhaul.

If damage to the vibration damper is extensive, inspect the crankshaft as outlined in Section 1.3. A loose or defective vibration damper, after extended operation, may result in a cracked crankshaft.

Inspect the damper inner and outer cones, damper hub and the end of the crankshaft for galling or burrs. Slight scratches or burrs may be removed with emery cloth. If seriously damaged, replace the parts and refinish the end of the crankshaft. Check the outside diameter of the inner cone for wear at the crankshaft front oil seal contact surface. If worn, replace the oil seal and cone (refer to Section 1.3.2).

Install Vibration Damper

1. If removed, pilot the damper inner cone over the end of the crankshaft, through the oil seal and up against the oil slinger, with the tapered end of the cone pointing toward the front end of the crankshaft.

2. Slide the damper and hub as an assembly over the end of the crankshaft (with the long end of the hub facing the inner cone) and up against the damper inner cone. *Do not* hit the damper with a hammer to position it on the crankshaft.

3. Slide the damper outer cone over the end of the crankshaft and up against the damper hub, with the tapered end of the cone pointing toward the hub.

4. Install the pulley on the crankshaft.

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

6. Tighten the crankshaft end bolt as follows:

a. Tighten the bolt to 180 lb-ft torque.

b. Strike the end of the bolt a sharp blow with a 2 to 3 pound lead hammer.

c. Tighten the bolt to 290-310 lb-ft torque and strike the bolt again.

d. Retighten the bolt to 290-310 lb-ft torque.

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 from an In-line or 6V engine, install the pulley retaining bolt and puller J 4794-01 as shown in Fig. 1. Then force the pulley off the crankshaft by turning the puller center screw in.

On pulleys that do not incorporate two tapped holes in the front face of the pulley, use a two arm universal type puller.

If a puller is required to remove a rigid type pulley from an 8V engine, use a universal type puller. Three tapped holes are provided in the pulley to facilitate removal.

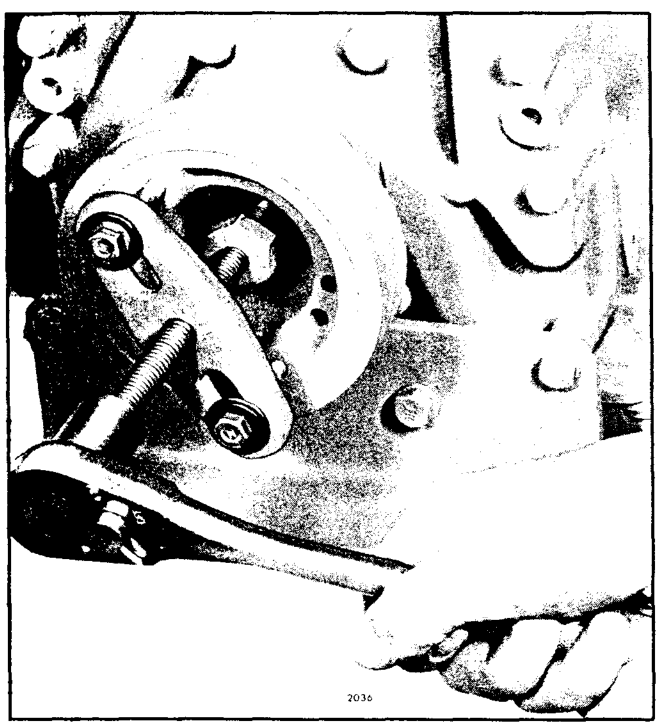


Fig. 1 - Removing Crankshaft Pulley Using Puller J 4794-01

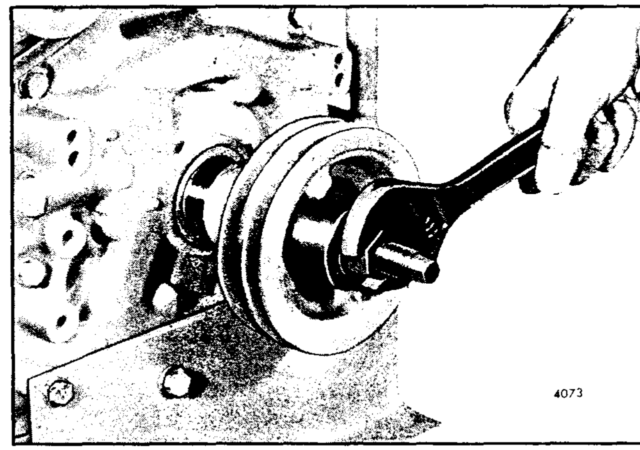


Fig. 2 - Installing Crankshaft Pulley Using Installer J 7773

4. Remove the outer and inner cones, if used.

5. If a rubber mounted pulley with an internal thread is being removed from an 8V engine, use puller J 5356. To use the tool, screw the 2-1/2 ″-16 thread into the pulley hub as far as possible with the center screw backed off. Then force the pulley off the crankshaft by turning the center screw in.

Inspection

The appearance of the rubber bushing does not determine the condition of a rubber mounted crankshaft pulley. Check for failure of the rubber bushing by locking the crankshaft and applying pressure to the crankshaft pulley. If the pulley cannot be rotated, the bushing is in satisfactory condition. If necessary, replace the rubber bushing.

Install Crankshaft Pulley

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

2. Slide the inner cone (Fig. 3), if used, on the crankshaft.

3. On an 8V engine, install two Woodruff keys (if removed) in the keyways in the front end of the crankshaft.

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

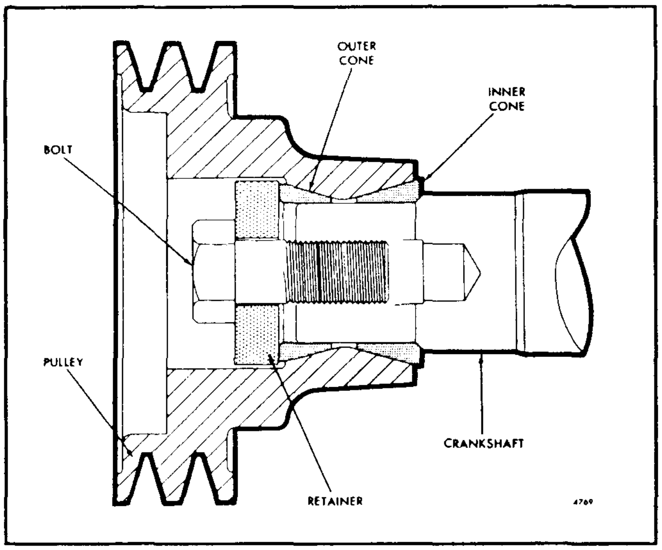


Fig. 3 - Cone Mounted Pulley

5. Install a rigid type pulley on an In-line or 6V engine with installer J 7773 as shown in Fig. 2. Then remove the installer.

6. Slide a rigid type pulley on an 8V engine. If necessary, hold a block of wood against the hub of the pulley and tap the pulley on the crankshaft with a hammer.

7. Slide the outer cone (Fig. 3), if used, on the crankshaft.

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

9. On certain 4-53 and 6V-53 engines, a splined crankshaft pulley is used. Place a drive flange washer over the splined end of the crankshaft. Align the splines and tap the pulley on the crankshaft with a plastic hammer. Place another drive flange washer on the bolt and thread it into the end of the crankshaft. Tighten the 3/4 ″-16 bolt to 290-300 lb-ft torque.

10. On in-line engines with cone mounted pulleys NOT stamped with the letter "A", tighten the 3/4 ″-16 bolt to 290-300 lb-ft torque.

11. On all in-line and 6V engines with the rigid type pulleys and cone mounted pulleys stamped with the letter "A", tighten the 3/4 ″-16 bolt to 200-220 lb-ft torque.

12. When pulleys stamped with the letter "U" (in a square box) are used, tighten the 3/4 ″-16 bolt to 290-310 lb-ft torque.

13. On 8V engines, tighten the 1 ″-14 crankshaft bolt to 290-310 lb-ft torque.

14. Install and adjust the belts.

FLYWHEEL

The flywheel is attached securely to the rear end of the crankshaft with six self-locking bolts. The bolt heads are prevented from "biting" into the flywheel by a scuff plate, which is used between the flywheel and the heads of the bolts. On an 8V engine, two dowels are provided in the rear end of the crankshaft for locating the flywheel. A ring gear is shrunk onto the rim of the flywheel.

The flywheel is machined to permit a true alignment of a power take-off or clutch with the flywheel, and the center bore of the flywheel provides for installation of a pilot bearing. The power take-off driving ring or clutch is bolted securely to the flywheel.

An oil seal ring, which provides an oil tight connection between the crankshaft and the flywheel, is fitted into a groove on certain flywheels.

On Torqmatic converter units, the flywheel is part of the converter and is covered in the *Torqmatic Converter Service Manual.*

The rugged construction of the flywheel makes necessity for service 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. If a clutch housing is attached to the flywheel housing, remove the flywheel as follows:

a. Remove the flywheel attaching bolts and the scuff plate.

b. Lift the flywheel off the end of the crankshaft and out of the clutch housing.

2. If a clutch housing isn't used, remove the flywheel as follows:

a. Remove the flywheel attaching bolts and the 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 doweled to the crankshaft, except on 8V engines.

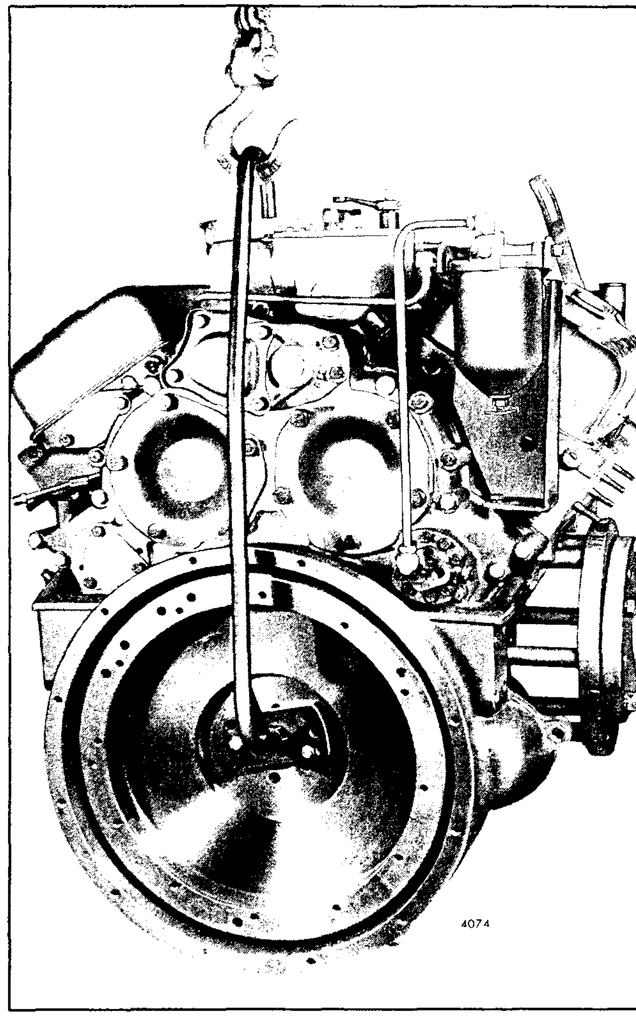


Fig. 1 - Removing Flywheel with Tool J 6361-01

b. Attach flywheel lifting tool J 6361-01 to the flywheel with two 3/8" -16 bolts of suitable length as shown in Fig. 1.

c. Attach a chain hoist to the lifting tool.

d. Remove the remaining flywheel attaching bolt.

e. Move the upper end of the tool back and forth to loosen the flywheel; then, withdraw the flywheel.

f. If equipped with a clutch pilot bearing, remove the bearing from the flywheel (see Section 1.4.1).

Inspection

Check the clutch contact face of the flywheel for cracks, scoring or overheating. If the flywheel clutch surface is scored, it may be refaced. However, do not remove more than .020" of metal from the flywheel and maintain all radii when refacing the flywheel.

If the contact face of the clutch wear plate shows signs of overheating or excessive scoring, replace the wear plate.

The flywheel seldom wears to the point of requiring service or replacement. However, the flywheel ring gear may become worn due to normal usage or damage by improper use of the starting motor to the extent that it must be replaced. Examine the teeth on the ring gear. If replacement is necessary, remove the ring gear as outlined below.

Remove Ring Gear from Flywheel

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. Before removing the gear, note the chamfer, if any, on the gear teeth so that the new gear may be installed in the same position.

2. Drive the ring gear off of the flywheel with a suitable drift and hammer. 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 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 in place against the shoulder on the flywheel. If the gear cannot be tapped into place readily, remove it and apply additional heat, heeding the caution about overheating.

Install Flywheel

1. On an 8V engine, check the extension of the dowels from the end of the crankshaft. The dowels must not extend more than 1/2" from the crankshaft.

2. If a pilot bearing is used in the bore of the flywheel and was removed, install the bearing. Install a new seal ring if one was previously used.

3. Mount the flywheel, using lifting tool J 6361-01 and a chain hoist, in position against the rear end of the crankshaft.

4. Apply a small quantity of International Compound No. 2, or equivalent, to the bolt threads and bolt head contact areas of the flywheel attaching bolts.

5. 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 on all engines, except 8V engines, to 110-120 lb-ft torque. On an 8V engine, tighten the bolts to 180-190 lb-ft torque.

6. Mount a dial indicator on the flywheel housing or clutch 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 the flywheel).

CLUTCH PILOT BEARING

The clutch pilot bearing is pressed into the bore of the flywheel assembly and serves as a support for the inner end of the clutch drive shaft.

On most applications, the clutch pilot bearing is held in place on one side by a shoulder in the flywheel and on the other side by a bearing retainer.

On certain applications, the clutch pilot bearing is held in place on one side by a bearing retainer, placed between the flywheel and the end of the crankshaft, and on the other side by the flywheel bolt scuff plate.

Lubrication

A double sealed clutch pilot bearing is sealed and prepacked with grease and requires no further lubrication. A single shielded clutch pilot bearing should be packed with all purpose grease such as Shell Alvania No. 2, or equivalent, if not previously packed by the manufacturer.

Remove Clutch Pilot Bearing (Transmission Removed)

With the flywheel attached to the crankshaft, the clutch pilot bearing may be removed as follows:

1. Remove the flywheel attaching bolts and scuff plate while holding the flywheel in position by hand, then reinstall two bolts to hold the flywheel in place.

   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, except on an 8V engine.

2. With the clutch pilot bearing remover adaptor J 5901-2 attached to slide hammer J 5901-1, insert the fingers of the adaptor through the pilot bearing and tighten the thumb screw to expand the fingers against the inner race of the bearing.

3. Tap the slide hammer against the shoulder on the shaft and pull the pilot bearing out of the flywheel.

Inspection

Wipe the prepacked double sealed bearing clean on the outside and then inspect it. *Shielded bearings must not be washed*; dirt may be washed in and the cleaning fluid could not be entirely removed from the bearing. Hold the inner race and revolve the outer race slowly by hand to check for free rolling of the balls on the races. Rough spots on the bearing are sufficient cause for rejecting it.

Install Clutch Pilot Bearing

1. Lubricate the outside diameter of the bearing with clean engine oil.

2. Start the pilot bearing straight into the bore of the flywheel, with the numbered side of the bearing facing away from the crankshaft.

3. Place bearing installer J 3154-04, with suitable adaptor plates, against the pilot bearing. Then, drive the bearing straight into and against the shoulder in the flywheel.

4. Install the flywheel as outlined in Section 1.4.

ENGINE DRIVE SHAFT FLEXIBLE COUPLING

The engine drive shaft flexible coupling is of the spring-loaded type having a splined hub to match with the splines on the transmission drive line shaft used on certain applications. The coupling, bolted to the engine flywheel, serves as a drive and also dampens out torque fluctuations between the engine and the transmission.

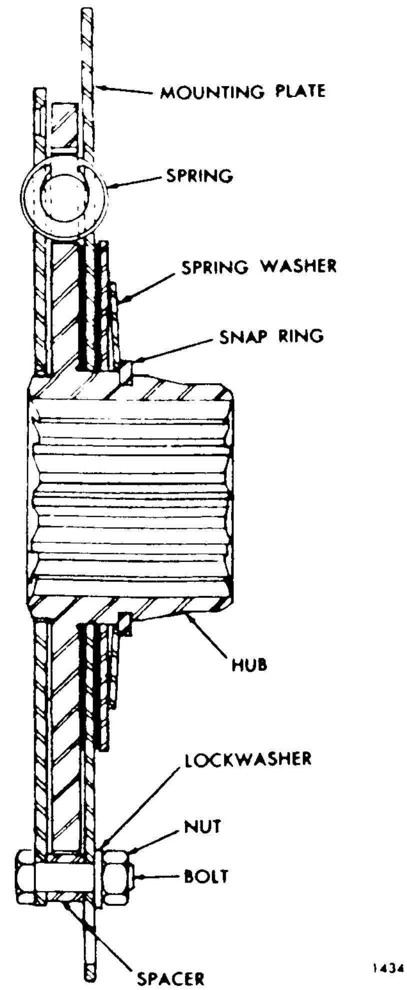


Fig. 1 - Engine Drive Shaft Flexible Coupling

Remove Coupling (Transmission Removed)

1. Remove the eight 3/8"-16 x 7/8" bolts which attach the coupling to the flywheel and remove the coupling.

Inspection

Wash the coupling in clean fuel oil and dry it with comrpessed air. Check for broken or worn springs. Springs may be replaced by removing the six bolts, lock washers, nuts and spacers holding the two plates together, and removing the smaller plate. After replacing the springs, bolt the plates together and tighten the nuts to 25-30 lb-ft torque.

Examine the hub splines for wear and check the flatness of the mounting plate (the plate which bolts to the flywheel). Since the plates, spacers and hubs are manufactured in matched sets, worn hubs or plates cannot be replaced individually, but must be replaced by a complete flexible coupling assembly.

Install Coupling

1. Align the bolt holes in the coupling with the tapped holes in the flywheel. Since one bolt hole is offset, the coupling can be attached in only one position. Install the eight 3/8"-16 x 7/8" bolts and tighten them securely.

FLYWHEEL HOUSING

The flywheel housing is a one-piece casting mounted against the rear end of the cylinder block. The flywheel housing provides a cover for the gear train and flywheel and also serves as a support for the starting motor and transmission.

The crankshaft rear oil seal, which is pressed into the housing, may be removed or installed without removing the housing (Section 1.3.2).

Remove Flywheel Housing

1. Remove the engine from its base as outlined in Section 1.1.

2. Remove the starter from the flywheel housing or the clutch housing.

3. Remove the flywheel.

4. Remove the oil pan.

5. Remove the clutch housing, if used.

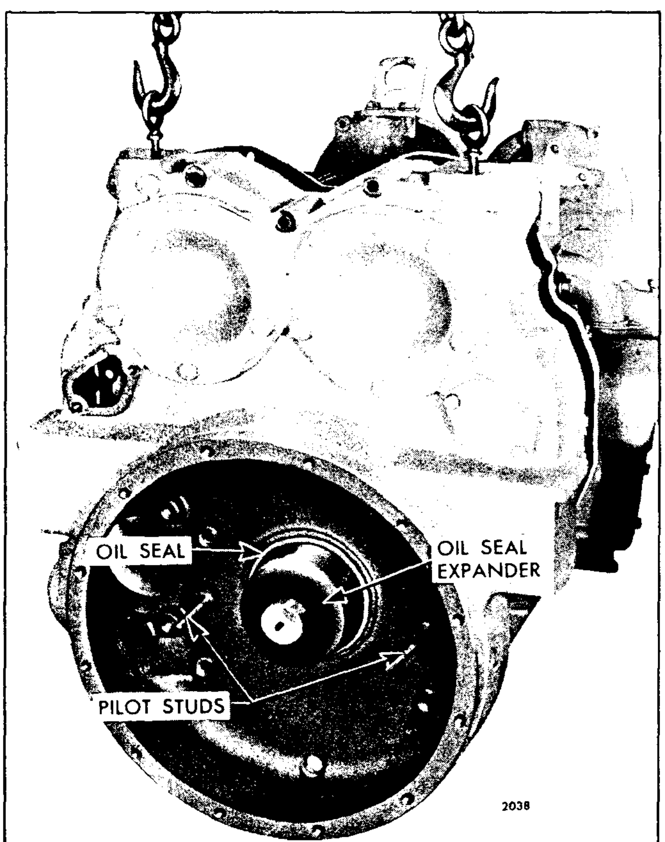


Fig. 1 - Installing Flywheel Housing

6. Remove the fuel pump, if it is mounted on the flywheel housing.

7. Remove the blower drive cover on 6V and 8V engines, the blower drive shaft retainer ring and the blower drive shaft on the 6V engine.

8. Remove the governor and blower drive support (6V engine).

9. Remove all of the bolts from the flywheel housing. Don't forget the blower-to-flywheel housing bolts on the 2-53 or 3-53 engines.

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

10. 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).

11. 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. 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.

12. Remove all traces of the old gaskets from the cylinder block rear end plate and the flywheel housing.

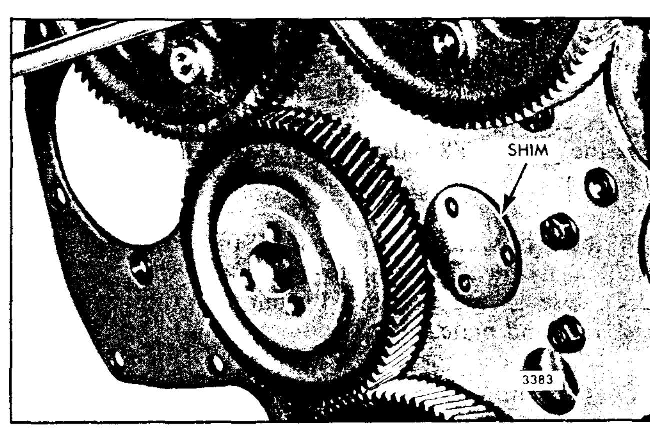


Fig. 2 - Location of Shim

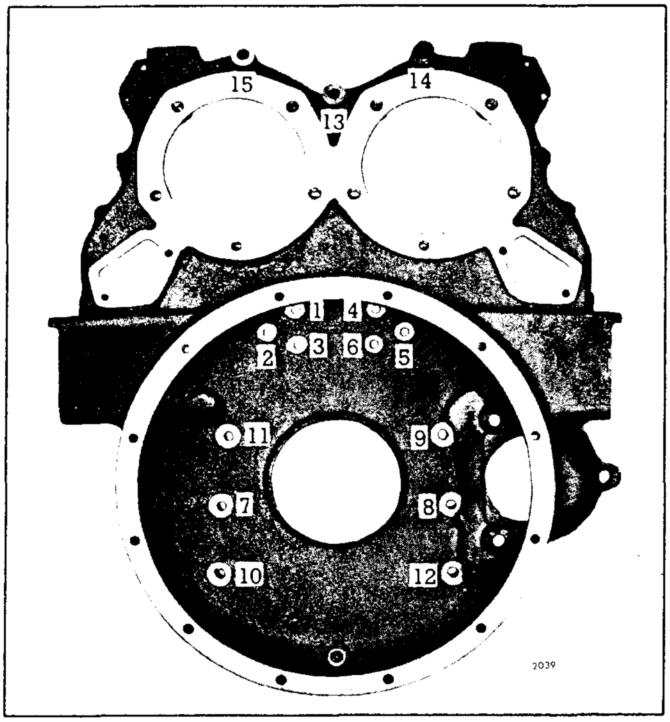


Fig. 3 - Flywheel Housing Bolt Tightening Sequence (Operation 1)--In-Line Engine

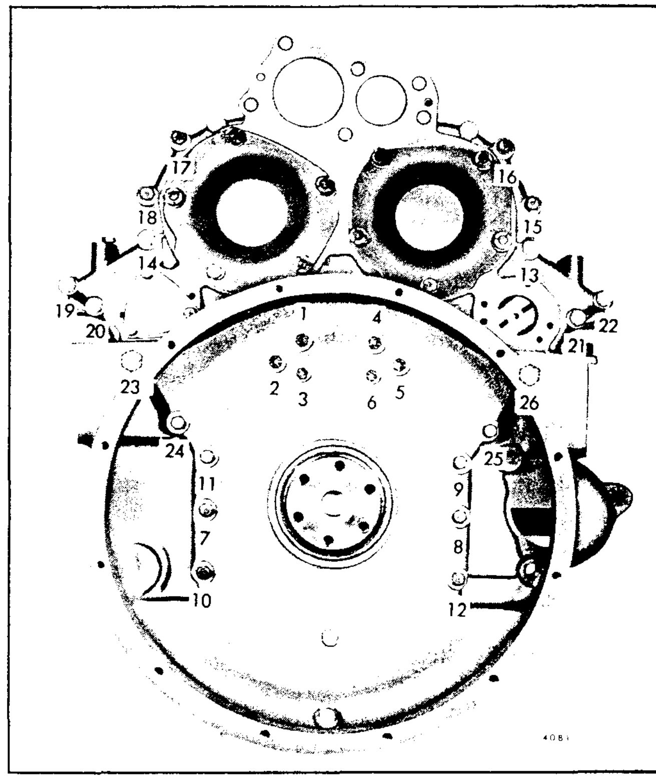


Fig. 4 - Flywheel Housing Bolt Tightening Sequence (Operation 1)--6V Engine

Inspection

Clean and inspect the flywheel housing for cracks or any other damage. Replace the housing if it is damaged.

Inspect the crankshaft rear oil seal 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. The V-type engines employ two gaskets (one large and one small). Affix the small (7/8 " dia.) gasket near the top of the end plate.

3. If 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. Coat the lip of the crankshaft oil seal lightly with engine oil (single-lip seal) or vegetable shortening (double-lip seal). Do not scratch or nick the sealing edge of the oil seal.

5. On In-line and 6V engines, to pilot the oil seal on the crankshaft successfully, use oil seal expander

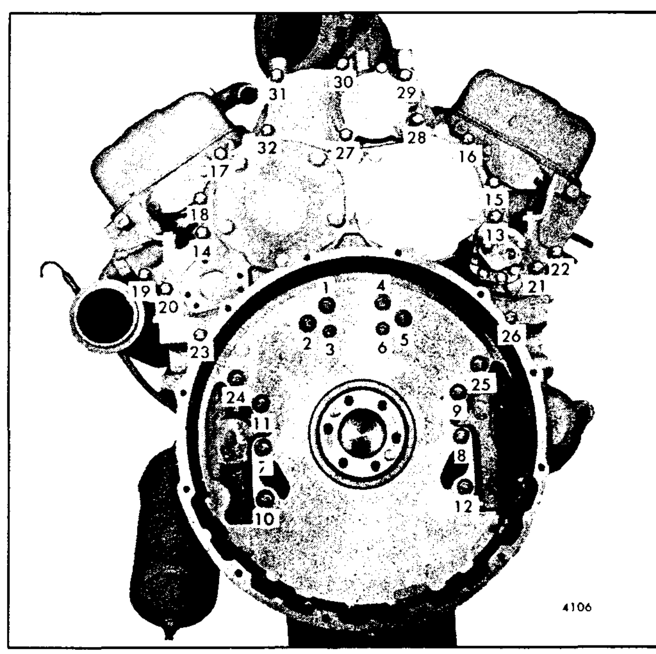


Fig. 5 - Flywheel Housing Bolt Tightening Sequence (Operation 1)--8V Engine

J 9769 (standard size seal) or J 21278 (oversize seal) on the end of the crankshaft. On 8V engines, use oil seal expander J 22425. Also thread two pilot studs J 7540 into the cylinder block to guide the housing in place (Fig. 1).

6. With the housing suitably supported, position it over the crankshaft and up against the cylinder block rear end plate and gasket(s).

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

> **NOTE:** If the engine is equipped with a clutch housing, do not install the six bolts numbered 7 through 12 (Fig. 3) until the clutch housing is installed.

8. On an In-line right hand rotation engine, start at No. 1 (No. 4 on left hand rotation engine) and draw the bolts up snug in the sequence shown in Fig. 3. On V engines, start at No. 4 on a right-hand rotation engine (No. 1 on a left-hand rotation engine) and draw the bolts up snug in the sequence shown in Fig. 4 and 5.

9. Refer to Fig. 6 for the final bolt tightening sequence on an In-line engine. Then start at No. 1 and tighten the bolts to the specified torque.

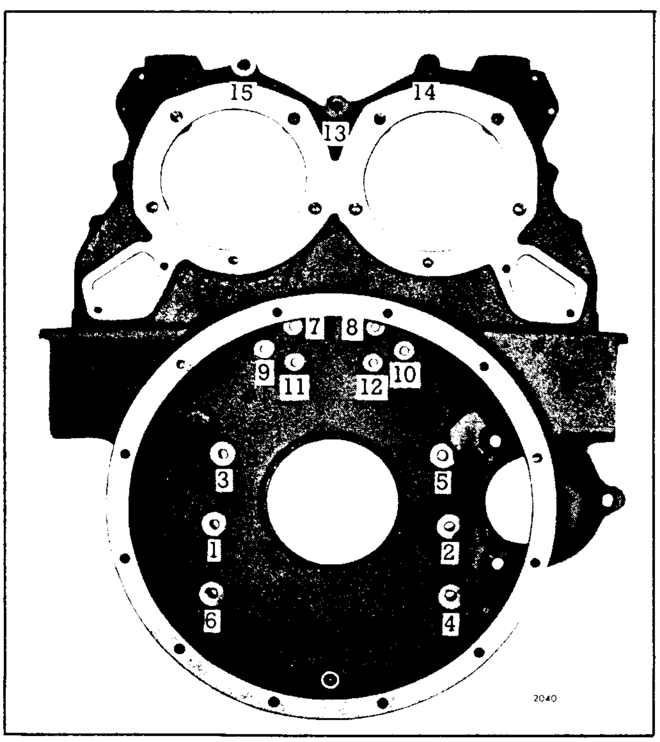


Fig. 6 · Flywheel Housing Bolt Tightening Sequence (Operation 2)--In-Line Engine

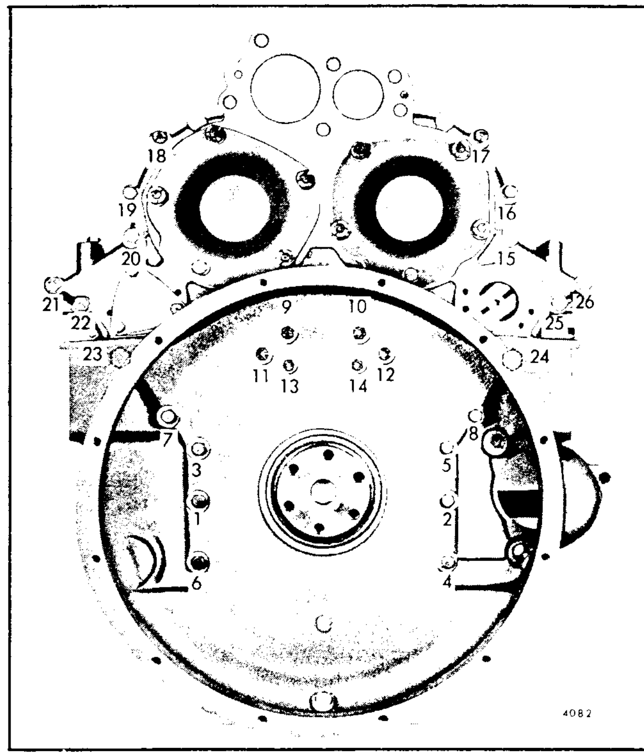


Fig. 7 · Flywheel Housing Bolt Tightening Sequence (Operation 2)--6V Engine

a. Tighten the 5/16"-18 bolts (numbers 11 and 12) to 19-23 lb-ft torque and the 3/8"-16 bolts

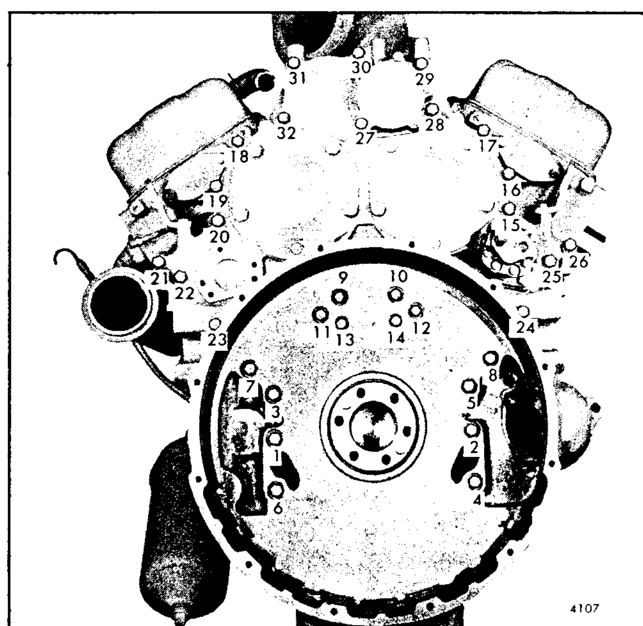


Fig. 8 · Flywheel Housing Bolt Tightening Sequence (Operation 2)--8V Engine (numbers 7 through 10) to 40-45 lb-ft torque. Tighten the remaining 3/8 ″-16 and 3/8 ″-24 bolts to 25-30 lb-ft torque.

NOTE: Prior to Engine Serial Numbers 2D-903, 3D-011 and 4D-103, the bolts numbered 7 through 12 in Fig. 3 were all 5/16 ″-18 bolts and must be tightened to 19-23 lb-ft torque.

b. On the two, three and four cylinder engines, 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. Refer to Fig. 7 or 8 for the final bolt tightening sequence for V engines; then, start at No. 1 and tighten the bolts to the specified torque. Tighten the 5/16 ″-18 bolts (numbers 13 and 14) to 19-23 lb-ft torque and the 3/8 ″-16 bolts (numbers 9 through 12) to 40-45 lb-ft torque. Tighten the remaining 3/8 ″-16 and 3/8 ″-24 bolts to 25-30 lb-ft torque.

NOTE: On an 8V engine when tightening the flywheel housing bolts, the idler gear hub bolts should always be tightened first. Also turn the crankshaft by hand while tightening the idler gear hub bolts to prevent any bind or brinelling of the rollers and races of the tapered roller bearing.

11. On a 6V engine, install the blower and governor drive support assembly as outlined in Section 2.7.1.1 or 2.7.2.1.

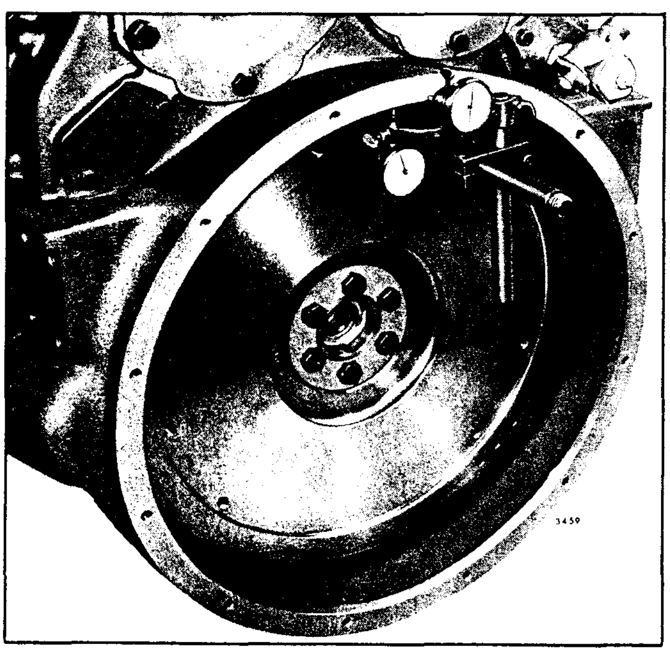


Fig. 9 - Checking Flywheel Housing Concentricity with Tool J 9737

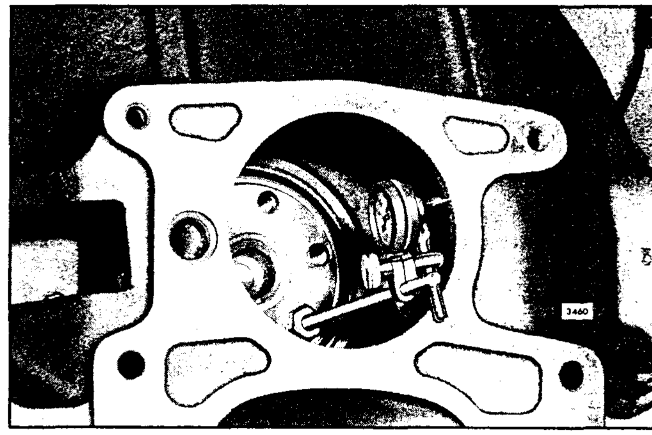


Fig. 10 - Checking Bore Runout

12. Check the flywheel housing concentricity and bolting flange face with tool J 9737 as follows:

a. Refer to Fig. 9 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.

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. Tap the front end of the crankshaft with a soft hammer or pry it with a pry bar 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.

f. Reinstall the flywheel housing and tighten the attaching bolts in the proper sequence and to the specified torque. Then recheck the run-out. If necessary, replace the flywheel housing.

13. Install the clutch housing, if used. Tighten the 3/8"-16 attaching bolts to 30-35 lb-ft torque and the 3/8"-24 nuts to 35-39 lb-ft torque.

a. Install tool J 9748 in one of the crankshaft bolt holes.

b. *Install the dial indicator J 8001-3 and position it* to read the bore runout of the housing (Fig. 10). Now check the runout by rotating the crankshaft. The runout should not exceed .008".

c. Reposition the dial indicator to read the face runout and rotate the crankshaft. The maximum allowable runout is .008".

d. If the bore or face runout is excessive, loosen the housing attaching bolts and nuts slightly and tap the housing with a soft hammer in the required direction until the runout is within limits. Tighten the attaching bolts and nuts evenly to 30-35 and 35-39 lb-ft torque respectively. Then recheck the runout.

14. Install the fuel pump (V-type engine), if removed.

15. Install the flywheel.

16. Use a new gasket and install the oil pan. On 8V engines, if the flywheel housing and oil pan include outriggers for the installation of reinforcement bolts, be sure the oil pan butts up against the flywheel housing before tightening the oil pan bolts. Install and tighten the 1/2"-13 reinforcement bolts.

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

18. Install the transmission.

19. Install the engine in the unit.

20. Fill the crankcase with lubricating oil.

21. Refill the cooling system.

PISTON AND PISTON RINGS

The trunk type malleable iron piston (Fig. 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 at 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 a 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 steel retainer. Thus, lubricating oil returning from the underside of the piston head and

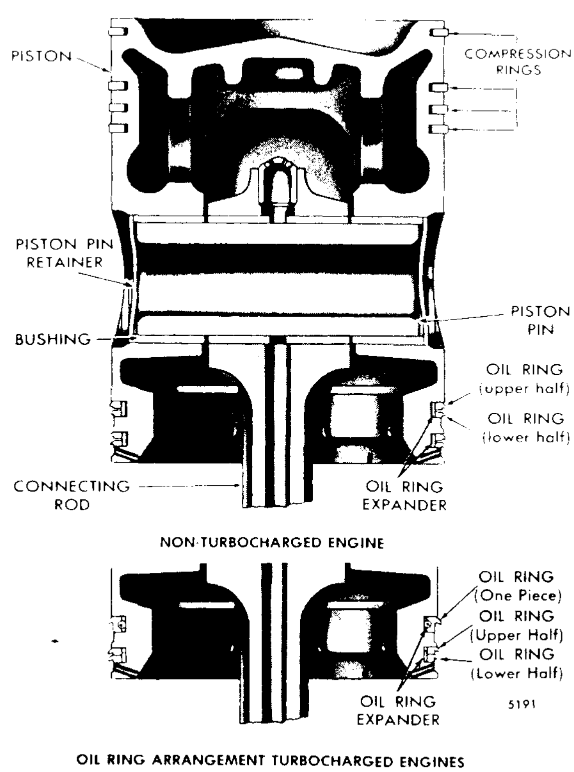


Fig. 1 - Typical Piston Assembly

working through the grooves in the piston pin 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 the 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 satisfactory.

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 the piston for non-turbocharged engines. On turbocharged engines, a one piece oil control ring is used in the upper position (Fig. 1) and the two piece ring is used in the lower position.

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.

Inspect Piston Rings

When an engine is hard to start, runs uneven or lacks power, the cause may be worn or sticking compression rings which must be replaced to restore uniform compression pressure in the cylinders.

The compression rings may be inspected through the ports in the cylinder liners after removing the air box covers. 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 the procedure for checking the compression pressure.

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 in the following manner:

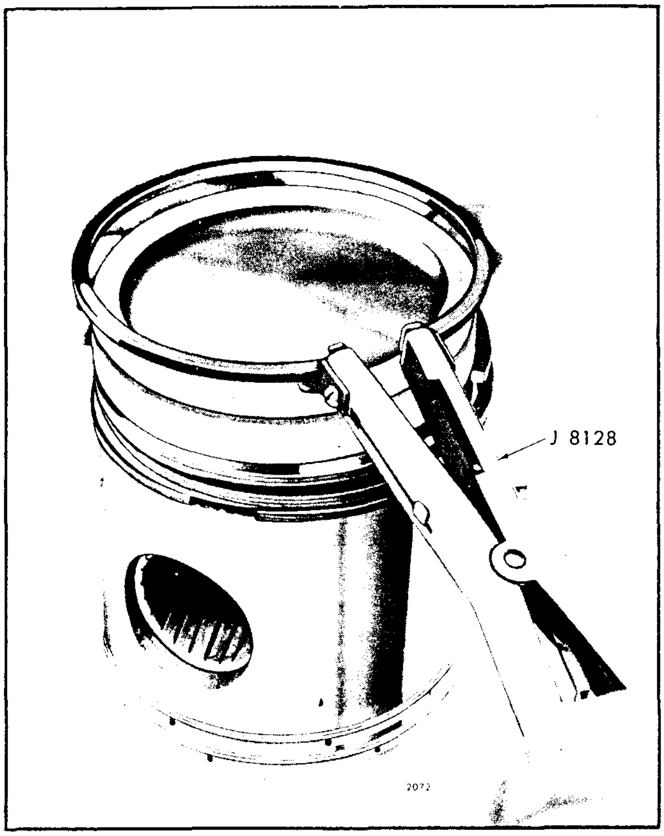


Fig. 2 - Removing or Installing Piston Ring

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.

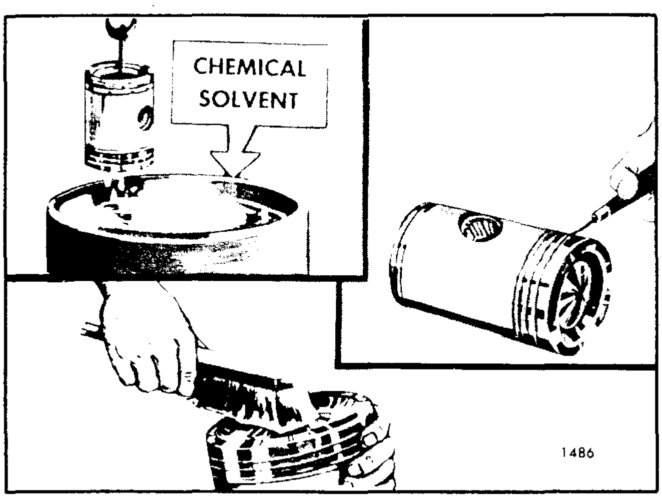


Fig. 3 - Cleaning Piston

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 Figs. 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 be removed from the bottom of the block.

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

Disassemble Piston and Connecting Rod

1. Secure the connecting rod in a vise equipped with soft jaws and remove the piston rings with tool J 8128 as shown in Fig. 2.

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

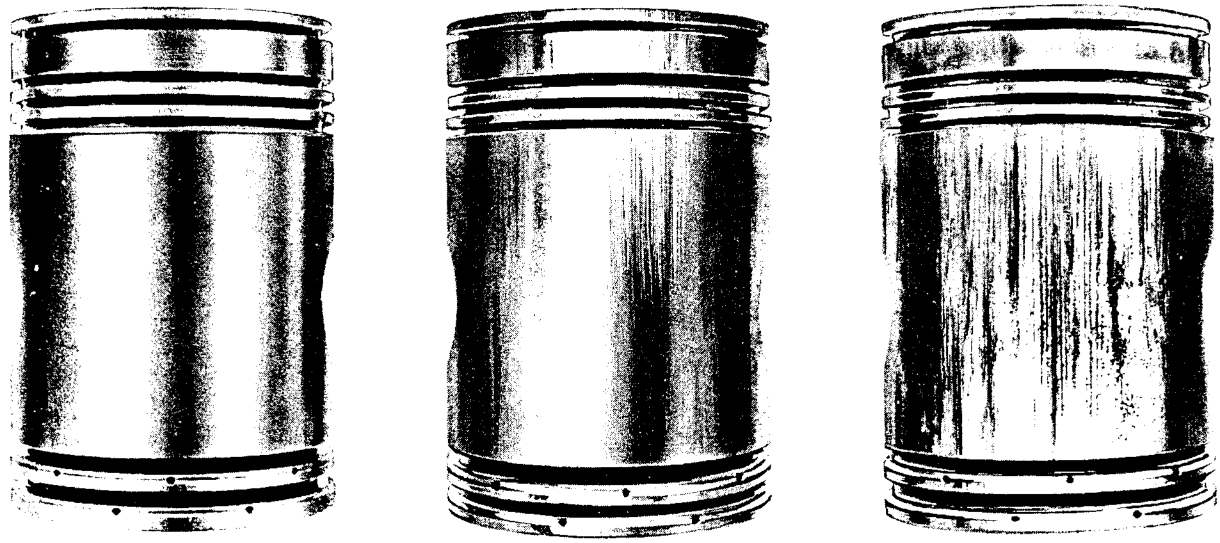
3. Withdraw the piston pin from the piston, thus freeing the connecting rod.

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 and dry it with compressed air. If fuel oil will not remove the carbon deposits, use a chemical solvent that will not attack the piston pin 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 be 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.



THIS PISTON SUITABLE FOR INSTALLATION AS IS

SLIGHTLY SCORED, USE ONLY AFTER REMOVING SCORE MARKS BY POLISHING WITH CROCUS CLOTH OR HARD INDIA STONE

BADLY SCORED—UNFIT FOR USE

4094

Fig. 4 - Comparison of Pistons

Clean the inside surfaces of the piston and the oil return holes in the piston skirt. Exercise care to avoid enlarging the holes while cleaning them.

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 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 Fig. 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, oil pull-over from the air cleaner, dribbling injectors, combustion blow-by and dilution of the lubricating oil.

Inspect and measure the piston pin and piston pin bushings. The piston pin-to-bushing clearance with new parts is .0025 " to .0034 ". A maximum clearance of .010 " is allowable with worn parts. The piston pin bushings in the connecting rod are covered in Section 1.6.1.

Inspect the piston pin for signs of fretting. When re-using a piston pin, the highly polished and lapped surface of the pin must not in any way be refinished. Polishing or refinishing any part of the piston pin surface is not recommended as it will result in very rapid bushing wear.

Remove Bushings from Piston

1. Place the piston in the holding fixture J 1513-1 so that the bushing bores are in alignment with the hole in the fixture base.

> **CAUTION:** Do not remove the bushings from the pistons used in turbocharged engines because they are not serviced separately.

2. Drive each bushing from the piston with the bushing remover J 4972-4 and handle J 1513-2 in the manner illustrated in Fig. 5.

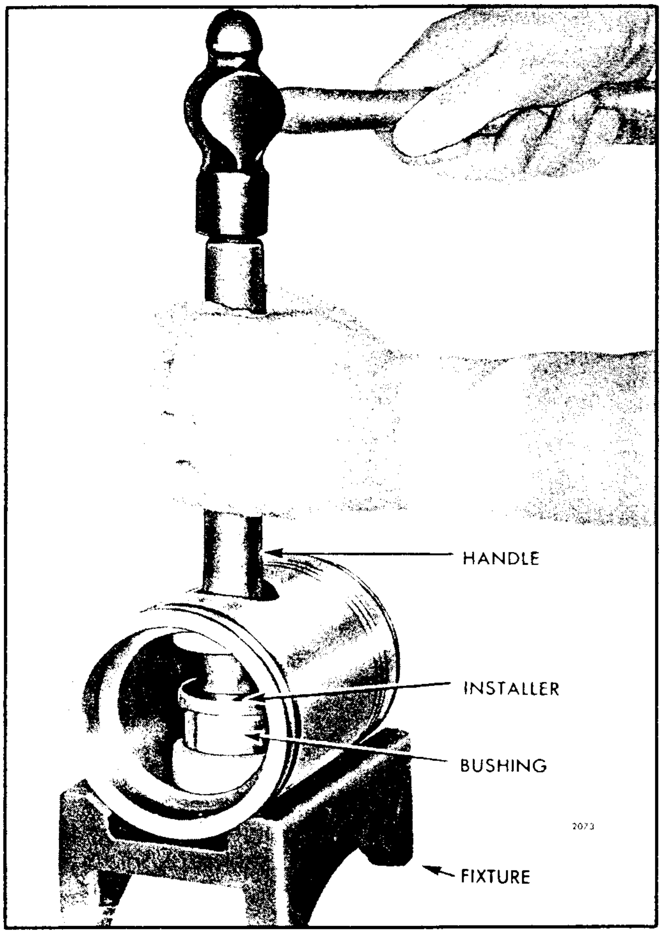


Fig. 5 - Removing or Installing Piston Pin Bushings

Install Bushings in Piston

1. Place the spacer J 7587-1 in the counterbore in the fixture J 1513-1 (small end up).

2. Place the piston on the fixture so that the spacer protrudes into the 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).

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 bushing in the same manner.

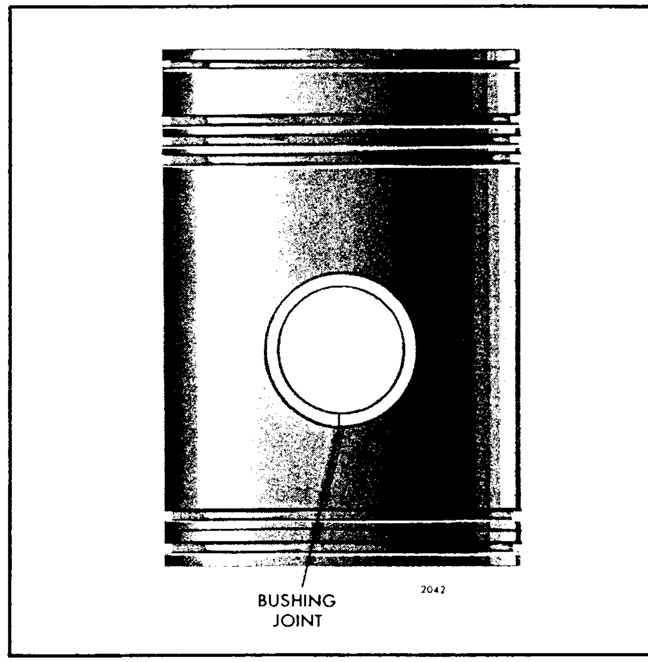


Fig. 6 - Location of Joint in Piston Pin Bushings

Ream Bushings in Piston

1. Clamp the reaming fixture J 5273 in a vise (Fig. 7), then insert the 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

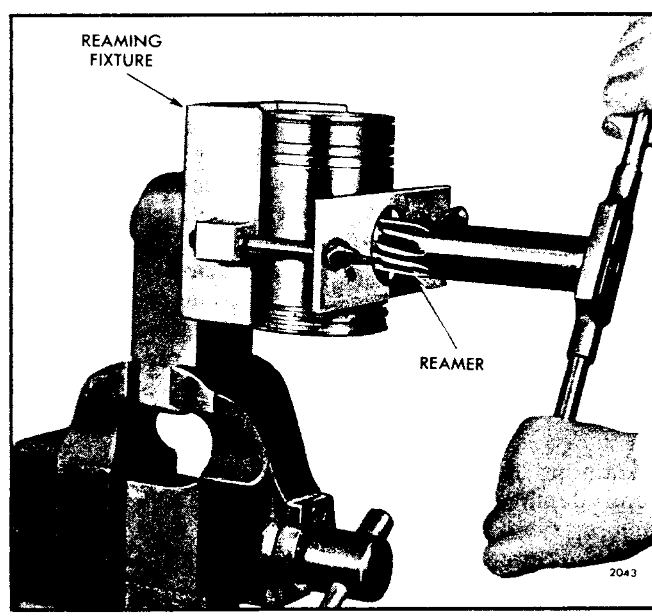


Fig. 7 - Reaming Piston Pin Bushings

the pilot end of the reamer J 4970-4 through the clamping bar, bushings and into the guide bushing.

3. With the piston, fixture and reamer in alignment, tighten the wing nuts securely.

4. Ream the bushings by turning the reamer in a clockwise direction only, when reaming or withdrawing the reamer. For the 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. The inside diameter of the bushings must be 1.3775 " to 1.3780 ".

Fitting Piston

Piston and cylinder liner measurements should be taken at room temperature (70 °F.).

Measure the piston skirt diameter in the area between the bottom of the compression ring grooves and the top of the oil control ring grooves, except near the piston pin bore.

The diameter of a new non-turbocharged engine piston is 3.8699 " to 3.8721 " and the diameter of a new turbocharged engine piston is 3.8669 " to 3.8691 ". The inside diameter of a new cylinder liner (non-turbocharged or turbocharged engines) is 3.8752 " to 3.8767 ". Therefore, with new parts, the piston to liner clearance for non-turbocharged engines is .0031 " to .0068 " and should not exceed .010 " with used parts. With turbocharged engines, the piston to liner clearance is .0061 " to .0098 " and should not exceed .012 " 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. Check this clearance 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 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.

Fitting Piston Rings

Use new piston rings whenever a piston is removed for inspection or replacement.

The current top compression (fire) ring can be identified by the bright chrome on the bottom side and oxide (rust color) on the top. The former ring had a plain metal color on both sides.

Insert one piston ring at a time far enough down in the cylinder liner to be within the normal area of ring travel. Use a piston to push the ring down to be sure it is parallel with the top of the liner. Then measure the ring gap with a feeler gage as shown in Fig. 9. Refer to Section 1.0 for the specified ring gap.

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 the ring toward the inside surface. This will prevent any chipping or peeling of the chrome plate. The ends of the ring must

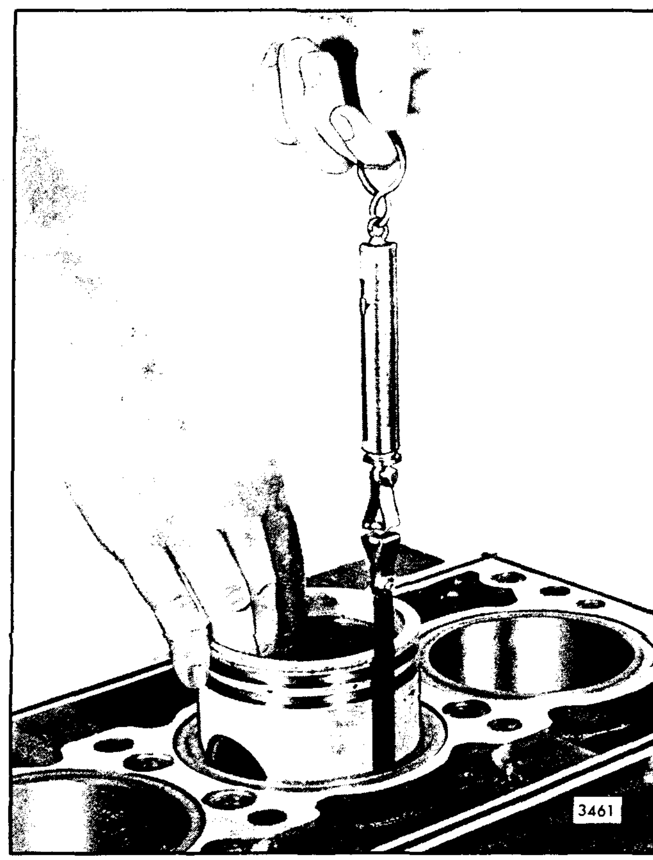


Fig. 8 - Measuring Piston-to-Liner Clearance

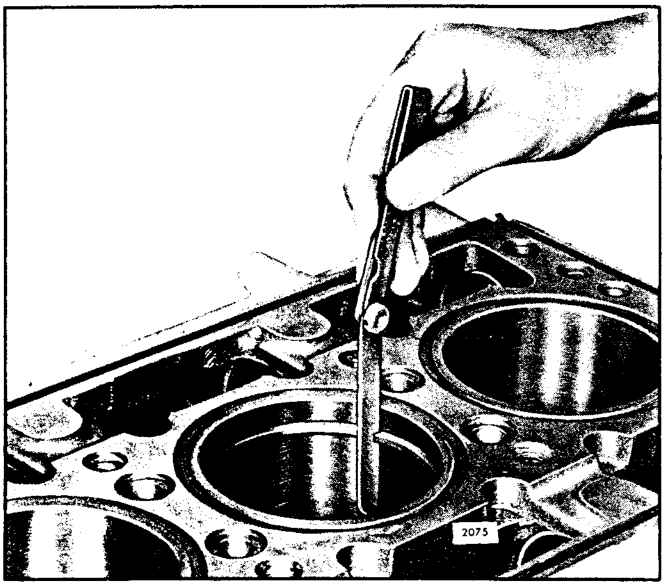


Fig. 9 - Measuring Piston Ring Gap

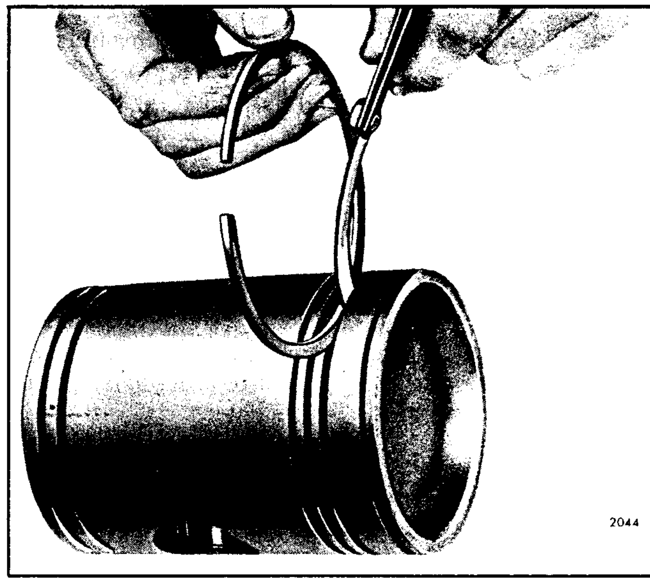


Fig. 10 - Measuring Piston Ring Side Clearance

remain square and the chamfer must be approximately .015 " on the outer edge.

Check the ring clearances in the piston grooves as illustrated in Fig. 10. Refer to Section 1.0 for the specified ring clearances and allowable wear limits.

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 Fig. 1 for the proper location of the piston rings on the piston.

> **IMPORTANT:** Lubricate the piston rings and piston with engine oil before assembling.

Assemble the compression rings on the piston with tool J 8128, as shown in Fig. 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 (Non-Turbocharged Engines)

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

1. Install an 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 pistcn 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.

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. 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 comsumption.

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

Install Oil Control Rings on Piston (Turbocharged Engines)

Install the upper oil control ring by hand with the scraper edge down as follows:

1. Install an oil ring expander (circular abutment) in the upper oil ring groove of the piston (Fig. 1). The expander must be completely seated in the groove.

CAUTION: Open the expander just enough to allow it to slip over the piston.

2. Install the upper oil control ring (one piece) in the piston upper oil ring groove.

Install the lower oil control rings (two pieces) by hand with the scraper edge of each ring down in the same manner as described above for the non-turbocharged engines.

CONNECTING ROD

Each connecting rod (Figs. 1 and 2) is made of steel forged to an "I" section with a closed hub at the upper 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 on engines equipped with an an oil cooler. Engines that are not equipped with an oil cooler do not use nozzle type connecting rods.

NOTE: Never intermix nozzle type connecting rods in an engine with non-nozzle type connecting rods.

A helically-grooved bushing is pressed into each side of the connecting rod at the upper end. A cavity of approximately 1/8" 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. 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 (if used) and the upper piston pin bushings pressed in place and bored to size.

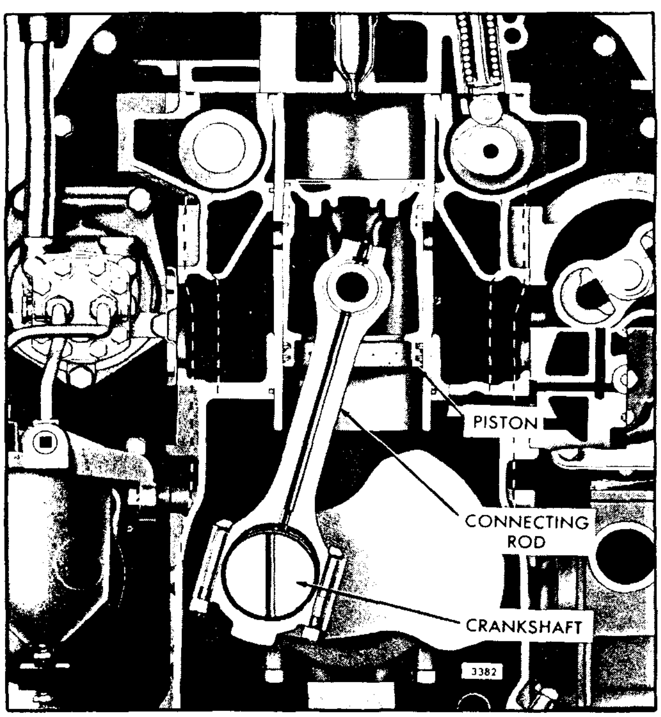


Fig. 1 - Connecting Rod Mounting

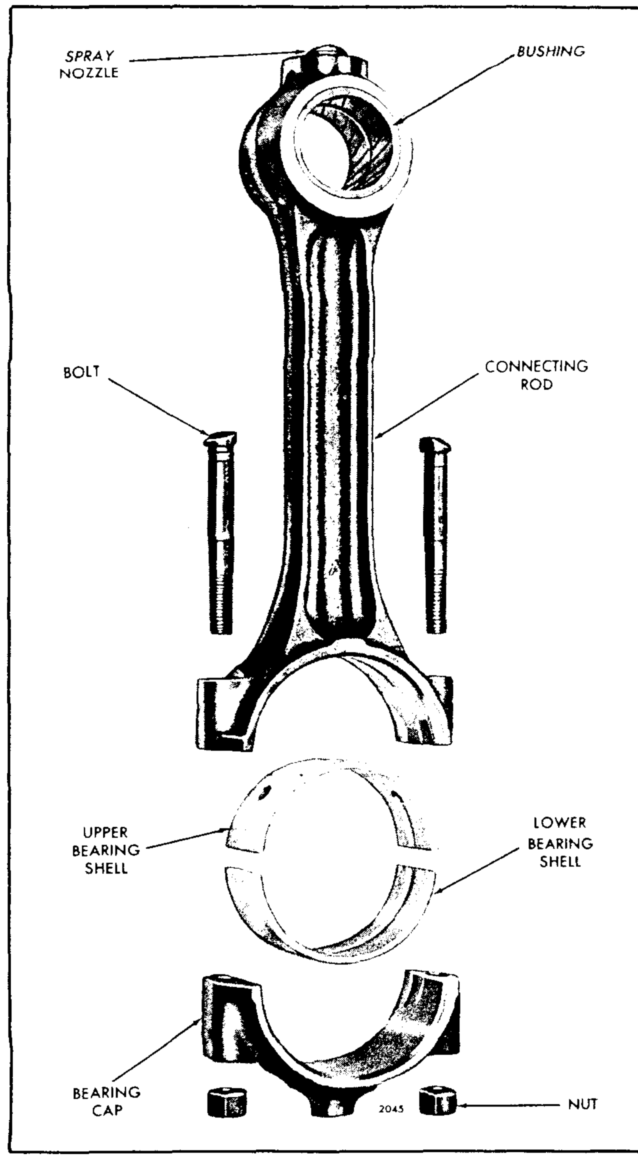


Fig. 2 - Typical Connecting Rod Details and Relative Location of Parts

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.

Blow dry compressed air through the oil passage in the connecting rod and the spray nozzle to be sure the holes are open.

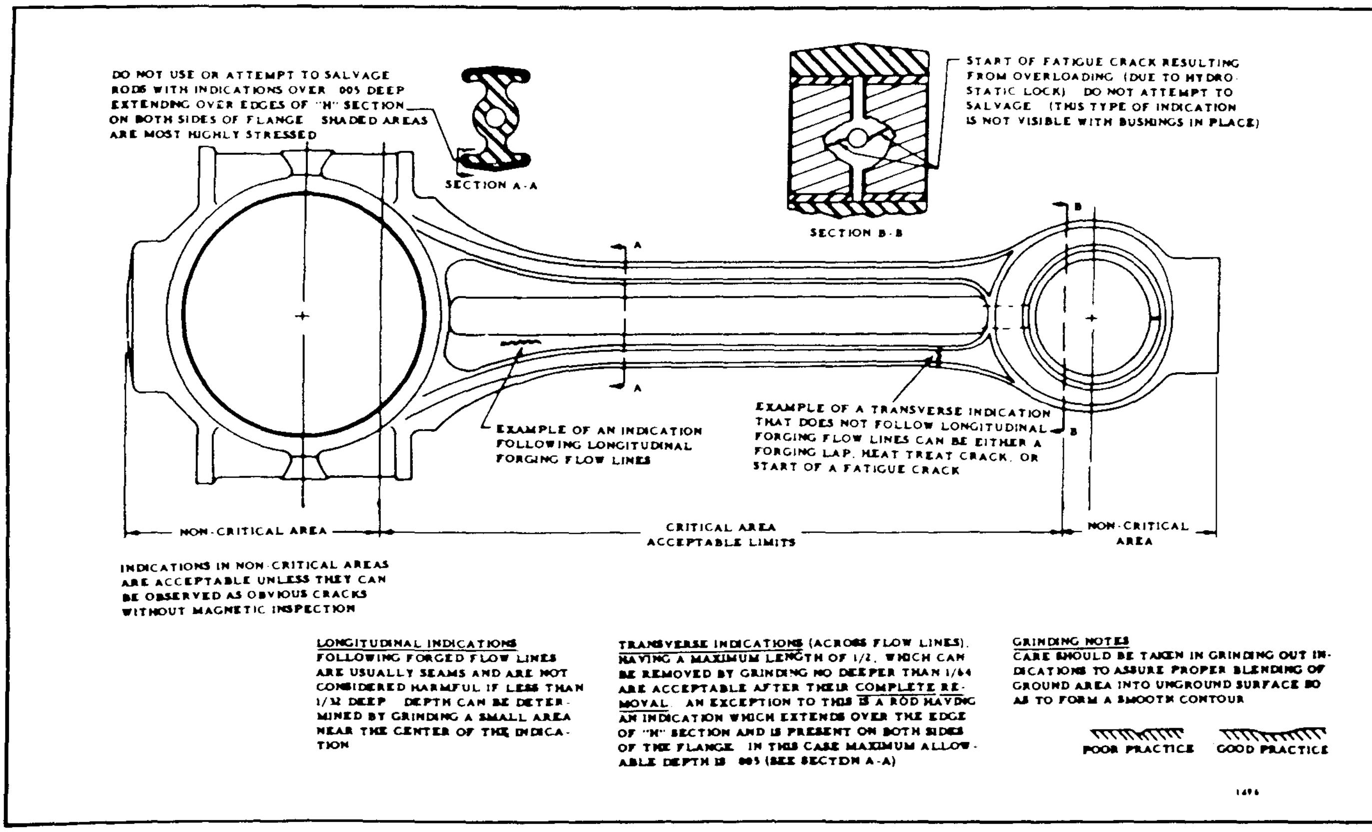


Fig. 3 - Magnetic Particle Inspection Limits for Connecting Rod

Check the connecting rod for cracks (Fig. 3) as outlined in Section 1.3 under *Crankshaft Inspection*.

Check the connecting rod bushings for signs of 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.

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 (Fig. 4) so that the bore in the bushings is aligned with the hole in the base of the holder.

2. Set the bushing remover J 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 from the connecting rod as outlined above.

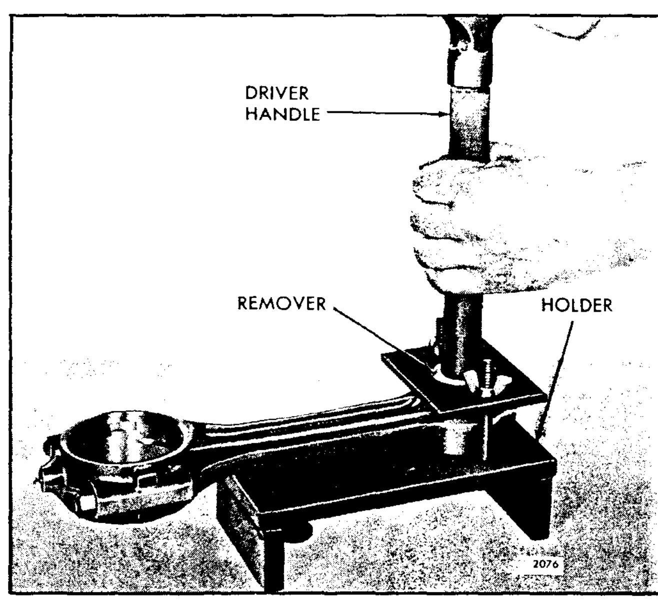


Fig. 4 - Removing or Installing Bushings

2. Place the connecting rod, spray nozzle remover J 8995 and a short sleeve in an arbor press as shown in Fig. 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 Fig. 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, 3/8" I.D. sleeve on top of the spray nozzle and under the ram of the press.

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

Install Bushings in Connecting Rod

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

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

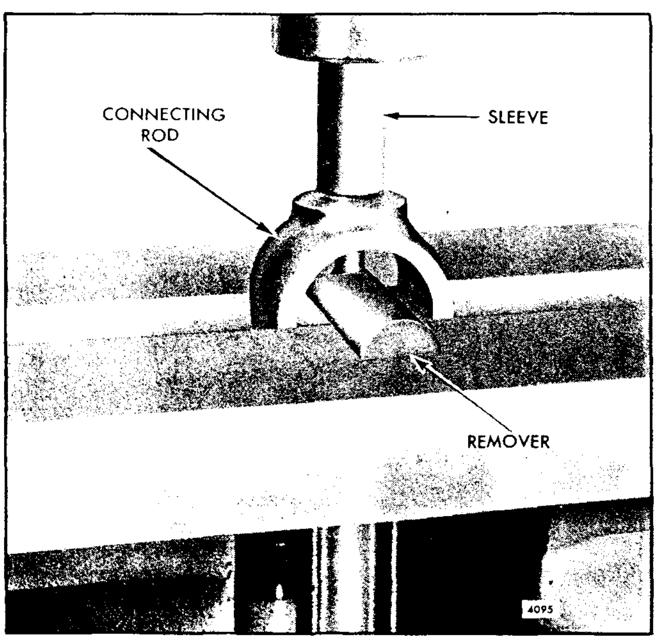


Fig. 5 - Removing Spray Nozzle from Connecting Rod

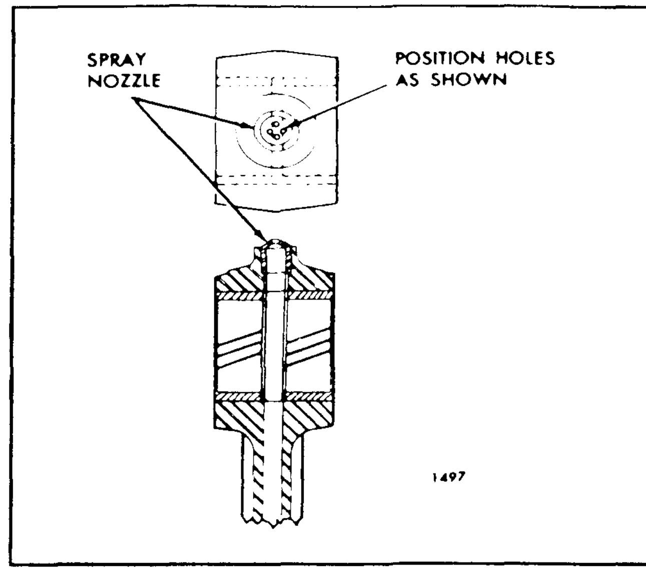


Fig. 6 - Location of Spray Nozzle in Connecting Rod

NOTE: When installing a bushing in the connecting rod, locate the joint at the top of the connecting rod (Fig. 7).

3. Insert installer J 4972-2 in the bushing, then insert handle J 1513-2 in the installer and drive the bushing into the connecting rod until the flange of the installer bottoms on the connecting rod (Fig. 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 bushings must be finished reamed after being installed in the connecting rod. Refer to Fig. 8 and ream the bushings as follows:

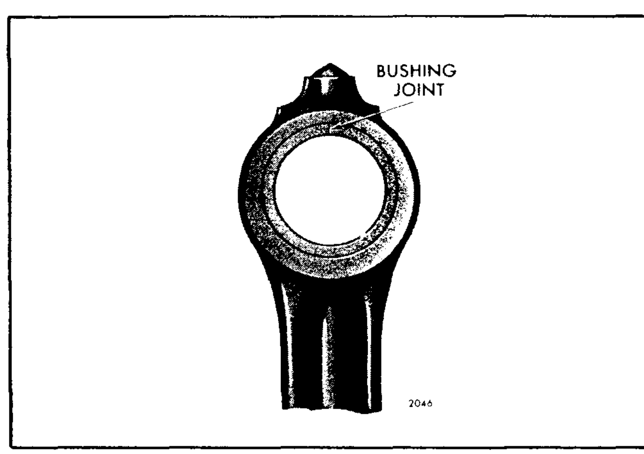


Fig. 7 - Location of Joint in Piston Pin Bushings

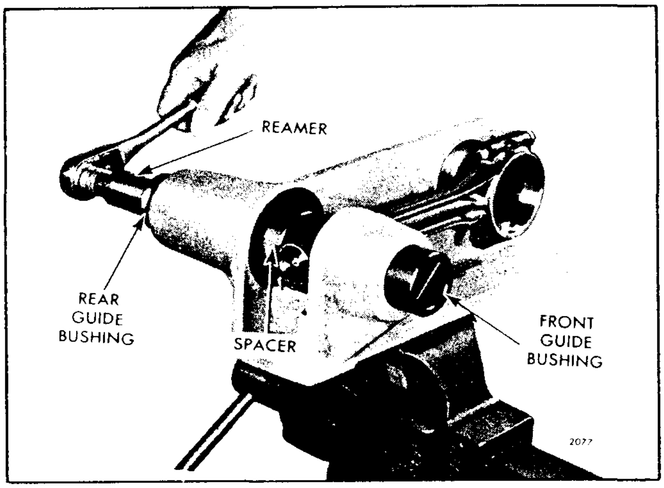


Fig. 8 - Reaming Piston Pin Bushings

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

2. Slide sleeve J 7608-5 on the arbor of the fixture (V-type engine connecting rod).

3. Place the crankshaft end of the connecting rod on the arbor of the fixture. Tighten the nuts on the 3/8" -24 bolts (In-line and V-type engines) to 40-45 lb-ft torque. Tighten the nuts on the 5/16" -24 bolts (early 6V engines) to 24-28 lb-ft torque.

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

5. Install spacer J 7608-3 in the fixture.

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

7. Install the rear guide bushing J 1686-5 on the reamer J 7608-21; then, slide the reamer and bushing into the fixture.

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

9. 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 (Fig. 9).

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

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 if the clearances are correct.

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

6. After the piston pin retainers have been installed, 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.

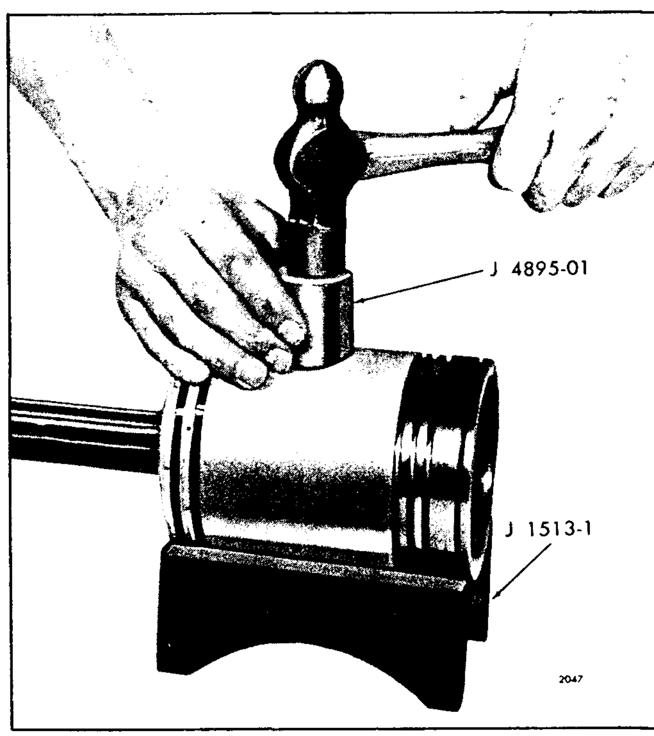


Fig. 9 - Installing Piston Pin Retainer with Tool J 4895-01

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 and consist of an upper shell seated in the connecting rod and a lower shell seated in the connecting rod cap (Fig. 2, Section 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 current connecting rod bearing shells used in the V-type engines incorporate a relief groove in each end of the shell to provide clearance for the 3/8" connecting rod bolts.

The connecting rod bearing caps are numbered 1, 2, 3, etc. on an In-line engine and 1R, 1L, 2R, 2L, etc. on the V-type engine, 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 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 formation) 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.

Check the oil filter elements for heavy sludge deposits. If necessary, replace the elements.

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 Fig. 6, Section 1.3.4. Use a micrometer and ball attachment J 4757 as illustrated in Fig. 7, Section 1.3.4.

The minimum thickness of a worn standard bearing shell should not be less than .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 (see *Shop Note* in Section 1.0).

One connecting rod bearing shell should not be replaced. If one bearing shell requires replacement, both the upper and lower shells should be replaced.

Inspect the crankshaft journals, as outlined in Section 1.3, for wear before replacement bearings are installed.

Bearing shells in .010" , .020" and .030" 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.

The following table 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
In-Line Engine		
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"
V-Type Engine		
Standard	.1247"	2.749"-2.750"
.002" Undersize	.1257"	2.747"-2.748"
.010" Undersize	.1297"	*2.739"-2.740"
.020" Undersize	.1347"	*2.729"-2.730"
.030" Undersize	.1397"	*2.719"-2.720"

*Dimension of Reground Crankshaft

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 sure the tang on the shell fits in the groove in the rod.

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 rejected on the basis of the dissimilar appearance.

3. Pull the piston and rod assembly down until the upper rod bearing seats firmly on the crankshaft journal.

4. Place the lower bearing shell - the one with the continuous oil groove - in the bearing cap, with the 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. Tighten the nuts on the 3/8" -24 bolts (In-line and "V" engines) to 40-45 lb-ft torque. Tighten the nuts on the former 5/16" -24 bolts (6V engine) to 24-28 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 crankcase 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 (Fig. 1) are of the replaceable wet type, made of hardened alloy cast iron, and are a slip fit in the cylinder block. The current liner is centrifugally cast, while the former liner was sand cast.

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 seal ring, recessed in the cylinder block bore, is used between the liner and the block to prevent water leakage into the air box.

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. On 6V (aluminum) and 8V-53 engines, the lower portion of the liner is cooled by water inside the cylinder block water-jacket surrounding the liner. However, regardless of the type of cooling, the current cylinder liner is applicable to all engines.

The angle of the ports in the cylinder liner 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 a liner and piston is directly related to the amount of abrasive dust and dirt introduced into the engine combustion chamber through the air intake. This dust, combined with lubricating oil on the cylinder wall, forms a lapping compound and will result in rapid wear. Therefore, to avoid pulling contaminated air into the cylinder, the air cleaners must be serviced regularly according to the surroundings in which the engine is operating.

Fig. 1 - Cylinder Liner

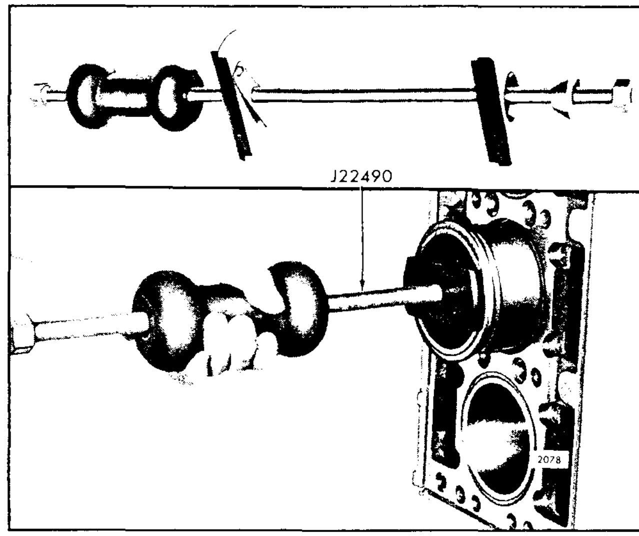


Fig. 2 - Removing Cylinder Liner

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.

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, remove the liner with tool set J 22490 (Fig. 2) as follows:

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

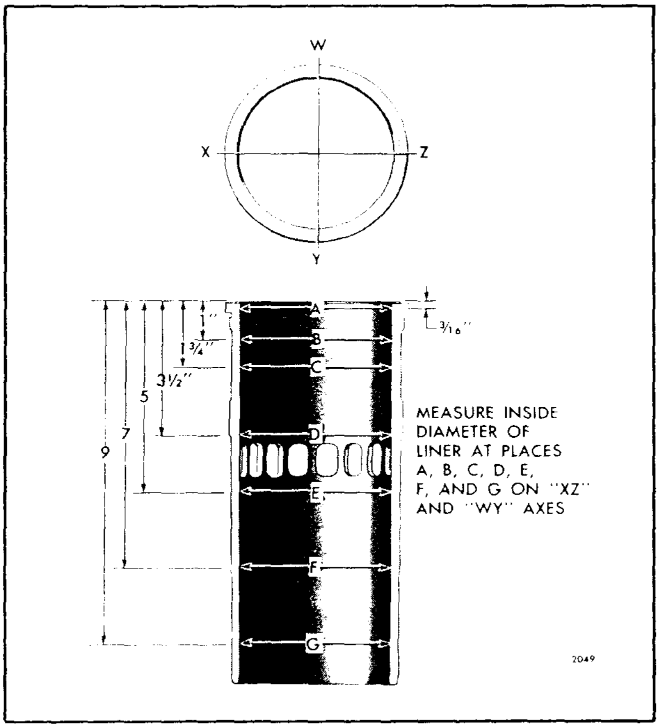


Fig. 3 - Cylinder Liner Measurement Diagram

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

If tool J 22490 is unavailable, tap the liner out with a hardwood block and hammer.

CAUTION: 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.

Inspect Used Cylinder Liner

When the cylinder liner is removed from the cylinder block, it must be thoroughly cleaned and then checked for:

Cracks

Scoring

Poor contact on outer surface

Flange irregularities

Inside diameter

Out-of-roundness

Taper

A cracked or excessively scored liner must be discarded. A slightly scored liner may be cleaned-up and re-used.

Install the liner in the cylinder block and measure the inside diameter of the liner at the various points shown in Fig. 3. If the taper exceeds .002" or the out-of-round exceeds .003", replace the liner. To check these dimensions, use dial bore gage J 5347 (Fig. 4) which has a dial indicator calibrated in .0001" increments. Set the gage on zero with master ring J 8385.

NOTE: Dial bore gage master setting fixture J 23059 may be used in place of master ring J 8385.

Hone Used Cylinder Liner

If the taper or out-of-round do not exceed the limits, hone the liner 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.

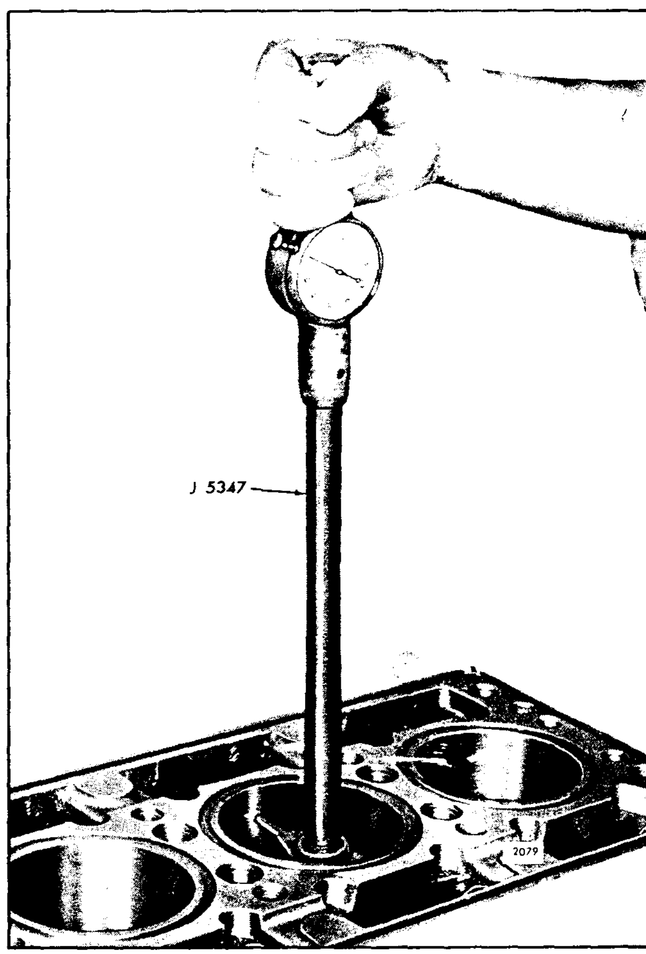


Fig. 4 - Checking Bore of Cylinder Liner

Whenever a liner is honed, it must be placed 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.

Work the hone J 5902-01, equipped with 120 grit stones J 5902-14, 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 1.0.

Inspect New Cylinder Liner

Both the former and current liners can be intermixed in In-line or 6V engines. Only the current liner can be used in 8V engines.

Install the cylinder liner in the block and measure the inside diameter at the various points shown in Fig. 3. Use dial bore gage J 5347 and set the gage on zero with master ring J 8385.

> **NOTE:** Dial bore gage master setting fixture J 23059 may be used in place of master ring J 8385.

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. Refer to Section 1.0 for the specified piston-to-liner clearance.

> **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 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 rests on the bottom of the counterbore in the block.

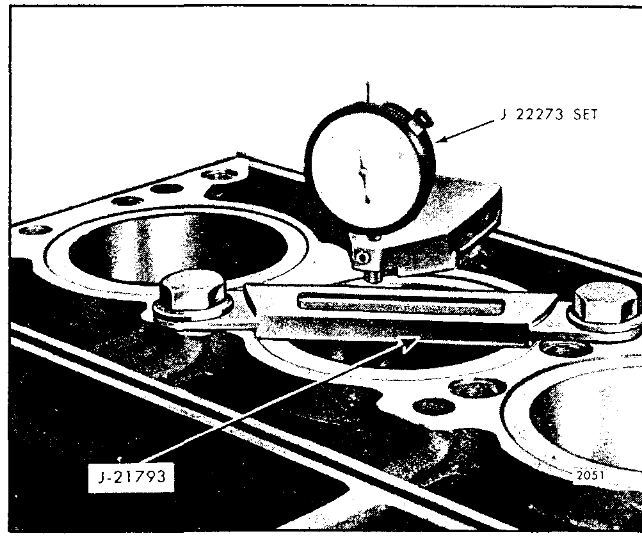


Fig. 5 - Checking Distance of Liner Flange Below Top Face of Block

> **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 certain 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 dial indicator set J 22273 (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 the engine serial number side of the block (In-line engine) or on the outer edge of the block (V-type engine).

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.

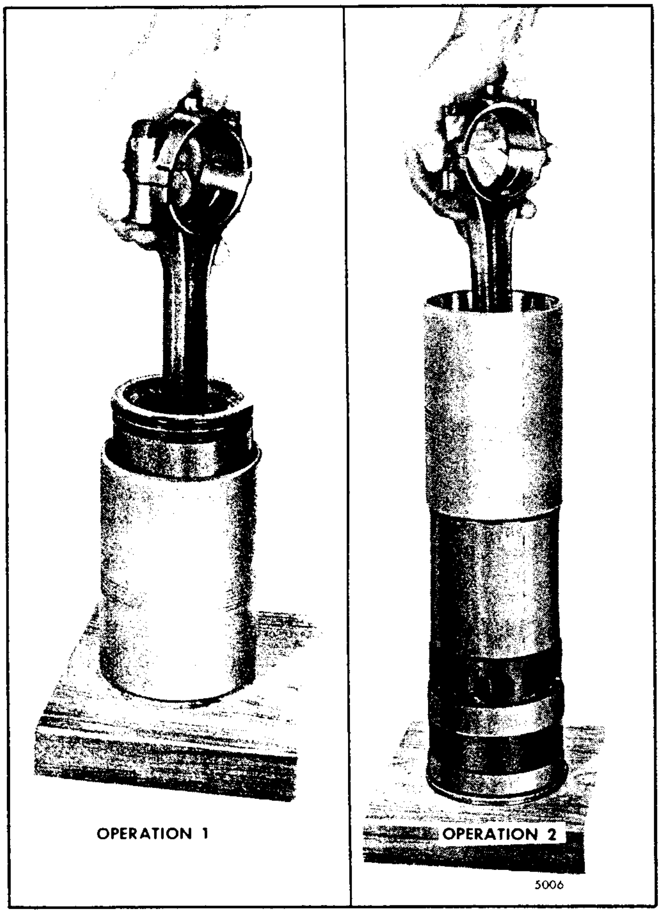


Fig. 6 - Installing Piston and Connecting Rod Assembly in Ring Compressor and Cylinder Liner

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, or number and letter, 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 numbers, or number and letter, 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 compressor.

CAUTION: Do not force the piston into the liner. The peripheral abutment type expanders apply considerably more force on the oil ring than the standard expander. Therefore, extra care during the loading operation must be taken to prevent ring breakage.

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

9. Push the piston down into the liner until the compression rings pass the liner ports.

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 grooves in the cylinder block are clean. Then, install the seal ring.

NOTE: The current cylinder block has an additional seal ring groove approximately 1/8"

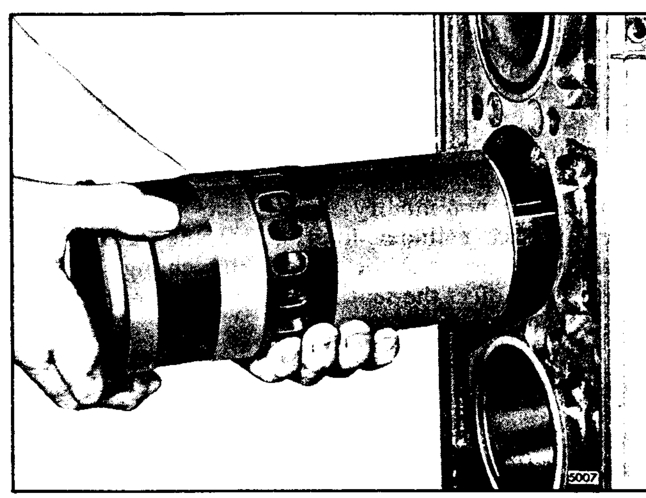


Fig. 7 - Installing Piston, Connecting Rod and Liner Assembly in Cylinder Block

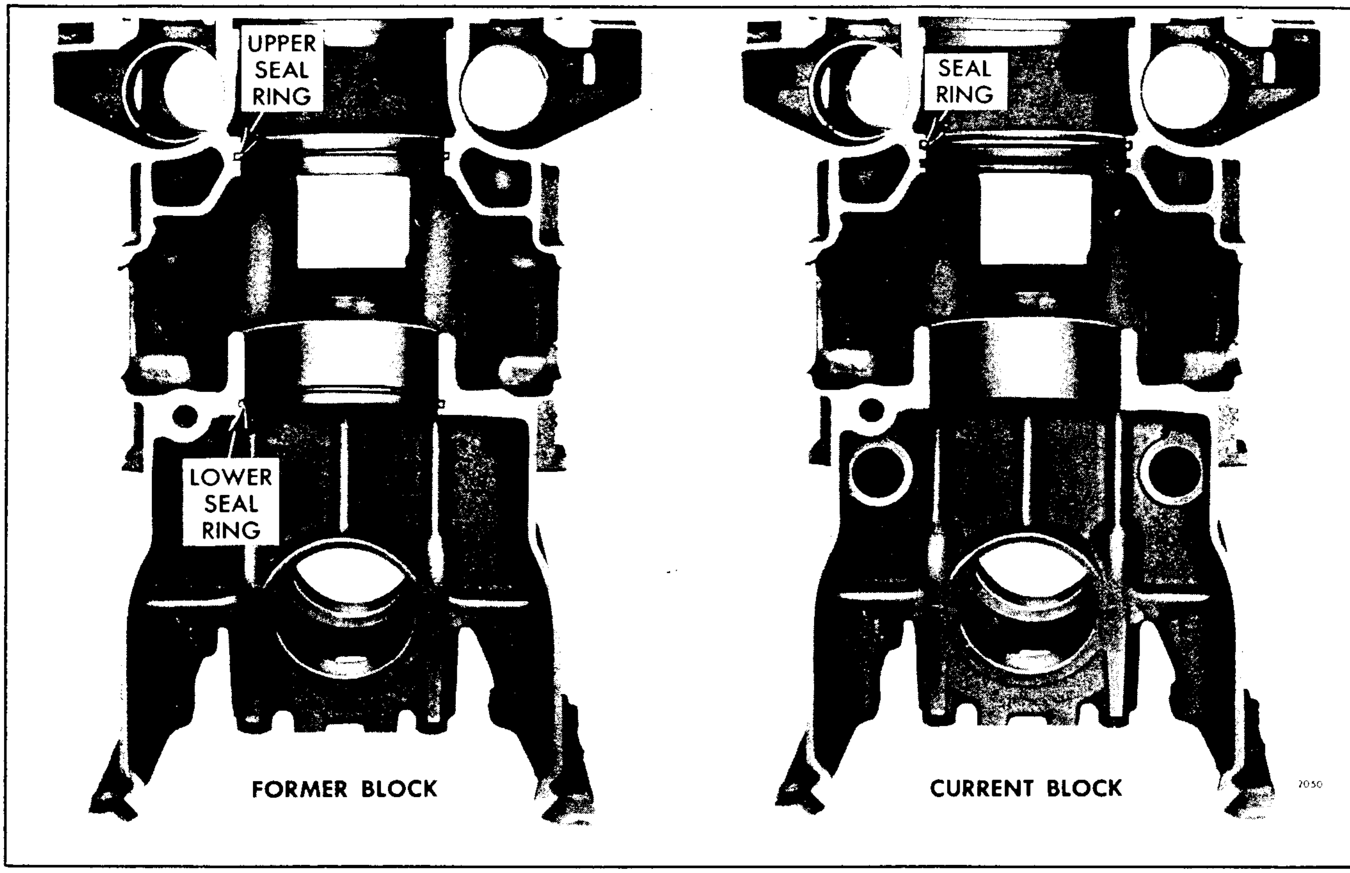


Fig. 8 - Cylinder Liner Seal Ring Locations in Cylinder Block Bores

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. The lower seal ring groove in the current cylinder block has been eliminated. Reinstallation of the lower seal ring is not necessary in the former cylinder block.

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 outer edge of the block (V-type engine) or the engine serial number side (In-line engine). Also, align the matchmarks on the liner and block. Now slide the entire assembly into the block bore and seal rings, being careful not to damage the seal rings.

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.

CAUTION: On a V engine, the distance from the center of the connecting rod bolts to the sides of the rod are not equal. Therefore, to avoid cocking the rods, the narrow sides of the rods must be together when attached to the crankshaft.

8. Place the lower bearing shell -- the one with the continuous oil groove -- in the connecting rod cap with the tang on the bearing 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 numbers on the cap and the rod adjacent to each other. On the 3/8" -24 bolts (In-line and "V" engines), tighten the nuts to 40-45 lb-ft torque. Tighten the nuts on the 5/16" -24 bolts (early 6V engines) to 24-28 lb-ft torque.

NOTE: Rework of an old 6V-53 rod assembly to utilize 3/8" bolts is not recommended.

IMPORTANT: The new 6V-53 rod assembly with 3/8" bolts should be used for replacement at the time of normal overhaul.

10. Check the connecting rod side clearance. The clearance between the side of the rod and the crankshaft should be .006" to .012" with new parts on an In-line or .008" to .016" clearance between the connecting rods on a V-type engine.

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.

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 a V-type engine, this unbalanced couple tends to move the ends of the engine in an elliptical path; 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 camshafts (V-type engine) or 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 camshafts (V-type engine) or balance shaft and camshaft (In-line engine), each set of weights (weights on the outer ends of each shaft comprise a set) rotates 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 weights are attached to the camshaft and balance shaft gears on two, three and four cylinder engines.

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

1. Remove the nut at each end of both shafts as outlined in Section 1.7.2.

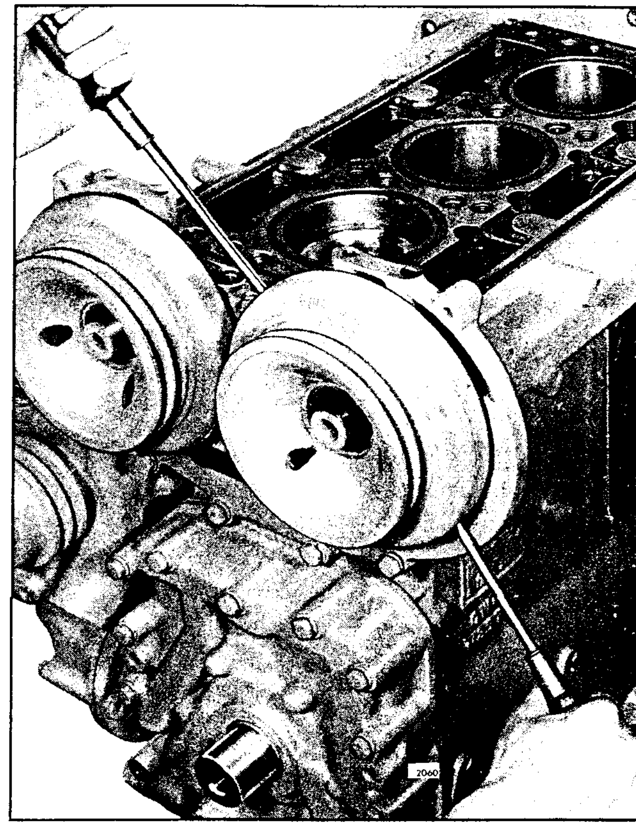


Fig. 1 - Removing Front Balance Weight (Pulley Type)

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 Fig. 1.

Install Front 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 Fig. 1, Section 1.7.2, and, tighten the gear retaining nuts to 300-325 lb-ft torque. Then tighten the front balance weight retaining nuts to 300-325 lb-ft torque. Remove the rag from 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.

The gear train on an In-line engine (Fig. 1) consists of a crankshaft gear, an idler gear, a camshaft gear, and a balance shaft gear. The governor drive gear, the upper blower rotor gear for the two and three cylinder engines, and the blower drive gear for the four cylinder engine are driven by the camshaft gear or balance shaft gear, depending upon the engine model.

The gear train on a 6V engine (Fig. 2) or an 8V engine (Fig. 3) consists of a crankshaft gear, an idler gear and two camshaft gears. The accessory drive (fuel pump drive--Section 2.2.1) gear is driven by a camshaft gear.

On In-line and 6V engines, the crankshaft gear is pressed on and keyed to the end of the crankshaft. On 8V engines, the crankshaft gear is keyed and bolted to the end of the crankshaft.

The idler gear rotates on a stationary hub.

The camshaft and balance shaft gears on In-line engines and the camshaft gears on 6V and 8V engines are pressed on and keyed to their respective shafts and each gear is secured by a retaining nut and lock plate.

The crankshaft, idler, camshaft and balance shaft gears on In-line and 6V engines are completely interchangeable with each other; however, the 8V crankshaft gear, idler gear and camshaft gears are not interchangeable with the In-line and 6V engine gears.

On In-line engines, the camshaft and balance shaft gears have additional weights attached to the rear face of each gear. Different size weights are used on the three and four cylinder engines. These weights are important in maintaining perfect engine balance. Additional balance weights are not required on 6V camshaft gears. On early 8V engines, the camshaft gears have additional weights attached to the rear face of each gear. On current 8V engines, additional balance weights are not required.

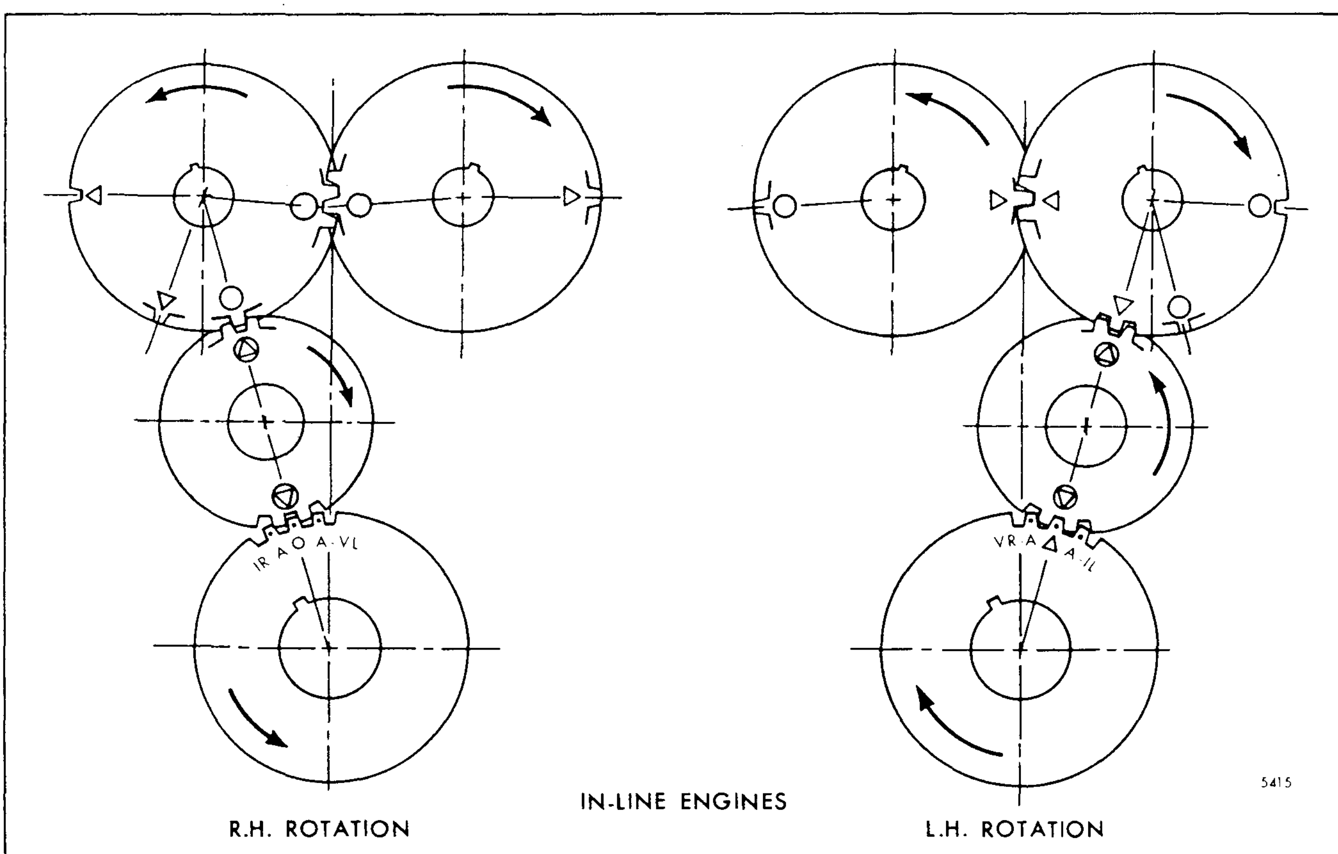


Fig. 1 - In-Line Engine Gear Train Timing Marks (Standard Timing Shown)

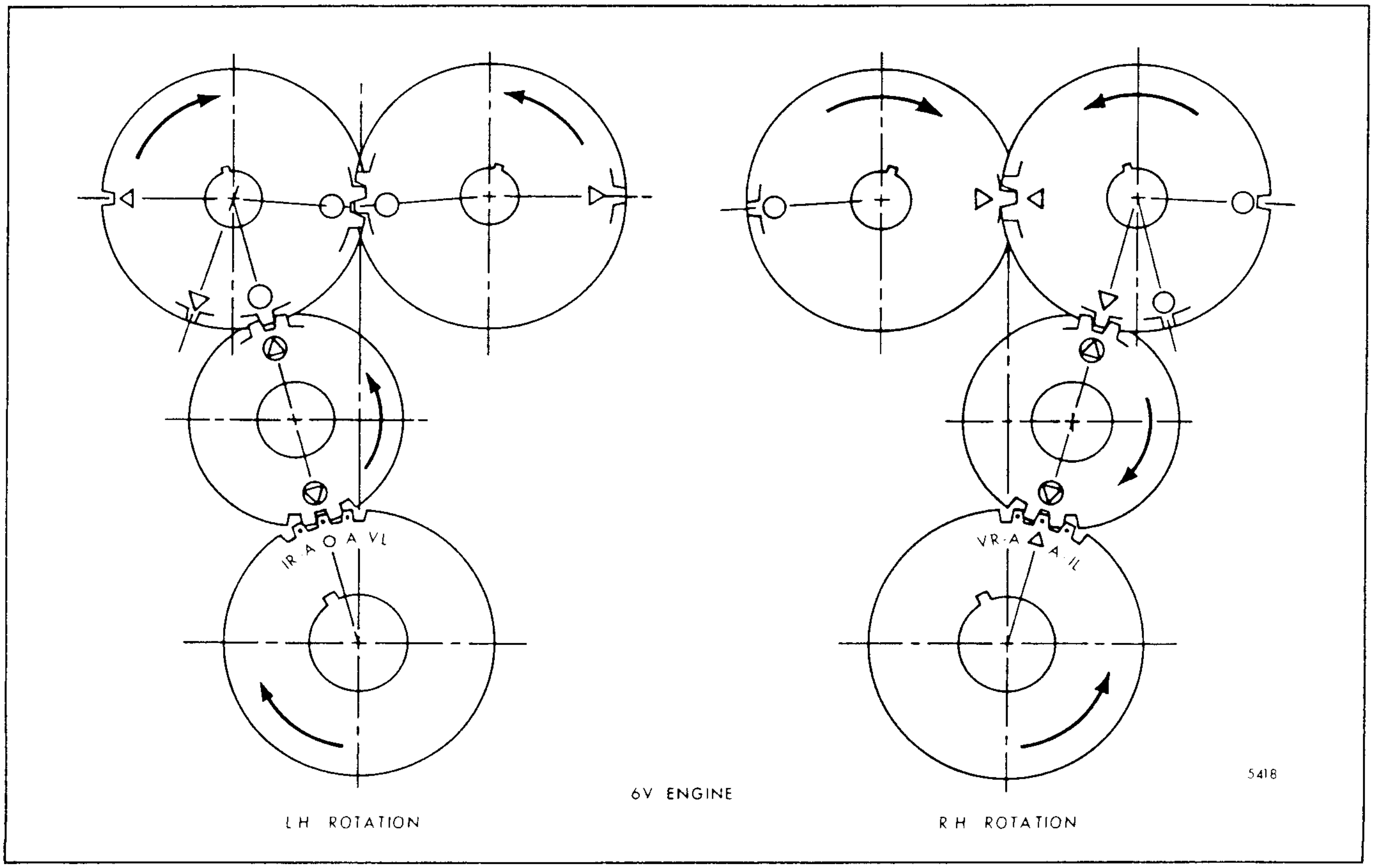


Fig. 2 - 6V Engine Gear Train Timing Marks (Standard Timing Shown)

The camshaft and balance shaft gears on an In-line engine, and the two camshaft gears on 6V and 8V engines, mesh with each other and run at the same speed as the crankshaft gear. Since the camshaft 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 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 and/or 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. Refer to Figs. 1, 2, and 3 for a typical gear train timing arrangement.

> **NOTE:** It is advisable to make a sketch indicating the position of the timing marks BEFORE removing or replacing any of the gears in the gear train.

The circle and the triangle are the basic timing symbols stamped on the gears. The letters stamped on the crankshaft gears identify the proper timing marks for the particular engine: "I" represents "In-line" engine, "V" represents V-type engine, "R" represents right-hand rotation engine, "L" represents left-hand rotation engine, and "A" represents advanced timing.

Effective with engine serial numbers 3D-64404, 4D-65954, 6D-66099 and 8D-3826, all Series 53 vehicle engines are built with advanced timing. The timing is advanced by aligning the proper "A" timing mark on the crankshaft gear with the circle-triangle timing mark on the idler gear.

IN-LINE ENGINE:

The camshaft and balance shaft gears are positioned so that the circle timing marks are adjacent to each other (Fig. 1). One circle-triangle timing mark on the idler gear is aligned with the second "circle" on the mating camshaft (or balance shaft) gear. The other timing mark on the idler gear is aligned with the proper timing mark on the crankshaft gear.

The crankshaft gear is stamped "IR-A" on the left

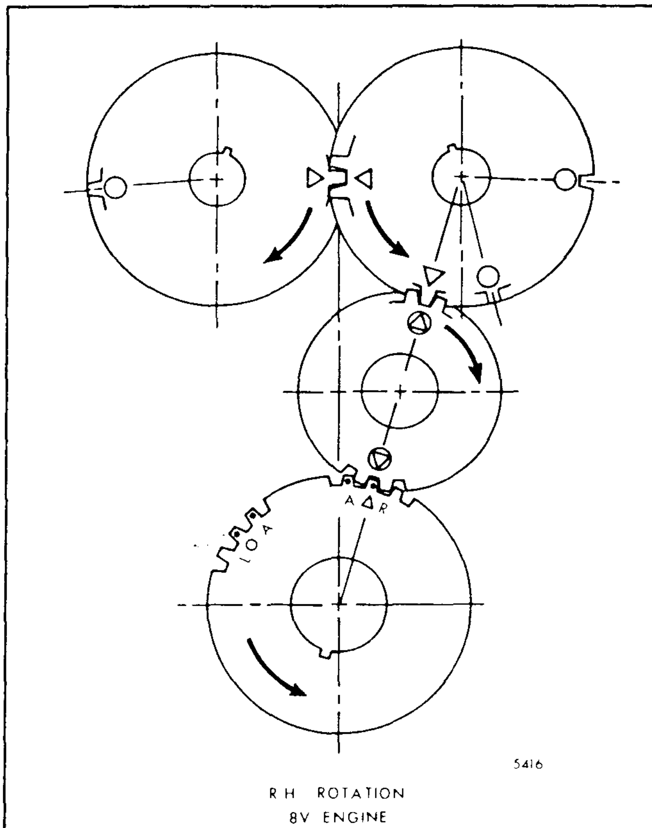


Fig. 3 - 8V Engine Gear Train Timing Marks (Standard Timing Shown)

side of the circle timing mark (Fig. 1)for a right-hand rotation engine. For *standard timing*, the circle on the crankshaft gear is aligned with the circle-triangle on the idler gear. For *advanced timing*, the "A" adjacent to the "IR" on the crankshaft gear is aligned with the circle-triangle on the idler gear.

The crankshaft timing gear is stamped "A-IL" on the right side of the triangle timing mark (Fig. 1) for a left-hand rotation engine. For *standard timing*, the "triangle" on the crankshaft gear is aligned with the circle-triangle on the idler gear. For *advanced timing*, the "A" adjacent to the "IL" on the crankshaft gear is aligned with the circle-triangle on the idler gear.

6V ENGINE:

The camshaft gears are positioned so that the triangle timing marks are adjacent to each other (Fig. 2). One circle-triangle timing mark on the idler gear is aligned with the second "triangle" on the mating camshaft gear. The other timing mark on the idler gear is aligned with the proper timing mark on the crankshaft gear.

The crankshaft gear is stamped "VR-A" on the left side of a triangle timing mark (Fig. 2)for a right-hand rotation engine. For *standard timing*, the "triangle" on the crankshaft gear is aligned with the circle-triangle on the idler gear. For *advance timing*, the "A" adjacent to the "VR" on the crankshaft gear is aligned with the circle-triangle on the idler gear.

The crankshaft timing gear is stamped "A-VL" on the right side of a circle timing mark (Fig. 2) for a left-hand rotation engine. For *standard timing*, the "circle" on the crankshaft gear is aligned with the circle-triangle on the idler gear. For *advanced timing*, the "A" adjacent to the "VL" on the crankshaft gear is aligned with the circle-triangle on the idler gear.

8V ENGINE:

The camshaft gears are positioned so that the triangle timing marks are adjacent to each other (Fig. 3). One circle-triangle timing mark on the idler gear is aligned with the second "triangle" on the mating camshaft gear. The other timing mark on the idler gear is aligned with the proper timing mark on the crankshaft gear.

The crankshaft gear is stamped "A-triangle-R". For *standard timing*, the triangle on the crankshaft gear is aligned with the circle-triangle on the idler gear. For *advanced timing*, the "A" on the crankshaft gear is aligned with the circle-triangle on the idler gear.

Refer to the *General Information* section for the various gear train arrangements.

There are no timing marks on the governor drive gear, blower rotor gears, blower drive gear or the accessory drive (fuel pump) gear. Therefore, it is not necessary to align these gears in any particular position when meshing the various gears with the camshaft or balance shaft gears.

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, remove the flywheel housing and inspect the gear train and its bearings. A rattling noise usually indicates excessive gear lash whereas a whining noise indicates too little gear lash.

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. The blower drive gear bearing on the four cylinder In-line engine is lubricated through an external pipe leading from the cylinder block main oil gallery to the gear hub support. The idler gear bearing and the accessory (fuel pump) drive gear on a 6V or 8V engine is lubricated by oil directly from the cylinder block main oil gallery to the bearing hubs.

ENGINE TIMING

The correct relationship between the crankshaft and camshaft(s) must be maintained to properly control fuel injection and the opening and closing of the exhaust valves.

The crankshaft timing gear can be mounted in only one position since it is keyed to the crankshaft. The camshaft gear(s) 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 will match as shown in Figs. 1, 2, and 3.

Pre-ignition, uneven 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 be 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 the flywheel for turning the crankshaft is necessary when performing the timing check. Then, proceed as follows:

1. Clean and remove the valve rocker cover.

2. Select any cylinder for the timing check.

3. Remove the injector as outlined in Section 2.1 or 2.1.1.

4. Carefully slide a rod, approximately 12" long, through the injector tube until the 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 engine rotation. Stop when the rod reaches the end of its upward travel. Remove the rod and turn the crankshaft, opposite the direction of rotation, between 1/16 and 1/8 of a turn.

5. Select a dial indicator with .001" graduations and a spindle movement of at least 1". 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 be 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".

Engine	*INDICATOR READING		
	Standard	Retarded 1-Tooth	Advanced 1-Tooth
	STANDARD TIMING		
(1) 2,3,4 & 6V	.228"	.204"	.245"
(2) 3,4,6V & 8V	.206"	.179"	.232"
	ADVANCED TIMING		
(2) 3,4,6V & 8V	.232"	.206"	.258"

* Indicator readings shown are nominal values. The allowable tolerance is ± .005 in.
(1) High velocity type injector cam.
(2) Low velocity type injector cam.

TABLE 1

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 on 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 a 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 1.0.

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

16. Install the injector as outlined in Section 2.1 or 2.1.1. 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 exhaust 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; but a letter "V" is not stamped on a high velocity camshaft. Note the indicator reading and compare it with the dimensions listed in Table 1 for the particular camshaft in the engine.

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

20. Install the valve rocker cover.

CAMSHAFT, BALANCE SHAFT AND BEARINGS

The camshaft and balance shaft used in the In-line engines, or the two camshafts used in the V-type engines, are located just below the top of the cylinder block. The camshaft and balance shaft in the In-line engines may be positioned on either side of the engine as required by the engine rotation and accessory arrangement. The camshafts in the V-type engine are positioned according to engine rotation.

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. Two end bearings (front and rear), two intermediate bearings and a center bearing are used in the four cylinder and 8V engines to support the camshafts. The camshafts in the three cylinder and 6V engine are supported by two end bearings and two intermediate bearings. The two cylinder engine camshaft is supported by two end bearings and a center bearing.

To facilitate assembly, letters signifying the engine models in which a shaft may be used 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 RC are stamped on a camshaft used in an RC model engine. For additional identification, a camshaft with no designation on the ends or a "7" stamped on the ends is a high-velocity high-lift camshaft. A camshaft stamped with a "V" or "V7" is a low velocity high-lift camshaft. Effective with engine 6D-60777, new camshafts stamped "V7L" are used in the 6V engine. These are low-velocity low-lift camshafts.

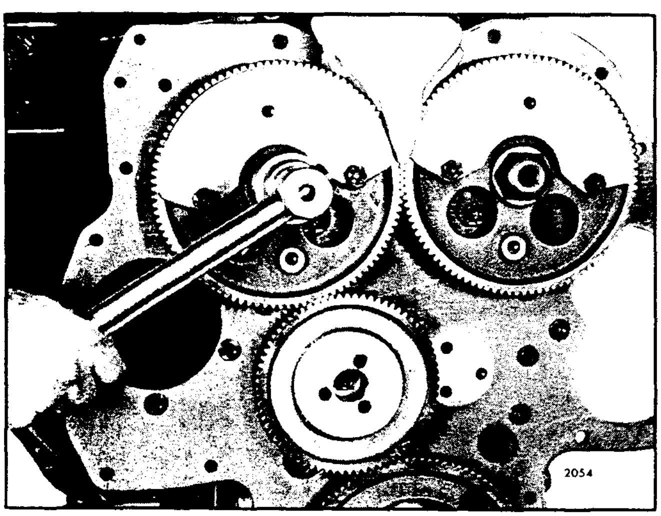


Fig. 1 - Removing or Installing Nut on Camshaft or Balance Shaft

On 6V-53 vehicle engines where the maximum speed rating has been increased from 2600 rpm to 2800 rpm, the present low lift camshaft must be used in conjunction with the new exhaust valve springs. Refer to Section 1.2.2.

NOTE: The low lift camshaft which provides a maximum valve cam lobe lift of .276" is stamped "V7L" on both ends.

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. On the current camshafts, the intermediate journal oil grooves were eliminated and a chamfer added to the intermediate journal oil holes. When replacing a former camshaft with a current camshaft, always use new bearings.

All of the camshaft and balance shaft bearings incorporate small slots through which lubricating oil 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 need

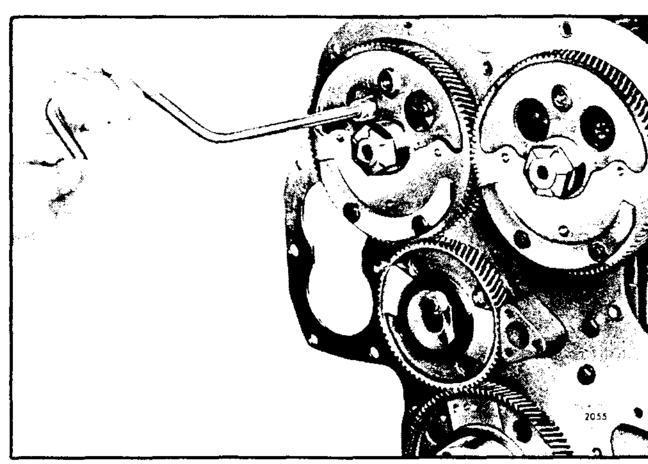


Fig. 2 - Removing or Installing Thrust Washer Retaining Bolts

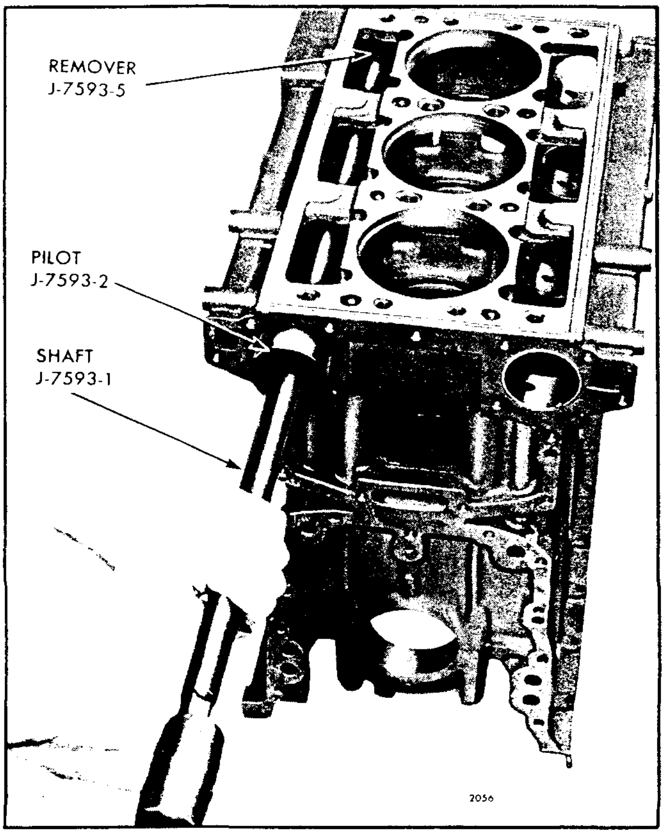


Fig. 3 - Removing End Bearing

replacing, remove the shafts from the engine in the following manner:

> **NOTE:** Refer to *Shop Notes* in Section 1.0 to install a cup plug in the front end of the camshaft.

1. Drain the engine cooling system.

2. Remove all accessories and assemblies with their attaching parts as necessary to permit the engine to be mounted on an 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(s). Refer to 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 (if used) to the gears, then remove the retainer plates.

7. Wedge a clean rag between the gears as shown in Fig. 1; then, remove the nuts from each end of both shafts with a socket wrench.

8. Remove the balance weights from the front end of the shafts as outlined in Section 1.7.

9. Remove the upper engine front cover (Section 1.7.8).

10. Remove the oil slinger from the front end of both shafts.

11. Remove the two retaining bolts that secure the camshaft or balance shaft thrust washer to the cylinder block by inserting a socket wrench through a hole in the web of the gear as shown in Fig. 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. Refer to Section 1.7.3.

2. Remove the end plugs from the camshaft, to facilitate the removal of any foreign material lodged behind the plugs, as follows:

   a. Clamp the camshaft in a vise equipped with soft jaws, being careful not to damage the cam lobes or machined surfaces of the shaft.

   b. Make an indentation in the center of the camshaft end plug with a 31/64 " drill (carboloy tip).

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

   d. Then, drill a hole straight through the center of the plug with a 1/4 " drill (carboloy tip).

   e. Use the 1/4 " drilled hole as a guide and redrill the plug with a 5/16 " drill (carboloy tip).

   f. Tap the drilled hole with a 3/8 "-16 tap.

   g. Thread a 3/8 "-16 adaptor J 8183 into the plug. Then, attach a slide hammer J 6471-1 to the adaptor and remove the plug by striking the weight against the handle.

   h. Insert a length of 3/8 " steel rod in the camshaft oil gallery and drive the remaining plug out.

NOTE: If a steel rod is not available, remove the remaining plug as outlined in Steps "a" through "g".

Inspection

Soak the camshaft in clean fuel oil. Then, run a wire brush through the oil gallery to remove any foreign material or sludge. Clean the exterior of the camshaft and blow out the oil gallery and the oil holes with compressed air. Clean the camshaft bearings and related parts with fuel oil and dry them with compressed air.

Inspect the cams and journals for wear or scoring. If the cams are scored, inspect the cam rollers as outlined in Section 1.2.1.

Check the runout at the center bearing with the camshaft mounted on the end bearing surfaces. Run out should not exceed .002 ″.

CAMSHAFT AND BALANCE SHAFT CYLINDER BLOCK BORE MACHINING CHART

Engine	Bearing Location	Dimension Minimum	Dimension Maximum
2,3,4, 6V & 8V	End	2.385"	2.386"
2,3,4, 6V & 8V	Intermediate*	2.375"	2.376"
4-53 & 8V	Center	2.365"	2.366"

*Center Bearing 2-53 Engine only

TABLE 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 the surfaces which the thrust washers contact; if these surfaces are scratched but not severely scored, smooth them down with an oil stone. If the score marks are too deep to be removed, or if parts are badly worn, use new parts.

The clearance between new shafts and new bearings is .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 block having 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 Table 1.

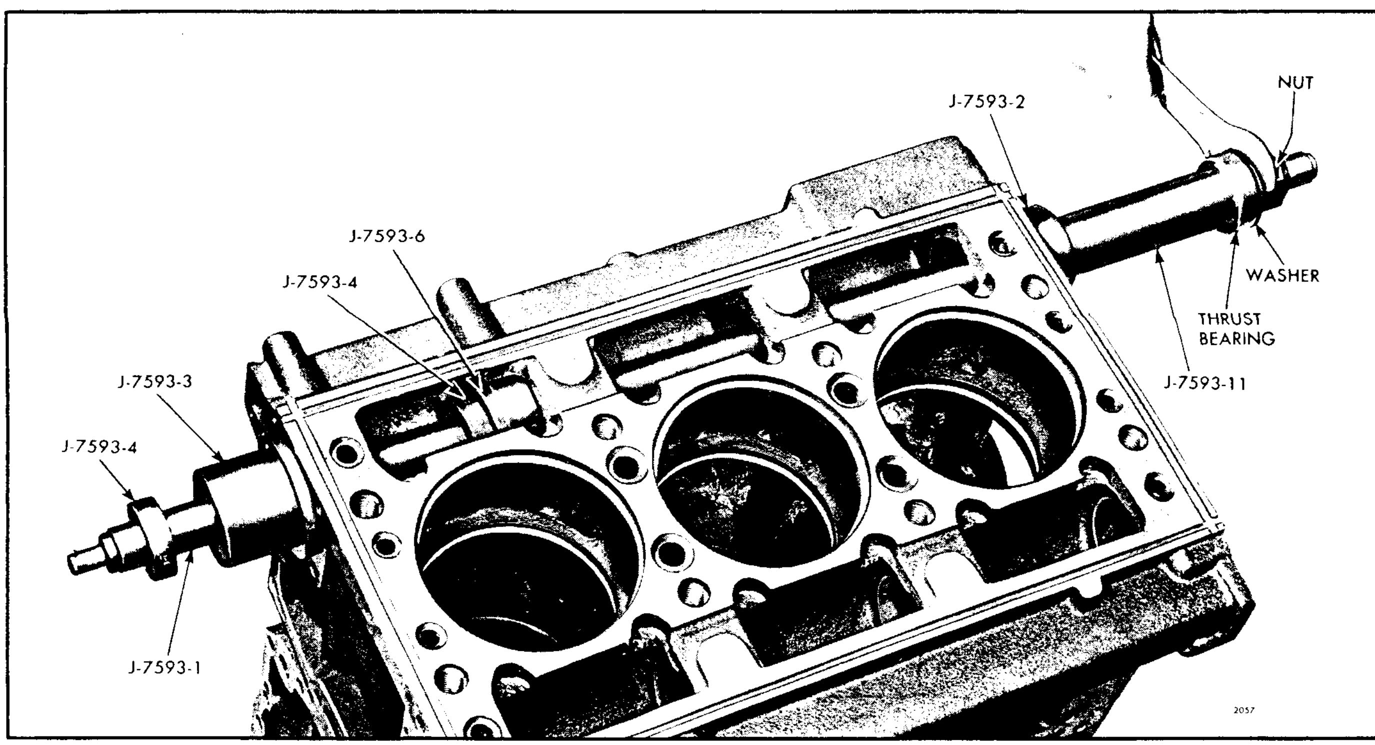


Fig. 4 - Installing Intermediate Camshaft Bearing

Remove Bearings

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

CAUTION: When removing the bearings be sure to note the position of the bearings 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 7593-02 may be used as shown in Fig. 3 and in A of Fig. 7.

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 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 the 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 and/or center bearings can be removed now in the same manner. The large diameter end of pilot J 7593-2 will fit into

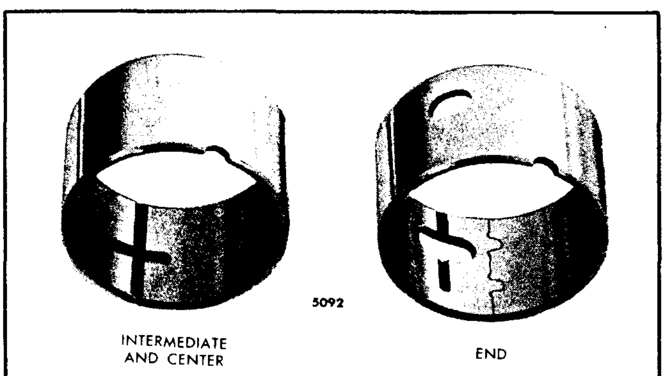


Fig. 5 · Camshaft and Balance Shaft Bearing Identification

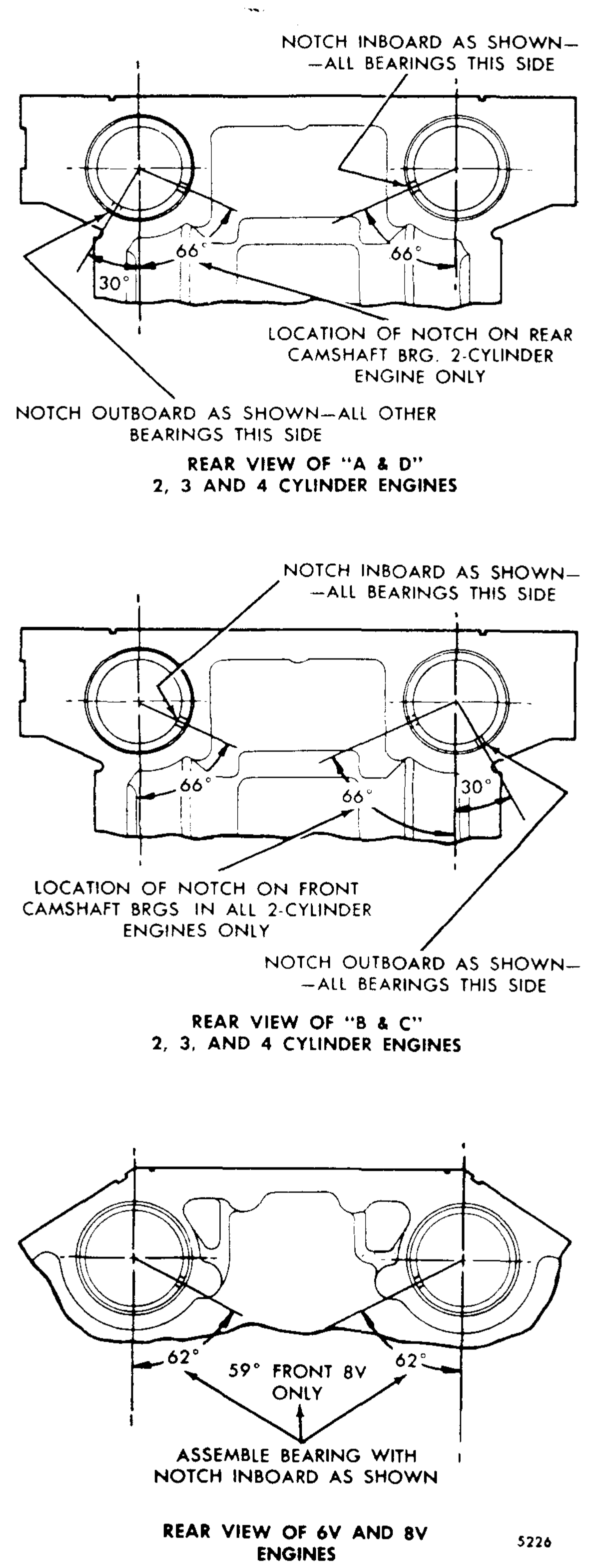


Fig. 6 · Location of Notch in Relation to Shaft Bore Centerline the camshaft bore and is used when removing the other end bearing and any remaining bearings.

Install Intermediate and/or Center Camshaft Bearings

Camshaft center and intermediate bearings must be installed prior to installing the camshaft end bearings. On the four cylinder In-Line and 8V engine, the center, rear intermediate and rear bearings are installed in that order by pressing the bearings from the rear to the front of the block. The front intermediate and front bearings are installed by pressing the bearings from the front to the rear of the block. Bearings are similarly installed in the three cylinder and 6V engine except that there is no center bearing. The center bearing for the two cylinder block is installed by pressing the bearing from the rear to the front of the block.

NOTE: Current bearings incorporate lubrication grooves on the inner bearing surface (Fig. 5).

To properly install the camshaft and balance shaft bearings, refer to Fig. 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 Table 2.

1. Insert pilot J 7593-2 in the bore of the block as shown in Fig. 4. Use the small end of the pilot if an

CAMSHAFT AND BALANCE SHAFT
BEARING COLOR CODE CHART

Bearing Position	Color Code		Outside Diameter	Inside Diameter
	Current	Former		
End	Brown	Black	Standard	Standard, .010" & .020" U.S.
	Brown	Yellow	.010" Oversize	Standard (only)
Inter-mediate	Orange	Red	Standard	Standard, .010" & .020" U.S.
	Orange	Blue	.010" Oversize	Standard (only)
Center (4-53-8V)	White	Green	Standard	Standard, .010" & .020" U.S.
	White	Red	.010" Oversize	Standard*

*The former red center bearing of the standard set is also used as the intermediate bearing of the oversize (O.D.) set.

Table 2

end bearing has been installed. Refer to B and C of Fig. 7.

2. Insert the new intermediate or center bearing into the camshaft bore and position it correctly. Install the center bearing first.

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 and note of Fig. 7.

5. 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 Fig. 4, is used on the three cylinder (In-Line) and 6V blocks. The long spacer J 7593-10 is used on the two cylinder block.

6. 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 bearing into place until the "C" washer butts up against installer J 7593-3 and prevents the shaft from further movement.

Install End Bearings

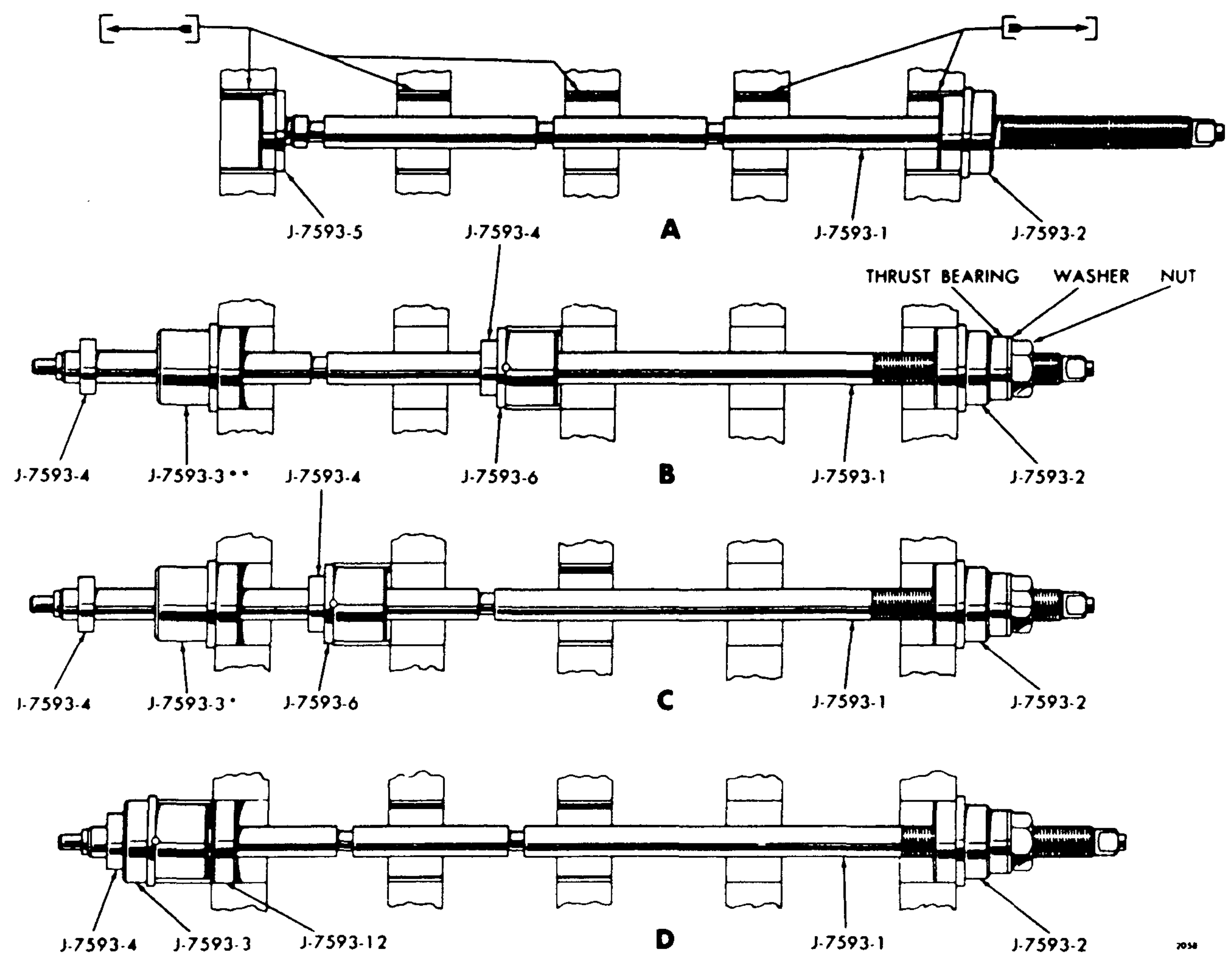
Refer to the camshaft and balance shaft color code chart and the cylinder block bore machining dimension chart when installing the end bearings.

1. Insert pilot J 7593-2 in the bore of the block as shown in "D" of Fig. 7. Use the small diameter of the pilot if a bearing 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 7593-2, 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 bearings with the pin on the installer. Then, slide the installer and the bearing on the shaft. Position the bearing correctly with the groove in the camshaft bore.

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.



*NOTE: Use J-7593-15 when installing the right front intermediate or left rear intermediate bearing in 6V cylinder block.

**NOTE: Use J-7593-15 in place of J-7593-3 as shown in Fig. B to install center bearing in 8V cylinder block.

Fig. 7 - Removing and Replacing Camshaft or Balance Shaft Bearings

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 Fig. 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 bearing is now installed in its correct position.

Install the remaining end bearings in the same manner.

Use of tool J 7593-03 assures that the bearings are properly spaced in relation to the end of the block. The center bearing (notch end) for a four and 8V cylinder block is 10.94 " from the rear face of the block. The center bearing for the two cylinder block is 5.54 " from the rear face of the block. The intermediate bearings for the four cylinder and three cylinder block are 5.54 " from the rear and front face of the block. The right rear and left front intermediate bearings for the 6V and 8V cylinder block are 5.54 " from the rear and front face of the block; and the right front and left rear intermediate bearings are 6.66 " from the front and rear face of the block.

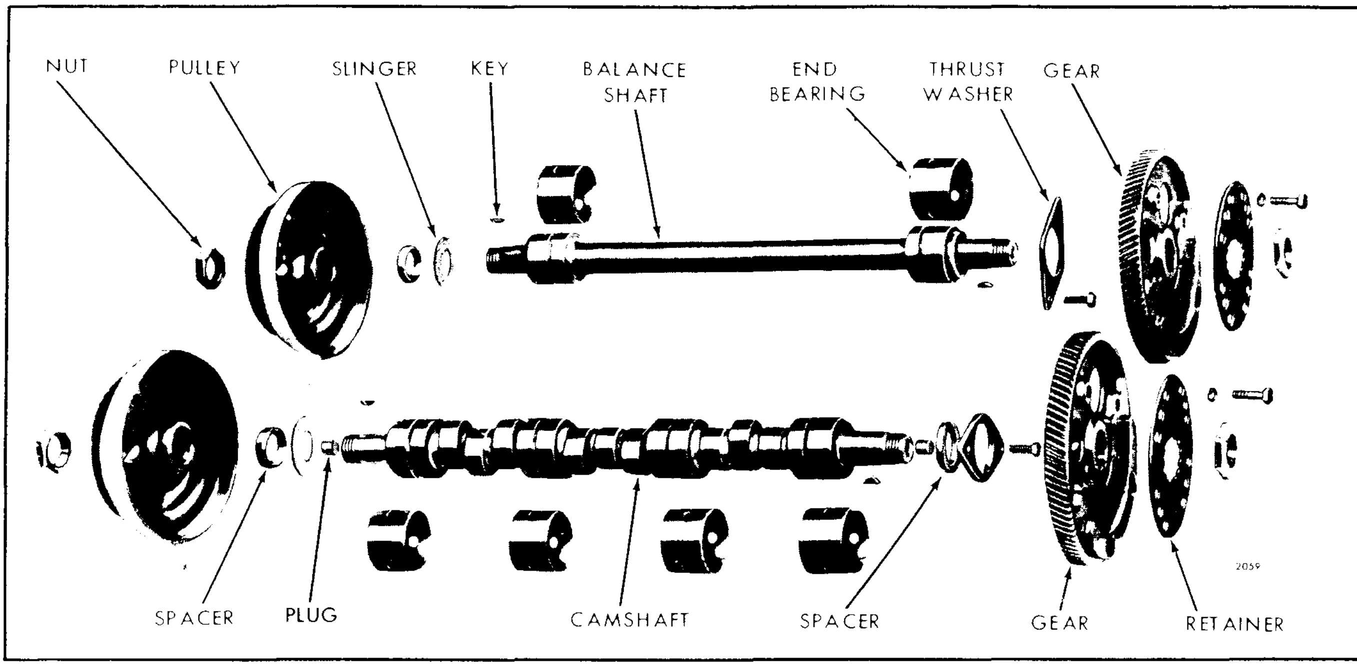


Fig. 8 · Camshaft and Balance Shaft Details and Relative Location of Parts

Assemble and Install Camshaft and Balance Shaft

Refer to Fig. 8 and assemble the camshaft and balance shaft.

1. Install new end plugs in the camshaft. Press the plugs in to a depth of 1.940 " to 2.060 ".

2. Install the gears and thrust washers on their respective shafts as outlined in Section 1.7.3.

3. 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 1.7.1.

4. Slide an oil slinger on the front end of both shafts.

5. Install the upper engine front cover, if used, (Section 1.7.8).

6. Secure the thrust washers in place as shown in Fig. 2 and tighten the bolts to 30-35 lb-ft torque.

7. Install the front balance weights (Section 1.7).

8. Attach the gear nut retainer plates (if used) to the gears with bolts and lock washers and tighten the bolts to 35-39 lb-ft torque.

9. Check the clearance between the thrust washer and the gear on both shafts. The clearance should be .005 " to .015 ", or a maximum of .019 " with used parts.

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

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

CAMSHAFT AND BALANCE SHAFT GEARS

The camshaft and balance shaft gears on an In-line engine, and the two camshaft gears on a V-type engine, are located at the flywheel end of the engine and mesh with each other and run at the same speed as the crankshaft.

Since the camshaft and balance shaft gears on In-line engines and the two camshaft gears on V-type engines must be in time with each other, timing marks are stamped on the rim of each gear. 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 (refer to Section 1.7.1).

Each gear is keyed to its respective shaft 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 on some engines. The retainer is attached to the gear by bolts threaded into tapped holes in the gear.

On the two, three and four cylinder In-line engines, external weights are attached to the rear face of each gear. Different size weights are used on the two, three and four cylinder engines. The weights are important in maintaining perfect engine balance. Additional weights are not required on the 6V engine camshaft gears or on the 8V engines effective with 8D-127.

When new service gears are used on an In-line engine, or an early 8V engine, 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.

Remove Camshaft and Balance Shaft Gears

1. Remove the camshaft and the balance shaft from the engine as outlined in Section 1.7.2.

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

3. Place 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.

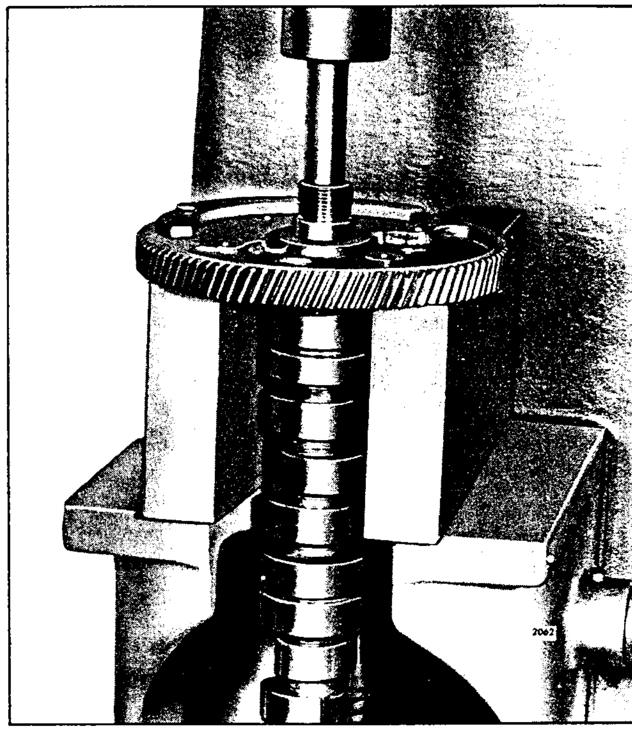


Fig. 1 - Removing Camshaft Gear

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 and, if either face is worn or scored, replace the washer. Also examine the surface on the camshaft and balance shaft which the thrust washer contacts. If this surface is scratched, but not severely scored, smooth it 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 the front of this manual for engine model identification.

2. Place the rear camshaft spacer over the timing gear end of the 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.

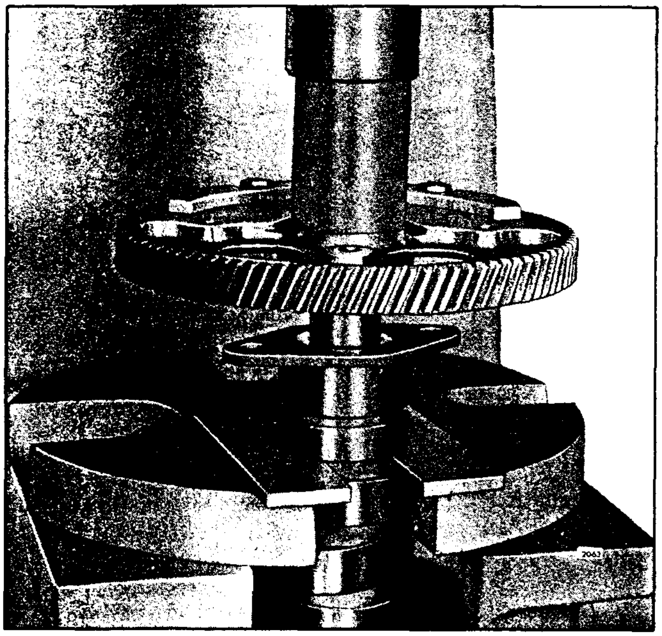


Fig. 2 - Installing Camshaft Gear

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 be .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 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

IN-LINE AND 6V ENGINES

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 and three bolts which pass through the flywheel housing, hub and end plate (Fig. 1).

Two timing marks (a triangle within a circle) are stamped on the idler gear diametrically opposite (180 °) to one another.

The inside diameter of the idler gear bearing is 2.186 "-2.187 " and the outside diameter of the idler gear hub is 2.1825 "-2.1835 ". Therefore, the clearance between the idler gear hub and the idler gear bearing is .0025 " to .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 " to 1.234 " and the standard thickness of the two thrust washers is .236 " to .240 "; thus, the clearance between the thrust washers and the idler gear is .006 " to .013 ", with a maximum allowable wear limit of .017 ".

On an In-line engine, the idler gear is positioned on the left-hand side for a right-hand rotating engine and on the right-hand side for a left-hand rotating engine as viewed from the rear. Refer to Fig. 5 under *General Description*.

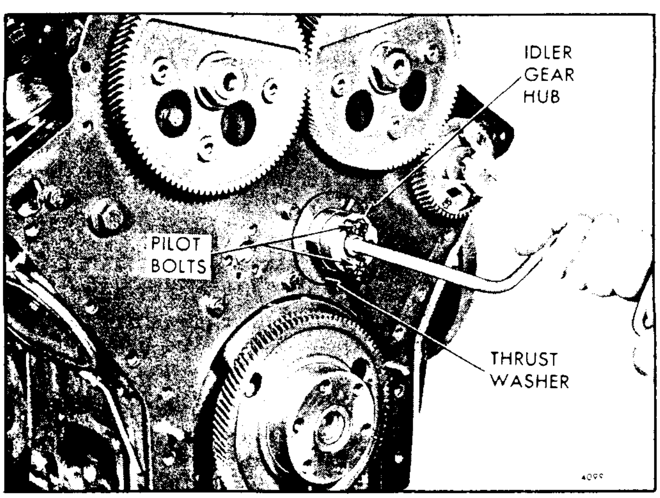


Fig. 1 · Installing Idler Gear Hub

On a 6V engine, the idler gear is positioned on the right-hand side for a right-hand rotating engine and on the left-hand side for a left-hand rotating engine, as viewed from the rear. Refer to Fig. 6 under *General Description*.

On early engines, an idler gear spacer (dummy hub) was used on the side opposite the idler gear. Currently the flywheel housing has an integral cast hub and a .015 " thick shim is used between the flywheel housing and the end plate.

Remove Idler Gear and Bearing Assembly (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

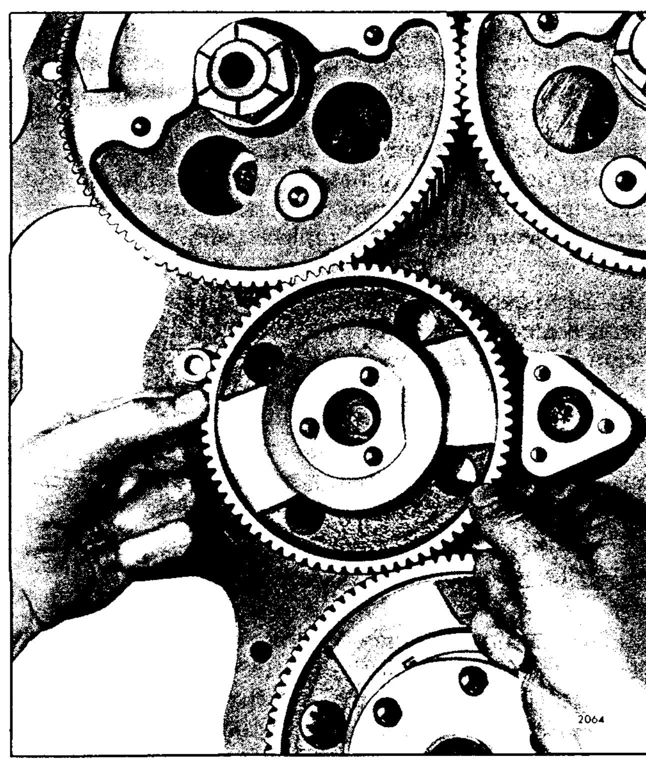


Fig. 2 · Installing Idler Gear

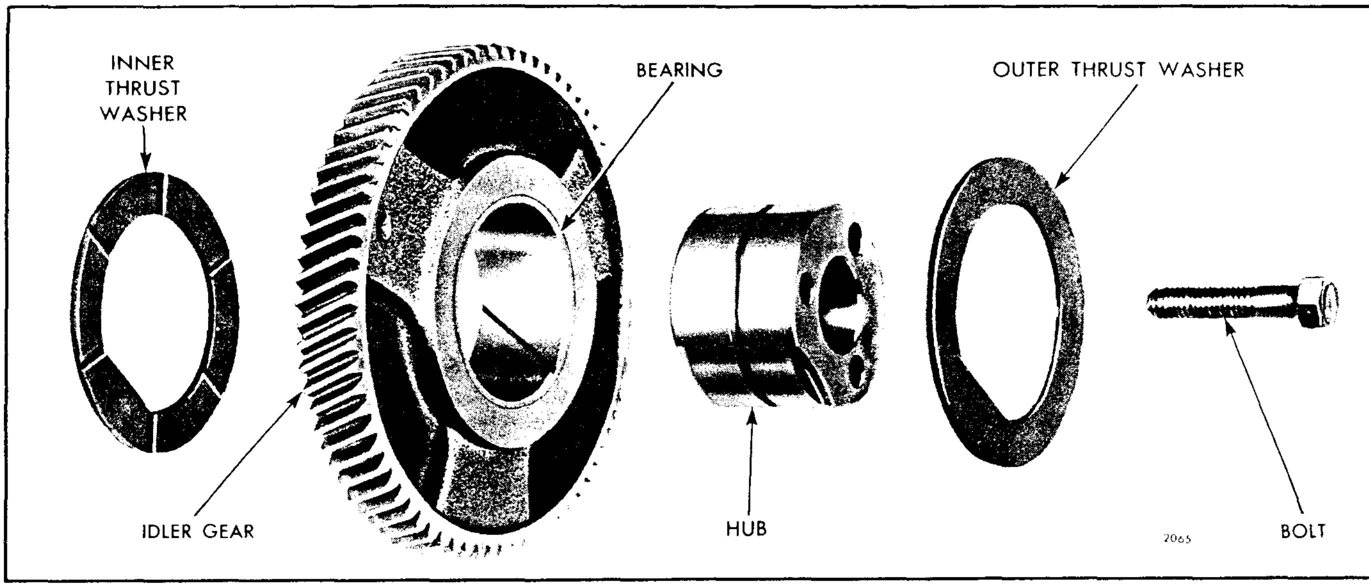


Fig. 3 - Idler Gear Details and Relative Location of Parts

the cylinder block. Then remove the idler gear hub and the idler gear inner thrust washer as an assembly.

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 bearing for scoring, pitting and wear. If the gear teeth are worn or the bearing is scored, pitted or worn excessively, replace the gear and bearing assembly or install a new bearing in the gear. Examine the outside diameter of the idler gear hub and thrust washers; if scored or worn excessively, replace them.

An idler gear bearing with two oil grooves has been incorporated in the idler gear and bearing assemblies beginning with engine serial numbers 2D-14301, 3D-6773, 4D-9458 and 6D-3334.

When a new bearing is installed in the idler gear, it must not protrude beyond the gear face on either side.

Install Idler Gear and Bearing Assembly

1. 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 3/8 ″-16 bolts through the idler gear hub and thread them into the cylinder block, as shown in Fig. 1, to be sure the bolt holes will be in alignment when the flywheel housing is installed.

4. Insert the 3/8 ″-16x1-3/4 ″ special bolt through the center of the idler gear hub and thread it into the cylinder block. Tighten the bolt to 40-45 lb-ft torque. Then remove the two 3/8 ″-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 the camshaft gear or balance shaft gear so that their timing marks will align with those on the idler gear. Refer to Figs. 1 and 2 in Section 1.7.1.

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

8. Apply a thin film of cup grease to the inner face (face with the oil grooves) of the outer idler gear 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 flat 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. The backlash should be .003 ″ to .005 ″ between new gears and should not exceed .007 ″ between used gears.

IDLER GEAR AND BEARING ASSEMBLY

8V ENGINE

Figure 4 illustrates the mounting of the roller bearing type idler gear. When replacing any part of the gear assembly, a complete roller bearing type idler gear assembly must be used.

The idler gear is mounted on a double row, tapered roller bearing which, in turn, is supported on a stationary hub. This hub is secured directly to the cylinder block by a bolt which passes through the hub and rear end plate.

The current idler gear bearing consists of two cups, two cones and an outer and inner spacer ring. The former idler gear bearing consists of a cup, two cones and a spacer ring.

The inner races of the idler gear bearing are pressed onto the gear hub and, therefore, do not rotate. A spacer separates the two bearing inner cones. The bearing cup(s) has a light press fit in the idler gear and is held against a flanged lip inside the idler gear on one side and by a bearing retainer secured with six bolts on the other side.

Two timing marks (a triangle within a circle) are stamped on the idler gear, diametrically opposite (180 °) to one another.

A dummy hub cast into the flywheel housing is used on the side opposite the idler gear. A shim is used between the dummy hub and the rear end plate. The flywheel housing bears against the inner races of the idler gear bearing and also against the dummy hub. Three self-locking bolts are used to attach the flywheel housing at the idler gear and dummy hub locations.

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

1. Remove the hub to cylinder block bolt and withdraw the assembly from the cylinder block rear end plate.

NOTE: Before removing the idler gear, check the idler gear, hub and bearing assembly for any perceptible wobble or shake when pressure is applied by firmly grasping the rim of the gear with both hands and rocking the gear in relation to the bearing. The bearing must be replaced if the gear wobbles or shakes. If the gear assembly is satisfactory, it is only necessary to check the pre-load before reinstallation.

Disassemble Idler Gear, Hub and Bearing Assembly

While removing or installing an idler gear bearing, the bearing MUST be rotated to avoid the possibility of damaging the bearing by brinelling the bearing cones. Brinelling refers to the marking of the cones by applying a heavy load through the rollers of a non-rotating bearing in such a way that the rollers leave impressions on the contact surfaces of the cones. These impressions may not be easily discerned during normal inspection. For example, a bearing may be brinelled if a load were applied to the inner cone of the bearing assembly in order to force the outer cone into the idler gear bore, thus transmitting the force through the bearing rollers. A brinelled bearing may have a very short life.

Refer to Fig. 4 for the location and identification of parts and disassemble the bearing as follows:

1. Remove the six bolts which secure the bearing retainer to the idler gear.

NOTE: Component parts of the idler gear

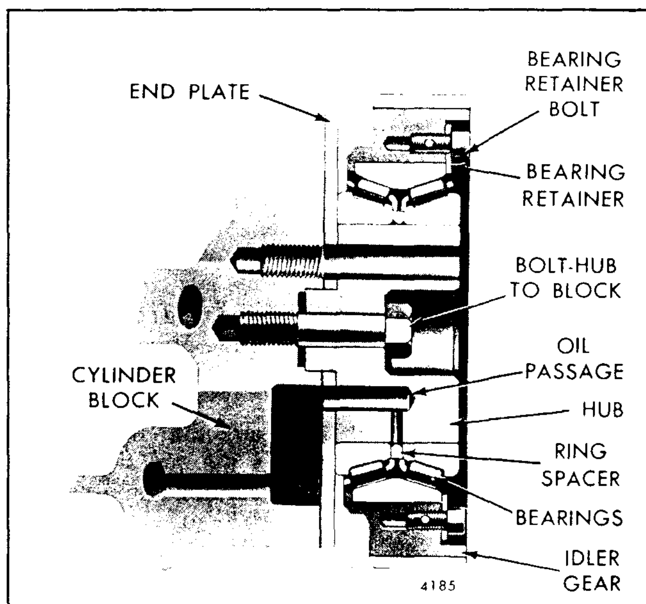


Fig. 4 - Idler Gear Mounting (Former Bearing)

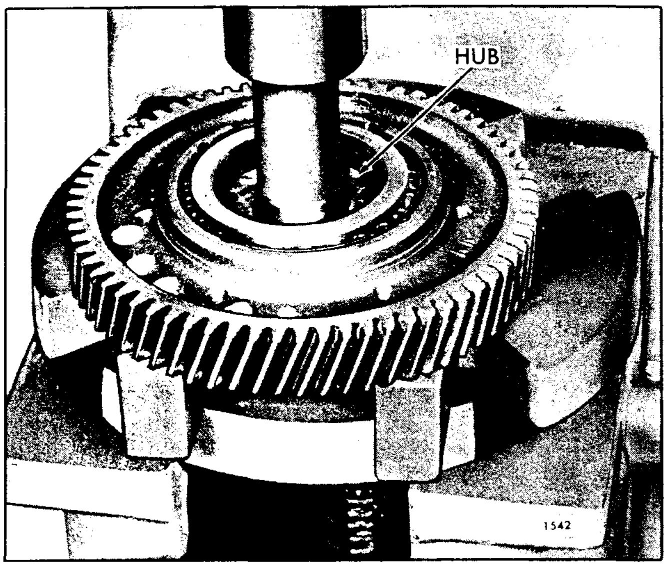


Fig. 5 - Pressing Hub Out of Bearing

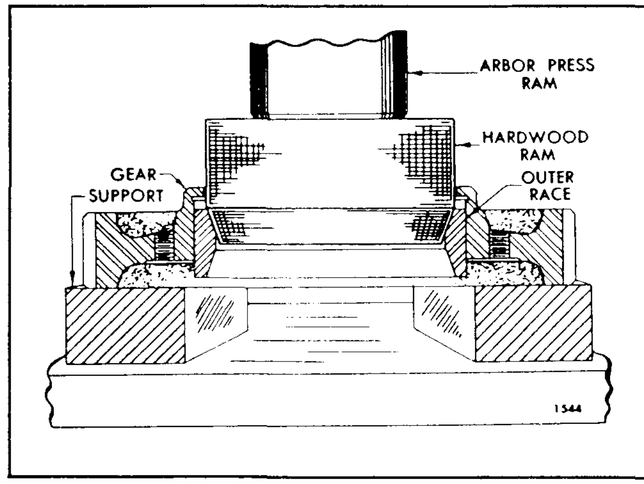


Fig. 6 - Hardwood Ram for Pressing Outer Bearing Race from Gear

bearing are mated; therefore, match-mark the parts during disassembly to ensure that they will be reassembled in their original positions.

2. Clean the idler gear and bearing assembly with fuel oil and dry it with compressed air.

3. Place the idler gear and bearing assembly in an arbor press with the bearing cone or inner race supported on steel blocks as shown in Fig. 5. While rotating the gear assembly, press the hub out of the bearing. Remove the gear assembly from the arbor press and remove the bearing cones and spacer.

4. Tap the bearing cups and spacer (current gear) or bearing cup (former gear) from the idler gear by using a brass drift alternately at four notches provided around the shoulder of the gear.

Inspection

Wash the idler gear, hub and bearing components thoroughly in clean fuel oil and dry them with compressed air.

Check the idler gear hub to ensure that no chips or foreign material is deposited in the holes so as to cause interference with the flywheel housing attaching bolts.

Inspect the bearing carefully for wear, pitting, scoring or flat spots on the rollers or cones. Replace the bearing if it is defective.

Examine the gear teeth for evidence of scoring, pitting and wear. If severely damaged or worn, replace the gear. Also inspect the other gears in the gear train.

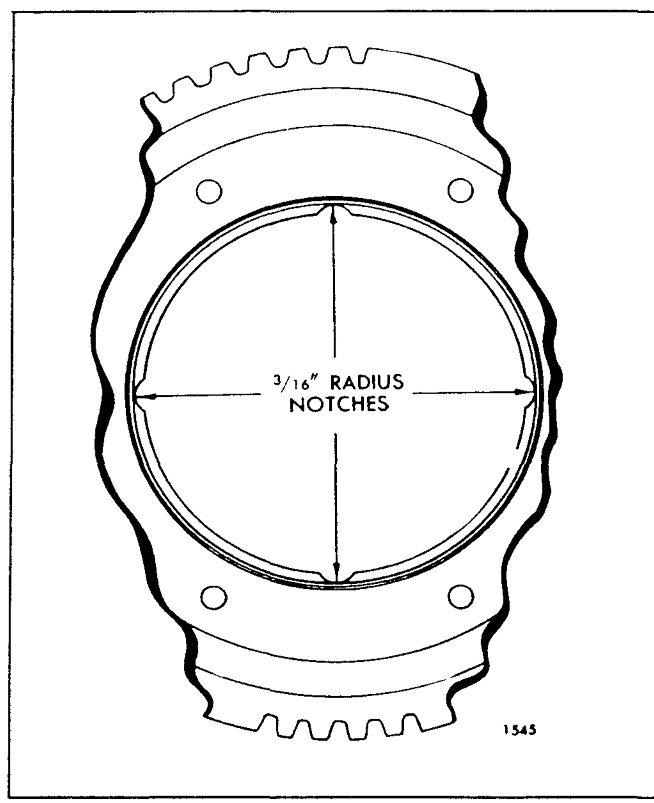


Fig. 7 - Location of Notches in Idler Gear

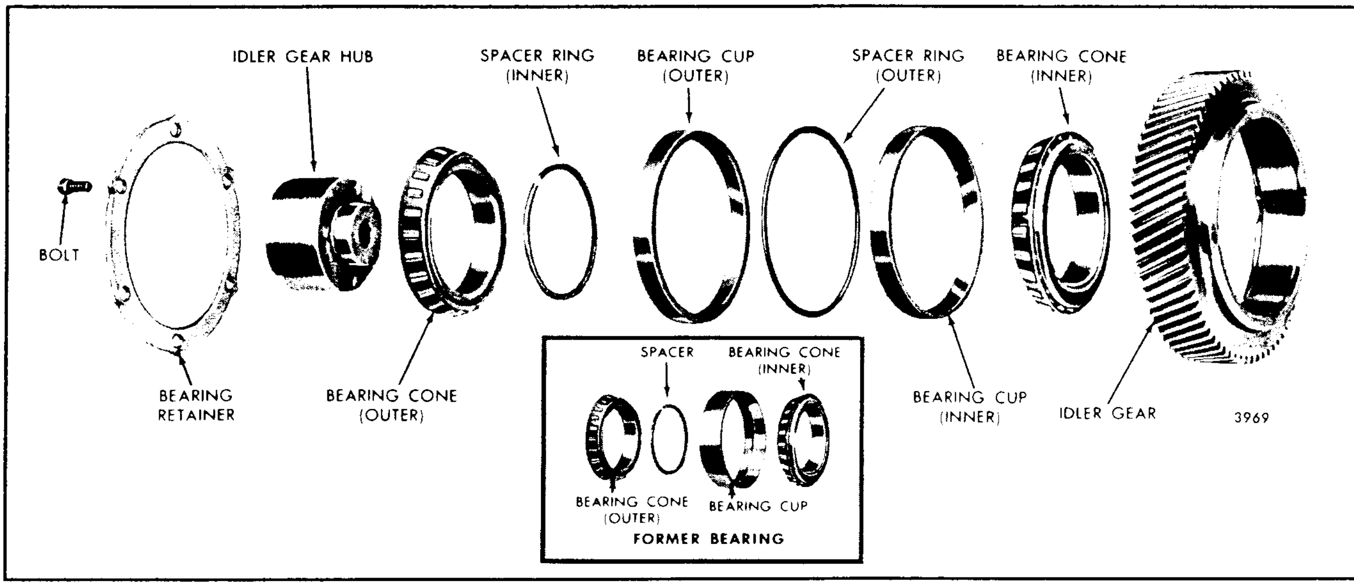


Fig. 8 - Idler Gear Details and Relative Location of Parts (Current Bearing)

Assemble Idler Gear, Hub and Bearing

CURRENT BEARING

Refer to Fig. 8 and assemble the bearing components in their *original positions* (refer to identification marks made during disassembly) as outlined below:

NOTE: The current idler gear bearing is a matched assembly. *Do not* mix the components.

1. Support the idler gear, shoulder down, on the bed of an arbor press. Start one of the bearing cups, numbered side up, squarely into the bore of the gear. Then press the bearing cup against the shoulder of the gear. Use a flat round steel plate (pre-load test plate) between the ram of the press and the bearing cup.

2. Lay the outer spacer ring on the face of the bearing cup.

3. Start the other bearing cup, numbered side down, squarely into the bore of the gear. Then press the cup tight against the spacer ring. Use a flat round steel plate (pre-load test plate) between the ram of the press and the bearing cup.

4. Press the inner bearing cone (numbered side up) on the idler gear hub, flush with the inner hub mounting face. Use the pre-load test plate (with the large center hole) between the ram of the press and the bearing.

5. Install the inner spacer ring on the idler gear hub so that the oil hole in the hub is 180 ° from the gap in the inner spacer ring.

6. Position the gear with both cups over the hub and the inner bearing cone.

7. Press the outer idler gear bearing cone over the hub while rotating the gear to seat the rollers properly between the cones. The bearing cones must be supported so as not to load the bearing rollers during this operation.

8. Before installing the gear and bearing assembly, check the pre-load.

FORMER BEARING

Assemble the bearing components in their original positions (refer to the identification marks made during disassembly) as outlined below.

1. Support the idler gear, shoulder side down, on an arbor press and start the outer bearing cone squarely into the bore of the gear. Then press the bearing cone tight against the shoulder of the gear, using a steel plate between the ram of the press and the bearing cone.

2. Support one bearing cone, numbered side down, on the arbor press and lower the idler gear and bearing cup assembly down over the bearing cone.

3. Place the spacer ring on the face of the bearing cone.

4. Place the second bearing cone, numbered side up, in the idler gear and bearing cup assembly and against the spacer ring.

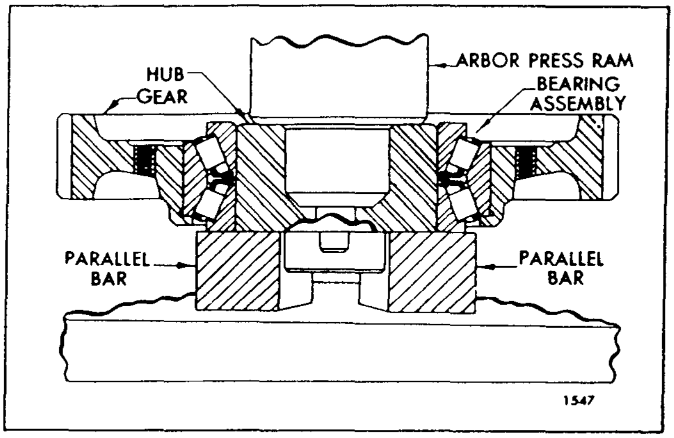


Fig. 9 - Pressing Hub into Bearing

5. Then position the idler gear hub over the bearing cones so that the oil hole in the hub is 180° from the gap in the spacer ring.

6. Press the hub into the idler gear bearing cones, while rotating the gear (to seat the rollers properly between the cones), until the face of the hub which will be adjacent to the cylinder block end plate is flush with the corresponding face of the bearing cone. The bearing cones should be supported so as not to load the bearing rollers during this operation (Fig. 9).

7. Prior to installing and securing the bearing retainer, check the pre-load of the bearing assembly as outlined below.

Check Pre-Load of Bearing

The rollers of the bearing are loaded between the bearing cup and bearing cones in accordance with design requirements to provide a rigid idler gear and bearing assembly. As the bearing cones are moved toward each other in a tapered roller bearing assembly, the rollers will be more tightly held between the cones and the cup. In the idler gear bearings, a slight pre-load is applied, by means of a selected spacer ring between the bearing cones, to provide rigidity of the gear and bearing assembly when it is mounted on its hub. This method of pre-loading is measured, in terms of "pounds-pull", by the effort required at the outer diameter of the gear to turn the bearing cup in relation to the bearing cones.

Any time an idler gear assembly has been removed from an engine for servicing or inspection, while performing engine overhaul or other repairs, the pre-load should be measured as part of the operation.

The idler gear bearing should be clean and lubricated with light engine oil prior to the pre-load test. Idler

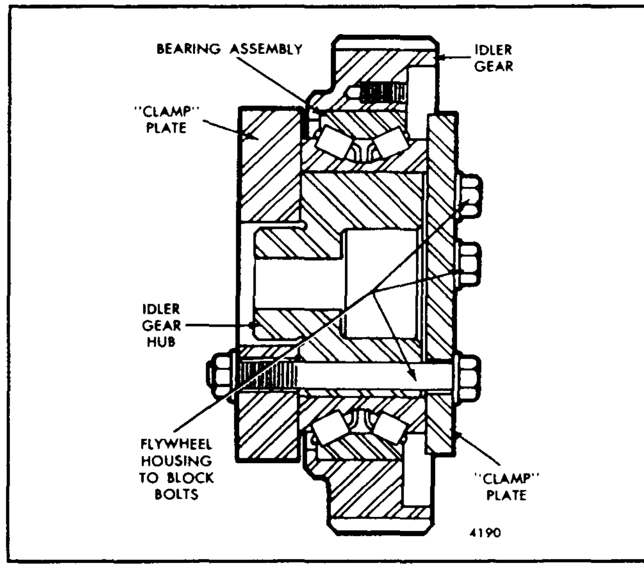


Fig. 10 - Fixture for Testing Bearing Pre-Load

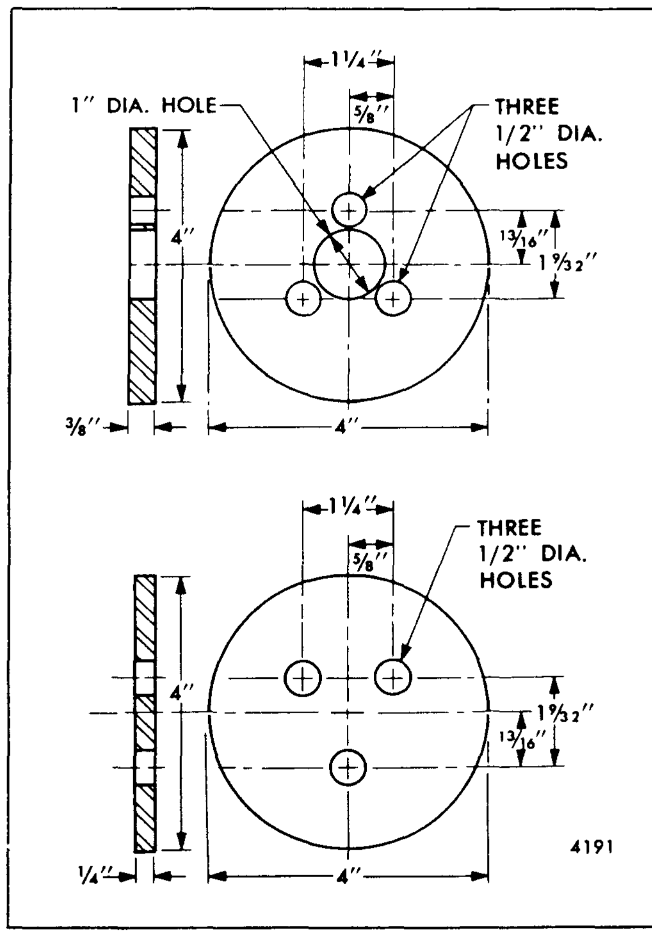


Fig. 11 - Plates for Bearing Test Fixture

gear assemblies which include new bearings should be "worked in" by grasping the gear firmly by hand and rotating the gear back and forth several times.

After the idler gear, hub and bearing are assembled together, the bearing should be checked to ascertain that the gear may be rotated on its bearing without exceeding the maximum torque specifications, nor be so loose as to permit the gear to be moved in relation to the hub by tilting, wobbling or shaking the gear.

If the mating crankshaft and camshaft gears are not already mounted on the engine, the torque required to rotate the idler gear may be checked by mounting the idler gear in position on the engine, using a round steel plate 4 " in diameter (pre-load test plate) against the hub and cone as outlined below.

1. Mount the idler gear assembly on the engine.

2. Install the center bolt through the gear hub and thread it into the cylinder block. Tighten the bolt to 40-45 lb-ft torque.

3. Place the steel plate (lower plate shown in Fig. 11) against the hub and bearing. Insert two 3/8 "-16 bolts and one 5/16 "-18 bolt through the plate and thread it into the cylinder block. Tighten the two 3/8 "-16 bolts to 40-45 lb-ft torque and the 5/16 "-18 bolt to 19-23 lb-ft torque.

4. Tie one end of a piece of lintless 1/8 " cord around a 1/8 " round piece of wood (or soft metal stock). Place the wood between the teeth of the gear, then wrap the cord around the periphery of the gear several times. Attach the other end of the cord to a spring scale, J 8129 (Fig. 12). Maintain a straight, steady pull on the scale, 90 ° to the axis of the hub, and note the pull, in pounds and ounces, required to start the gear rotating. Make several checks to obtain an average reading. If the pull is within 1-1/4 lb. minimum to 6 lbs. 12 ounces maximum and does not fluctuate more than 2 lbs. 11 ounces, the idler gear and bearing assembly are satisfactory for use.

If the crankshaft and camshaft gears are mounted on the engine, a suitable fixture which may be held in a vise can be made as shown in Fig. 10 with two plates as shown in Fig. 11. One of the plates is used to take the place of the flywheel housing and the other the cylinder block. *Engine - mounted* conditions are simulated by tightening the 3/8 "-16 attaching bolts and nuts to 40-45 lb-ft torque.

Check the pre-load as follows:

1. Clamp the idler gear between the two plates as shown in Fig. 10. Insert the bolts and tighten the three 3/8 "-16 bolts and nuts to 40-45 lb-ft torque.

2. Clamp the idler gear assembly and fixture in a vise as shown in Fig. 12.

3. Attach the cord to the idler gear and spring scale and check the pre-load as outlined in Step 4 of the previous method.

If the scale reading is within the specified 1-1/4 to 6-3/4 lbs., but fluctuates more than the permissible 2 lbs. 11 ounces, the idler gear and bearing assembly must NOT be installed on the engine. Fluctuations in scale reading may be caused by the cones not being concentric to each other, damaged cones or rollers, or dirt or foreign material within the bearings. In these cases, the bearing should be inspected for the cause of fluctuation in the scale readings and corrected or a new bearing installed.

A scale reading which exceeds the specified maximum indicates binding of the bearing rollers or rollers improperly installed. When the scale reading is less than the specified minimum, the bearing is more likely worn and the bearing should be replaced.

After the pre-load test is completed, remove the steel plates. Attach the bearing retainer to the idler gear with six self-locking bolts. Tighten the bolts to 12-15 lb-ft torque.

Install Idler Gear, Hub and Bearing Assembly

1. Position the crankshaft gear and the camshaft gear so that the timing marks will align with those on the idler gear (refer to Section 1.7.1).

2. With these marks in alignment, start the idler gear into mesh with the crankshaft gear and the camshaft gear and simultaneously rotate the gear hub so that

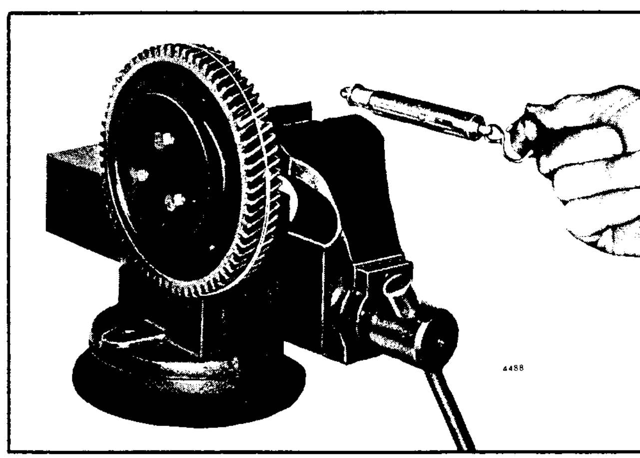


Fig. 12 - Checking Pre-Load of Idler Gear Bearing

the oil hole in the rear end plate is in line with the oil hole in the hub and the three bolt holes are in line.

3. Roll the idler gear into position and gently tap the hub until it seats against the rear end plate.

4. After making sure that the hub is tight against the rear end plate, secure the idler gear assembly in place with the 3/8 "-16 x 1-3/4 " special bolt. Tighten the bolt to 40-45 lb-ft torque.

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

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

CRANKSHAFT TIMING GEAR

In-line and 6V Engine

The crankshaft timing gear is keyed and pressed on the crankshaft and drives the camshaft gear (In-line or 6V engines) or balance shaft gear (In-line engines) through an idler gear.

Since the camshaft must be in time with the crankshaft, timing marks are located on the rim of the idler gear with corresponding timing marks stamped on the crankshaft gear and camshaft and balance shaft gears (refer to Section 1.7.1).

Remove Crankshaft Timing Gear (Flywheel Housing Removed)

The crankshaft timing gear is a .001 " to .003 " press fit on the crankshaft. Remove the gear as follows:

1. Remove the crankshaft rear oil seal sleeve, if used. To remove the sleeve, peen the outside diameter of the sleeve until it stretches sufficiently so it can be slipped off of the crankshaft.

2. Before removing the crankshaft gear, align the timing marks of the gear train and note their location so the gear can be reinstalled in its original position.

3. Attach bar type puller J 4871 to the crankshaft gear with three long bolts or hooks, flat washers and nuts through the holes in the gear as shown in Fig. 1.

4. Turn the center screw of the puller to pull the crankshaft gear off of the crankshaft.

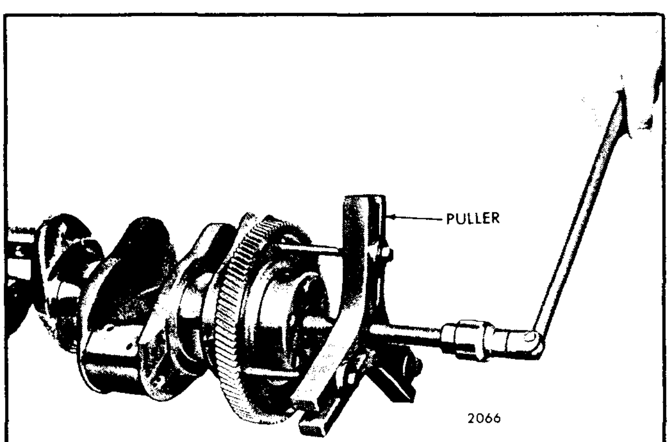


Fig. 1 - Removing Crankshaft Timing Gear

Inspection

Clean the gear with fuel oil and dry it with compressed air. Examine the gear teeth for evidence of scoring, pitting or wear. If severely damaged or worn, install a new gear. Also check the other gears in the gear train.

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. Align the proper timing mark on the crankshaft gear with the corresponding mark on the idler gear (refer to Section 1.7.1).

> **NOTE:** When advanced timing is required, align the timing mark "A" with the timing mark on the idler gear.

4. 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 and

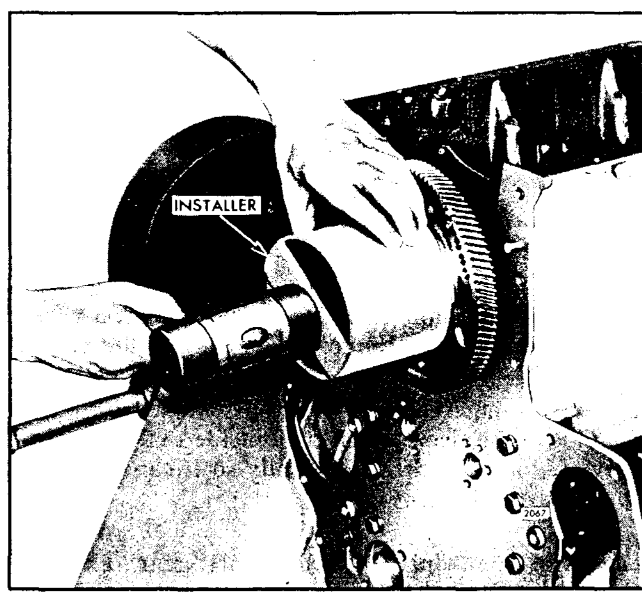


Fig. 2 - Installing Crankshaft Timing Gear

drive the gear up against the shoulder on the crankshaft as shown in Fig. 2.

5. Check the gear backlash with the mating gear. The backlash should be .003 "-.005 " with new gears or .008 " maximum with used gears.

6. Install a new crankshaft rear oil seal sleeve, if required, as outlined in Section 1.3.2.

CRANKSHAFT TIMING GEAR

8V Engine

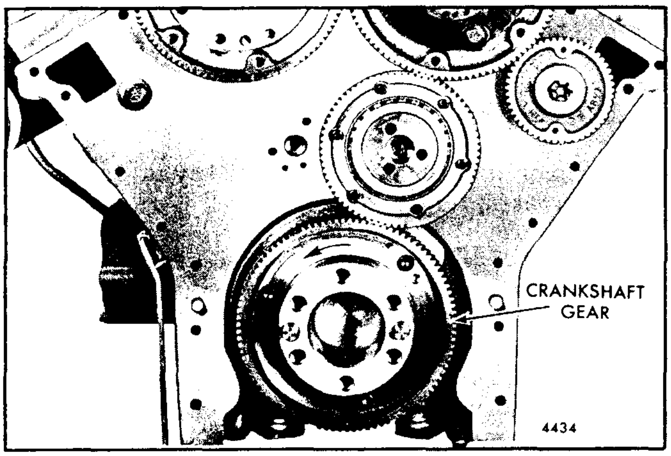


Fig. 3 - Crankshaft Timing Gear Mounting (R.H. Rotation Engine Shown)

The crankshaft timing gear on an 8V engine is keyed and fastened to the crankshaft with three 3/8 "-24 x 3/4 " socket head bolts.

Since the camshafts must be in time with the crankshaft, timing marks are located on the rim of the idler gear with corresponding timing marks stamped on the crankshaft gear and camshaft gears (refer to Section 1.7.1).

Remove Crankshaft Timing Gear (Flywheel Housing Removed)

The crankshaft timing gear is a .001 " to .003 " press fit on the crankshaft. Remove the gear as follows:

1. Remove the crankshaft rear oil seal sleeve, if used. To remove the sleeve, peen the outside diameter of the sleeve until it stretches sufficiently so it can be slipped off of the crankshaft.

2. Before removing the crankshaft gear, align the timing marks of the gear train and note their location so the gear can be reinstalled in its original position.

3. Remove the three socket head bolts securing the gear to the crankshaft.

4. Provide a base for the puller screw by placing a steel plate across the cavity in the end of the crankshaft. Then remove the gear with a suitable puller.

Inspection

Clean the gear with fuel oil and dry it with compressed air. Examine the gear teeth for evidence of scoring, pitting or wear. If severely damaged or worn, install a new gear. Also check the other gears in the gear train.

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. Align the proper timing mark on the crankshaft gear with the corresponding mark on the idler gear (refer to Section 1.7.1).

> **NOTE:** When advanced timing is required, align the timing mark "A" with the timing mark on the idler gear.

4. Start the three 3/8 "-24 socket head bolts into the crankshaft. Then slowly draw the gear tight against the shoulder on the crankshaft by tightening the bolts uniformly to 35-39 lb-ft torque.

5. Check the backlash with the mating gear. The backlash should be .003 " to .005 " with new gears or .008 " maximum with used gears.

6. Install a new crankshaft rear oil seal sleeve, if required, as outlined in Section 1.3.2.

BLOWER DRIVE GEAR AND SUPPORT ASSEMBLY

4-53 AND 6V-53 ENGINE

The blower drive gear is driven by the camshaft gear (4-53 engine) or the left-bank camshaft gear (6V-53 engine). The gear is keyed and pressed onto a shaft, which is supported in the blower drive support. This support, on a 4-53 engine, is attached to the rear end plate on the blower side of the engine (Fig. 1). On a 6V-53 engine, the blower drive support is mounted on the flywheel housing (Fig. 2).

Service the blower drive support on a 6V-53 engine as outlined in Section 2.7.1.1. The following procedures apply only to the 4-53 engine.

Remove and Install Blower Drive Shaft

1. Remove the air inlet housing from the blower (refer to Section 3.3).

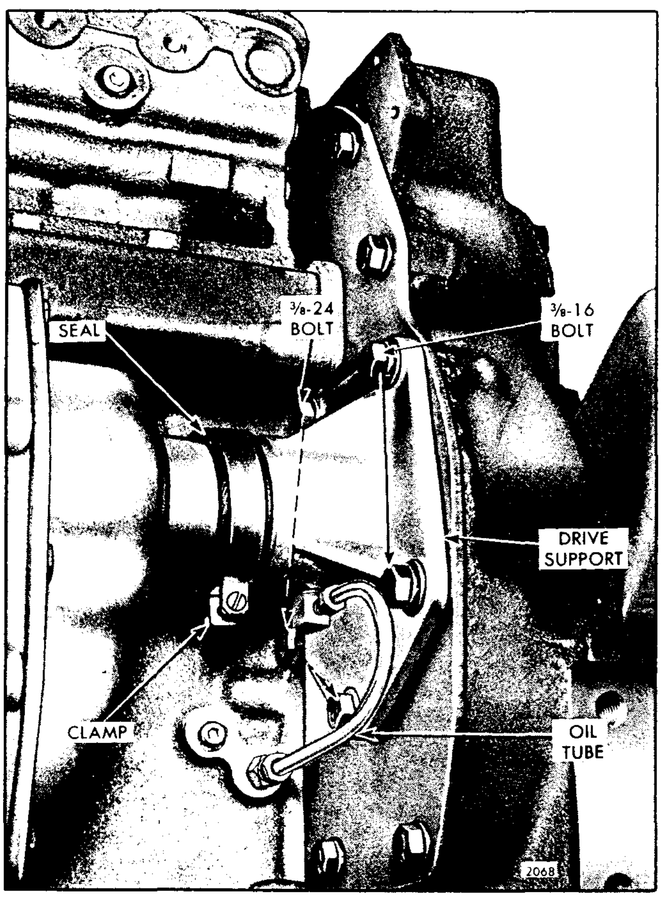


Fig. 1 - Blower Drive Support Mounting on 4-53 In-Line Engine

2. Refer to Fig. 1 and loosen the blower drive seal clamp.

3. Slide the clamp and seal off of the blower drive support.

4. Remove the four blower-to-block bolts. Then carefully lift the blower away from the blower drive support and the cylinder block so the serrations on the blower drive shaft are not damaged.

5. Withdraw the blower drive shaft from the blower drive support.

6. Install the shaft by reversing the removal procedures.

Remove Blower Drive Support Assembly

1. Remove the blower and the blower drive shaft as outlined above.

2. Disconnect the lubricating oil tube (Fig. 1) from the blower drive support.

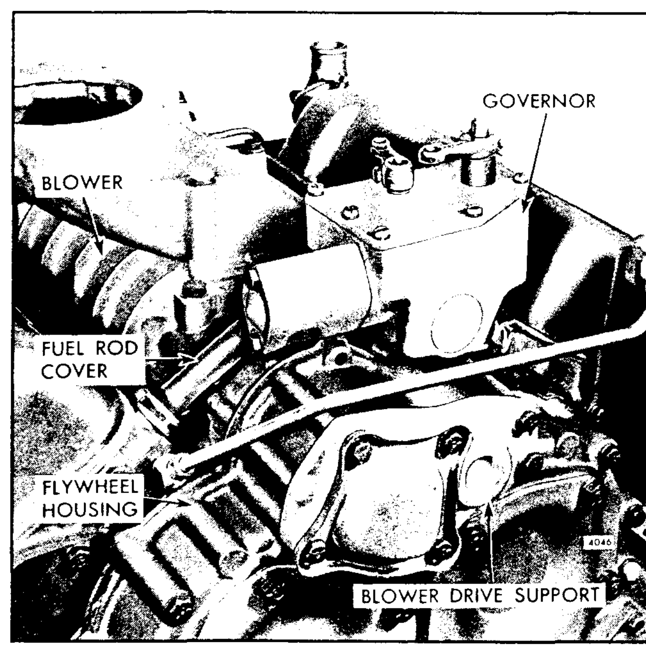


Fig. 2 - Blower Drive Support Mounting on 6V-53 Engine

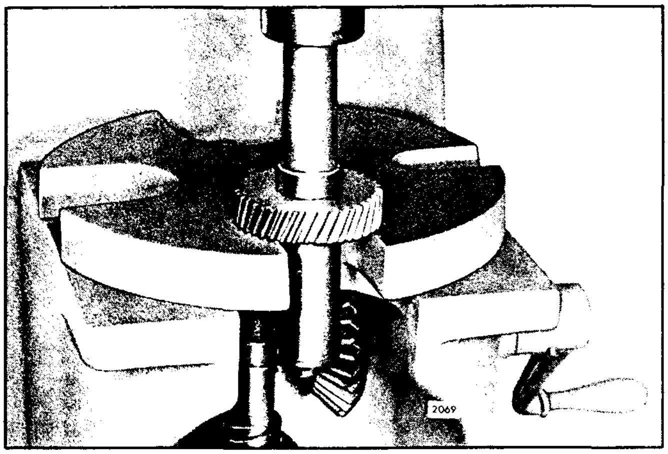


Fig. 3 - Pressing Blower Drive Gear From Shaft

3. Remove the blower drive support attaching bolts.

4. Tap the blower drive support to loosen it, then carefully withdraw the support from the rear end plate so the blower drive gear teeth will not be damaged.

Disassemble Blower Drive Support Assembly

1. Remove the snap ring and the thrust washer from the shaft.

2. If there are burrs on the edges of the snap ring groove, remove them with a stone. Then withdraw the gear and shaft from the support.

3. Support the blower drive gear in an arbor press (Fig. 3).

4. Place a short 1-1/8 " diameter brass rod on the end of the shaft and press the shaft out of the gear.

Inspection

Thoroughly clean the parts with fuel oil and dry them with compressed air.

Inspect the inside diameter and thrust surfaces of the blower drive gear support for scoring and wear. Also check the outside diameter of the blower drive gear shaft for wear. The clearance between the shaft and the support should not be less than .0035 " (with new parts) or more than .007 " (with used parts).

Inspect the serrations on the blower drive shaft and, if worn so that excessive backlash is felt when the shaft is inserted into the blower drive gear shaft, install a new blower drive shaft.

Examine the blower drive support thrust washer for scoring and wear. Replace the thrust washer if necessary. The thickness of a new blower drive support thrust washer is .093 " to .103 ".

Inspect the gear teeth for evidence of scoring, pitting, burning and wear. If necessary, install a new gear.

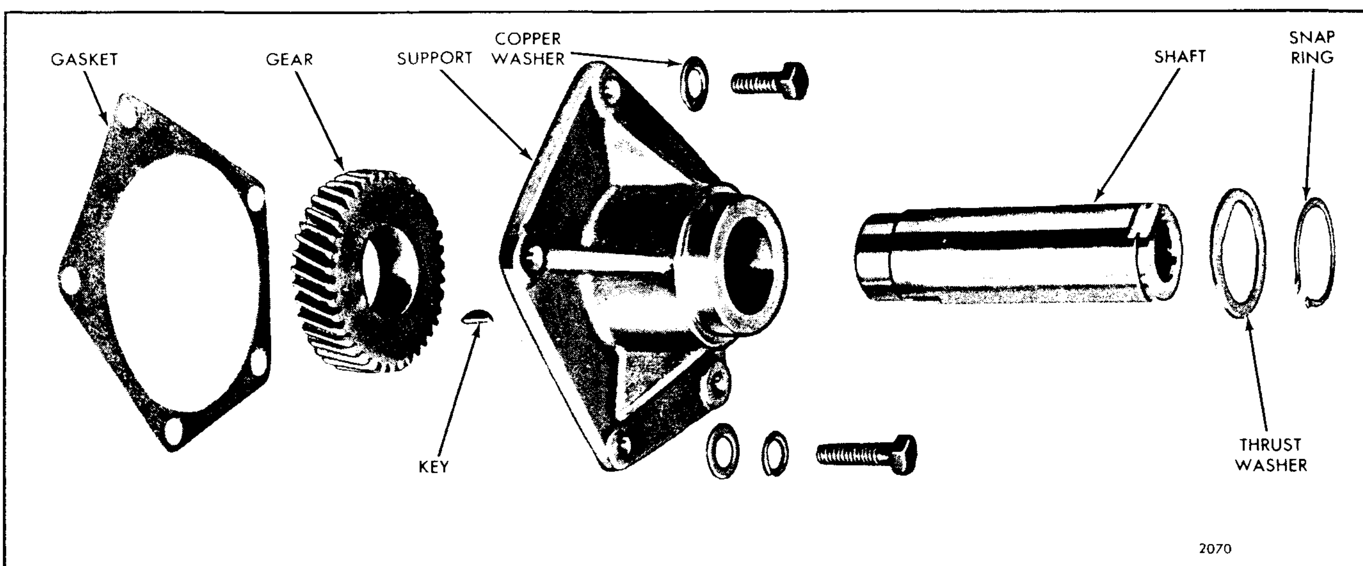


Fig. 4 - Blower Drive Gear and Support Assembly Details and Relative Location of Parts (In-Line Engine)

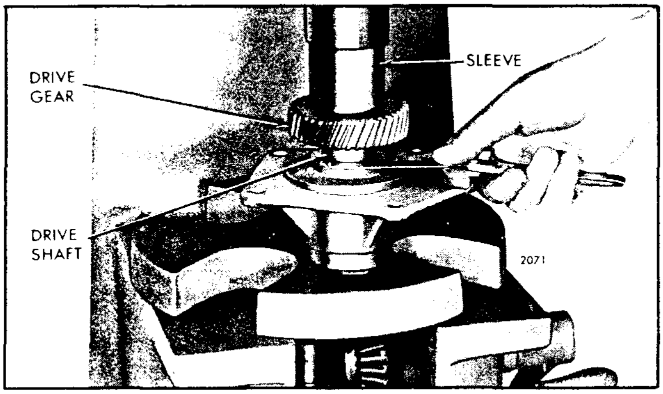


Fig. 5 - Pressing Blower Drive Gear On Shaft

Assemble Blower Drive Support Assembly

Refer to Fig. 4 for the relative position of the parts and assemble the blower drive support as follows:

1. Lubricate the blower drive gear shaft with clean engine oil and insert the shaft into the blower drive support.

2. Assemble the thrust washer and the snap ring on the shaft.

3. Install the key in the shaft, if it was removed.

4. Place the shaft and support in an arbor press.

5. Position the gear on the shaft so the keyway in the gear is in alignment with the key in the shaft. Then place a sleeve on the gear and press the gear on the shaft until the clearance between the gear and support is .004 " to .006 " (Fig. 5).

Install Blower Drive Support Assembly

1. Affix a new blower drive support gasket to the cylinder block rear end plate.

2. Install the blower drive support assembly by reversing the removal procedure.

3. Tighten the 3/8 "-24 support-to-end plate bolts (with copper washers) and the 3/8 "-16 support-to-flywheel housing bolts (with plain washers and lock washers) to 35 lb-ft torque.

BLOWER DRIVE GEAR AND SUPPORT ASSEMBLY

8V-53 ENGINE

The blower drive gear is driven by the right-bank camshaft gear. The drive gear is pressed onto a shaft which is supported in the blower drive support. The blower drive support assembly is attached to the blower rear end plate and the forward face of the cylinder block end plate.

The blower drive support bearing receives oil under pressure from the horizontal oil passage in the blower rear end plate which leads to the oil passage in the blower drive support.

Remove and Install Blower Drive Shaft

1. If an air compressor is attached to the rear right-hand face of the flywheel housing, disconnect and remove it from the flywheel housing.

2. Remove the five bolts and lock washers securing the blower drive hole cover to the flywheel housing. Remove the cover and gasket.

3. Remove the two bolts securing the blower drive shaft retainer to the blower drive coupling support, then remove the retainer.

4. Pull the blower drive shaft out of the blower drive hub and cam. If necessary, use a pair of small nose pliers.

5. Install the blower drive shaft by reversing the removal procedure.

Remove Blower Drive Support Assembly

1. Remove the blower, governor and drive support assembly from the engine as outlined under *Remove Blower* in Section 3.4.1.

2. Remove the six bolts, lock washers, plain washers and one socket head bolt securing the blower drive support to the blower rear end plate.

3. Tap each end of the blower drive support with a plastic hammer to loosen it from the gasket and dowel pins. Then remove the drive support assembly and gasket.

Disassemble Blower Drive Support

Refer to Figs. 6 and 7 and disassemble the blower drive support as follows:

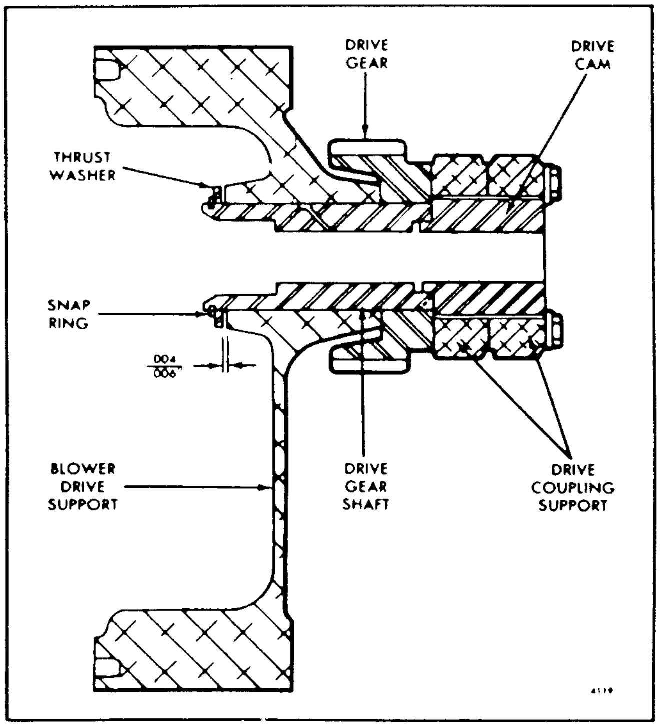


Fig. 6 - Blower Drive Support Assembly

1. Remove the thrust washer retaining snap ring from the blower drive gear shaft with a pair of snap ring pliers. Then remove the thrust washer from the shaft.

2. If there are any burrs on the edges of the snap ring groove, remove them with a fine stone. Then withdraw the drive gear and shaft from the support.

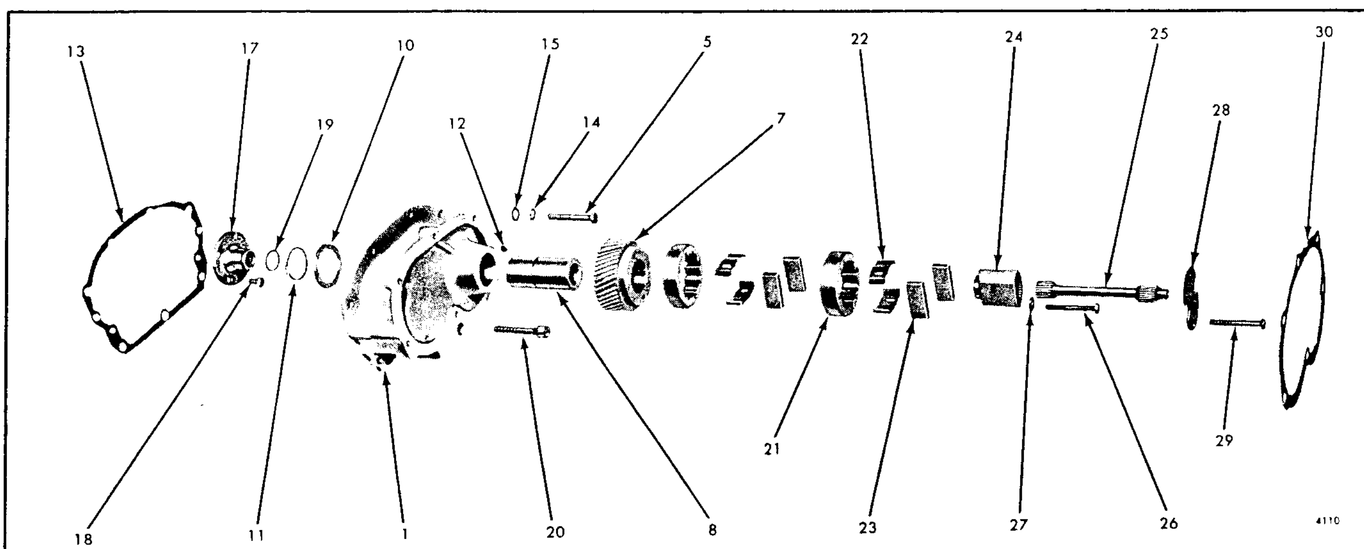
3. Support the blower drive gear and shaft, rear face of the gear up, on two wood blocks on the bed of an arbor press.

4. Place a short brass rod on the end of the shaft and press the drive gear shaft out of the gear. Catch the shaft by hand to prevent damage to the shaft.

Inspection

Wash all of the parts in clean fuel oil and dry them with compressed air.

Inspect the inside diameter and thrust surfaces of the blower drive gear support for scoring and wear. Also check the outside diameter of the blower drive gear shaft for wear. The clearance between the shaft and



1. Support--Blower Drive
5. Bolt--Drive Support
7. Gear--Blower Drive
8. Shaft--Drive Gear
10. Washer--Thrust
11. Snap Ring--Thrust Washer Retaining
12. Pipe Plug
13. Gasket--Drive Support to Blower End Plate
14. Lock Washer
15. Plain Washer
17. Hub--Blower Drive
18. Bolt--Drive Hub
19. Seal--Drive Hub Oil
20. Bolt--Drive Support to Blower
21. Support--Blower Drive Spring
22. Seat--Drive Spring
23. Spring--Blower Drive
24. Cam--Blower Drive
25. Shaft--Blower Drive
26. Bolt--Drive Cam Retaining
27. Plain Washer Retainer
28. Retainer--Drive Shaft
29. Bolt--Drive Shaft
30. Gasket--Drive Support to Cylinder Block End Plate

Fig. 7 - Blower Drive Support Details and Relative Location of Parts (8V-53 Engine)

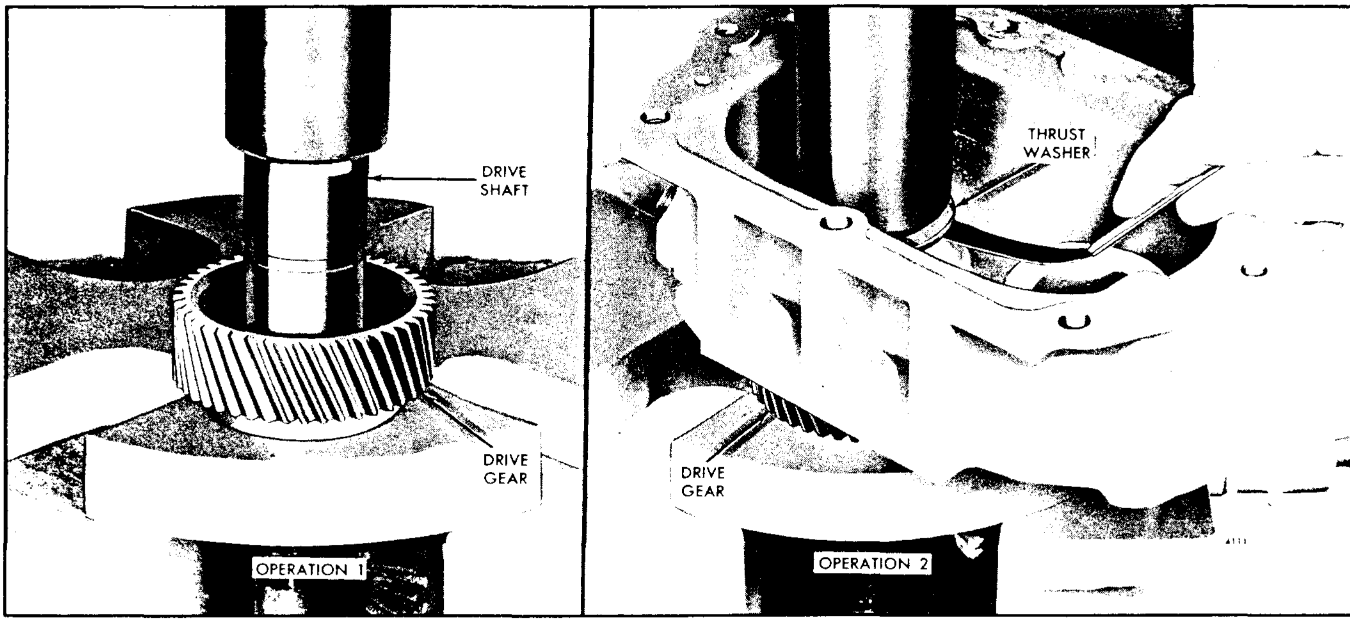


Fig. 8 - Installing Blower Drive Gear Shaft in Drive Gear

the support should not be less than .002 " (with new parts) or more than .007 " (with used parts).

Inspect the serrations on the blower drive shaft and, if worn so that excessive backlash is felt when the blower drive shaft is inserted into the blower drive cam and drive hub, install a new blower drive shaft.

Examine the blower drive support thrust washer for scoring and wear. Replace the thrust washer if necessary. The thickness of a new blower drive support thrust washer is .119 " to .121 ".

Inspect the gear teeth for evidence of scoring, pitting, burning and wear. If necessary, install a new gear.

Assemble Blower Drive Support Assembly

Refer to Figs. 6 and 7 for the relative position of the parts and assemble the blower drive support as follows:

1. Lubricate the drive gear end of the blower drive gear shaft with engine oil. Then start the shaft straight into the shaft bore in the drive gear from the recessed side.

2. Place the blower drive gear and shaft on the bed of an arbor press as shown in Fig. 8, Operation 1. Then press the shaft straight into the drive gear approximately one half inch.

3. Lubricate the blower drive gear shaft with engine oil. Then insert the shaft into the shaft bore in the support.

4. Place the thrust washer, oil groove side facing the support, on the blower drive gear shaft. Then install the snap ring in the groove in the shaft.

5. Support the blower drive gear, shaft and support on the bed of an arbor press as shown in Fig. 8, Operation 2. Then press the drive gear shaft into the drive gear until the clearance between the thrust washer and the support is .004 "-.006 " (Fig. 6).

Install Blower Drive Support Assembly

1. Affix a new blower drive support gasket to the forward face of the support.

2. Place the blower drive support assembly over the two dowel pins in the blower rear end plate and against the gasket.

3. Install the six bolts, lock washers, plain washers and one socket head bolt. Tighten the bolts to 20-24 lb-ft torque.

4. Install the blower, governor and drive support assembly on the engine as outlined under *Install Blower* in Section 3.4.1.

ACCESSORY DRIVES

Accessory drives have been provided at the rear of the engines to accommodate both gear–driven and belt–driven accessories.

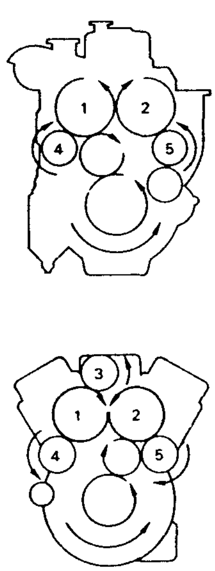
For the possible accessory drive locations and rotation of the drive at a particular position, refer to Fig. 1.

The drive for direct gear–driven accessories, such as air compressors or hydraulic pumps, consists of a drive hub, coupling and drive plate (Fig. 2) or a spacer, drive plate, drive coupling and hub (Fig. 3).

On certain 4–53 engines, the spacer has been eliminated and a drive coupling 1.940" long and a drive disc .560" wide is used.

The drive plate and spacer, when used, are bolted to the camshaft or balance shaft gear. The accessory is bolted to the flywheel housing and driven by a drive hub keyed to the accessory shaft and splined to the coupling which is splined to the drive plate attached to the camshaft or balance shaft gear. The current drive coupling, shown in Fig. 3, has 21 external teeth; the former coupling had 23 external teeth.

Belt–driven accessories, such as battery–charging generators or air compressors, are driven off the camshaft or balance shaft gears by a drive hub and pulley (Fig. 4), or a spacer, accessory drive plate, accessory drive shaft, accessory drive retainer assembly and pulley (Fig. 5).



ACCESSORY DRIVE POSITION	DRIVE RATIO
INLINE ENGINE	
1	1:1
2	1:1
4 BLOWER	2.47:1
GOV.	1.98:1
5 BLOWER	2.47:1
GOV.	1.98:1
V-ENGINE	
1	1:1
2	1:1
3	*2.47:1
4	1.98:1
5	1.98:1
*2.20:1 ON 8V ENGINE	

L – 5325

Fig. 1 – Accessory Drive Locations

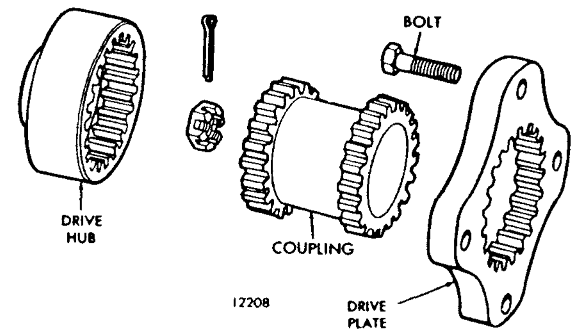


Fig. 2 – Air Compressor Drive

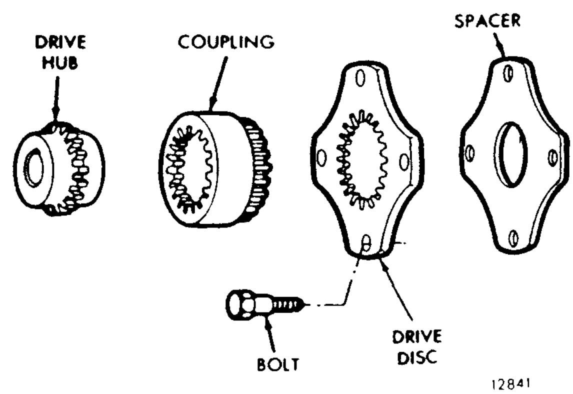


Fig. 3 – Hydraulic Pump Drive

In the first arrangement, illustrated in Fig. 4, the drive hub is bolted to the camshaft or balance shaft gear. The oil seal retainer is bolted to the flywheel housing and the pulley is keyed to the drive hub shaft which extends through the oil seal retainer.

In the second arrangement, shown in Fig. 5, the spacer and accessory drive plate are bolted to the camshaft or balance shaft gear. The accessory drive shaft is splined to the drive plate at one end and supported by a bearing in the accessory drive retainer at the other end. The accessory drive retainer, which also incorporates an oil seal, is bolted to the flywheel housing. The pulley is keyed to the drive shaft which extends through the drive retainer assembly.

Remove Accessory Drive

Remove the direct gear–driven type accessory drive as follows:

1. Remove any external piping or connections to the accessory.

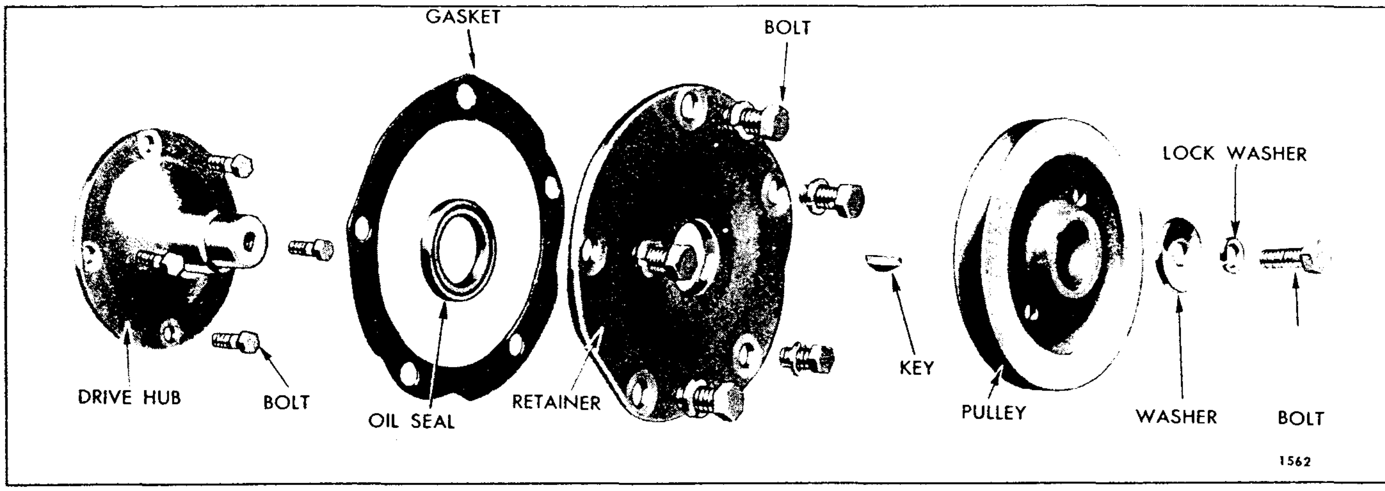


Fig. 4 – Components of Accessory Drive for Belt–Driven Accessory (Drive Hub Type)

2. Remove the five bolts and lock washers attaching the accessory to the flywheel housing. Pull the accessory straight out from the flywheel housing.

3. Remove the drive coupling.

4 Remove the drive hub from the accessory shaft, if necessary.

5. Place a clean, lintless cloth in the flywheel housing opening, underneath the accessory drive plate, to prevent bolts from accidentally falling into the gear train. Remove the lock wires, if used. Then remove the four bolts (and lock washers, if used) and remove the accessory, the drive plate and the spacer, if used.

Remove the drive assembly for a belt–driven type accessory as follows:

1. Remove any external piping or connections to the accessory.

2. Loosen the accessory and slide it toward the drive pulley. Then remove the drive belt and accessory.

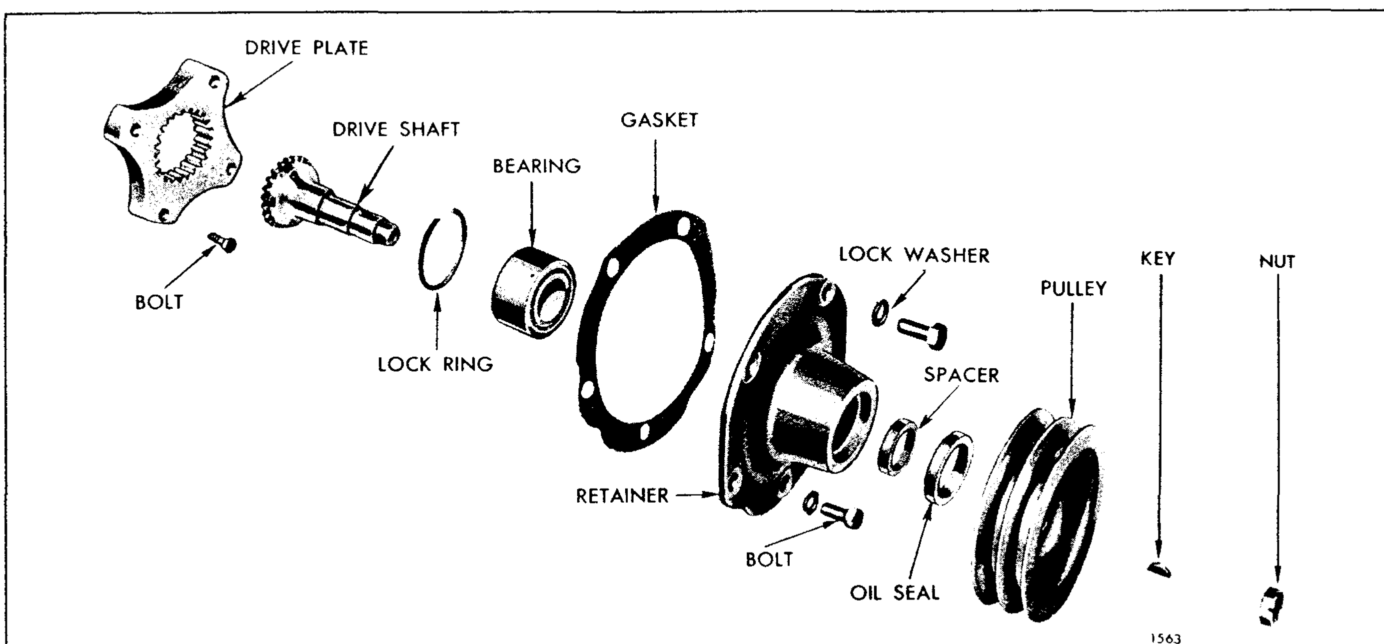


Fig. 5 – Components of Accessory Drive for Belt–Driven Accessory (Drive Plate Type)

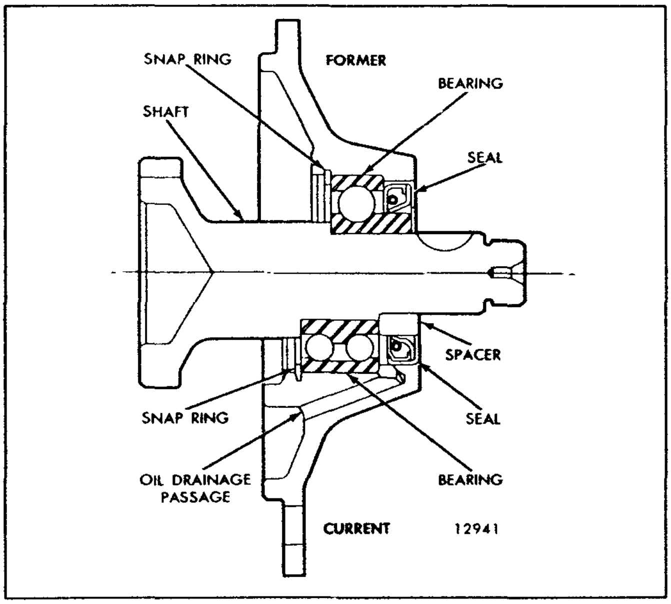


Fig. 6 – Former and Current Drive Plate Type Accessory Drive

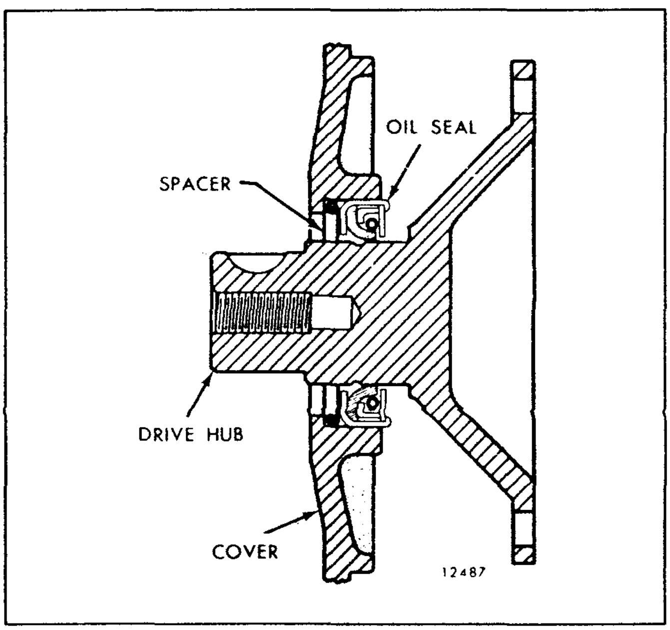


Fig. 7 – Location of Oil Seal Spacer

3. Remove the bolt and washer (Fig. 4), or nut (Fig. 5), retaining the pulley on the drive shaft.

4 Use a suitable gear puller to remove the pulley from the drive shaft. Remove the Woodruff key.

5. Remove the five bolts and lock washers which attach the drive retainer assembly to the flywheel housing. Remove the retainer assembly.

6. Remove the accessory drive shaft, drive plate and spacer (Fig. 5), or drive hub (Fig. 4), in a manner similar to that outlined in Step 5 under removal of the direct gear–driven type accessory drive.

7. Remove the snap ring and ball bearing from the accessory drive shaft retainer assembly shown in Fig. 5.

Inspection

Clean the accessory drive parts with clean fuel oil and dry them with compressed air.

- **CAUTION: To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.**

Examine the gear teeth of the drive shaft, drive coupling, drive hub or drive plate for wear. If worn excessively, replace them with new parts.

Inspect the ball bearing used to support the accessory drive shaft shown in Fig. 5. Wash the bearing in clean fuel oil and dry it with compressed air.

- **CAUTION: To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.**

Shielded bearings must not be washed; dirt may be washed in and the cleaning fluid could not be entirely removed from the bearing. Wipe the outside of the bearing clean, then hold the inner race and revolve the outer race slowly by hand. If the bearing is worn or does not roll freely, replace the bearing. Inspect the accessory drive hub, shown in Fig. 4, for grooving at the area of contact with the lip of the oil seal. If the hub is grooved to a point where the effectiveness of the oil seal is lost, a ring type oil seal spacer is available which serves to reposition the seal, thus providing a new sealing surface for the lip of the seal (Fig. 7).

Install Accessory Drive

1. Remove old gasket material from the flywheel housing. Use care so that no gasket material falls into the gear train compartment.

2. Insert a clean, lintless cloth in the flywheel housing opening to prevent bolts from accidentally falling in the gear train. Align the bolt holes in the accessory drive plate and spacer (if used), or the accessory drive hub, with the tapped holes in the camshaft or balance shaft gear. Then secure the plate and spacer, or drive hub, with four bolts (and lock washers or lock wire, if used). Remove the cloth from the flywheel housing opening.

3. If a gear–driven accessory is used as shown in Figs. 2 and 3, install the accessory drive coupling. When replacing the drive hub on the accessory shaft, drive

the hub squarely on the shaft (refer to Section 12.4). Then proceed as follows:

a. Place a new gasket on the flange and align the holes in the gasket with the bolt holes in the flange. Use a light coat of grease to retain the gasket in position.

b. Place the accessory in position against the flywheel housing, rotating it, if necessary, to align the teeth of the accessory hub with those in the drive coupling. Secure the accessory to the flywheel housing with five bolts and lock washers.

4. If the accessory drive shown in Figs. 5 or 6 is used, assemble as follows:

a. Install the accessory drive plate and spacer as outlined in Steps 1 and 2 above.

b. Place the drive shaft retainer on the bed of an arbor press, with the mounting flange side up. Press the double-row ball bearing straight in until the bearing contacts the shoulder in the bore of the retainer. Install the snap ring.

On former accessory drives (Fig. 6), install the bearing with the protruding face of the inner race towards the retainer.

c. Turn the retainer over and press the oil seal into the bore of the retainer with the lip of the seal toward the bearing.

d. Turn the retainer over again, bearing side up, and press the accessory drive shaft in the bearing until the shoulder on the shaft contacts the bearing.

e. Apply a light coat of grease to the mounting flange of the retainer and place a new gasket in position against the flange. Align the holes in the gasket with the bolt holes in the flange.

f. Place the retainer and drive shaft assembly against the flywheel housing, rotating the shaft slightly, if necessary, to permit the teeth of the drive shaft to mesh with the teeth in the drive plate. Secure the retainer assembly to the flywheel housing with five bolts and lock washers.

g. On current accessory drives, install the spacer over the shaft and against the bearing.

h. Install the Woodruff key in the drive shaft. Start the pulley straight on the shaft, aligning the keyway in the pulley with the key on the shaft. Use a soft hammer to tap the pulley on the shaft.

i. Thread the 3/4"–16 pulley retaining nut on the end of the drive shaft and tighten it to 120–140 lb-ft (163–190 N·m) torque.

j. Install the accessory on the engine and slip the drive belt over the pulleys. Position the accessory to provide the proper tension on the belt and secure it in place.

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.

5. Assemble the accessory drive shown in Fig. 4 as follows:

a. Press a new oil seal in the oil seal retainer, if the seal was removed.

b. Coat the mounting flange of the retainer lightly with grease and place a new gasket against the flange. Align the holes in the gasket with the bolt holes in the flange.

c. With the accessory drive hub in place (see Step 2 above), slip the retainer and oil seal assembly over the end of the shaft. Use care not to damage the oil seal. Secure the retainer to the flywheel housing with five bolts and lock washers.

d. Install the Woodruff key. Start the pulley straight on the shaft, aligning the keyway in the pulley with the key on the shaft. Use a soft hammer to tap the pulley on the shaft.

e. Install the washers and the pulley retaining bolt and draw the bolt up tight.

f. Install the accessory on the engine and slip the drive belt over the pulleys. Position the accessory to provide the proper tension on the belt and secure it in place.

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.

ENGINE FRONT COVER (Upper)

In-Line and 6V Engines

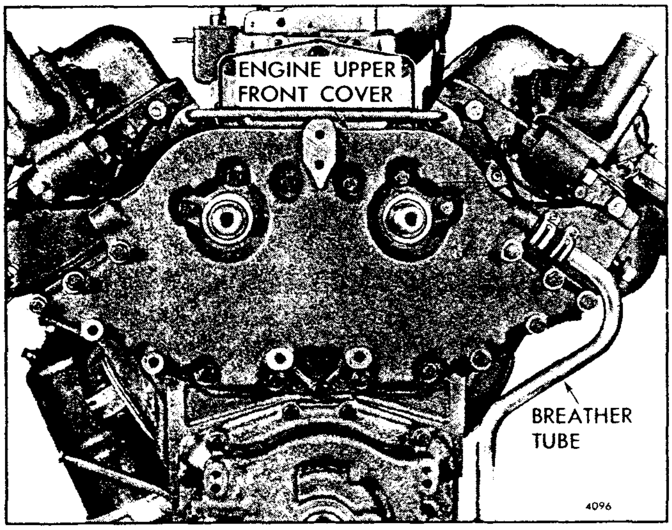


Fig. 1 – 6V Engine Upper Front Cover Mounting

The upper engine front cover is mounted against the cylinder block at the upper front end of the engine. On a 6V engine, the crankcase is ventilated through a breather tube connected to the cover (Fig. 1). The camshaft and balance shaft oil seals (In–line engine) or camshaft oil seals (6V engine) are pressed into the cover.

● To reduce operating noise levels, the upper front covers on 3, 4, and 6V–53 turbocharged industrial engines have been changed, effective with unit serial numbers 3D0197864, 4D0211728, and 6D0231643. On 3 and 4-53T units a new cast iron upper front cover with strategically placed cast-in ribs has replaced the former aluminum cover. On 6V-53T engines the current cast iron covers have been revised by the addition of cast-in ribs on their inside walls. The ribs make the covers less prone to vibration. Interchangeability is not affected, and only the new 3 and 4-53T cover and the revised 6V-53T cover will be available to service Series 53 turbocharged industrial engines.

Remove Cover

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. Remove the seal by prying against the washers with pry bars. Install the new seals with installer J 9790.

If necessary, remove the engine cover as follows:

1. Remove the various parts and subassemblies from the engine as outlined in their respective sections of this manual.
2. Remove the pulleys from the front end of the camshaft and balance shaft (In–line engine) or the camshafts (6V engine). Refer to Section 1.7.2.
3. Remove the upper front cover–to–cylinder block attaching bolts.
4. Tap the cover and dowel pin assembly away from the cylinder block.
5. Remove the Woodruff keys and oil seal spacers from the shafts.
6. Remove all traces of the old gasket material from the cylinder block and cover.

Inspection

Check the oil seals and the spacers for wear or damage. Replace them if necessary.

On a 6V engine, remove, clean and reinstall the wire mesh pad (element) in the upper front cover.

Remove Oil Seals

1. Support the inner face of the cover on wood blocks at least one inch thick to protect the dowel pins in the cover.
2. 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.

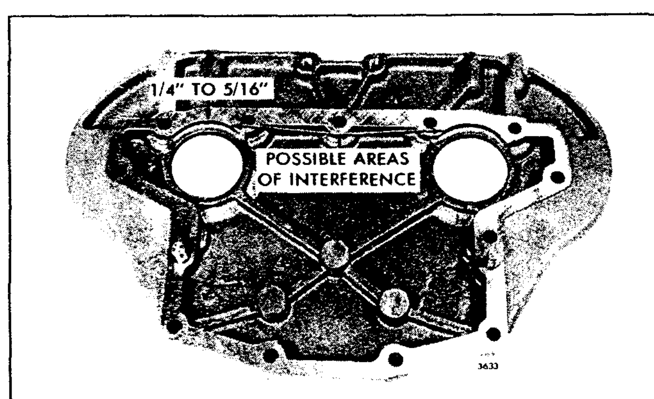


Fig. 2 – In–Line Engine Upper Front Cover

3. Position a new oil seal in the cover with the lip of the seal pointing toward the inner face of the cover. Keep the lip of the oil seal clean and free from scratches.

4. Press the seal into the cover with installer J 9790 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 Cover

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 (47 N·m) torque.

3. Apply cup grease to the outside diameter of the oil seal spacers, then slide them on the shafts.

   Current engines use an oil slinger between the oil seal spacer and the shoulder on the camshaft and between 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.

   If oil slingers are installed on in–line engines built prior to serial numbers 2D–9278, 3D–573 and 4D–944, check the distance from the holes to the gasket flange (Fig. 2). If necessary, machine or grind the cover to provide sufficient clearance for the slingers.

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 (407–441 N·m) torque.

SHOP NOTES - TROUBLESHOOTING - SPECIFICATIONS - SERVICE TOOLS

SHOP NOTES

CHECKING BEARING CLEARANCES

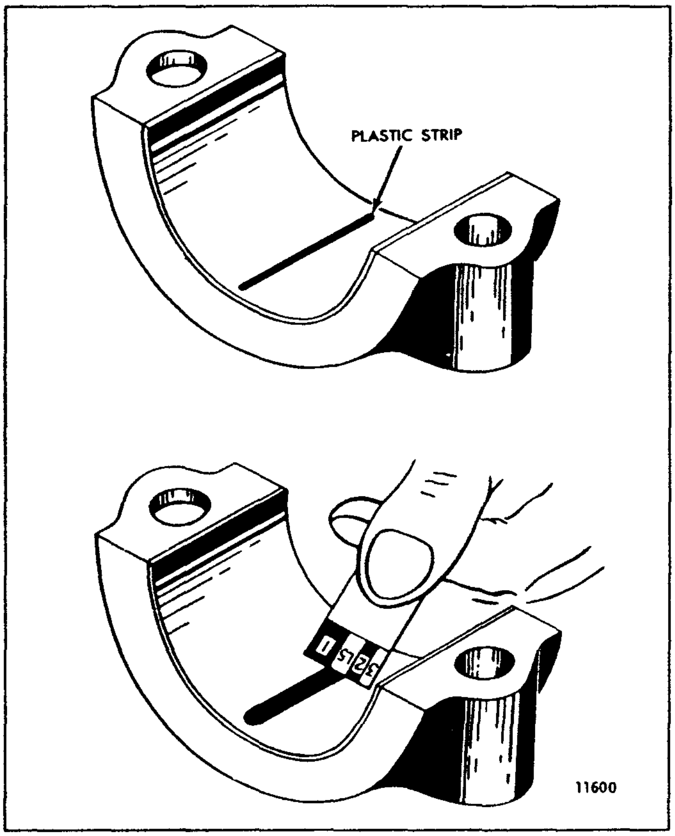


Fig. 1 – Using Plastic Strip to Measure Bearing–to–Crankshaft Clearance

A strip of soft plastic squeezed between the crankshaft journal and the connecting rod bearing or main bearing may be used to measure the bearing clearances.

The strip is a specially molded plastic "wire" manufactured commercially and is available 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 the bearing clearances as follows:

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

   When checking the 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 with 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 1/4" off center (Fig. 1).

3. Rotate the crankshaft about 30° from bottom dead center and reinstall the bearing cap. Tighten the bolts to the 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 on the envelope (Fig. 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 Measure each end of the plastic; the difference between the readings is the approximate amount of taper.

IN–FRAME OVERHAUL

Polyethylene plastic plugs (J 34697) help prevent solvent and debris from entering the crankcase while cleaning the airbox during in–frame overhaul or cylinder kit replacement.

CAMSHAFT CUP PLUG INSTALLATION

When an oil leak occurs at the drive plug area in the front end of the camshaft, install a cup plug in the end of the camshaft rather than removing and replacing the drive plug. It is not necessary to remove the camshaft from the engine when installing the cup plug.

Install the cup plug as follows:

1. Clean the hole in the front end of the camshaft and apply Permatex No. 1 sealant, or equivalent, to the outer diameter of the cup plug.

2. Install the plug to a depth of .180"–.210" with tool J 24094.

CYLINDER BLOCK LINE BORING

To line bore the main bearing bores, install the main bearing caps in the block and torque the bolts with their hardened washers to 120–130 lb-ft (163–177 N·m). The main bearing cap bolts are specially designed and must not be replaced by ordinary bolts. There should be a minimum of .0002" (In-line) or .0003" (V-engine) interference fit between the main bearing block saddle and the main bearing caps. If not, the cap must be replaced.

The tolerences shown below must be maintained during the reboring operation. If tolerances are not held, severe gear train damage may occur during engine operation.

1. All bores must be concentric within .001" TIR. If the bore cannot be held to .001" TIR, the block must be scrapped.

2. The surfaces from which all critical dimensions are measured for line boring are the dowel locating holes (.6245"–.6255" in diameter) at each end of the right pan rail, looking from the gear train end of the cylinder block. The crankshaft centerline is 4.239" to 4.241" in from the centerline of the dowel locating holes and 4.5985" to 4.6015" up from the pan rail surface.

3. Bore diameters for standard and oversized main bearing shells are shown in the following table:

Main Bearing	Main Bearing Bore Diameter
Standard (InLine 53)	3.251" - 3.252"
Standard (V-53)	3.751" - 3.752"
.010" Oversize (InLine 53)	3.261" - 3.262"
.010" Oversize (V-53)	3.761" - 3.762"
.020" Oversize (InLine 53)	3.271" - 3.272"
.020" Oversize (V-53)	3.771" - 3.772"

TABLE 1

4. The straightness of the finished bore must not vary more than .001" from end to end in the cylinder block.

5. After boring the block, stamp all main bearing caps to show they have been bored oversize and the amount (.010" or .020").

After installing oversize O.D. main bearing shells, always check bearing clearances before putting the engine back in service. Use the procedure found in this section.

• WELDING ENGINE CYLINDER HEADS

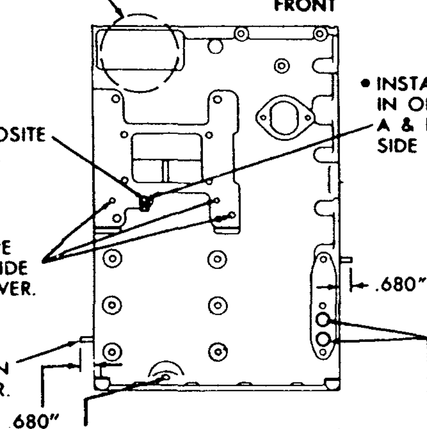
The welding of series 53 cylinder heads is not recommended. The welding of cylinder heads has been used as a salvage procedure for several years. As a salvage procedure, the resultant product has not been considered as good as a new casting.

REUSING CROSSHEAD PISTON ASSEMBLY COMPONENTS

Components of the piston assemblies can, in certain instances, be reused. Undamaged piston pins, crowns and bushings that meet dimensional limits for used parts can be reused if installed within the same piston assembly from which they were removed.

The crown, pin and bushing of a crosshead piston assembly should be considered as matched. If a crown is replaced, the piston pin and bushing must also be replaced. The reason for this is that the bushing takes the shape of the saddle area of the piston dome during engine operation. Installing a used bushing in a new crown can result in uneven piston pin loading and possible piston pin damage. If a bushing needs replacement, a new pin must also be used. Conversely, if a new pin is required, the bushing must also be replaced. Before reusing any crosshead piston assembly components, see wear limits in this Section.

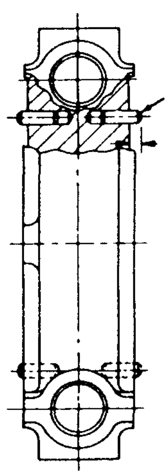
CYLINDER BLOCK PLUGGING INSTRUCTIONS (IN-LINE ENGINES)



STANDARD PIPE PLUG TORQUE*		
PIPE PLUG SIZE	lb-ft	Nm
1/8	10-12	14-16
1/4	14-16	19-22
3/8	18-22	24-30
1/2	23-27	31-37
3/4	33-37	45-50

*CAUTION — Do Not Over Torque Teflon Wrapped Pipe Plugs.

CUTAWAY VIEW OF REAR MAIN BEARING CAP



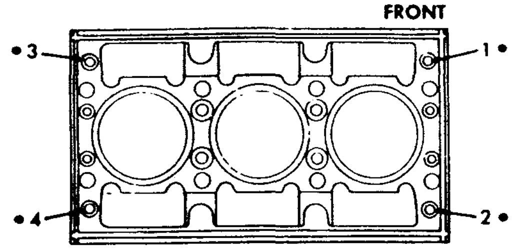
NOTES

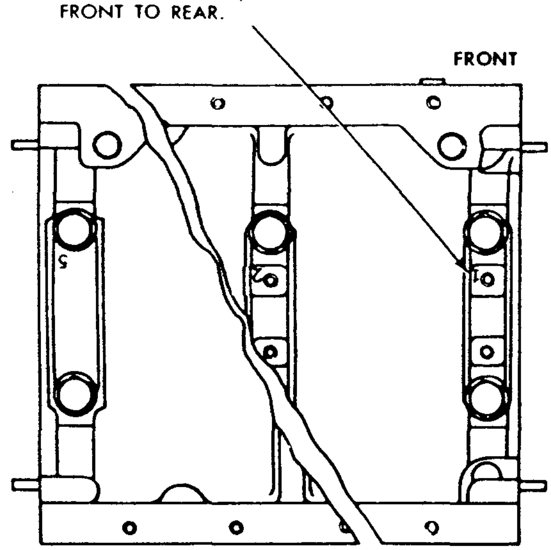
1. INSTALL PLUGS FLUSH TO BELOW TOP OF FINISHED SURFACES OF BLOCK.

- **APPLY LOCTITE J 26558-92 PIPE SEALER WITH TEFLON OR EQUIVALENT PRIOR TO INSTALLATION.**

• TOP SURFACE PLUGGING INSTRUCTIONS 7/16" SPECIAL CUP PLUG

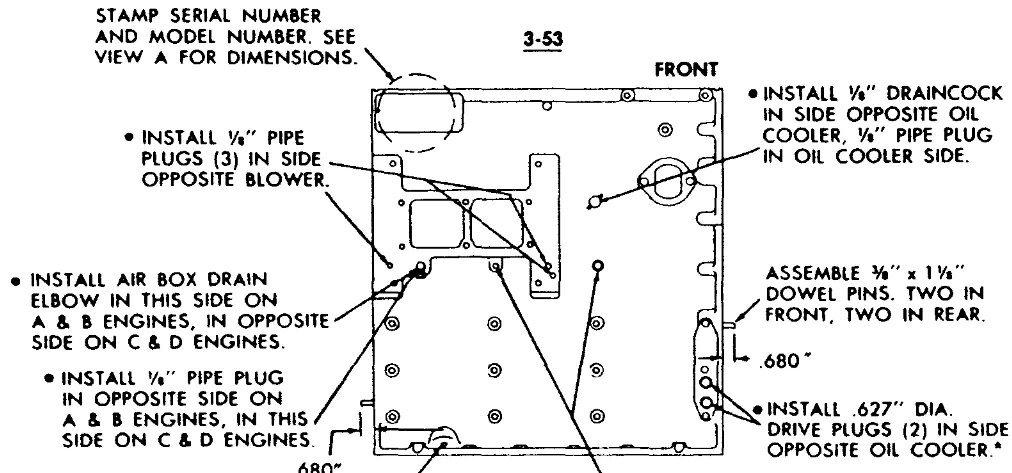
	HOLES PLUGGED			
2-53	1	2	3	4
RA,RD		X	X	X
RB,RC	X	X	X	
3-53, 4-53				
RA,LA,RD,LD		X		X
RB,LB,RC,LC	X		X	





REV. 9-77

CYLINDER BLOCK PLUGGING INSTRUCTIONS (IN-LINE ENGINES)

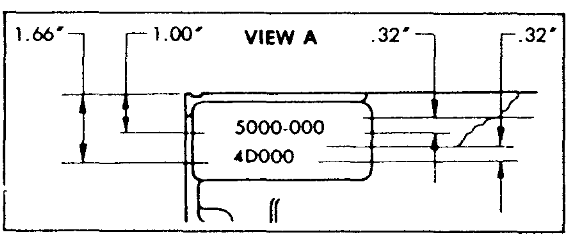


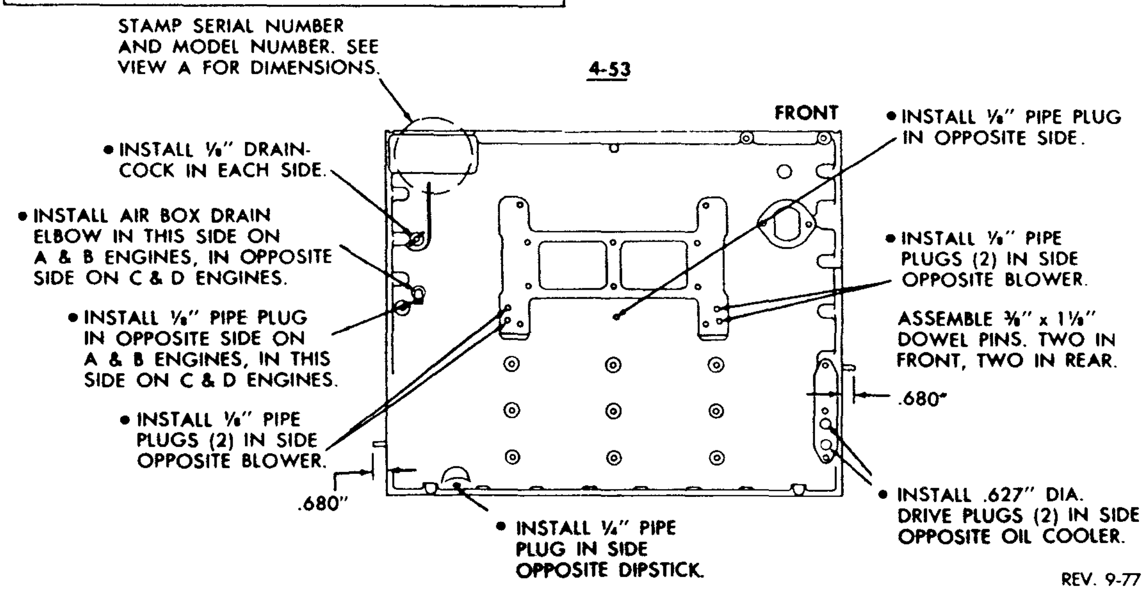
STANDARD PIPE PLUG TORQUE		
PIPE PLUG SIZE	lb-ft	Nm
1/8	10-12	14-16
1/4	14-16	19-22
3/8	18-22	24-30
1/2	23-27	31-37
3/4	33-37	45-50

NOTES

1. INSTALL PLUGS FLUSH TO BELOW TOP OF FINISHED SURFACES OF BLOCK.

- **APPLY LOCTITE J 26558-92 PIPE SEALER WITH TEFLON OR EQUIVALENT PRIOR TO INSTALLATION.**

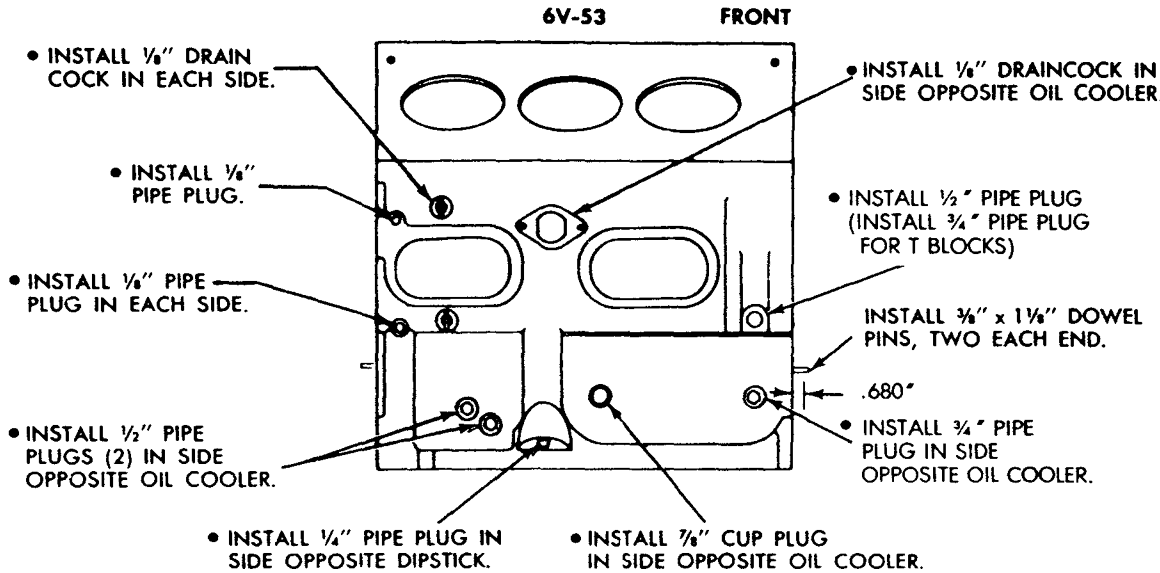




REV. 9-77

*Some Engine Require .751" Drive Plug at this Location.

CYLINDER BLOCK PLUGGING INSTRUCTIONS (6V AND 8V ENGINES)



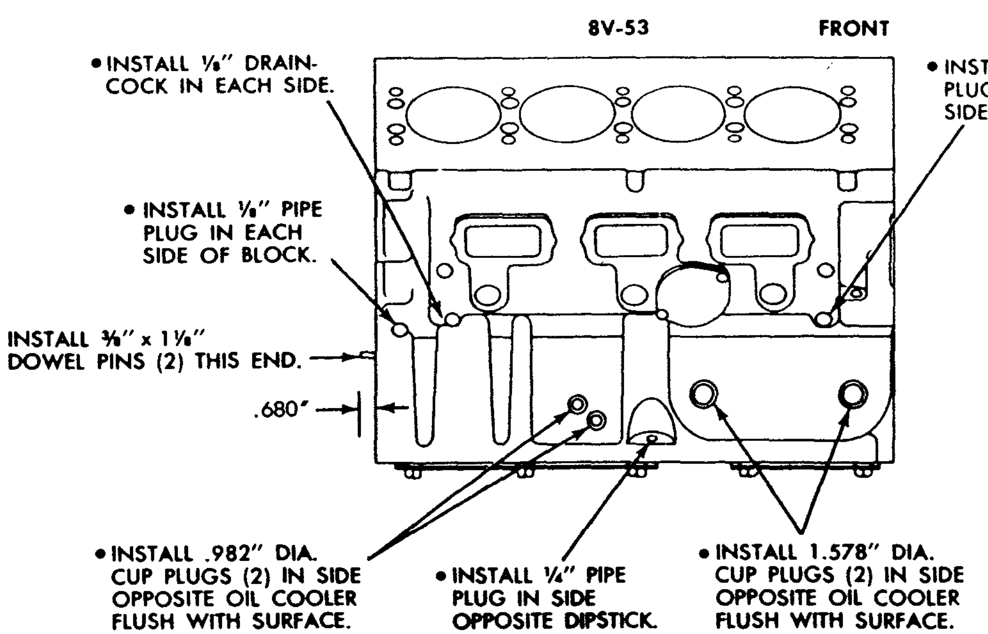
NOTES

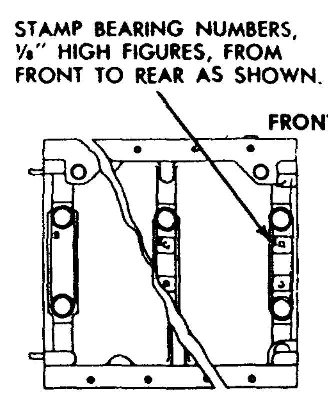
1. INSTALL PLUGS FLUSH TO BELOW TOP OF FINISHED SURFACES OF BLOCK.

- **APPLY LOCTITE J 26558-92 PIPE SEALER WITH TEFLON OR EQUIVALENT PRIOR TO INSTALLATION.**

STANDARD PIPE PLUG TORQUE

PIPE PLUG SIZE	lb-ft	Nm
1/8	10-12	14-16
1/4	14-16	19-22
3/8	18-22	24-30
1/2	23-27	31-37
3/4	33-37	45-50



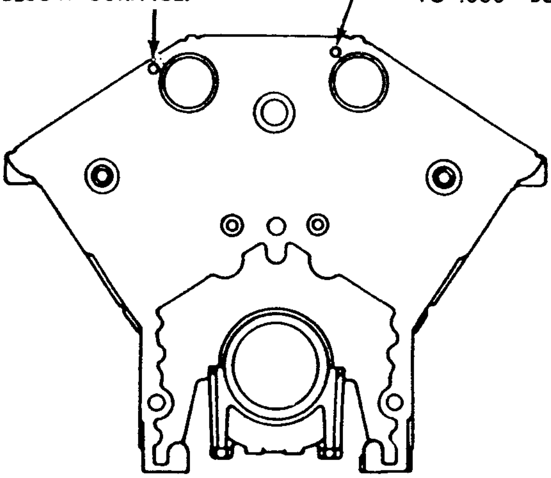


REV. 6-82

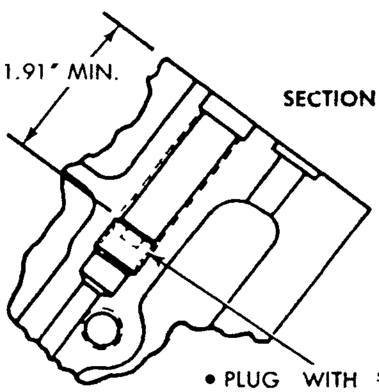
CYLINDER BLOCK PLUGGING INSTRUCTIONS (6V AND 8V ENGINES)

INSTALL 5/16" x 5/16" DOWEL PIN AT EACH END. (COPPER-FLASHED FOR 8V-53, PLAIN FOR 6V-53) FLUSH TO .020" BELOW SURFACE.

• INSTALL 5/16" SPEC. CUP PLUG, FRONT AND REAR ON 8V-53, REAR ONLY ON 6V-53 FLUSH TO .030" BELOW SURFACE.



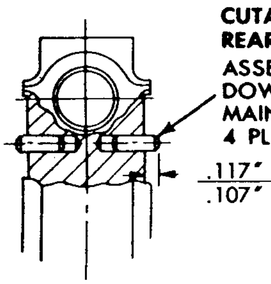
REAR



SECTION A-A

• PLUG WITH 3/8" SOCKET CUP SET SCREW RIGHT AND LEFT BANK AT REAR 8V-53 ONLY

NOTES
1. INSTALL PLUGS FLUSH TO BELOW TOP OF FINISHED SURFACES OF BLOCK.
•APPLY LOCTITE J 26558-92 PIPE SEALER WITH TEFLON OR EQUIVALENT PRIOR TO INSTALLATION.



CUTAWAY SECTION OF REAR MAIN BEARING CAP

ASSEMBLE 5/16" x 1/2" DOWEL PINS IN REAR MAIN BEARING CAP. 4 PLACES

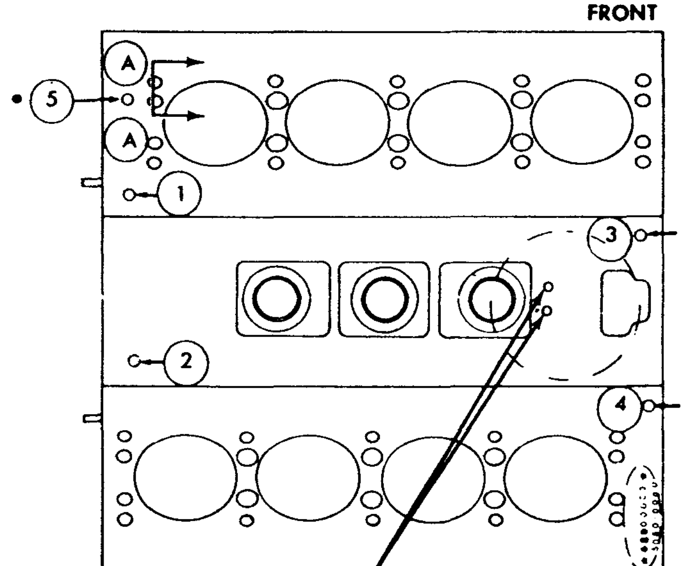
TOP SURFACE PLUGGING INSTRUCTIONS

USE 5/16" COPPER FLASHED DOWEL PIN EXCEPT WHERE NOTED. INSTALL PINS FLUSH TO .020" BELOW SURFACE.

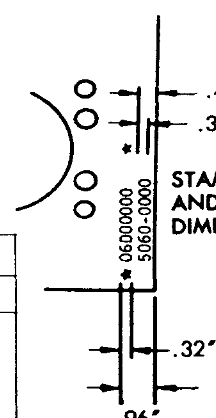
	HOLE NOS. 1	2	3	4	5
6V-53*	X	X		X	X
8V-53	X	X	X	X	

• *NO. 2 HOLE, PLUG WITH 5/16" PLAIN DOWEL PIN. NO. 5 HOLE, PLUG WITH 1/8" PIPE PLUG FLUSH TO .12" BELOW SURFACE.

FRONT



PLUG WITH .075" SPECIAL PLUG BLOCK 5149781 ONLY



STAMP SERIAL NUMBER AND MODEL NUMBER TO DIMENSIONS SHOWN.

STANDARD PIPE PLUG TORQUE		
PIPE PLUG SIZE	lb-ft	Nm
1/8	10-12	14-16
1/4	14-16	19-22
3/8	18-22	24-30
1/2	23-27	31-37
3/4	33-37	45-50

REV. 6-82

TROUBLESHOOTING

EXHAUST VALVE

Probable Causes

1. STICKING VALVE
2. IMPROPER VALVE SEATING
3. VALVE SEAT PITTED OR OVERHEATED
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
11. OIL RUNNING DOWN VALVE STEM

SUGGESTED REMEDY

1. Check for carbon deposits, a bent valve guide, defective spring or antifreeze (ethylene glycol) in the lubricating oil. Replace a bent guide. Clean–up and reface the valve. Replace the valve, if necessary.

2. Check for excessive valve–to–guide clearance, bent valve 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 of the engine for overload, inadequate cooling or improper timing. Reface the valve and insert. Replace the valve if it is warped or too badly pitted. Use a harder–face valve if operating conditions warrant.

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

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

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

7. Black carbon deposits extending from the valve seats to the guides indicates cold operation due to light loads or to the use of too heavy a fuel. Rusty brown valve heads with carbon deposits forming narrow collars near the guides indicate hot operation due to overloads, inadequate cooling or improper timing which results in carbonization of the lubricating oil. Clean–up the valves, guides and inserts. Reface the valves and inserts or replace them if they are warped, pitted or scored.

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

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

10. Check for a gear train failure or for improper gear train timing.

11. Check the operation of the engine for excessive idling and resultant low engine exhaust back pressure. Install valve guide oil seals.

SPECIFICATIONS

Specifications, clearances and wear limits are listed below. It should be specifically noted that the clearances apply only when all new parts are used at the point where the various specifications apply. This also applies to references within the text of the manual. The column entitled "Limits" in this chart lists the amount of wear or increase in clearance which can be tolerated in used engine parts and still ensure satisfactory performance. It should be emphasized that the figures given as "Limits" must be qualified by the 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 text.

TABLE OF SPECIFICATIONS, NEW CLEARANCES AND WEAR LIMITS

These limits also apply to oversize and undersize parts.

ENGINE PARTS (Standard Size, New)	MINIMUM	MAXIMUM	WEAR LIMITS
CYLINDER BLOCK			
Block bore:			
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"	.0020"
Taper		.0015"	.0020"
Cylinder liner counterbore:			
Diameter	4.8200"	4.8350"	
Depth	.3000"	.3020"	
Main bearing bore:			
Inside diameter (vertical axis, In-line)	3.2510"	3.2520"	
Inside diameter (vertical axis, V-type)	3.7510"	3.7520"	
Cam and balance shaft bore (O.S. cam brg.):			
End (all engines)	2.3850"	2.3860"	
Intermediate (3-53, 4-53, 6V and 8V)	2.3750"	2.3760"	
Center (2-53)	2.3750"	2.3760"	
Center (3-53, 4-53, 6V and 8V)	2.3650"	2.3660"	
Top surface of block:			
Flatness—transverse (all)			.0030"
Flatness—longitudinal (2-53)			.0050"
Flatness—longitudinal (3-53 and 6V)			.0060"
Flatness—longitudinal (4-53 and 8V)			.0070"
Depth of counterbores (top surface):			
Cylinder head seal strip groove	.0970"	.1070"	
Water holes	.1090"	.1150"	
Water holes (at ends of 6V block)	.0920"	.0980"	
Oil holes	.0920"	.0980"	
CYLINDER LINER			
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 (inside diameter)		.0020"	.0030"
Taper (inside diameter)		.0010"	.0020"
Depth of flange BELOW block	.0465"	.0500"	.0500"
Variation in depth between adjacent liners		.0020"	.0020"

TROUBLESHOOTING

EXHAUST VALVE

Probable Causes

1. STICKING VALVE
2. IMPROPER VALVE SEATING
3. VALVE SEAT PITTED OR OVERHEATED
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
11. OIL RUNNING DOWN VALVE STEM

SUGGESTED REMEDY

1. Check for carbon deposits, a bent valve guide, defective spring or antifreeze (ethylene glycol) in the lubricating oil. Replace a bent guide. Clean–up and reface the valve. Replace the valve, if necessary.

2. Check for excessive valve–to–guide clearance, bent valve 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 of the engine for overload, inadequate cooling or improper timing. Reface the valve and insert. Replace the valve if it is warped or too badly pitted. Use a harder–face valve if operating conditions warrant.

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

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

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

7. Black carbon deposits extending from the valve seats to the guides indicates cold operation due to light loads or to the use of too heavy a fuel. Rusty brown valve heads with carbon deposits forming narrow collars near the guides indicate hot operation due to overloads, inadequate cooling or improper timing which results in carbonization of the lubricating oil. Clean–up the valves, guides and inserts. Reface the valves and inserts or replace them if they are warped, pitted or scored.

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

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

10. Check for a gear train failure or for improper gear train timing.

11. Check the operation of the engine for excessive idling and resultant low engine exhaust back pressure. Install valve guide oil seals.

SPECIFICATIONS

Specifications, clearances and wear limits are listed below. It should be specifically noted that the clearances apply only when all new parts are used at the point where the various specifications apply. This also applies to references within the text of the manual. The column entitled "Limits" in this chart lists the amount of wear or increase in clearance which can be tolerated in used engine parts and still ensure satisfactory performance. It should be emphasized that the figures given as "Limits" must be qualified by the 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 text.

TABLE OF SPECIFICATIONS, NEW CLEARANCES AND WEAR LIMITS

These limits also apply to oversize and undersize parts.

ENGINE PARTS (Standard Size, New)	MINIMUM	MAXIMUM	WEAR LIMITS
CYLINDER BLOCK			
Block bore:			
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"	.0020"
Taper		.0015"	.0020"
Cylinder liner counterbore:			
Diameter	4.8200"	4.8350"	
Depth	.3000"	.3020"	
Main bearing bore:			
Inside diameter (vertical axis, In-line)	3.2510"	3.2520"	
Inside diameter (vertical axis, V-type)	3.7510"	3.7520"	
Cam and balance shaft bore (O.S. cam brg.):			
End (all engines)	2.3850"	2.3860"	
Intermediate (3-53, 4-53, 6V and 8V)	2.3750"	2.3760"	
Center (2-53)	2.3750"	2.3760"	
Center (3-53, 4-53, 6V and 8V)	2.3650"	2.3660"	
Top surface of block:			
Flatness—transverse (all)			.0030"
Flatness—longitudinal (2-53)			.0050"
Flatness—longitudinal (3-53 and 6V)			.0060"
Flatness—longitudinal (4-53 and 8V)			.0070"
Depth of counterbores (top surface):			
Cylinder head seal strip groove	.0970"	.1070"	
Water holes	.1090"	.1150"	
Water holes (at ends of 6V block)	.0920"	.0980"	
Oil holes	.0920"	.0980"	
CYLINDER LINER			
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 (inside diameter)		.0020"	.0030"
Taper (inside diameter)		.0010"	.0020"
Depth of flange BELOW block	.0465"	.0500"	.0500"
Variation in depth between adjacent liners		.0020"	.0020"

ENGINE PARTS (Standard Size, New)	MINIMUM	MAXIMUM	WEAR LIMITS
PISTONS and RINGS (TRUNK TYPE)			
Piston:			
Diameter (at skirt):			
Non-turbocharged engines	3.8699"	3.8721"	
Turbocharged engines	3.8679"	3.8701"	
Clearance—piston skirt-to-liner:			
Non-turbocharged engines	.0027"	.0068"	.0100"
Turbocharged engines	.0047"	.0088"	.0120"
Out-of-round or taper		.0005"	
Inside dia.—pin bushing	1.3775"	1.3780"	
Inside dia.—pin bushing (current turbo)	1.5025"	1.5030"	
Compression rings:			
Gap (chrome ring)	.0200"	.0460"	.0600"
Gap (cast iron ring)	.0200"	.0360"	.0600"
Clearance—ring-to-groove:			
Top (No. 1)	.0030"	.0060"	.0120"
No. 2	.0070"	.0100"	.0140"
No. 3 and 4	.0050"	.0080"	.0130"
No. 3 and 4 (21:1 ratio piston)	.0045"	.0070"	.0120"
Oil control rings:			
Gap	.0100"	.0250"	.0440"
Clearance—ring-to-groove	.0015"	.0055"	.0080"
PISTONS and RINGS (CROSSHEAD TYPE)			
Piston crown:			
Saddle-to-crown distance	2.8325"	2.8395"	
Diameter:			
Top	3.8486"	3.8516"	
Below both comp. rings	3.8636"	3.8666"	
Above/below seal ring groove	3.8666"	3.8676"	
Above/below bearing saddle	2.8350"	2.8380"	
Compression rings:			
Gap (top fire ring)	.0230"	.0380"	.0600"
Gap (No. 2 and 3)	.0200"	.0300"	.0600"
Clearance – ring-to-groove:			
Top fire ring	.0030"	.0066"	.0086"
No. 2 (rectangular sect.)	.0070"	.0100"	.0140"
No. 3 (rectangular sect.)	.0050"	.0080"	.0130"
Piston skirt:			
Diameter	3.8695"	3.8717"	
Clearance – skirt-to-liner	.0035"	.0072"	.0110"
Seal ring bore	.3700"	.3704"	.3706"
Piston pin bore	1.3775"	1.3785"	1.3790"
Oil control rings:			
Gap (two rings – lower groove)	.0100"	.0250"	.0440"
Gap (one ring – upper groove)	.0070"	.0170"	.0370"
Clearance (two rings – lower groove)	.0015"	.0055"	.0080"
Clearance (one ring – lower groove)	.0005"	.0040"	.0065"

ENGINE PARTS (Standard Size, New)	MINIMUM	MAXIMUM	WEAR LIMITS
PISTON PINS (TRUNK TYPE)			
Diameter (non–turbo and former turbo)	1.3746″	1.3750″	
Diameter (current turbo)	1.4996″	1.5000″	
Clearance—pin–to–piston bushing	.0025″	.0034″	.0100″
Clearance—pin–to–conn. rod bushing	.0010″	.0019″	.0100″
PISTON PINS (CROSS–HEAD TYPE)			
Length	3.2250″	3.2450″	
Diameter	1.3746″	1.3750″	1.3730″
Slipper bearing (bushing):			
Thickness*	.0870″	.0880″	.0860″
Clearance (bushing edge–groove in piston)	.0005″	.0105″	.0120″
CONNECTING ROD			
Length—center–to–center	8.7990″	8.8010″	
Inside diameter (upper bushing)	1.3760″	1.3765″	
Normal side clearance (In–line)	.0030″	.0120″	
Normal side clearance (V–type)	.0020″	.0160″	
CRANKSHAFT			
Journal diameter:			
Main bearing (In–line)	2.9990″	3.0000″	
• Main bearing (V–Type)	3.4985″	3.5002″	
Conn. rod bearing (In–line)	2.4990″	2.5000″	
• Conn. rod bearing (V–Type)	2.7485″	2.7502″	
Outboard bearing (8V–53)		2.8770″	2.8780″
Journal out–of–round		.00025″	.0030″
Journal taper		.0005″	.0030″
#Runout on journals—total indicator reading:			
2–53, 3–53 and 4–53 engine		.0020″	
#Runout at No. 2 and No. 4 journals (8V)		.0020″	
#Runout at No. 3 journal (8V)		.0040″	
#Runout on outboard journal (8V)		.0010″	
Thrust washer thickness	.1190″	.1220″	
End play (end thrust clearance)	.0040″	.0160″	.0180″

* Center land is .0002″ – .0008″ thinner than adjacent lands.

Runout tolerance given for guidance when regrinding crankshaft. Crankshaft for 2–53 supported on No. 1 and No. 3 journals; runout measured at No. 2 journal. Crankshaft for 3–53 supported on No. 1 and No. 4 journals; runout measured at No. 2 and No. 3 journals. Crankshaft for 4–53 supported on No. 1 and No. 5 journals; runout measured at No. 2, 3 and 4 journals. Crankshaft for 6V supported on No. 1 and No. 4 journals; runout measured at No. 2 and No. 3 journals. Crankshaft for 8V supported on No. 1 and No. 5 journals; runout measured at No. 2, 3, 4 and outboard journals.
When the 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.

ENGINE PARTS (Standard Size, New)	MINIMUM	MAXIMUM	WEAR LIMITS
CONNECTING ROD BEARING			
Inside diameter (vertical axis, In–line)	2.5015″	2.5035″	
Inside diameter (vertical axis, V–type)	2.7511″	2.7531″	
Bearing–to–journal clearance (In–line)	.0015″	.0045″	.0060″
Bearing–to–journal clearance (V–type)	.0011″	.0041″	.0060″
Bearing thickness 90° part line (In–line)	.1245″	.1250″	.1230″
Bearing thickness 90° part line (V–type)	.1247″	.1252″	.1230″
MAIN BEARINGS			
Inside diameter (vertical axis, In–line)	3.0020″	3.0030″	
Inside diameter (vertical axis, V–type)	3.5030″	3.5040″	
Bearing–to–journal clearance	.0010″	.0040″	.0060″
Bearing thickness 90° part line (In–line)	.1245″	.1250″	.1230″
Bearing thickness 90° part line (V–type)	.1240″	.1245″	.1230″
OUTBOARD BEARING			
Clearance—bearing–to–crankshaft (8V)	.0035″	.0071″	.0080″
CAMSHAFT			
Diameter (at bearing journals)	2.1820″	2.1825″	
End thrust	.0030″	.0150″	.0190″
Runout at center bearing (mounted end brg.)		.0020″	
Thrust washer thickness	.2080″	.2100″	
BALANCE SHAFT			
Diameter (at bearing journals)	2.1820″	2.1825″	
End thrust	.0030″	.0150″	.0190″
Thrust washer thickness	.2080″	.2100″	
CAMSHAFT and BALANCE SHAFT BEARINGS			
Inside diameter	2.1870″	2.1880″	
Clearance—bearing–to–shaft	.0035″	.0070″	.0080″
CAMSHAFT and BALANCE SHAFT GEARS			
Backlash	.0005″	.0050″	.0070″
IDLER GEAR (IN–LINE and 6V ENGINES)			
Backlash	.0005″	.0050″	.0070″
Bearing inside diameter	2.1860″	2.1870″	
Clearance—bearing–to–hub	.0025″	.0045″	.0070″
End play	.0060″	.0130″	.0170″
Hub outside diameter	2.1825″	2.1835″	
Thrust washer thickness	.1180″	.1200″	

ENGINE PARTS (Standard Size, New)	MINIMUM	MAXIMUM	WEAR LIMITS
CRANKSHAFT TIMING GEAR			
Backlash	.0005″	.0050″	.0070″
Inside diameter (97 tooth gear)	4.0580″	4.0590″	
Inside diameter (111 tooth gear)	4.0575″	4.0585″	
Outside diameter (crankshaft)	4.0600″	4.0610″	
BLOWER DRIVE GEAR			
Backlash	.0030″	.0050″	.0070″
Thrust washer thickness (4–53 and 6V)	.0930″	.1030″	
Thrust washer thickness (8V)	.1190″	.1210″	
End play (blower drive gear shaft)	.0040″	.0120″	
GOVERNOR DRIVE GEAR			
Backlash	.0030″	.0050″	.0070″
FUEL PUMP DRIVE GEAR			
Backlash	.0030″	.0050″	.0070″
Bearing (inside diameter)	1.1220″	1.1230″	
Clearance – Bearing–to–hub	.0020″	.0035″	
End play	.0050″	.0180″	.0220″
Hub (outside diameter)	1.1200″	1.1205″	
Thrust washer thickness	.1580″	.1600″	
CYLINDER HEAD			
Cam follower bore (current)	1.0626″	1.0636″	
Cam follower bore (former)	1.0620″	1.0630″	
Exhaust valve insert counterbore:			
Diameter (2–valve head)	1.4390″	1.4400″	
Diameter (4–valve head)	1.1590″	1.1600″	
EXHAUST VALVE SEAT INSERTS			
Outside diameter (2–valve)	1.4405″	1.4415″	
Outside diameter (4–valve)	1.1605″	1.1615″	
Seat width	.0468″	.0781″	.0781″
Valve seat runout		.0020″	.0020″
EXHAUST VALVES			
Stem diameter (2–valve)	.3100″	.3105″	
Stem diameter (current 4–valve)	.2480″	.2488″	
Stem diameter (former 4–valve)	.2475″	.2485″	
Valve head–to–cylinder head:			
2–valve head	.002″ protr.	.032″ recess.	.037″ recess.
Current 4–valve head	flush	.024″ recess.	.039″ recess.
Former 4–valve head	.006″ protr.	.018″ recess.	.033″ recess.

ENGINE PARTS (Standard Size, New)	MINIMUM	MAXIMUM	WEAR LIMITS
CONNECTING ROD BEARING			
Inside diameter (vertical axis, In–line)	2.5015″	2.5035″	
Inside diameter (vertical axis, V–type)	2.7511″	2.7531″	
Bearing–to–journal clearance (In–line)	.0015″	.0045″	.0060″
Bearing–to–journal clearance (V–type)	.0011″	.0041″	.0060″
Bearing thickness 90° part line (In–line)	.1245″	.1250″	.1230″
Bearing thickness 90° part line (V–type)	.1247″	.1252″	.1230″
MAIN BEARINGS			
Inside diameter (vertical axis, In–line)	3.0020″	3.0030″	
Inside diameter (vertical axis, V–type)	3.5030″	3.5040″	
Bearing–to–journal clearance	.0010″	.0040″	.0060″
Bearing thickness 90° part line (In–line)	.1245″	.1250″	.1230″
Bearing thickness 90° part line (V–type)	.1240″	.1245″	.1230″
OUTBOARD BEARING			
Clearance—bearing–to–crankshaft (8V)	.0035″	.0071″	.0080″
CAMSHAFT			
Diameter (at bearing journals)	2.1820″	2.1825″	
End thrust	.0030″	.0150″	.0190″
Runout at center bearing (mounted end brg.)		.0020″	
Thrust washer thickness	.2080″	.2100″	
BALANCE SHAFT			
Diameter (at bearing journals)	2.1820″	2.1825″	
End thrust	.0030″	.0150″	.0190″
Thrust washer thickness	.2080″	.2100″	
CAMSHAFT and BALANCE SHAFT BEARINGS			
Inside diameter	2.1870″	2.1880″	
Clearance—bearing–to–shaft	.0035″	.0070″	.0080″
CAMSHAFT and BALANCE SHAFT GEARS			
Backlash	.0005″	.0050″	.0070″
IDLER GEAR (IN–LINE and 6V ENGINES)			
Backlash	.0005″	.0050″	.0070″
Bearing inside diameter	2.1860″	2.1870″	
Clearance—bearing–to–hub	.0025″	.0045″	.0070″
End play	.0060″	.0130″	.0170″
Hub outside diameter	2.1825″	2.1835″	
Thrust washer thickness	.1180″	.1200″	

ENGINE PARTS (Standard Size, New)	MINIMUM	MAXIMUM	WEAR LIMITS
CRANKSHAFT TIMING GEAR			
Backlash	.0005″	.0050″	.0070″
Inside diameter (97 tooth gear)	4.0580″	4.0590″	
Inside diameter (111 tooth gear)	4.0575″	4.0585″	
Outside diameter (crankshaft)	4.0600″	4.0610″	
BLOWER DRIVE GEAR			
Backlash	.0030″	.0050″	.0070″
Thrust washer thickness (4–53 and 6V)	.0930″	.1030″	
Thrust washer thickness (8V)	.1190″	.1210″	
End play (blower drive gear shaft)	.0040″	.0120″	
GOVERNOR DRIVE GEAR			
Backlash	.0030″	.0050″	.0070″
FUEL PUMP DRIVE GEAR			
Backlash	.0030″	.0050″	.0070″
Bearing (inside diameter)	1.1220″	1.1230″	
Clearance – Bearing–to–hub	.0020″	.0035″	
End play	.0050″	.0180″	.0220″
Hub (outside diameter)	1.1200″	1.1205″	
Thrust washer thickness	.1580″	.1600″	
CYLINDER HEAD			
Cam follower bore (current)	1.0626″	1.0636″	
Cam follower bore (former)	1.0620″	1.0630″	
Exhaust valve insert counterbore:			
Diameter (2–valve head)	1.4390″	1.4400″	
Diameter (4–valve head)	1.1590″	1.1600″	
EXHAUST VALVE SEAT INSERTS			
Outside diameter (2–valve)	1.4405″	1.4415″	
Outside diameter (4–valve)	1.1605″	1.1615″	
Seat width	.0468″	.0781″	.0781″
Valve seat runout		.0020″	.0020″
EXHAUST VALVES			
Stem diameter (2–valve)	.3100″	.3105″	
Stem diameter (current 4–valve)	.2480″	.2488″	
Stem diameter (former 4–valve)	.2475″	.2485″	
Valve head–to–cylinder head:			
2–valve head	.002″ protr.	.032″ recess.	.037″ recess.
Current 4–valve head	flush	.024″ recess.	.039″ recess.
Former 4–valve head	.006″ protr.	.018″ recess.	.033″ recess.

ENGINE PARTS (Standard Size, New)	MINIMUM	MAXIMUM	WEAR LIMITS
VALVE GUIDES			
Distance below top of head (2–valve)	.0100"	.0400"	
Distance below top of head (4–valve)	.1500"	.1800"	
Diameter—inside (2–valve)	.3125"	.3135"	
Diameter—inside (4–valve)	.2505"	.2515"	
Clearance—valve–to–guide (2–valve)	.0020"	.0040"	.0060"
Clearance—valve–to–guide (current 4–valve)	.0017"	.0035"	.0050"
Clearance—valve–to–guide (former 4–valve)	.0020"	.0040"	.0050"
ROCKER ARMS and SHAFTS			
Diameter—rocker shaft	.8735"	.8740"	
Diameter—inside (rocker arm bushing)	.8750"	.8760"	
Diameter—inside (valve rocker arm bore)	.8753"	.8763"	
Clearance—shaft–to–injector rocker bushing	.0010"	.0025"	.0040"
Clearance—shaft–to–valve rocker bore	.0013"	.0028"	.0040"
CAM FOLLOWERS			
Diameter	1.0600"	1.0610"	
Clearance—follower–to–current head	.0016"	.0036"	.0060"
Clearance—follower–to–former head	.0010"	.0030"	.0060"
Rollers and pins:			
Clearance—pin–to–bushing	.0013"	.0021"	.010" Horiz.
Side clearance—roller–to–follower	.0150"	.0230"	.0230"

STANDARD PIPE PLUG TORQUE SPECIFICATIONS

Use sealing compound on plugs without gaskets or teflon.

NPTF SIZE THREAD	TORQUE (lb–ft)	TORQUE (N·m)	NPTF SIZE THREAD	TORQUE (lb–ft)	TORQUE (N·m)
1/8	10–12	14–16	3/4	33–37	45–50
1/4	14–16	19–22	1	75–85	102–115
3/8	18–22	24–30	1-1/4	95–105	129–143
1/2	23–27	31–37	1-1/2	110–130	150–177

STANDARD BOLT AND NUT TORQUE SPECIFICATIONS

THREAD SIZE	260M BOLTS TORQUE (lb–ft)	(N·m)	THREAD SIZE	280M OR BETTER TORQUE (lb–ft)	(N·m)
1/4–20	5–7	7–9	1/4–20	7–9	10–12
1/4–28	6–8	8–11	1/4–28	8–10	11–14
5/16–18	10–13	14–18	5/16–18	13–17	18–23
5/16–24	11–14	15–19	5/16–24	15–19	20–26
3/8–16	23–26	31–35	3/8–16	30–35	41–47
3/8–24	26–29	35–40	3/8–24	35–39	47–53
7/16–14	35–38	47–51	7/16–14	46–50	62–68
7/16–20	43–46	58–62	7/16–20	57–61	77–83
1/2–13	53–56	72–76	1/2–13	71–75	96–102
1/2–20	62–70	84–95	1/2–20	83–93	113–126
9/16–12	68–75	92–102	9/16–12	90–100	122–136
9/16–18	80–88	109–119	9/16–18	107–117	146–159
5/8–11	103–110	140–149	5/8–11	137–147	186–200
5/8–18	126–134	171–181	5/8–18	168–178	228–242
3/4–10	180–188	244–254	3/4–10	240–250	325–339
3/4–16	218–225	295–305	3/4–16	290–300	393–407
7/8–9	308–315	417–427	7/8–9	410–420	556–569
7/8–14	356–364	483–494	7/8–14	475–485	644–657
1–8	435–443	590–600	1–8	580–590	786–800
1–14	514–521	697–705	1–14	685–695	928–942

Grade identification markings are normally stamped on the heads of the bolts. To aid identification of the various bolts used in Detroit Diesel engines, refer to the following chart.

Grade Identification Marking on Bolt Head	GM Number	SAE Grade Designation	Nominal Size Diameter (inch)	Tensile Strength Min. (psi)
None	GM 255-M	1	No. 6 thru 1 1/2	60,000
None	GM 260-M	2	No. 6 thru 3/4 over 3/4 to 1 1/2	74,000 60,000
Bolts and Screws	GM 280-M	5	No. 6 thru 1 over 1 to 1 1/2	120,000 105,000
Hex Head Sems Only	GM 275-M	5.1	No. 6 thru 3/8	120,000
Bolts and Screws	GM 290-M	7	1/4 thru 1 1/2	133,000
Bolts and Screws	GM 300-M	8	1/4 thru 1 1/2	150,000
Bolts and Screws	GM 455-M	None	No. 6 thru 1 1/2	55,000

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BOLT IDENTIFICATION CHART

EXCEPTIONS TO STANDARD BOLT AND NUT TORQUE SPECIFICATIONS

APPLICATION	THREAD	(lb–ft)	(lb–in)	(N·m)
Cam follower guide bolts	1/4–20	12–15		16–20
Idler gear bearing retaining bolts (8V)	1/4–20	12–15		16–20
Injector control shaft bracket bolts	1/4–28	10–12		14–16
Governor to flywheel housing bolts	5/16–18	10–12		14–16
Idler gear hub and spacer bolts	5/16–18	19–23		26–31
Oil pan bolts	5/16–18	10–20		14–27
Connecting rod nuts (6V engine – former)	5/16–24	24–28		33–38
Air box cover bolts (6V – 1/4" thick clamp)	3/8–16	8–10		11–14
Air box cover bolts (except 1/4" clamp)	3/8–16	12–15		16–20
Flywheel housing bolts	3/8–16	25–30		34–41
Idler gear hub and spacer bolts	3/8–16	40–45		54–61
Injector clamp bolts	3/8–16	20–25		27–34
Valve rocker cover bolts (cast cover)	3/8–16	8–13		11–18
Connecting rod nuts	3/8–24	40–45		54–61
Flywheel housing bolts	3/8–24	25–30		34–41
Fuel connector (for flared end fuel pipe)	3/8–24	20–28		27–38
• Fuel connector (for O–ring sealed fuel pipe)	3/8–24	37		50
• Fuel pipe nuts (uncoated)	3/8–24		160	18.3
• Fuel pipe nuts (Endurion ®)	3/8–24		130	14.69
• Fuel pipe nuts (Jacobs brake)	3/8–24		120	13.6
• Fuel pipe nuts (Load limiting device)	3/8–24	–	160	18.3
C/S outboard main bearing support bolt (8V)	7/16–14	75–85		102–115
Rocker arm bracket bolts	7/16–14	50–55		68–75
*Flywheel bolts (Section 1.4)	1/2–20			
*Main bearing cap bolts	9/16–12	120–130		163–177
*Flywheel bolts (8V) (Section 1.4)	9/16–18			
*Cylinder head bolts	5/8–11	170–180		231–244
Flange mounted air compressor drive shaft nut	3/4–10	#		#
Accessory drive pulley retaining nut	3/4–16	120–140		163–190
Air compressor drive pulley nut	3/4–16	80–100		108–136
Crankshaft end bolt (In-line and 6V engines)	3/4–16	290–300		393–407
C/S end bolt pulley stamped "A"	1–14	200–220		271–298
Crankshaft end bolt (8V)	1–14	290–310		393–421
Crankshaft and balance shaft nut	1-1/8–18	300–325		407–441

* Lubricate at assembly with International Compound No. 2, or equivalent (refer to Parts Catalog or Microfiche, Section 12.8000A).
# 100 lb–ft (136 N·m) plus increase torque to line up cotter pin.

SERVICE TOOLS

TOOL NAME	TOOL NO.
CYLINDER BLOCK	
Bore gage	J 5347–B
Cylinder bore plug set	J 34697
Deck checker (measure crankshaft centerline–to–fire deck)	PT 5075–B
Dial bore gage master setting fixture	J 23059–01
Engine overhaul stand	J 29109
• Adaptor plate (In–line)	J 7622–01
• Adaptor plate (6V)	J 8683
• Adaptor plate (8V)	J 21966
• Adaptor plate (2, 3, 4–53, 6V–53, 8V–53))	J 33850
Pipe plug remover and installer (1/8' dia.)	J 34650
Sled gage	J 22273–01
• Loctite "chisel" gasket remover	PT 7275
CYLINDER HEAD	
• Cam follower service fixture adaptor	J 33421–22
• Load cell, cam follower roller fixture	J 33421–25
Cylinder head guide studs (set of 2)	J 9665
Cylinder head lifting	J 22062–01
Engine barring tool	J 22582
Injector body brush	J 8152
piston ring gap feeler gage set	J 3172
Push rod remover (set of 3)	J 3092–01
Socket	J 8932–01
Spring tester	J 22738–02
Valve guide cleaner (2–valve head)	J 5437
Valve guide cleaner (4–valve head)	J 7793
Valve guide installer (2–valve head)	J 7560
Valve guide installer (4–valve head)	J 24519
Valve guide oil seal installer (4–valve head)	J 29579
Valve guide remover (2–valve head)	J 6569
Valve guide remover (4–valve head)	J 7775
• Valve seat grinder, model V.I.P. (consists of dash (–) items)	J 7040–A
– Valve seat dial gage	J 8165–2
– Valve seat grinder	J 8165–1A
Valve seat grinder adaptor kit (2–valve head)	J 7924–02
Valve seat grinder adaptor kit (4–valve head)	J 7792–01
Valve seat insert installer (2–valve head)	J 6976
Valve seat insert installer (4–valve head)	J 7790
Valve seat insert remover	J 23479–15
Valve seat insert remover collet (2–valve head))	J 23479–7
Valve seat insert remover collet (4–valve head))	J 23479–8
Valve spring checking gage	J 25076–B
Valve spring compressor (2 or 4–valve head)	J 7455
CRANKSHAFT	
Front oil seal installer	J 22153
Front oil seal sleeve installer (In–line 6V)	J 22524
Pulley installer	J 7773

TOOL NAME	TOOL NO.
Pulley remover	J 5356
Rear oil seal expander (8V)	J 22425-A
Rear oil seal (O.S.) expander	J 21278-01
Rear Oil seal sleeve installer	J 21277
Handle	J 3154-1
Rear oil seal sleeve installer (8V)	J 4194-01
Timing gear installer	J 7557
Timing gear remover	J 4871
Micrometer ball attachment	J 4757
Oil seal expander	J 9769
Oil seal expander (In-line and 6V)	J 7454
Oil seal installer	J 9479
Oil seal installer	J 9727-A
Handle	J 3154-1
Oil seal installer	J 9783
Puller	J 24420-A
FLYWHEEL	
Flywheel lifting fixture	J 25026
Flywheel lifting tool	J 6361-01
Removing and replacer set	J 3154-04
Slide hammer puller set	J 5901-01
FLYWHEEL HOUSING	
Oil seal expander (8V)	J 22425-A
Oil seal expander (O.S. seal)	J 21278-01
Oil seal expander (Std. size seal)	J 9769
Dial indicator	J 8001-3
Post	J 9748
Sleeve	J 8001-2
Aligning studs (set of 2)	J 7540
Concentricity gage	J 9737-C
PISTON, CONNECTING ROD and CYLINDER LINER	
Bore gage	J 5347-B
Connecting rod bushing reamer set	J 7608-02
Connecting rod holding	J 7632
Cylinder hone set (2 1/2" to 5 3/4" range)	J 5902-01
Cylinder liner remover set	J 22490
Dial bore gage master setting fixture	J 23059-01
Hold down clamp	J 21793-B
Master ring - cylinder liner	J 8385-01
Micrometer ball attachment	J 4757
Piston and connecting rod bushing installer and remover	J 7587
Piston bushing reamer set	J 4970-02
Piston bushing reaming fixture	J 5273
Piston pin alignment tool (cross-head)	J 35619
• Piston pin bushing reamer set	J 3071-B
Piston pin retainer installer	J 23762-A
Piston pin retainer installer (cross-head)	J 35572
Piston pin retainer installer (turbo trunk)	J 24107-01

TOOL NAME	TOOL NO.
Piston pin retainer leak detector (plastic)	J 23987–01
• Piston pin retainer leak detector (all metal)	J 35134
Piston ring compressor	J 6883–01
Piston ring remover and installer	J 8128
Piston to liner feeler gage set	J 5438–01
Sled gage	J 22273–01
Spray nozzle remover	J 8995
Piston pin bushing reamer set	J 3071–B
CAMSHAFT	
Bar type puller	J 24420–A
Bearing remover/installer set	J 7593–03
Camshaft cup plug installer	J 24094
Camshaft oil seal installer	J 21899
Slide hammer	J 6471–02
Spring scale	J 8129
Upper front cover seal installer	J 9790

SECTION 2

FUEL SYSTEM AND GOVERNORS

CONTENTS

FUEL SYSTEM

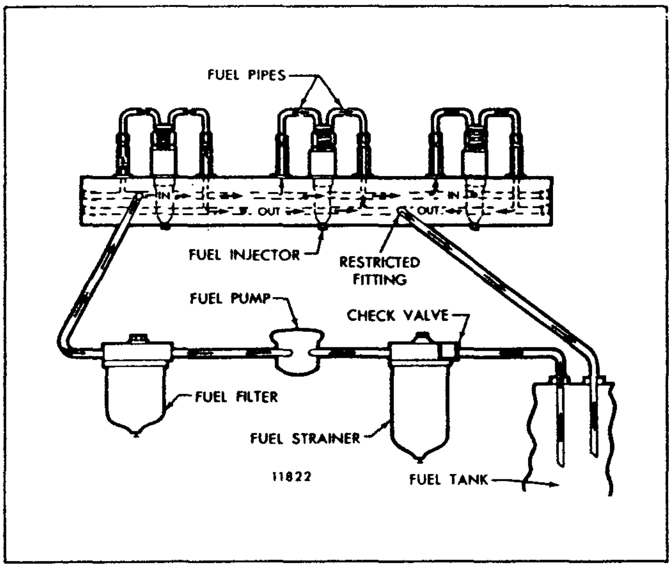


Fig. 1 – Typical Fuel System for In–Line Engines

The fuel system (Figs. 1 and 2) includes the fuel injectors, fuel pipes (inlet and outlet), fuel manifolds (integral with the cylinder head), fuel pump, fuel strainer, fuel filter and fuel lines.

Fuel is drawn from the supply tank through the fuel strainer and enters the fuel pump at the inlet side. Leaving the pump under pressure, the fuel is forced through the fuel filter and into the inlet fuel manifold, then through fuel pipes into the inlet side of each injector.

The fuel manifolds are identified by the words "IN" (top passage) and "OUT" (bottom passage) which are cast in several places in the side of the cylinder head. This aids installation of the fuel lines. Surplus fuel returns from the outlet side of the injectors to the fuel return manifold and then back to the supply tank.

All engines are equipped with a restrictive fitting in the fuel outlet manifold to maintain the fuel system pressure. On V–type engines, the restricted fitting is located at the rear of the left–bank cylinder head. Refer to Section 13.2 for the size fitting required.

A check valve may be installed in the supply line between the fuel tank and the fuel strainer to prevent fuel from draining back when the engine is shut down.

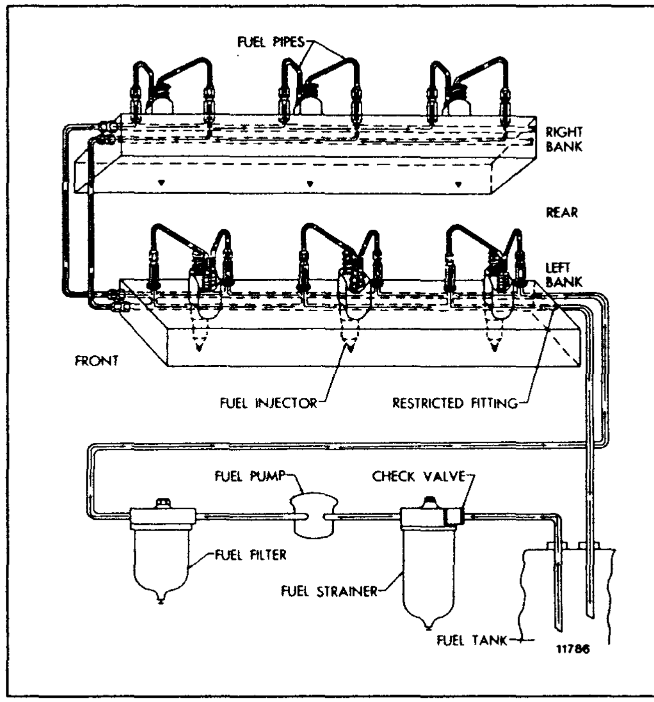


Fig. 2 – Fuel System for 6V–53 Engines

FUEL INJECTOR

MECHANICAL UNIT INJECTOR (MUI)

CROWN VALVE

The fuel injector (Fig. 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 fuel injector performs four functions (Times – Atomizes – Meters – Pressurizes):

1. Accurately times the moment of fuel injection.
2. Atomizes the fuel for vaporization and mixing with the air in the combustion chamber.
3. Meters and injects the correct amount of fuel required to maintain engine speed and to handle the load.
4. Creates the high pressure required for proper fuel injection.

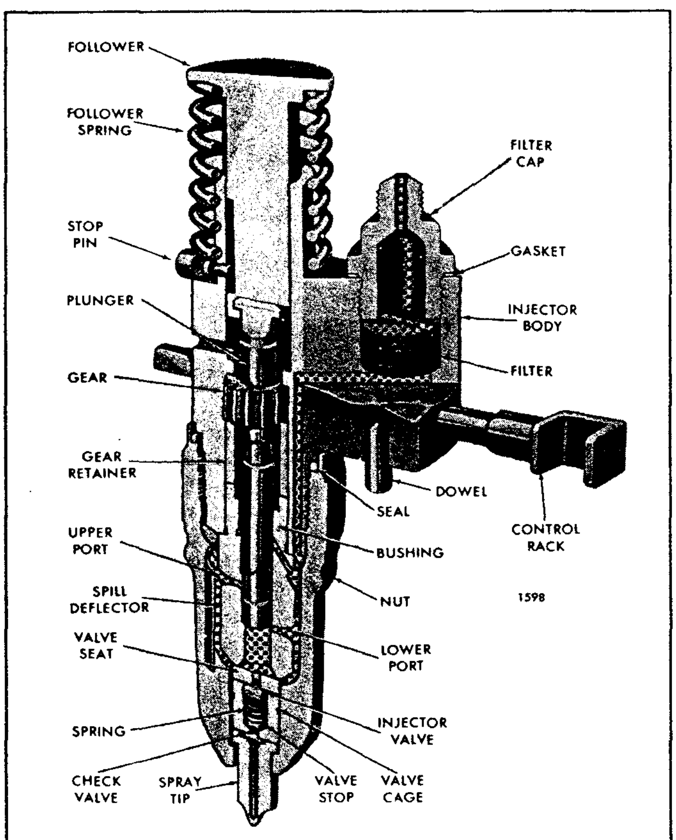


Fig. 1 – Fuel Injector Assembly

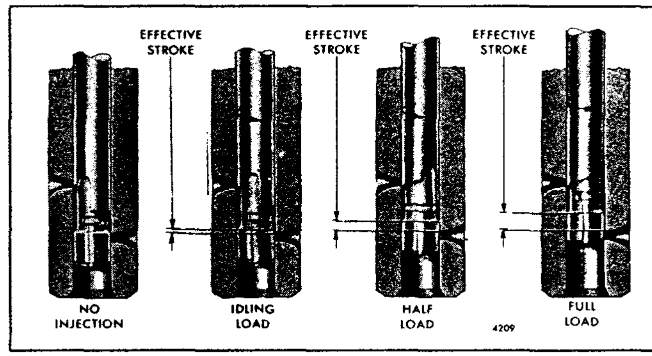


Fig. 2 – Fuel Metering from No Load to Full Load

Combustion required for satisfactory engine operation is obtained by injecting, under pressure, a small quantity of accurately timed, metered and finely atomized fuel oil into the combustion chamber.

Metering and timing during fuel injection is accomplished by an upper and lower helix machined in the lower end of the injector plunger. (Fig. 2) illustrates the fuel metering from no load to full load by rotation of the plunger in the bushing.

(Fig. 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 effective stroke of the plunger and the flow rate of the spray tip.

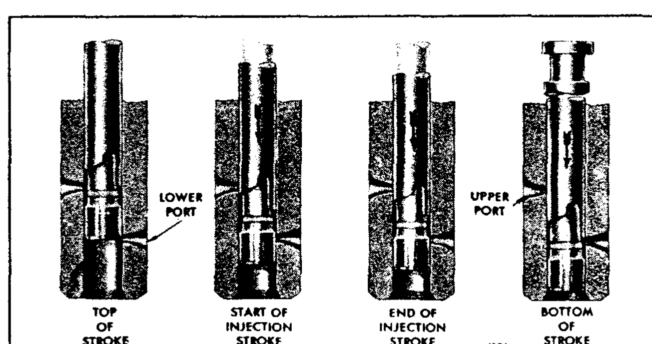


Fig. 3 – Phases of Injector Operation Through Vertical Travel of Plunger

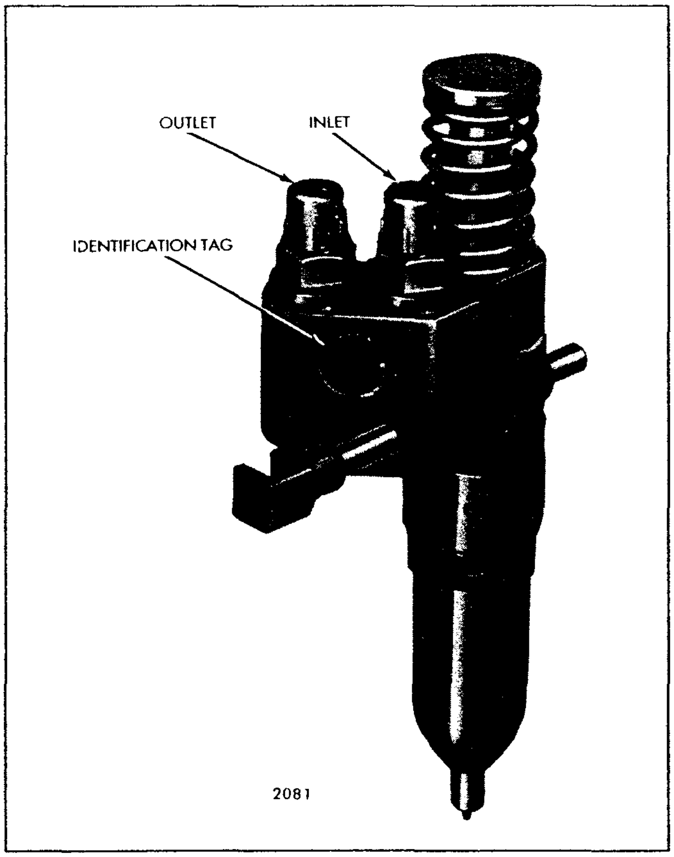


Fig. 4 – Injector Identification

Since the helix angle and the plunger design determines the operating characteristics of a particular injector, it is imperative that the specified injectors are used for each engine. If injectors of different types are mixed in an engine, erratic operation will result and may cause serious damage to the engine or to the equipment which it powers.

Each fuel injector has a circular disc pressed into a recess at the front side of the injector body for identification purposes (Fig. 4).

Each injector control rack (Fig. 1) 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 or fine tuning of all of the injector racks.

The injectors used in engines with a four valve cylinder head require an offset injector body due to the restricted area around the exhaust valve mechanism. A narrower injector clamp is required with the offset injector body and may not be used with the standard injectors. Most offset body injectors, designated as the "S" type, incorporate a clamp seat which is machined lower on the injector body and requires the current narrower clamp (Fig. 5).

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

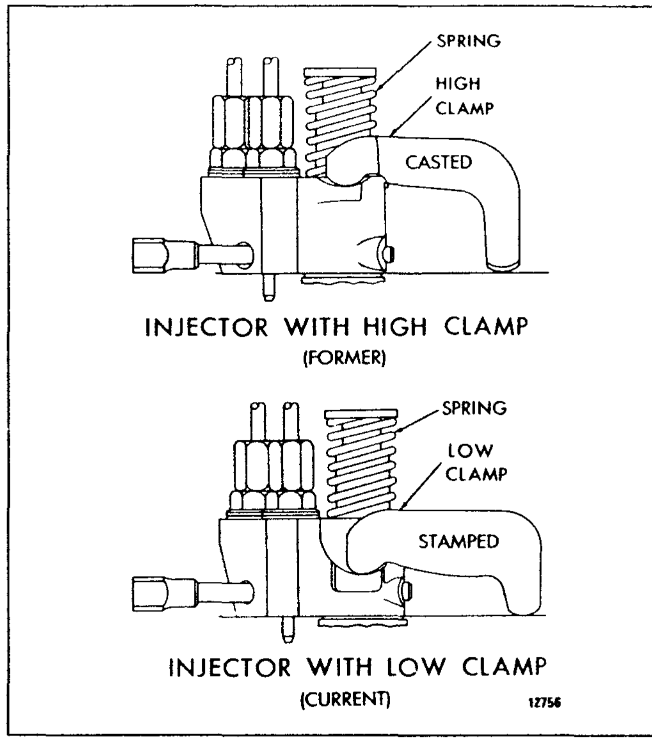


Fig. 5 – Comparison of High Clamp and Low Clamp Injectors

Operation

Fuel, under low pressure, enters the injector at the inlet side through a filter cap and filter positioned over the rack (Fig. 1). From the filter, 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 bushing. The plunger operates up and down in the bushing, and is supplied fuel through the two funnel-shaped ports in the bushing wall.

The motion of the injector rocker arm is transmitted to the plunger by the follower which bears against the follower spring (Fig. 6). In addition to the reciprocating motion, the plunger can be rotated around its axis by the gear which meshes with the control rack. To accomplish fuel metering an upper helix and a lower helix are machined in the lower part of the plunger. The helix relationship to the ports changes with the rotation of the plunger.

As the plunger moves downward, under pressure of the injector rocker arm, some of the fuel under the plunger moves into the supply chamber through the lower port until the port is covered by the lower end of the plunger. The fuel below the plunger continues to move up through the T–drilled passage in the plunger into the fuel metering recess and into the supply chamber through the upper port until that port is covered by the upper helix of the plunger. With the upper and lower ports both covered the remaining fuel trapped under the plunger is subjected to increased pressure by the continued downward movement of the plunger.

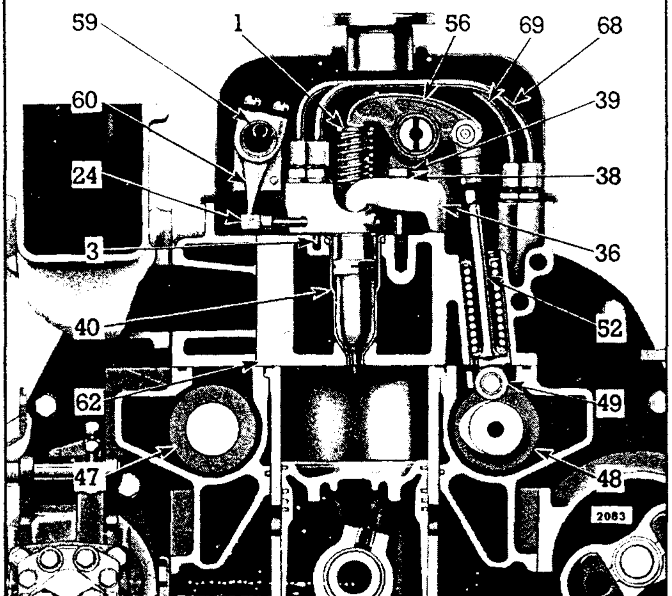


Fig. 6 – Fuel Injector Mounting

When sufficient pressure is built up, the injector valve is lifted off of its seat and the fuel is forced through small orifices in the spray tip and atomized into the combustion chamber until the lower port becomes uncovered.

A check valve, mounted in the spray tip, prevents air in the combustion chamber from entering the fuel injector through the spray holes.

At the end of the stroke the injector plunger is then returned to its *original* position by the injector follower spring. (Fig. 3) shows the various phases of injector operation by the vertical travel of the injector plunger.

On the return stroke of the plunger, the bore of 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 returns to the fuel return manifold and then back to the fuel tank, is directly adjacent to the inlet opening.

Changing the position of the helices, by rotating the plunger, retards or advances the closing of the ports and the beginning and ending of the injection cycle. At the same time, it increases or decreases the amount of fuel injected into the cylinder. (Fig. 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 covered 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 all the way in (full injection), the upper port is covered 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 fuel injector is one of the most important and precisely built parts of the engine. The injection of the correct amount of atomized fuel into the combustion chamber at exactly the right time depends upon this unit. Because the injector operates against the high compression pressure in the combustion chamber, efficient operation demands that the injector assembly is 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.

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. This pressure prevents particles of dirt and dust from entering the room through the door and windows. A suitable air outlet will remove solvent fumes along with the outgoing air.

Provide the injector repair room with a supply of filtered, moisture–proof compressed air for drying the injector parts after they have been cleaned. Use wash pans of rust–proof material and deep enough to permit all of the injector parts to be completely covered by the cleaning solvent when submerged in wire baskets of 16 mesh wire screen. Use baskets which will support the parts so as to avoid contact with the dirt which settles at the bottom of the pans.

Rags should never be used for cleaning injector parts since lint or other particles will clog parts of the injector when it is assembled. A lint–free paper tissue is a suitable material for wiping injector parts.

When servicing an injector, follow the general instructions outlined below:

1. Whenever the fuel pipes are removed from an injector, cover the filter caps with shipping caps to keep dirt out

of the injector and prevent damage. Also, protect the fuel pipes and fuel connectors from damage and the 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. Replace the filters only at the time of complete disassembly and overhaul of an injector.

3. Whenever an injector has been removed and reinstalled or replaced in an engine, make the following adjustments as outlined in Section 14:

   a. Time the injector.

   b. Position the injector control rack.

4. 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 (refer to Section 15.3).

5. When a reconditioned injector is to be placed in stock, fill it with injector test oil J 26400. *Do not use fuel oil.* Install shipping caps on both filter caps immediately after filling. Store the injector in an *upright* position to prevent test oil leakage.

   NOTICE: Make sure that new filters have been installed in a reconditioned injector which is to be 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 than the original unit.

- DDC recommends that flared end fuel pipes not be reused.

Remove Injector

1. Clean and remove the valve rocker cover. Discard the gasket.

2. Remove the fuel pipes from both the injector and the fuel connectors (Fig. 6).

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

- DDC recommends that flared end fuel pipes not be reused.

3. Crank the engine to bring the upper ends of the push rods of the injector and valve rocker arms in line horizontally. 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 because the bolt could be loosened.

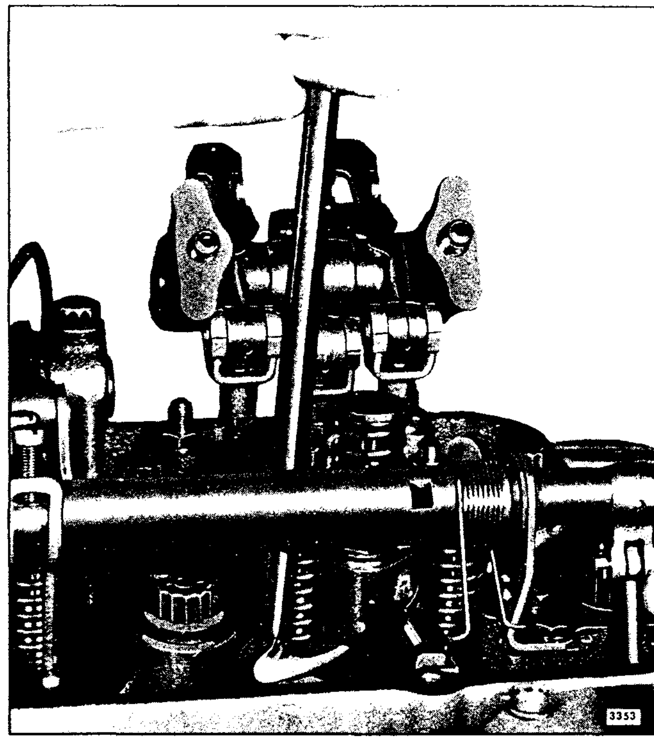


Fig. 7 – Removing Injector from Cylinder Head

CAUTION: To reduce the risk of personal injury when barring over or "bumping" the starter, personnel should keep their hands and clothing away from the moving parts of the engine as there is a remote possibility the engine could start.

4. Remove the two rocker shaft bracket bolts and swing the rocker arms away from the injector and valves (Fig. 7).

5. Remove the injector clamp bolt, special washer and clamp.

6. Loosen the inner and outer adjusting screws or adjusting screw and locknut on the injector rack control lever and slide the lever away from the injector.

7. Lift the injector from its seat in the cylinder head (Fig. 7).

8. Cover the injector hole in the cylinder head to keep foreign material out.

9. Clean the exterior of the injector with clean solvent and dry it with compressed air.

CAUTION:To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.

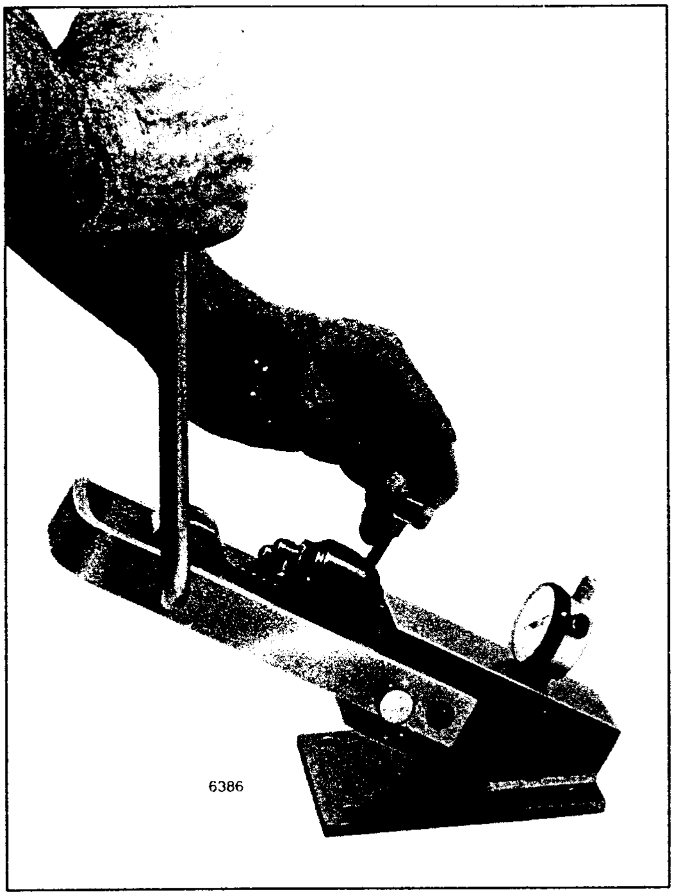


Fig. 8 – Checking Rack for Freeness in Tester J 29584

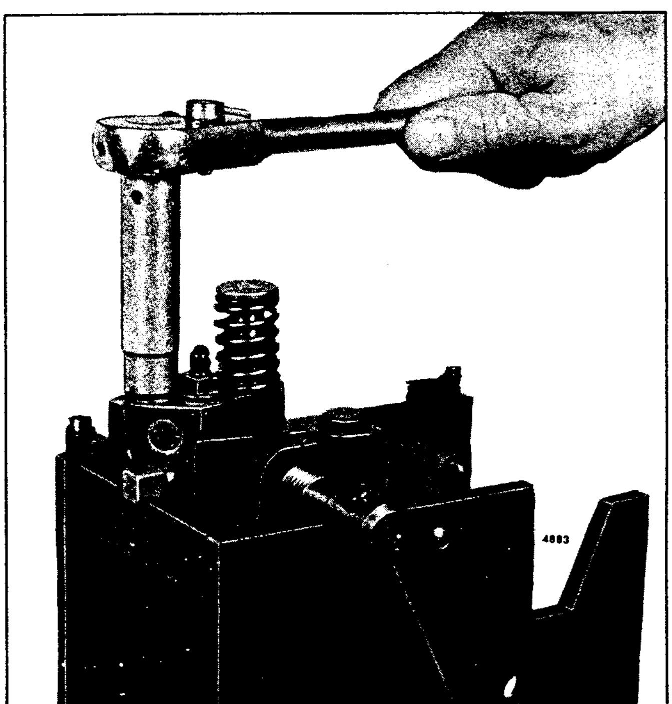


Fig. 9 – Removing Filter Cap

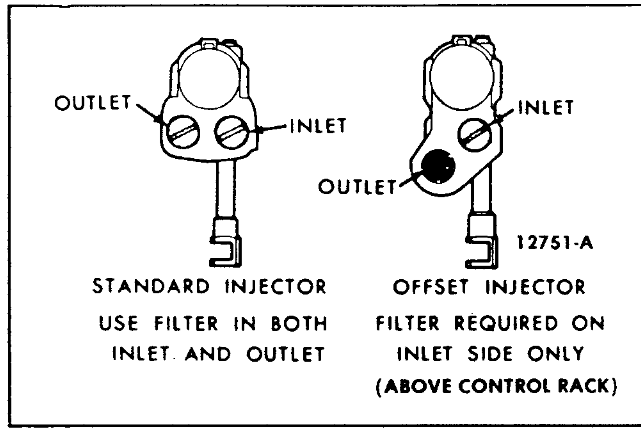


Fig. 10 – Location of Filter in Injector Body

Inspect and Test Prior to Reuse

This inspection and test process is necessary if the injector is being considered for reuse rather than complete overhaul. Submerge the injector in clean solvent to wash it. Blow dry with compressed air.

CAUTION:To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.

1. Inspect the following injector parts for external wear, rust and corrostion.

   Follower spring
   Injector body
   Body nut
   Spray tip
   Injector rack
   Filter caps

2. Inspect the following parts for wear or abrasion deterioration.

   Top of the follower
   Follower spring
   Injector body
   Spray tip orifices

3. Check the rack for freeness and the plunger movement in Tester J 29584.

   With the injector control rack held in the *no–fuel* position, operate the handle to 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 until the follower reaches the top of its travel (Fig. 8). If the rack falls freely the injector passes the test. If the injector fails the rack freeness test, either the plunger is scored or there is a misalignment of the body, bushing or nut due to irregular or dirty parts.

4. Check the injector for leaks using Tester J 23010–A as outlined in Section 2.0 – Shop Notes.

5. Check the spray pattern, atomization and valve opening pressure using Tester J 23010–A as outlined in Section 2.0 – Shop Notes.

6. Perform injector fuel output test using Calibrator J 22410–A as outlined in Section 2.0 – Shop Notes.

   If the injector passes the above tests, it can be reused.

If the results of the above tests reveal marginal performance, removal of the plunger may assist with further diagnosis of internal injector problems. Plungers that reveal scratches, score marks, abnormal wear, helix chipping or other obvious damage would indicate that the injector should not be reused.

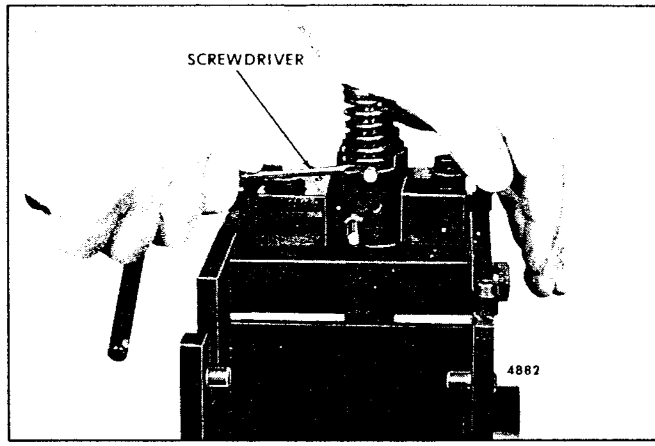


Fig. 11 – Removing Injector Follower Stop Pin

Disassemble Injector

1. Support the injector upright in injector holding fixture J 22396 (Fig. 9) and remove the filter caps, gaskets and filters.

   Whenever a fuel injector is disassembled, discard the filters and gaskets and replace with new filters and gaskets. In the offset injector, a filter is used in the inlet side only. No filter is required in the outlet side (Fig. 10).

2. Compress the follower spring (Fig. 11). Then, raise the spring above the stop pin with a screwdriver and withdraw the pin. Allow the spring to rise gradually.

3. Refer to (Fig. 12) and remove the plunger follower, plunger and spring as an assembly.

4. Using socket J 4983–01, loosen the nut on the injector body (Fig. 13).

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.

   When an injector has been in use for some time, the spray tip, even though clean on the outside, may not be pushed readily from the nut with the fingers. In this event, support the nut on a wood block and drive the tip down through the nut, using tool J 1291–02 (Fig. 14).

6. Refer to (Fig. 15) and remove the spill deflector. Then, lift the bushing 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 and discard the seal ring from the body.

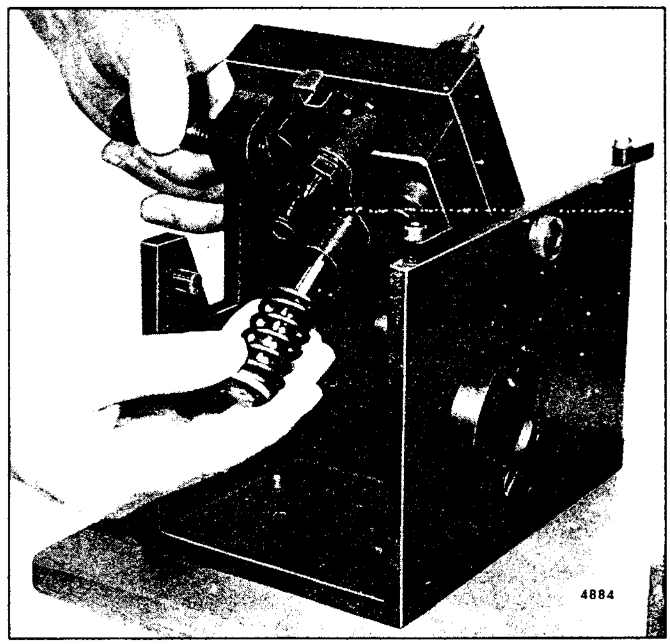


Fig. 12 – Removing or Installing Plunger Follower, Plunger and Spring

Clean Injector Parts

Since most injector problems 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 a suitable solvent and dry them with clean, filtered compressed air.

CAUTION:To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.

Use lint free towels to wipe off the parts. Clean out 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.

Clean the spray tip with Tool J 1243 (Fig. 16). Turn the reamer in a clockwise direction to remove the carbon deposits.

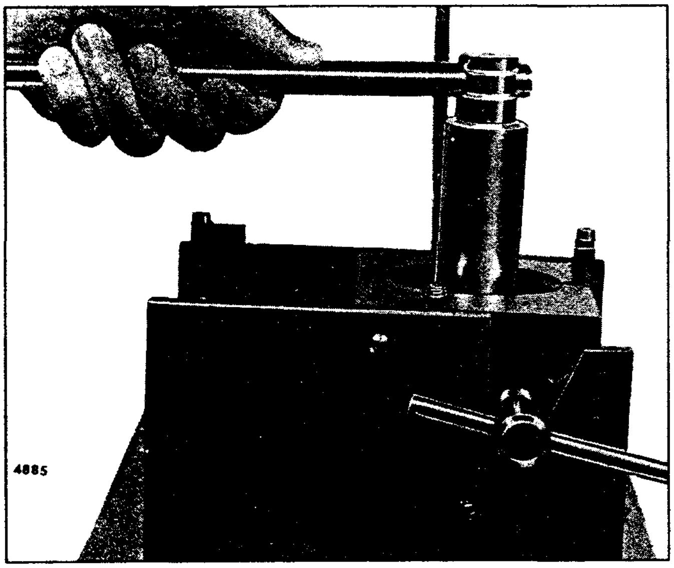


Fig. 13 – Removing Injector Nut Using Tool J 4983-01

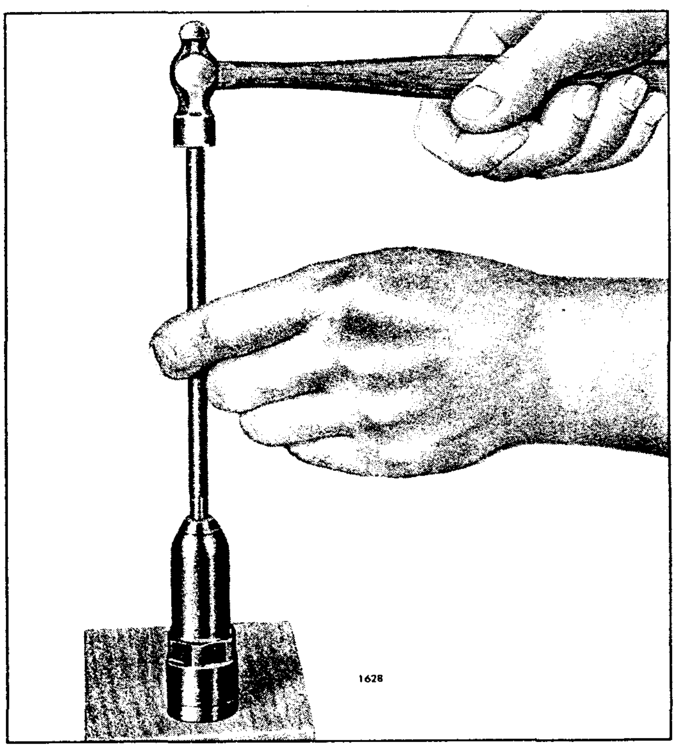


Fig. 14 – Removing Spray Tip from Injector Nut Using Tool J 1291-02

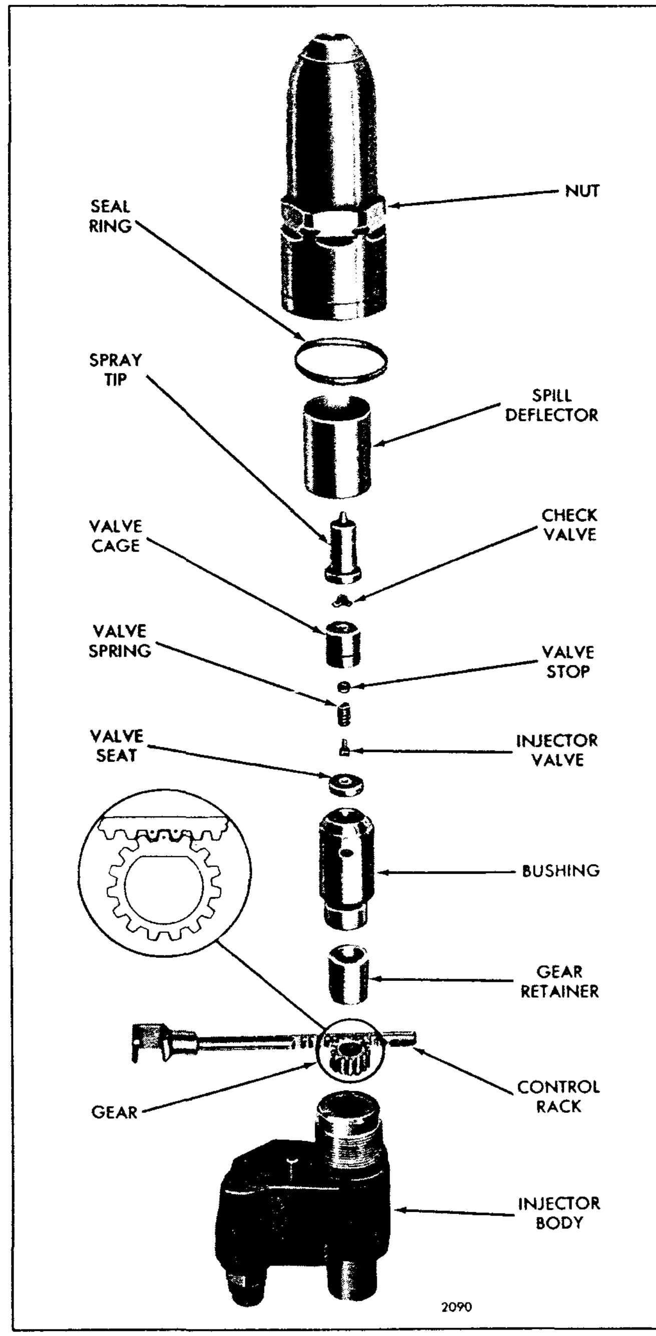


Fig. 15 – Injector Rack, Gear, Spray Tip and Valve Assembly Details and Relative Location of Parts

Wash the tip in solvent and dry it with compressed air. Clean the spray tip orifices with pin vise J 4298-1, and the proper size spray tip cleaning wire. Use wire J 21459-01 to clean .005" diameter holes and wire J-21461-01 to clean .006" diameter holes (Fig. 17).

Before using the wire, hone the end until it is smooth and free of burrs and taper the end a distance of 1/16" with stone J 8170. Allow the wire to extend 1/8" from tool J 4298-1. Ultra sonic cleaning is also an acceptable method.

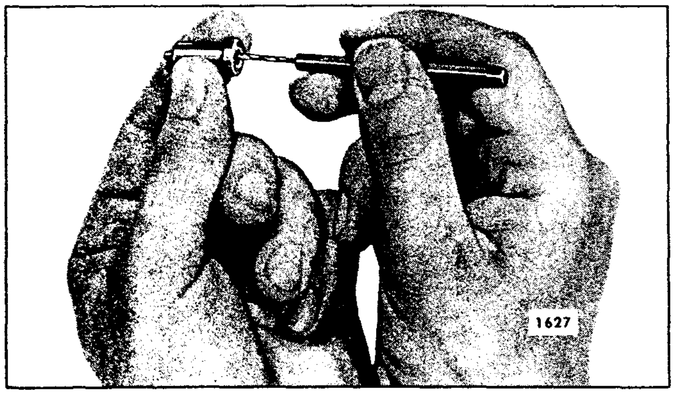


Fig. 16 – Cleaning Injector Spray Tip Using Tool J 1243

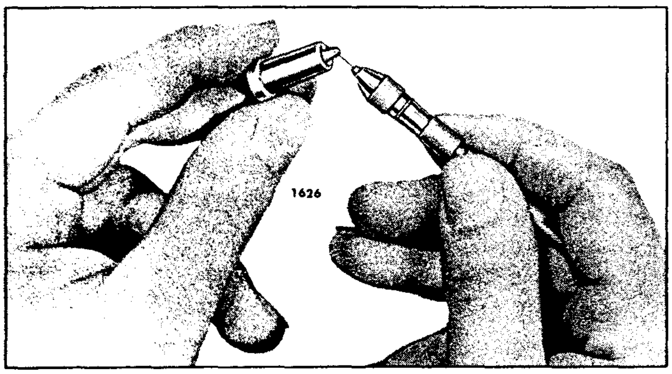


Fig. 17 – Cleaning Spray Tip Orifices Using Tool J 4298–1

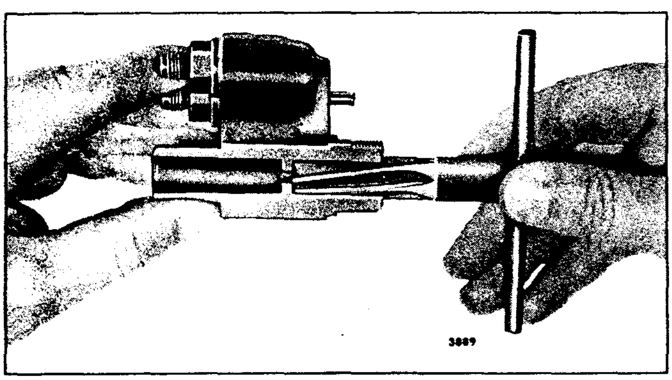


Fig. 18 – Cleaning Injector Body Ring with Tool J 21089

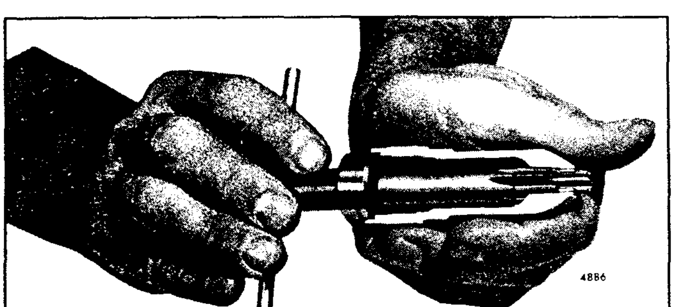


Fig. 19 – Cleaning Injector Nut Spray Tip Seat Using Tool J 4986–01

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 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.

NOTICE: Do not buff the spray tip area excessively. *Do not use a steel wire buffing wheel or the spray tip holes may be distorted.*

When the body of the spray tip is clean, lightly buff the tip end in the same manner to clean the spray tip orifice area.

Wash the spray tip in clean solvent and dry it with compressed air.

CAUTION:To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kpa) air pressure.

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) into the ring bore of the injector body (Fig. 18). Turn the reamer in a clockwise direction and remove any burrs inside the ring bore. Then, wash the injector body in clean solvent and dry it with compressed air.

Carefully, insert reamer J 4986–01 in the injector nut (Fig. 19). Turn it in a clockwise direction a few turns, then remove the reamer and check the face of the seat for reamer contact over the entire surface. If necessary, repeat the reaming procedure until the reamer does make contact with the entire face of the seat.

Wash the injector nut in clean solvent 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 solvent and dry them 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 test oil. *Keep the parts of each injector assembly together.*

Inspect Injector Parts (Visual and Dimensional)

NOTICE: Injector components manufactured after January 1, 1988 may or may not be blued, at the discretion of the manufacturer. Bluing has no effect on a part's performance or service life.

1. Follower:

   Measure between the top of the follower and the slot. This dimension must be 1.647 ± .002" (Fig. 20).

   Check the stop pin groove in the side of the follower to be sure it is smooth and not damaged. The follower should not be reused if there is more than .002" wear on the top or if there is any other visible damage or wear.

2. Follower Spring:

   Examine the outside diameter of the follower spring coils for wear caused by the rocker arms contacting the coils. If worn, do not reuse.

   Also, inspect for damage from rust pitting, nicks or notches in the coils, broken coils, broken coil ends and notches under the coil ends. If damaged, do not reuse.

   Check the follower spring tension with spring Tester J 29196.

   The current injector follower spring (.142" diameter wire) 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". The former spring wire was .120" diameter.

   It is recommended that at the time of overhaul, all injectors in an engine be converted to incorporate the current spring (.142" diameter wire). However, in the event that one or two injectors are changed, the remaining injectors need not be reworked to incorporate the current spring.

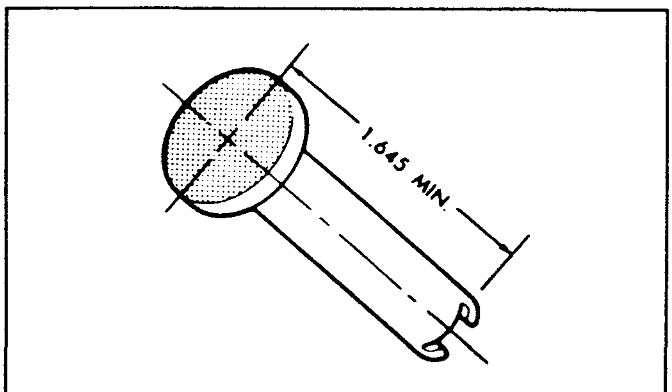


Fig. 20 – Injector Follower

3. Injector Body:

   Inspect the injector body threads, the bushing seating surface and the filter cap gasket sealing surfaces fordamage. Then, inspect the rack hole, body seal ring sealing surface, clamp radius and dowel pin.

4. Filter Caps:

   Check the condition of the jumper line sealing surfaces on the filter caps, the copper gasket sealing surfaces, the threads and the fuel passage.

5. Control Rack

   Check the injector control rack for straightness, the teeth for wear and the width of the notch in the clevis. Also, check the rack for nicks, burrs, rust and hardness.

   The notch in the clevis should be .3125" to .3145". A .250" inside diameter bushing may be used to check the rack for straightness. A slightly bent rack will not pass freely back and forth through the bore of the bushing.

6. Gear and Gear Retainer:

   Inspect the gear and the gear retainer for nicks, burrs or rust and the gear teeth for wear.

7 & 8 Plunger Bushing Assembly

Effective with injectors manufactured in October, 1985, the P & B (plunger and bushing) assemblies of all fuel injectors have a revised finish on the inside diameter of the bushing that provides greater resistance to scoring during injector operation.

Revised P & B assemblies are identified with a black locating pin at the top of the bushings. Injector assemblies containing revised P & B's are date stamped on the body with a "10–85" (for October, 1985) or later build date. Revised P & B assemblies are physically interchangeable with early P & B assemblies. However, because of the increased resistance to scoring provided by the revised assemblies, DDC recommends using the revised assemblies when rebuilding fuel injectors.

NOTICE: Do not attempt to install the plunger of one P & B into the bushing of another P & B and vise–versa. Since the components of P & B assemblies are supplied as precision matched sets, any attempt to mix them can result in P & B seizure and serious injector damage.

Check the bushing lapped sealing surface for scratches, the bushing internal diameter for scoring, the condition of the dowell pin and check for corrosion or varnish (Fig. 21).

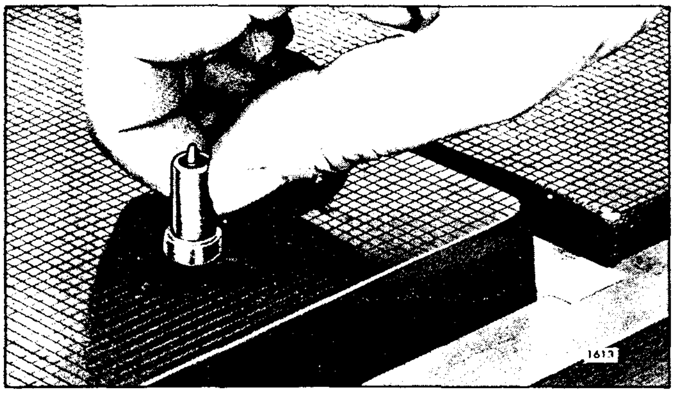


Fig. 25 – Lapping Spray Tip on Lapping Blocks J 22090

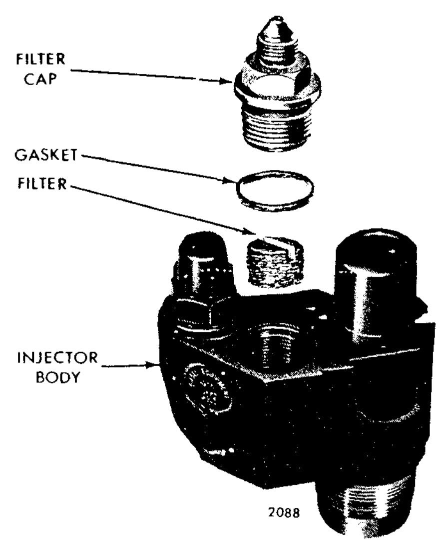


Fig. 26 – Details of Injector Filters and Caps and Their Relative Location

Lapping Injector Parts

If necessary, lap the sealing surfaces indicated in (Fig. 24) 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 flat on the block (Fig. 25) and, using a figure eight motion, move it back and forth across the block. Do not press on the part, but use just enough pressure to keep the part flat on the block. It is important that the part be kept flat on the block at all times.
4. After each four or five passes, clean the lapping powder from the part by drawing it across a clean piece of tissue placed on a flat surface and inspect the part. *Do not lap excessively.*
5. When the part is flat, wash it in clean 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 the "mirror" finish required for easy inspection.
8. Wash all of the lapped parts in clean solvent and dry them with compressed air.

CAUTION:To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.

Assemble Injector

1. Secure the body in vise J 22396–1.

● 2. Insert new filter(s) in the top of the body (Fig. 26). The current production service filter (stainless steel wire mesh pellet) is installed dimple end down, slotted end up. The former service filter (fiberglass–filled nylon cone) was installed with the pointed (cone) end up.

Insert a new filter in the inlet side (located over the injector rack) in an offset injector. No filter is required at the outlet side (Fig. 27).

● 3. Place a new gasket on each filter cap. Lubricate the threads and install the filter caps (Fig. 28). Using a 9/16" deep socket and a torque wrench tighten the filter caps as follows:

Non–blued cap on
non–blued body . . . . 62 lb–ft (84 N·m) torque

Blued cap on
blued body . . . . 70 lb–ft (95 N·m) torque

Non–blued cap on blued
body or blued cap on
non–blued body . . . . 62 lb–ft (84 N·m) torque

4. Install clean shipping caps to protect the sealing surfaces and to prevent dirt from entering the injector.
5. Lubricate thread protector J 29197 with injector test oil. Remove the injector from the vise and hold the injector body, bottom end up. Place the protector over the threads of the injector body.

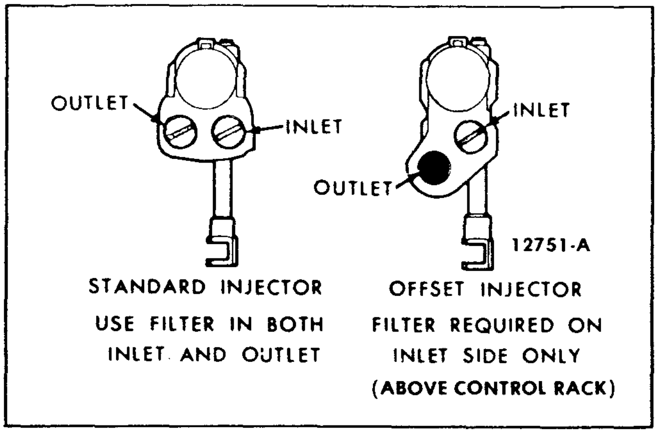


Fig. 27 – Location of Filter in Injector Body

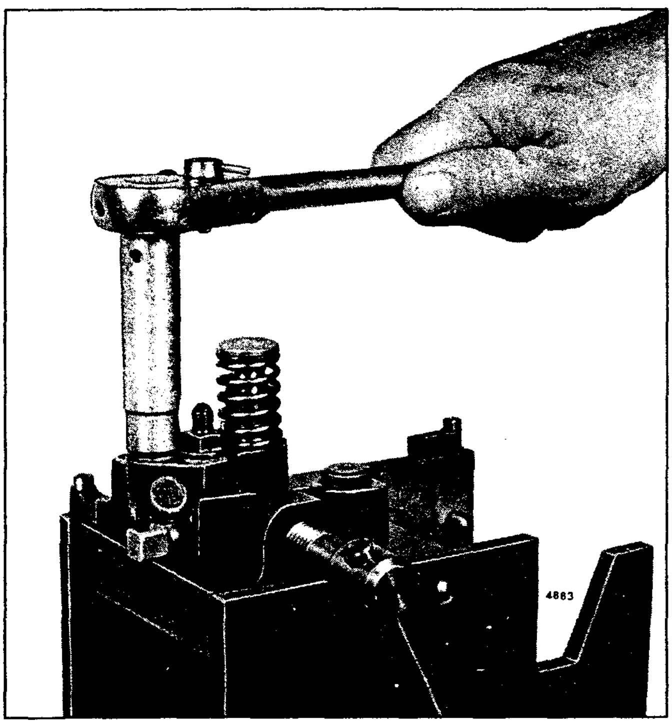


Fig. 28 – Installing Filter Cap

6. Lubricate the new seal ring and place the new seal over the nose of the protector and down onto the shoulder of the injector body. Do not allow the seal to roll or twist.

   - A new round (in cross–section) injector nut seal ring replaced the former diamond–shaped ring, effective with injectors manufactured approximately November 1, 1987. Only the round seal ring is serviced.

7. Remove the protector (J 29197).

8. Slide the control rack into the injector body.

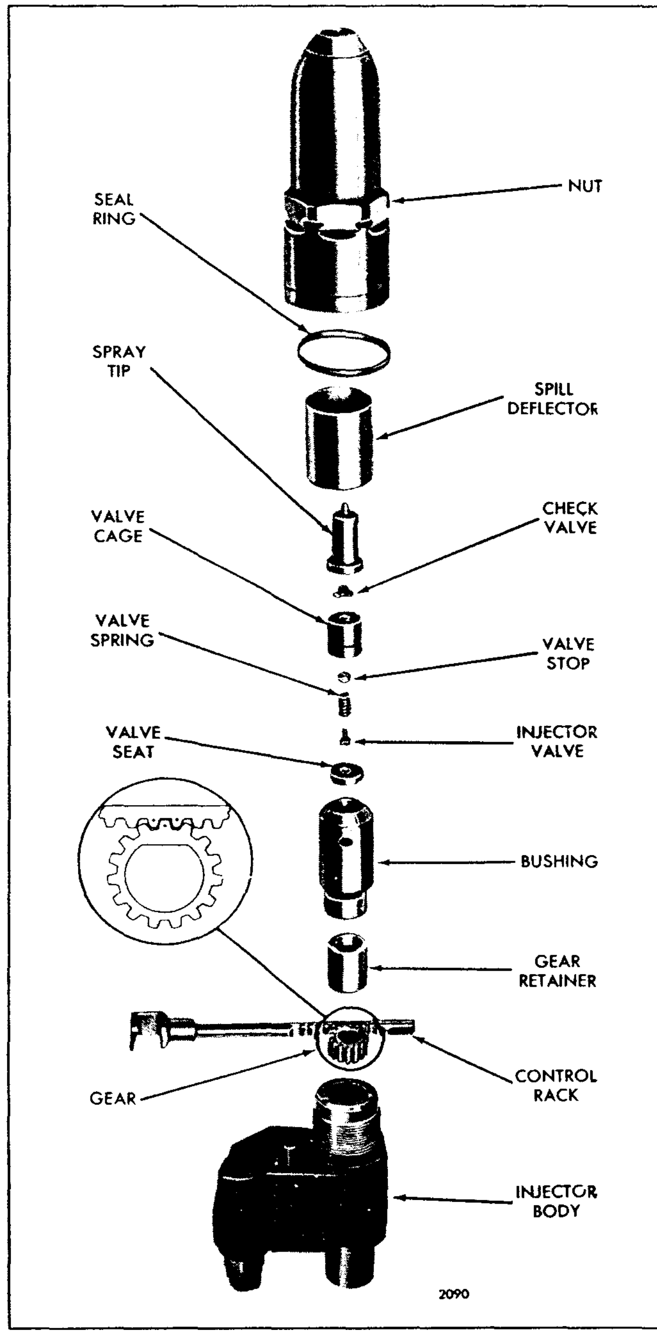


Fig. 29 – Injector Rack, Gear, Spray Tip and Valve Assembly Details and Relative Location of Parts

9. Refer to (Fig. 29) and note the marked teeth on the control rack and gear. Then, look into the body bore and move the rack until you can see the drill marks. Hold the rack in this position.

10. Place the gear in the injector body so that the marked tooth is engaged between the two marked teeth on the rack (Fig. 29).

11. Place the gear retainer on top of the gear.

12. Align the locating pin in the bushing with the slot in the injector body, then slide the end of the bushing into place.

13. Support the injector body, bottom end up, in injector vise J 22396–1.

14. Install the spill deflector over the barrel of the bushing.

15. Insert the valve stop, valve spring and injector valve into the valve cage.

16. Place the valve seat centrally on the top of the bushing.

17. Place the valve cage and related parts (injector valve down) on top of the valve seat.

18. Locate the check valve centrally on the cage and place the spray tip over the check valve and against the valve cage.

19. 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. 30). 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.

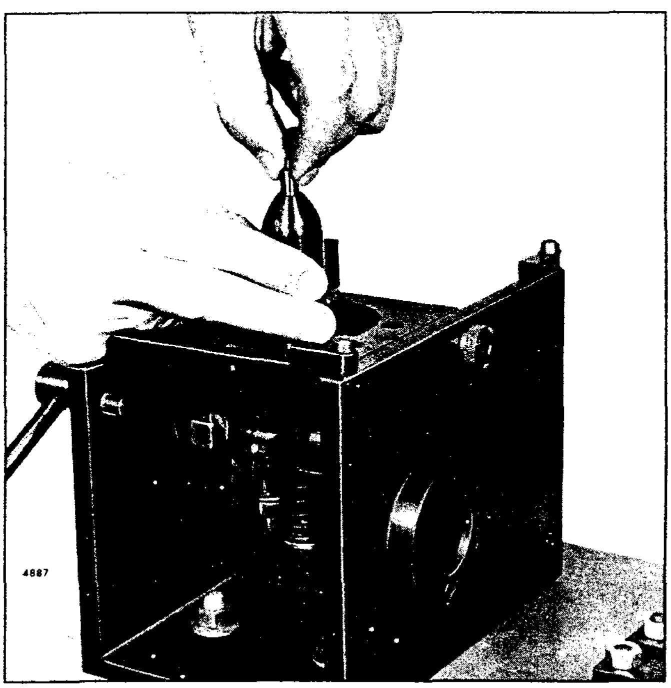


Fig. 30 – Tightening Injector Nut by Hand

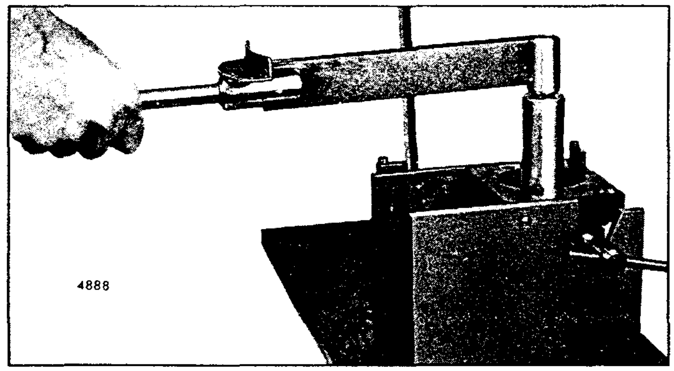


Fig. 31 – Tightening Injector Nut with Torque Wrench Using Tool J 4983–01

● 20. Use socket J 4983–01 and a torque wrench to tighten the injector nut as follows:

Non–blued nut on non–blued body . . . . 50 lb–ft (68 N·m) torque

Blued nut on blued body . . . . 80 lb–ft (108 N·m) torque

Non–blued nut on blued body or blued nut on non–blued body . . . . 65 lb–ft (88 N·m) torque

21. After assembling a fuel injector, always check the area between the nut and the body. If the seal is still visible after the nut is assembled, try another nut and a new seal which may allow assembly on the body without extruding the seal and forcing it out of the body–nut crevice.

NOTICE: Do 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.

22. Turn the injector over and push the rack all the way in.

23. Place the follower spring on the injector body.

24. Refer to (Fig. 32) and place the stop pin on the injector body so that the follower spring rests on the narrow flange of the stop pin.

25. Refer to (Fig. 33) and slide the head of the plunger into the follower.

26. Align the slot in the follower with the stop pin hole in the injector body.

27. Align the flat side of the plunger with the flat in the gear.

28. 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 into position. When in place, the spring will hold the stop pin in position.

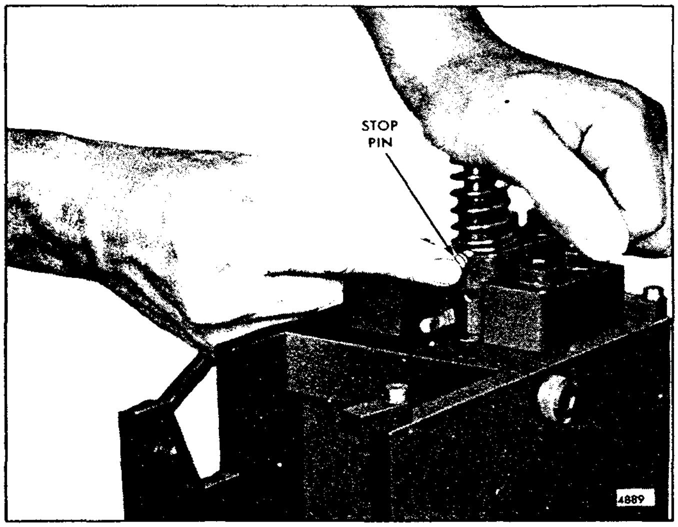


Fig. 32 – Installing Injector Follower Stop Pin

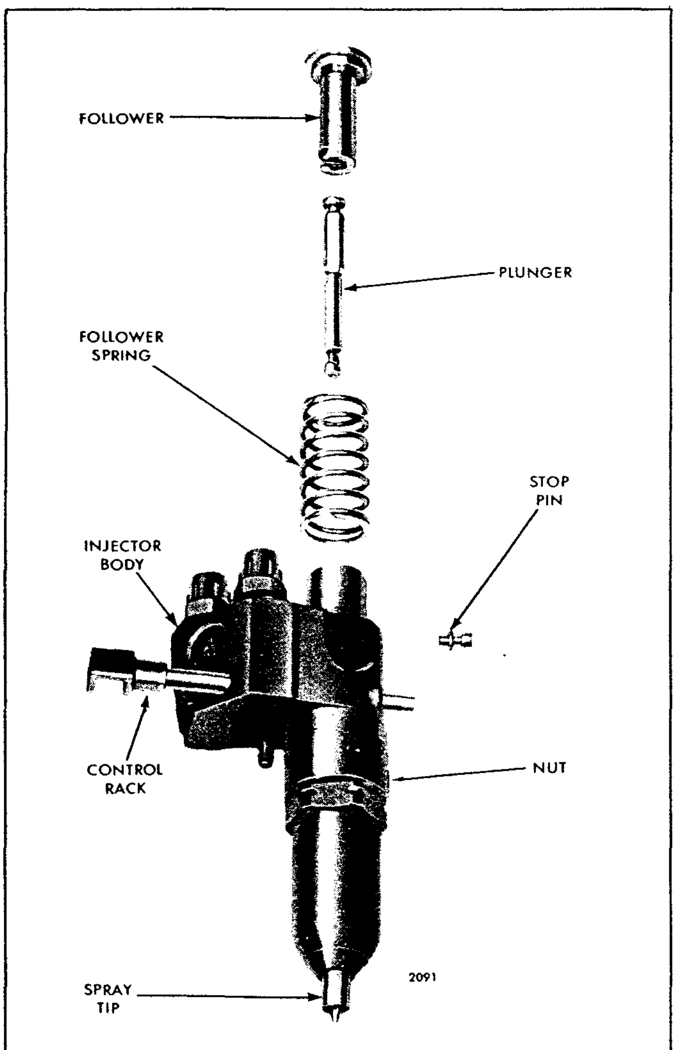


Fig. 33 – Injector Plunger, Follower and Relative Location of Parts

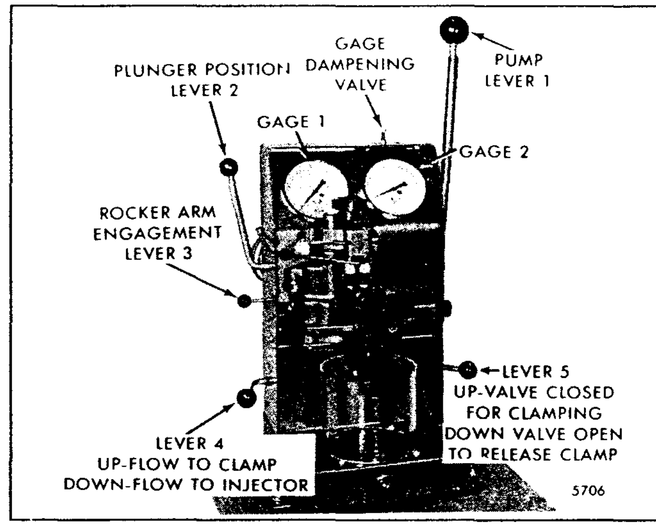


Fig. 34 – Injector in Position for Testing with Tester J 23010-A

Check Injector Output

Perform the injector fuel output test using Calibrator J 22410-A as outlined in Section 2.0 – Shop Notes.

Check Atomization and Spray Pattern

This test determines spray pattern uniformity and atomization.

1. Clamp the injector properly and purge the air from the system (Fig. 34).
2. Move lever 4 down.
3. Position the injector rack in the *full-fuel* position.
4. Place pump lever 1 in the *vertical* position.
5. Move lever 3 to the *forward detent* position.
6. The injector follower should be depressed rapidly using pump lever 1 (at 40 to 80 strokes per minute) to simulate operation in the engine. Observe the spray pattern to see that all spray orifices are open and dispersing the test oil evenly. The beginning and ending of injection should be sharp and the test oil should be finely atomized with no drops of test oil forming on the end of the tip.

Check Pressure Holding and Test for Leaks

This test determines if the body-to bushing mating surfaces in the injector are sealing properly and indicates proper plunger-to-bushing fit.

1. Clamp the injector properly in Tester J 23010-A and purge the air from the system (Fig. 34).
2. Close The Thru-Flow valve, but do not overtighten.
3. Move lever 2 to the rear, *horizontal* position.

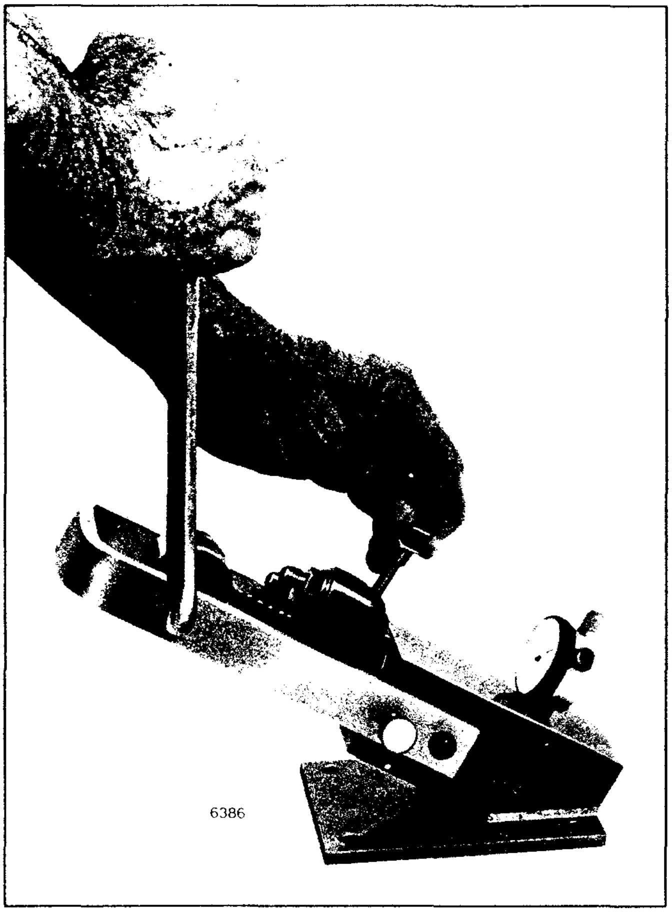


Fig. 35 - Checking Rack for Freeness in Tester J 29584

4. Operate pump lever 1 until gage 1 slowly reaches 100–200 psi (689–1378 kPa), check for injector nut seal ring leaks. Then, move lever 2 until the plunger closes both bushing parts. Operate pump lever 1 and increase the gage reading to 1500–2000 psi (10 335–13 780 kPa). Check for leaks at the filter cap gaskets and the body plugs. Allow the plunger to go back to the *normal* position. Operate pump lever 1 and bring the pressure up to 500 psi (3445 kPa). Note the time for the pressure to drop from 450 psi to 250 psi (3100 kPa to 1723 kPa). This should not occur in less than 7 seconds. This test determines if the body–to–bushing mating surfaces in the injector are sealing properly.

5. To unclamp the injector use the following procedure:

   a. Open the Thru–Flow valve to release the pressure in the system.

   b. Move lever 5 *down* to release the clamping pressure.

   c. Swing out the adaptor plate and remove the injector after the seals in the clamping head are free and clear of the injector filter caps.

   d. Carefully, return lever 5 to the *up (horizontal)* position.

Check Rack Freeness and Spray Tip Concentricity

Place the injector in Tester J 29584 (Fig. 35) and check rack freeness.

With the injector control rack held in the *no–fuel* position, operate the handle to 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 until the follower reaches the top of its travel. If the rack falls freely the injector passes the test.

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. Generally, this will free the rack. Then, if the rack isn't free, change the injector nut. In some cases it may be necessary to disassemble the injector to eliminate the cause of the misaligned parts or to remove dirt.

To assure correct alignment, check the concentricity of the spray tip as follows:

1. Place the injector in Tester J 29584 (Fig. 35) and adjust the dial indicator to zero.
2. Rotate the injector 360° and note the total runout as indicated on the dial.
3. If the total runout exceeds .008", remove the injector from the gage. Loosen the injector nut, center the spray tip and tighten the nut to 55–65 lb–ft (75–88 N·m) torque. Recheck the spray tip concentricity. If, after several attempts, the spray tip cannot be positioned satisfactorily, replace the injector nut.

Box and Store Injector

If the reconditioned injector is to be placed in stock, fill it with injector test oil J 26400. *Do not use fuel oil.* Install shipping caps on both filter caps immediately after filling. Store the injector in an *upright* position to prevent test oil leakage.

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 undue stresses from being exerted against the spray tip.

Use injector tube bevel reamer J 5286–9 or a cylinderical wire brush (Section 2.1.4), to clean the carbon from the injector tube. Exercise care to remove ONLY the carbon so that the proper tip protrussion is maintained. Pack the flutes of the reamer with grease to retain the carbon removed from the tube.

Fuel Pipe Usage	Torque
Endurion®–coated	130 lb–in. (14.69 N·m)
Uncoated	160 lb–in. (18.3 N·m)
Jacobs Brakes*	120 lb–in. (13.6 N·m)
Load limiting devices	160 lb–in. (18.3 N·m)

**Not serviced. Available from Jacobs Manufacturing Company.*

Be sure the fuel injector is filled with fuel oil. If necessary, add clean fuel oil at the inlet filter cap until it runs out of the outlet filter cap.

Install the injector in the engine as follows:

1. Insert the injector into the injector tube with the dowel in the injector body registering with the locating hole in the cylinder head.
2. Slide the rack control lever over so that it fully engages the injector rack clevis.
3. Install the injector clamp, special washer (with curved side toward injector clamp) and bolt. Tighten the bolt to 20–25 lb-ft (27–34 N·m) torque. Make sure that the clamp does not interfere with the injector follower spring or the exhaust valve springs.

   NOTICE: Check the injector control rack for free movement. Excess torque can cause the control rack to stick or bind.

4. 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 2.0 – Specifications.

   NOTICE: 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 shaft bracket bolts. Refer to *Install Rocker Arm and Shaft* in Section 1.2.1 and note the position of the exhaust valve bridges before, during and after tightening the rocker shaft bolts.

• 5. Install fuel pipes:

   Remove the shipping caps. Align the fuel pipes and connect them to the injectors and the fuel connectors.

   NOTICE: DDC recommends that the original fuel pipes not be reused. New flared end fuel pipes should be installed. When installing flared end fuel pipes, use fuel pipe nut wrench J 8932–01 and "clicker" type torque wrench J 24405 (calibrated in inch–pounds) to apply proper torque and avoid damaging the fuel pipes. Refer to the chart for torque specifications. Fuel leakage from damaged or improperly installed fuel pipes can cause lube oil dilution, which may result in serious engine damage.

   NOTICE: Because of their low friction surface, Endurion® –coated nuts on fuel jumper lines must be tightened to 130 ***lb–in*** (14.69 N·m) torque, instead of the 160 ***lb–in*** (18.3 N·m) required with uncoated nuts. To avoid possible confusion when tightening jumper line nuts, do not mix lines with uncoated and Endurion® –coated nuts on the same cylinder head.

   Jacobs brake jumper lines and jumper lines used with load–limiting devices do not have coated nuts. Tighten these to the values shown on the Chart.

   NOTICE: 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 (refer to Fuel Jumper Line Maintenance & Pressurize Fuel System – Check for Leaks in Section 2.0 – Shop Notes).

   An indication of fuel leakage at the fittings of the fuel injector supply lines and connector nut seals could be either low lubricating oil pressure (dilution) or fuel odor coming from the crankcase breathers or an open oil filler cap. When any of the above are detected, remove the valve rocker cover.

   A close inspection of the rocker cover, cylinder head, fuel lines and connectors will usually show if there is a fuel leakage problem. Under normal conditions, there should be a coating of lubricating oil throughout the cylinder head area and puddles of oil where the fuel pipes contact the connectors and where the fuel connectors contact the cylinder head. If these areas do not have the normal coating of lubricating oil, it is likely that fuel oil is leaking and washing off the lubricating oil.

   Remove and replace the leaking fuel pipes and/or connectors. Use new gasket(s) and reinstall the rocker cover. Then, drain the lubricating oil and change the oil filter elements. Refer to Section 13.3 (Lubrication Specifications) and refill the crankcase to the proper level with the recommended grade of oil.

6. 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 will only be necessary to adjust the valve clearance and time the injector for the one cylinder, and to position the injector rack control levers.

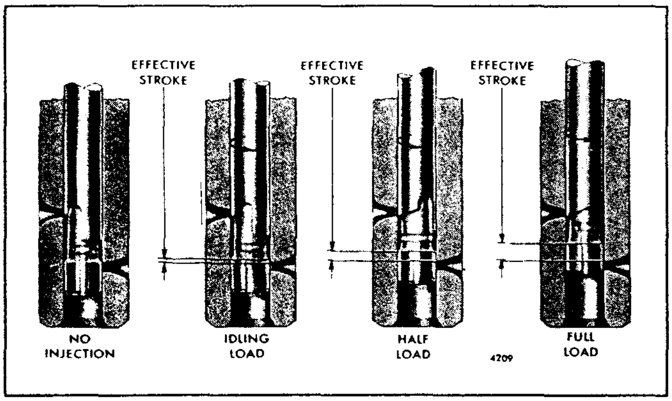


Fig. 3 – Fuel Metering from No Load to Full Load

Metering and timing during fuel injection is accomplished by an upper and lower helix machined in the lower end of the injector plunger. (Fig. 3) illustrates the fuel metering from no load to full load by rotation of the plunger in the bushing.

(Fig. 4) illustrates the phases of injector operation by the vertical travel of the injector plunger.

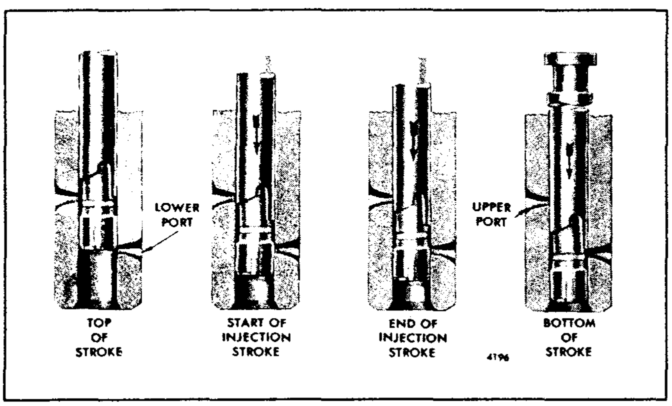


Fig. 4 – Phases of Injector Operation Through Vertical Travel of Plunger

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 effective stroke of the plunger and the flow rate of the spray tip.

Since the helix angle and the plunger design determines the operating characteristics of a particular injector, it is imperative that the specified injectors are used for each engine. If injectors of different types are mixed in an engine, erratic operation will result and may cause serious damage to the engine or to the equipment which it powers.

Each fuel injector has a circular disc pressed into a recess at the front side of the injector body for identification purposes (Fig. 1).

Each injector control rack (Fig. 2) 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 or fine tuning of all injector racks.

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

- New O–ring sealed fuel pipes are used on the mechanical unit injectors in marine engines, effective with units built approximately April, 1988. These fuel pipes feature a three–piece connector (collar, nut, o–ring seal) at both ends (Fig. 38). The primary sealing element is the replaceable fluoroelastomer (Viton) O–ring seal.

- To conform with this change, new connectors are installed in the cylinder head and new fuel injectors with redesigned filter caps are used. The connectors and caps have a 1/2" – 20 female thread to accept the 1/2"–20 male thread on the fuel pipe nuts.

- Flared tube design and O–ring design fuel pipes are not interchangeable on a part–for–part basis. The new pipes, connectors, and injector filter caps must be used together to insure interchangeability. The injector filter cap is not compatible with the former nylon cone fuel inlet filter. It must be used with the current stainless steel mesh pellet filter.

Operation

Fuel, under low pressure, enters the injector at the inlet side through a filter cap and filter positioned over the racks (Fig. 2). From the filter, 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 bushing. The plunger operates up and down in the bushing, and is supplied fuel through the two funnel–shaped ports in the bushing wall.

The motion of the injector rocker arm is transmitted to the plunger by the follower which bears against the follower spring (Fig. 5). In addition to the reciprocating motion, the plunger can be rotated around its axis by the gear which meshes with the control rack. To accomplish fuel metering, an upper helix and a lower helix are machined in the lower part of the plunger. The helix relationship to the ports changes with the rotation of the plunger.

As the plunger moves downward, under pressure of the injector rocker arm, some of the fuel under the plunger moves into the supply chamber through the lower port until the port is covered by the lower end of the plunger. The fuel below the plunger continues to move up through a central passage in the plunger into the fuel metering recess and into the supply chamber through the upper port until that port is covered by the upper helix of the plunger. With the upper and lower ports both covered, the remaining fuel trapped 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 check valve. The fuel in the check valve cage, spring cage, 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 of 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.

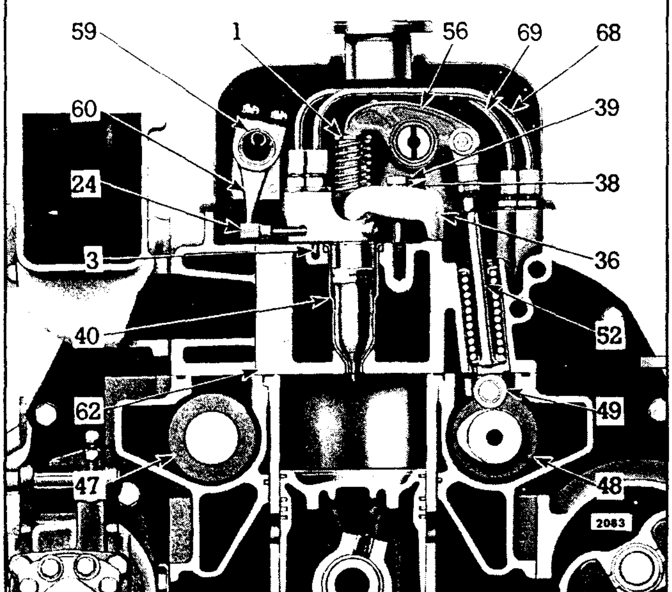


Fig. 5 – Fuel Injector Mounting

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. (Fig. 4) 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 returns to the fuel return manifold and then back to the fuel tank, is directly adjacent to the inlet opening.

Changing the position of the helices, by rotating the plunger, retards or advances the closing of the ports and the beginning and ending of the injection period. At the same time, it increases or decreases the amount of fuel injected into the cylinder. (Fig. 3) 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 all the way 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 fuel injector is one of the most important and precisely built parts of the engine. The injection of the correct amount of fuel into the combustion chamber at exactly the right time depends upon this unit. Because the injector operates against high compression pressure in the combustion chamber, efficient operation demands that the injector assembly is 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.

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. This pressure prevents particles of dirt and dust from entering the room through the doors and windows. A suitable air outlet will remove solvent fumes along with the outgoing air.

Provide the injector repair room with a supply of filtered, moisture-proof compressed air for drying the injector parts after they have been cleaned. Use wash pans of rust-proof material and deep enough to permit all of the injector parts to be completely covered by the cleaning solvent, when submerged in wire baskets of 16 mesh wire screen. Use baskets which will support the parts so as to avoid contact with the dirt which settles at the bottom of the pans.

Rags should never be used for cleaning injector parts since lint or other particles will clog parts of the injector when it is assembled. A lint-free paper tissue is a suitable material for wiping injector parts.

When servicing an injector, follow the general instructions outlined below:

1. Whenever the fuel pipes are removed from an injector, cover the filter caps with shipping caps to keep dirt out of the injectors and prevent damage. Also, protect the fuel pipes and fuel connectors from damage and the 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. Replace the filters only at the time of complete disassembly and overhaul of an injector.
3. Whenever an injector has been removed and reinstalled or replaced in an engine, make the following adjustments as outlined in Section 14:
   a. Time the injector.
   b. Position the injector control rack.
4. 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 (refer to Section 15.3).
5. When a reconditioned injector is to be placed in stock, fill it with injector test oil J 26400. *Do not use fuel oil.* Install shipping caps on both filter caps immediately after filling. Store the injector in an *upright* position to prevent test oil leakage.

   NOTICE: Make sure that new filters have been installed in a reconditioned injector which is to be 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 than the original unit.

Remove Injector

1. Clean and remove the valve rocker cover. Discard the gasket.
2. Remove the fuel pipes from both the injector and the fuel connectors (Fig. 5).

   NOTICE: 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 to bring the upper ends of the push rods of the injector and valve rocker arms in line horizontally. 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 because the bolt could be loosened.

   CAUTION: To reduce the risk of personal injury when barring over or "bumping" the starter, personnel should keep their hands and clothing away from the moving parts of the engine as there is a remote possibility the engine could start.
4. Remove the two rocker shaft bracket bolts and swing the rocker arms away from the injector and valves (Fig. 6).
5. Remove the injector clamp bolt, special washer and clamp.
6. Loosen the inner and outer adjusting screws or adjusting screw and locknut on the injector rack control lever and slide the lever away from the injector.

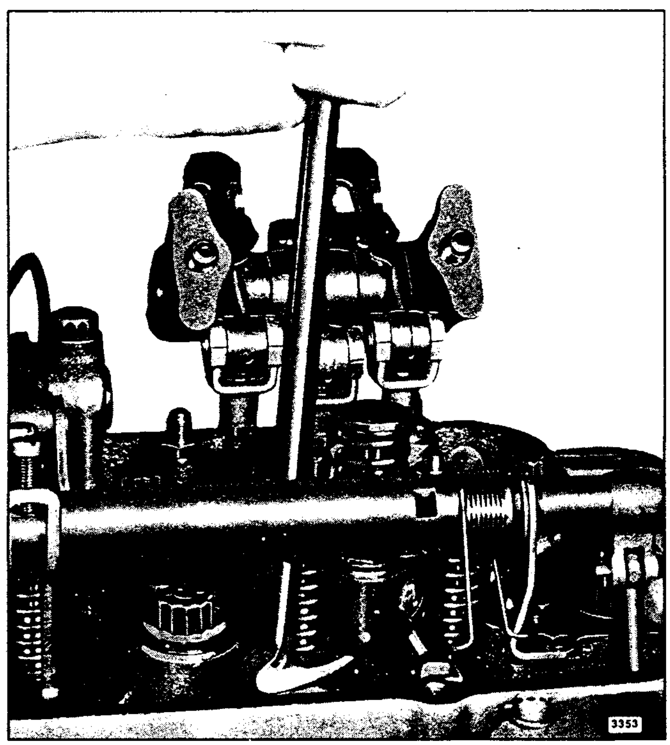


Fig. 6 – Removing Injector from Cylinder Head

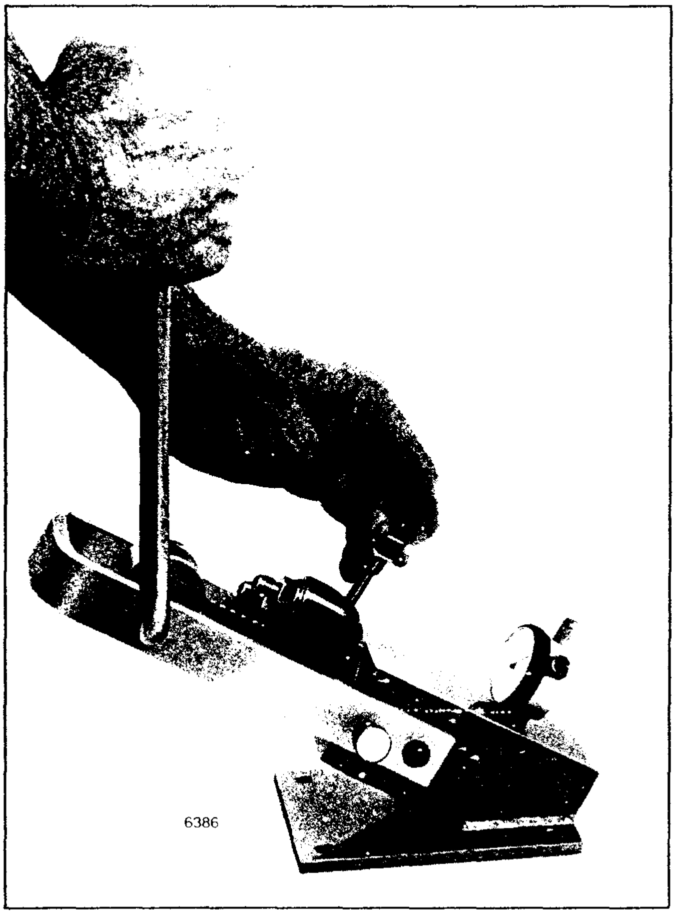


Fig. 7 – Checking Rack for Freeness in Tester J 29584

7. Lift the injector from its seat in the cylinder head (Fig. 6).

8. Cover the injector hole in the cylinder head to keep foreign material out.

9. Clean the exterior of the injector with clean solvent and dry it with compressed air.

CAUTION: To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.

Inspect and Test Prior to Reuse

This inspection and test process is necessary if the injector is being considered for reuse rather than complete overhaul. Submerge the injector in clean solvent to wash it. Blow dry with compressed air.

CAUTION: To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.

1. Inspect the following injector parts for external wear, rust and corrosion.

   Follower spring
   Injector body
   Body nut
   Spray tip
   Injector rack
   Filter caps

2. Inspect the following parts for wear or abrasion deterioration.

   Top of the follower
   Follower spring
   Injector body
   Spray tip orifices

3. Check the rack for freeness and the plunger movement in Tester J 29584.

   With the injector control rack held in the *no-fuel* position, operate the handle to 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 until the follower reaches the top of its travel (Fig. 7). If the rack falls freely, the injector passes the test. If the injector fails the rack freeness test, either the plunger is scored or there is a misalignment of the body, bushing or nut due to irregular or dirty parts.

4. Check the injector for leaks using Tester J 23010–A as outlined in Section 2.0 – Shop Notes.

5. Check the spray pattern, atomization and valve opening pressure using Tester J 23010–A as outlined in Section 2.0 – Shop Notes.

6. Perform injector fuel output test using Calibrator J 22410–A as outlined in Section 2.0 – Shop Notes.

   If the injector passes the above tests, it can be reused.

If the results of the above tests reveal marginal performance, removal of the plunger may assist with further diagnosis of internal injector problems. Plungers that reveal scratches, score marks, abnormal wear, helix chipping or other obvious damage would indicate that the injector should not be reused.

Disassemble Injector

1. Support the injector upright in injector holding fixture J 22396 (Fig. 8) and remove the filter caps, gaskets and filters.

   Whenever a fuel injector is disassembled, discard the filters and gaskets and replace with new filters and gaskets. In the offset injector, a filter is used in the inlet side only. No filter is required in the outlet side (Fig. 9).

2. Compress the follower spring (Fig. 10). Then, raise the spring above the stop pin with a screwdriver and withdraw the pin. Allow the spring to rise gradually.

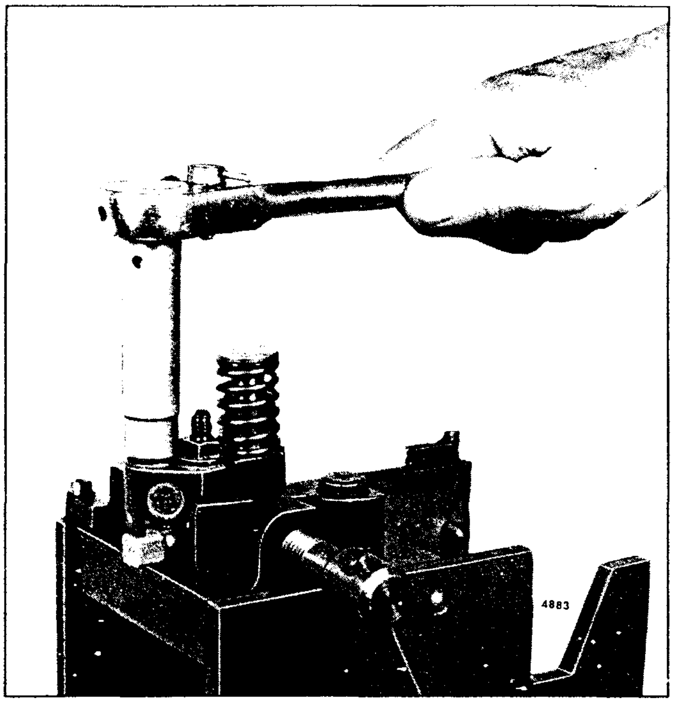


Fig. 8 – Removing Filter Cap

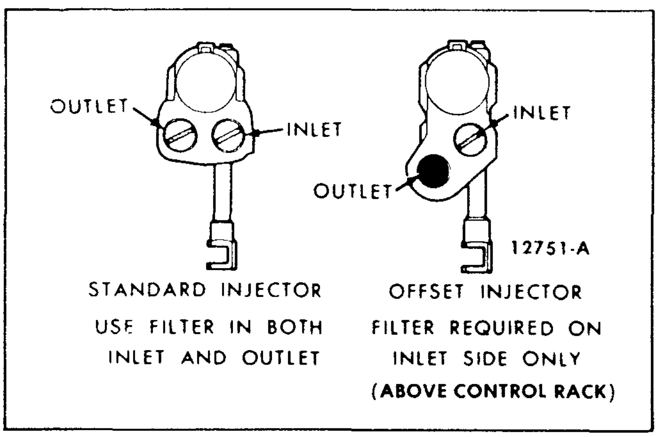


Fig. 9 – Location of Filter in Injector Body

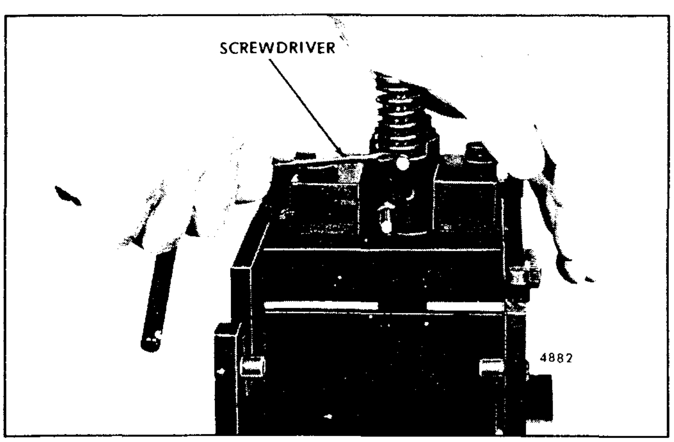


Fig. 10 – Removing Injector Follower Stop Pin

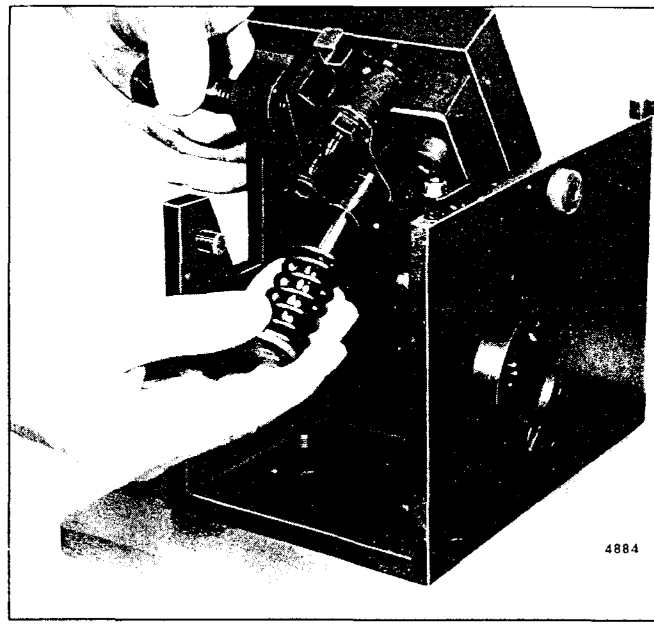


Fig. 11 – Removing or Installing Plunger Follower, Plunger and Spring

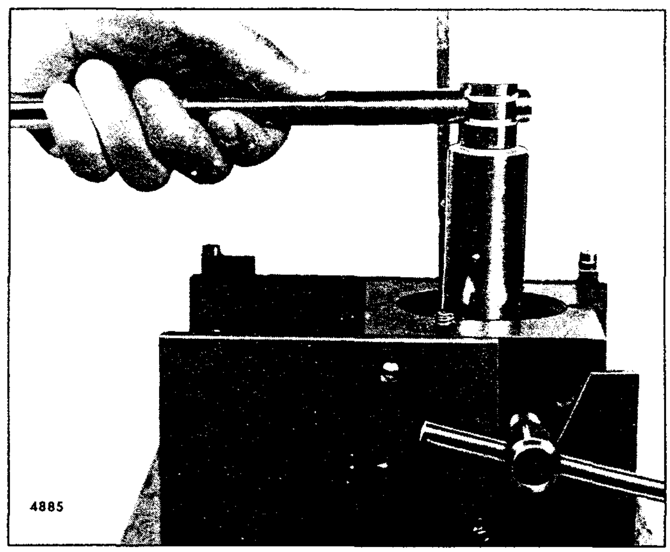


Fig. 12 – Removing Injector Nut Using Tool J 4983–01

3. Refer to (Fig. 11) and remove the plunger follower, plunger and spring as an assembly.

4. Using socket J 4983–01, loosen the nut on the injector body (Fig. 12).

5. Lift the injector nut straight up, being careful not to dislodge the spray tip and valve parts. Remove the spray tip, spring cage, valve spring, spring seat, check valve cage and check valve.

When an injector has been in use for some time, the spray tip, even though clean on the outside, may not be pushed readily from the nut with the fingers. In this event, support the nut on a wood block and drive the tip down through the nut, using tool J 1291–02 (Fig. 13).

6. Refer to (Fig. 14) and remove the spill deflector. Then, lift the bushing 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.

Clean Injector Parts

Since most injector problems 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 a suitable cleaning solvent and dry them with clean, filtered compressed air. Use lint free towels to wipe off the parts. Clean out the passages, drilled holes and slots in all of the injector parts.

CAUTION:To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.

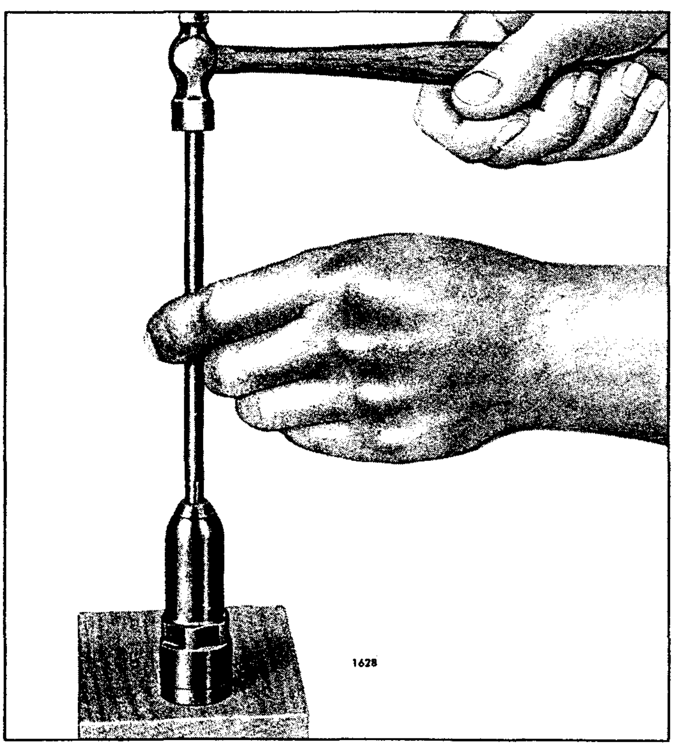


Fig. 13 – Removing Spray Tip from Injector Nut Using Tool J 1291–02

Carbon on the inside of the spray tip may be loosened for easy removal by soaking for approximately fifteen (15) minutes in a suitable solution prior to the external cleaning and buffing operation.

Clean the spray tip with tool J 24838 (Fig. 15).

NOTICE: Care must be exercised when inserting the carbon remover J 24838 in the spray tip to avoid contacting the needle valve seat in the tip.

Wash the tip in solvent and dry it with compressed air. Clean the spray tip orifices with pin vise J 4298–1 and the proper size spray tip cleaning wire. Use wire J 21460–01 to clean .0055″ diameter holes and wire J 21461–01 to clean .006″ diameter holes (Fig. 16).

Before using the wire, hone the end until it is smooth and free of burrs and taper the end a distance of 1/16″ with stone J 8170. Allow the wire to extend 1/8″ from tool J 4298–1. Ultra sonic cleaning is also an acceptable method.

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 24838 and hold the body of the tip against the buffing wheel. In this way, the spray tip is rotated while being buffed.

NOTICE: Do not buff the spray tip area excessively. *Do not use a steel wire buffing wheel or the spray tip holes may be distorted.*

When the body of the spray tip is clean, lightly buff the tip end in the same manner to clean the spray tip orifice area.

Wash the spray tip in clean solvent and dry it with compressed air.

CAUTION:To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.

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. 17). Turn it in a clockwise direction a few turns, then remove the reamer and check the face of the ring for reamer contact over the entire face of the ring. If necessary, repeat the reaming procedure until the reamer does make contact with the entire face of the ring. Clean up the opposite side of the ring in the same manner.

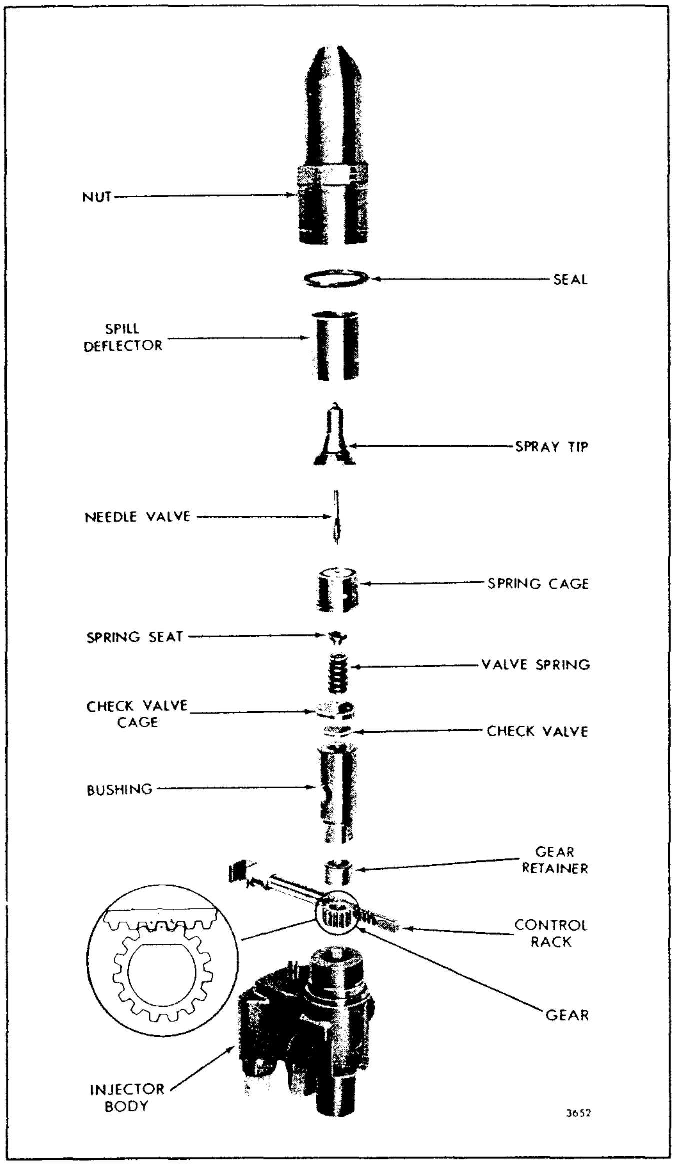


Fig. 14 – Injector Rack, Gear, Spray Tip and Valve Assembly Details and Relative Location of Parts

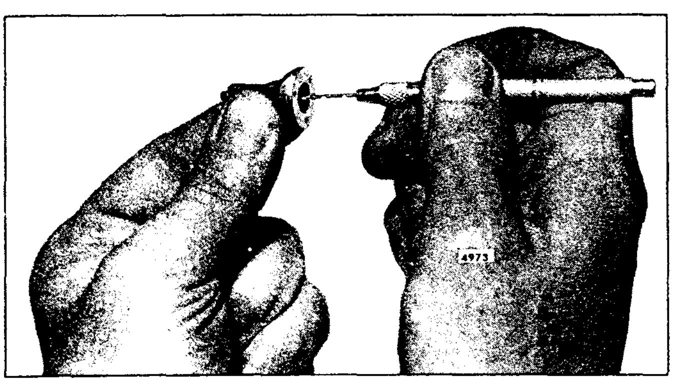


Fig. 15 – Cleaning Injector Spray Tip with Tool J 24838

Carefully, insert reamer (J 21089) into the ring bore of the injector body. Turn the reamer in a clockwise direction

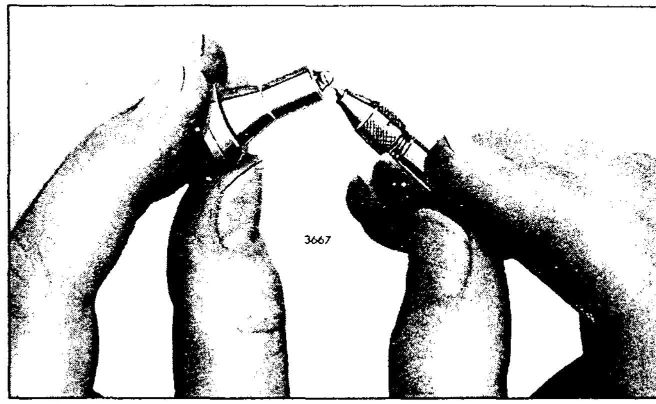


Fig. 16 – Cleaning Spray Tip Orifices with Tool J 4298–1

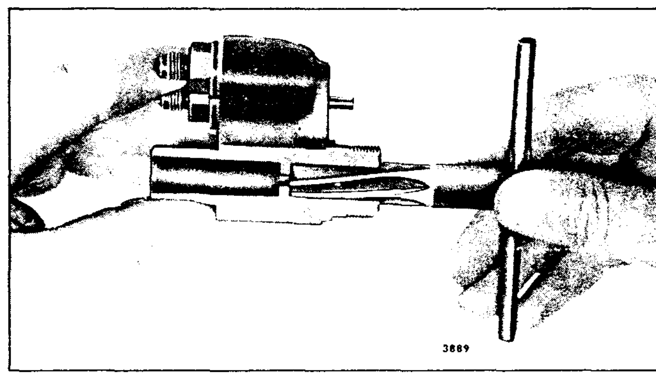


Fig. 17 – Cleaning Injector Body Ring with Tool J 21089

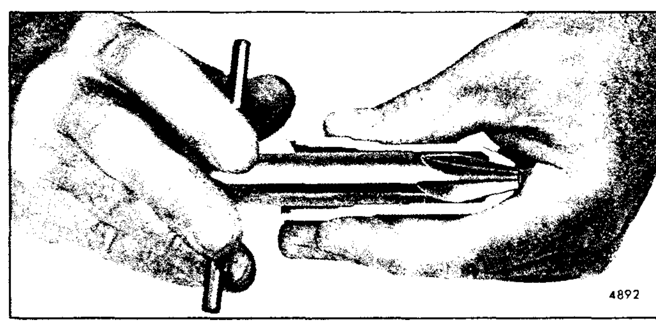


Fig. 18 – Cleaning Injector Nut Lower End with Tool J 9418–5

and remove any burrs inside the ring bore. Then, wash the injector body in clean solvent and dry it with compressed air.

- **NOTICE:** Do not damage the injector body ring during this operation. This spiral ring forms part of the injector body and is not serviced. If the ring is damaged, the injector body must be replaced.

Remove the carbon deposits from the lower end of the injector nut with reamer J 9418–5 (Fig. 18). Clean the tip seat with reamer J 9418–1. Use care to minimize removing metal or setting up burrs on the spray tip seat. Remove only enough metal to produce a clean uniform seat to prevent leakage between the tip and the nut.

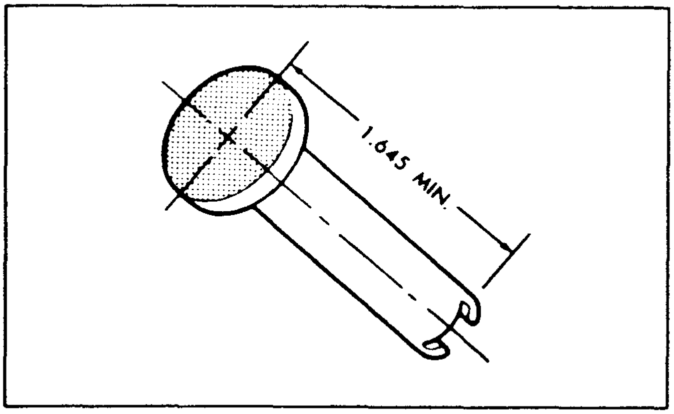


Fig. 19 – Injector Follower

Wash the injector nut in clean solvent 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 solvent and dry them 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/bushing together as they are matched parts.*

After washing, submerge the parts in a clean receptable containing clean test oil. *Keep the parts of each injector assembly together.*

Inspect Injector Parts (Visual and Dimensional)

1. Follower

   Measure between the top of the follower and the slot. This dimension must be 1.647 ± .002″ (Fig. 19).

   Check the stop pin groove in the side of the follower to be sure it is smooth and not damaged. The follower should not be reused if there is more than .002″ wear on the top or if there is any other visible damage or wear.

2. Follower Spring:

   Examine the outside diameter of the follower spring coils for wear caused by the rocker arms contacting the coils. If worn, do not reuse.

   Also, inspect for damage from rust pitting, nicks or notches in the coils, broken coils, broken coil ends and notches under the coil ends. If damaged, do not reuse.

   Check the follower spring tension with spring Tester J 29196.

   The current injector follower spring (.142″ diameter wire) 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″. The former spring wire was .120″ diameter.

   It is recommended that at the time of overhaul, all injectors in an engine be converted to incorporate the current spring (.142″ diameter wire). However, in the event that one or two injectors are changed, the remaining injectors need not be reworked to incorporate the current spring.

3. Injector Body:

   Inspect the injector body threads, the bushing seating surface and the filter cap gasket sealing surfaces for damage. Then, inspect the rack hole, body seal ring sealing surface, clamp radius and dowel pin.

4. Filter Cap:

   Check the condition of the jumper line sealing surfaces on the filter caps, the copper gasket sealing surfaces, the threads and the fuel passage.

5. Control Rack

   Check the injector control rack for straightness, the teeth for wear and the width of the notch in the clevis. Also, check the rack for nicks, burrs, rust and hardness.

   The notch in the clevis should be .3125″ to .3145″. A .250″ inside diameter bushing may be used to check the rack for straightness. A slightly bent rack will not pass freely back and forth through the bore of the bushing.

6. Gear and Gear Retainer

   Inspect the gear and the gear retainer for nicks, burrs or rust and the gear teeth for wear.

• 7. & 8. Plunger and Bushing Assembly:

   • Effective with injectors manufactured in October, 1985, the P & B (plunger and bushing) assemblies of all fuel injectors have a revised finish on the inside diameter of the bushing that provides greater resistance to scoring during injector operation.

   • Revised P & B assemblies are identified with a black locating pin at the top of the bushings. Injector assemblies containing revised P & B's are date stamped on the body with a "10–85" (for October, 1985) or later build date. Revised P & B assemblies are physically interchangeable with early P & B assemblies. However, because of the increased resistance to scoring provided by the revised assemblies, DDC recommends using the revised assemblies when rebuilding fuel injectors.

   • **NOTICE:** Do not attempt to install the plunger of one P & B into the bushing of another P & B and vise–versa. Since the components of P & B assemblies are supplied as precision matched sets, any attempt to mix them can result in P & B seizure and serious injector damage.

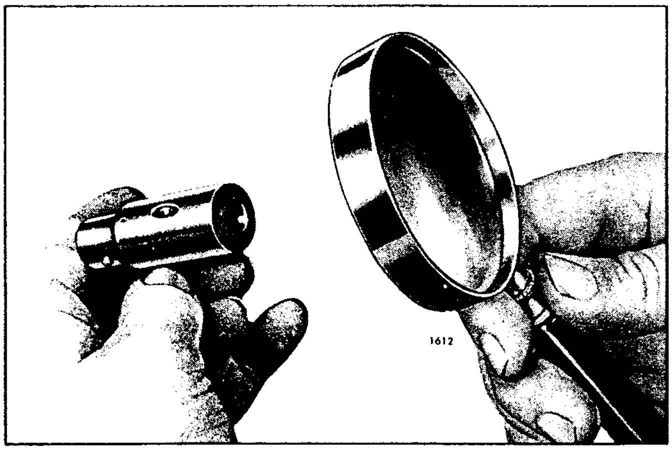


Fig. 20 – Examining Sealing Surface with a Magnifying Glass

7. Bushing:

   Check the bushing lapped sealing surface for scratches, the bushing internal diameter for scoring, the condition of the dowell pin and check for corrosion or varnish (Fig. 20).

8. Plunger:

   Check the plunger for corrosion or varnish, scoring, scratching or wear and chips along the edge of the helix (Fig. 21).

9. Check Valve:

   Inspect the check valve for cracks and scratches on the lapped surfaces or for corrosion and varnish.

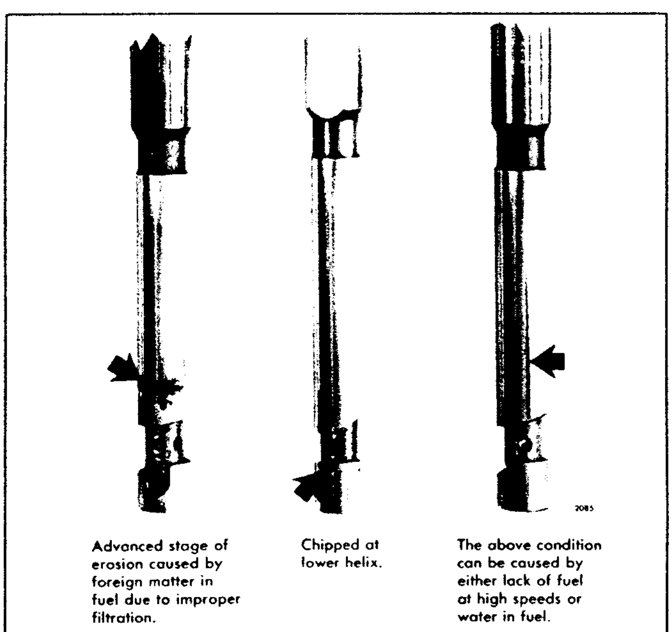


Fig. 21 – Unusable Injector Plungers

10. Check Valve Cage:

    Inspect the check valve cage for cracks and scratches on the lapped surfaces or for corrosion, varnish and wear.

11. Valve Spring:

    Check the injector valve spring for wear on the coil ends, broken coil ends and notches under the coil ends. Then, check for corrosion, nicks and cavitation erosion on the inside at approximately 1-1/2 coils from the end.

    NOTICE: A high V.O.P. (valve opening pressure) valve spring and seat are being used in certain high output engine injectors. The high V.O.P. spring is made of a thicker diameter wire than the standard valve spring and has a smaller inside diameter (.174" I.D. vs .184" I.D.). A no. 15 (.180") drill may be used to distinguish the two springs. The drill will fit into the standard spring, but not into the high V.O.P. spring. The high V.O.P. spring seat can be distinguished from the standard spring seat by its smaller diameter post and the groove on the end of this post. To ensure proper operation, the high V.O.P. spring and seat must be used together. *Do not mix injectors containing standard springs and seats with injectors having high V.O.P. springs and seats in the same engine.*

12. Spring Seat:

    Check the surfaces for wear.

13. Spring Cage:

    Inspect for cracks, corrosion or varnish and scratches on the lapped sealing surfaces. Also, inspect the spring seat surface and the needle valve seating surface for wear.

14. Spray Tip:

    Check for cracks, enlarged spray holes, corrosion on the outside diameter taper and oxide scale on the spray hole end. Then, check the nut-to-tip sealing surface and the lapped sealing surface for scratches. Do not reuse if there is scale, cracks or enlarged spray holes.

15. Needle Valve:

    Check the spray tip needle valve for erosion at the seat shoulder, scratches and overheating (discolored).

16. Nut:

    Check the nut for damaged threads, the condition of the seal ring seating area, the condition of spray tip seating area and the spray tip hole for being corroded irregularly.

17. Spill Deflector:

    Inspect both ends of the spill deflector for sharp edges or burrs.

18. Part Thickness:

Check the minimum thickness of the parts (see Table 1).

Part Name	Minimum Thickness
Spray Tip (shoulder)	.199"
Check Valve Cage	.163"—.165"
Check Valve	.022"
Valve Spring Cage	.602"

TABLE 1 – MINIMUM THICKNESS (Used Parts)

19. Needle Valve Lift:

Measure the needle valve lift, using tool J 9462–02 (Fig. 22) as follows:

a. Zero the indicator by placing the bottom surface of the plunger assembly on a flat surface and zero the indicator dial.

b. 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.

c. While holding the spray tip and needle valve assembly tight against the gage, read the needle valve lift on the indicator. The lift should be .008" to .018". If it exceeds .018", the tip assembly must be replaced. If it is less than .008", inspect for foreign material between the needle valve and the tip seat.

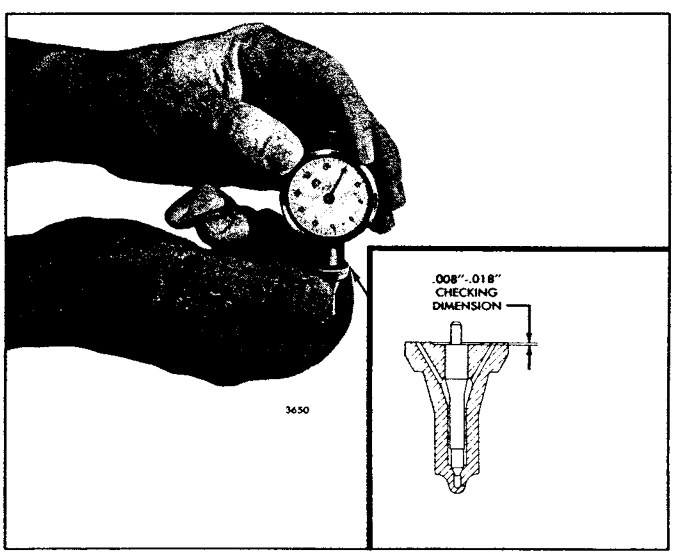


Fig. 22 – Checking Needle Valve Lift with Tool J 9462–02

d. If the needle valve lift is within 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 and seat indicates the spray tip and needle valve assembly should be replaced.

20. Classify Spray Tip:

Match the plunger/bushing assembly with the proper spray tip using Flow Gage J 25600–A (see Section 2.0).

Recondition Injector

If any of the injector parts listed below cannot be reconditioned satisfactorily, use new parts. Al parts must be cleaned to be free of rust, varnish and carbon before reuse.

1. Follower:
   - Resurface or replace if worn beyond dimensional limits.
2. Follower Spring:
   - Reuse unless damaged, worn or won't meet test specifications.
3. Body:
   - Lap bushing seat.
   - Reblue.
   - Repair damaged threads.
   - Replace body if the clamp radius is badly worn or if the threads are less than 90% good.
4. Filter Caps:
   - Recondition tapered seat.
   - Clean and deburr hole.
   - Reblue.
   - Replace if the threads or sealing surfaces are damaged.
5. Control Rack:
   - Deburr teeth – check for straightness.
   - Replace if the teeth show significant wear.
6. Gear and Gear Retainer:
   - Deburr.
   - Replace if cracked or significantly worn.
7. Bushing:
   - Replace if scored, cracked or if residue cannot be removed.
   - Lap the check valve seat (sealing) surface.
8. Plunger:
   - Clean – remove varnish.
   - Replace if scored, chipped or scratched.
9. Check Valve:
   - Lap both flat (sealing) surfaces.
   - Replace if scratched, cracked or badly worn.

10. Check Valve Cage:
    - Lap both flat sealing surfaces.
    - Replace if cracked or too thin (see Table 1).
11. Valve Spring:
    - Replace. Do not reuse unless there is absolutely no wear or damage.
12. Spring Seat:
    - Replace if there is a hole worn in the rounded end where the needle quill touches.
13. Spring Cage:
    - Lap both flat (sealing) surfaces.
    - Replace if cracked or too thin (see Table 1) or if the needle has worn a pocket around the small hole.
14. Spray Tip:
    - Regrind seat.
    - Lap flat sealing surface.
    - Regrind the needle conicol seat.
    - Replace if beyond flow limits i.e., eroded spray holes.
15. Nut:
    - Remove carbon from the seat and tapered I.D.
    - Reblue.
    - Replace if the threads are damaged more than 10% or if the small I.D. is badly eroded.
16. Spill Deflector:
    - Remove burrs.
    - Reuse if the ends are smooth and even and the deflector is not cracked.

Normally, new parts do not require lapping prior to use. Wash the service parts in clean solvent to remove the solitified preservative. However, if new parts become nicked or burred during handling, then lapping will be necessary to provide adequate sealing between the flat parts.

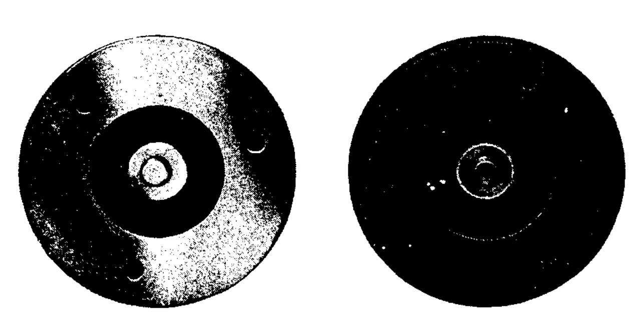


Fig. 23 – Spray Tip Sealing Surface Identification

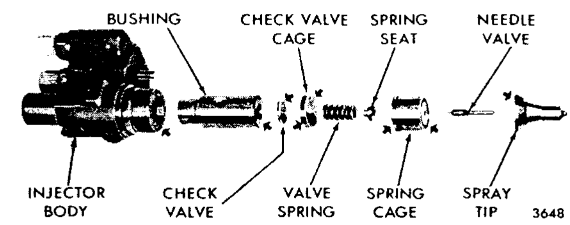


Fig. 24 – Sealing Surfaces which May Require Lapping

The sealing surface of current spray tips is precision lapped by a new process which leaves the surface with a dull satin–like finish; the lapped surface on former spray tips was bright and shiny (Fig. 23). DDC does not recommended lapping the surface of a *new* current spray tip.

Lapping Injector Parts

If necessary, lap the sealing surfaces indicated in (Fig. 24) as follows:

1. Clean the lapping blocks (J 22090) with compressed air. Do not use a cloth or any other material for this purpose.

   CAUTION:To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.

2. Spread a good quality 600 grit dry lapping powder on one of the lapping blocks.

3. Place the part to be lapped flat on the block (Fig. 25) and, using a figure eight motion, move it back and forth across the block. Do not press on the part, but use just enough pressure to keep the part flat on the block. It is important that the part be kept flat on the block at all times.

4. After each four or five passes, clean the lapping powder from the part by drawing it across a clean piece of tissue placed on a flat surface and inspect the part. *Do not lap excessively.*

5. When the part is flat, wash it in cleaning solvent and dry it with compressed air.

   CAUTION:To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.

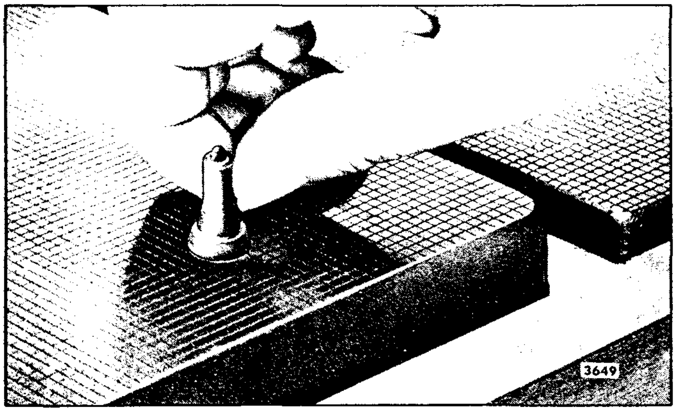


Fig. 25 – Lapping Spray Tip on Lapping Blocks J 22090

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.

CAUTION:To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.

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 parts in clean solvent and dry them with compressed air.

CAUTION:To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.

Assemble Injector

1. Secure the body in vise J 22396–1.

• 2. Insert new filter(s) in the top of the body (Fig. 26). The current production service filter (stainless steel wire mesh pellet) is installed dimple end down, slotted end up. The former service filter (fiberglass–filled nylon cone) was installed with the pointed (cone) end up.

Insert a new filter in the inlet side (located over the injector rack) in an offset injector. No filter is required at the outlet side (Fig. 27).

• 3. Place a new gasket on each filter cap. Lubricate the threads and install the filter caps. Tighten injector filter caps with a 9/16" deep socket as follows:

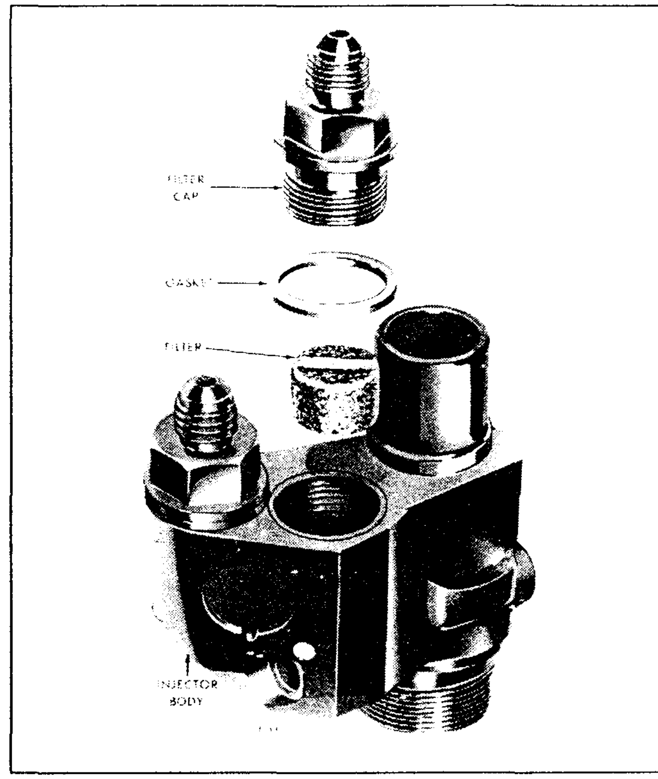


Fig. 26 – Details of Injector Filters and Caps and Their Relative Location

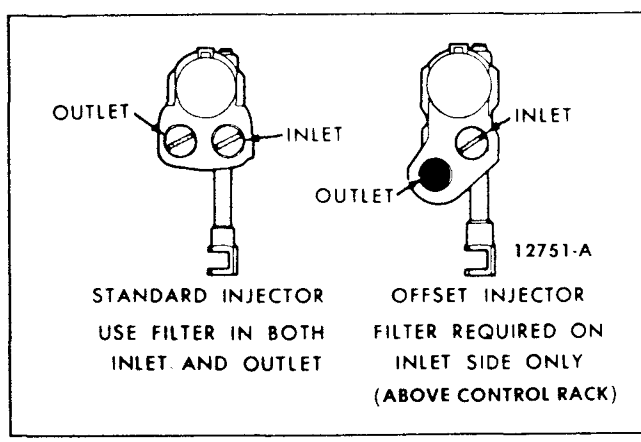


Fig. 27 – Location of Filter in Injector Body

Non–blued cap on non–blued body	62 lb–ft (84 N·m) torque
Blued cap on blued body	70 lb–ft (95 N·m) torque
Non–blued cap on blued body or blued cap on non–blued body	62 lb–ft (84 N·m) torque
Cap for O–Ring sealed fuel pipe	70 lb–ft (95 N·m) torque

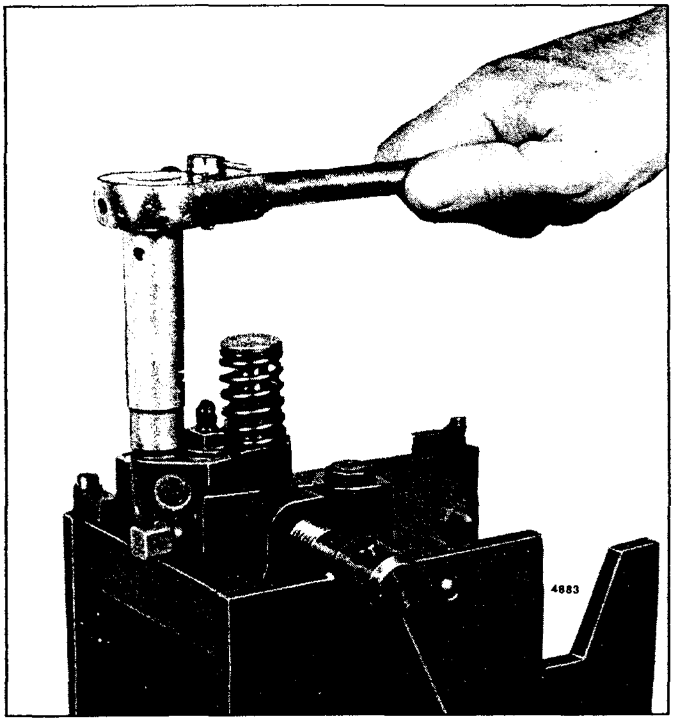


Fig. 28 – Installing Filter Cap

4. Install clean shipping caps to protect the sealing surfaces and to prevent dirt from entering the injector.

5. Lubricate the injector nut seal ring installer J 29197 with injector test oil. Remove the injector from the vise and hold the injector body, bottom end up. Place the installer over the threads of the injector body.

6. Lubricate the new seal ring and place the new seal over the nose of the protector and down onto the shoulder of the injector body. Do not allow the seal to roll or twist.

   - A new round (in cross-section) injector nut seal ring replaced the former diamond-shaped ring, effective with injectors manufactured approximately November 1, 1987. Only the round seal ring is serviced.

7. Remove the protector (J 29197).

8. Slide the control rack into the injector body.

9. Refer to (Fig. 29) and note the marked teeth on the control rack and gear. Then, look into the body bore and move the rack until you can see the drill marks. Hold the rack in this position.

10. Place the gear in the injector body so that the marked tooth is engaged between the two marked teeth on the rack (Fig. 29).

11. Place the gear retainer on top of the gear.

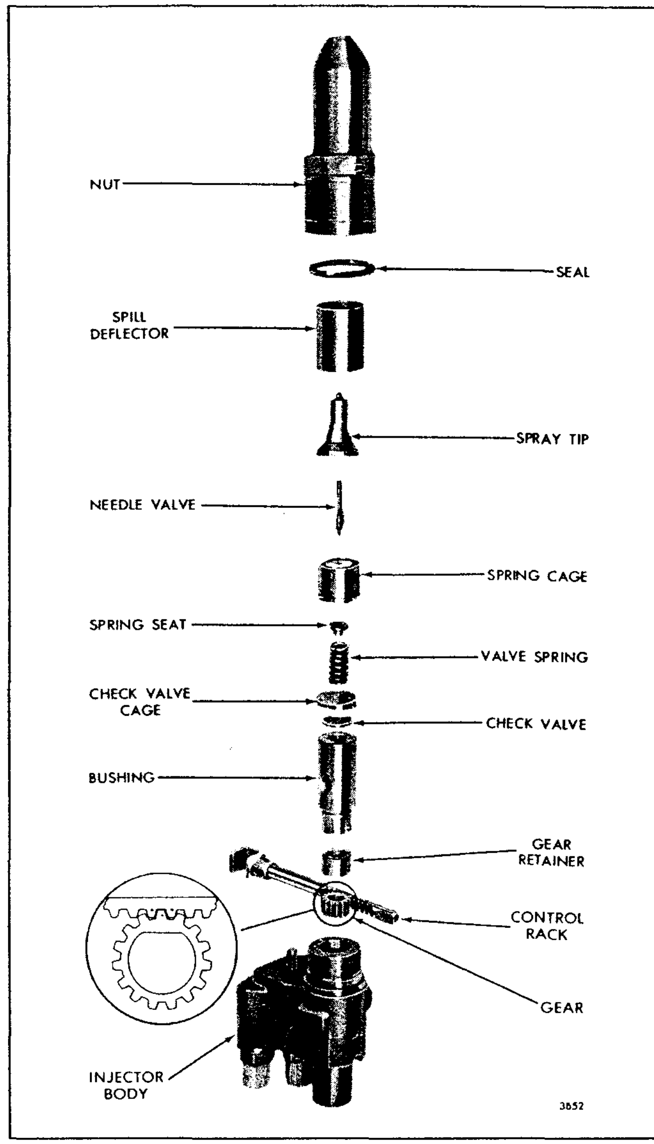


Fig. 29 – Injector Rack, Gear, Spray Tip and Valve Assembly Details and Relative Location of Parts

12. Align the locating pin in the bushing with the slot in the injector body, then slide the end of the bushing into place.

13. Support the injector body, bottom end up, in injector vise J 22396-1.

14. Install the spill deflector over the barrel of the bushing.

15. Perform the spray tip test, as outlined in Section 2.0 using injector tip Tester J 22640-A before proceeding with the injector assembly.

16. Place the check valve (without the .010" hole) centrally on the top of the bushing. Then, place the check valve cage over the check valve and against the bushing. The check valve cage must not rest on the check valve.

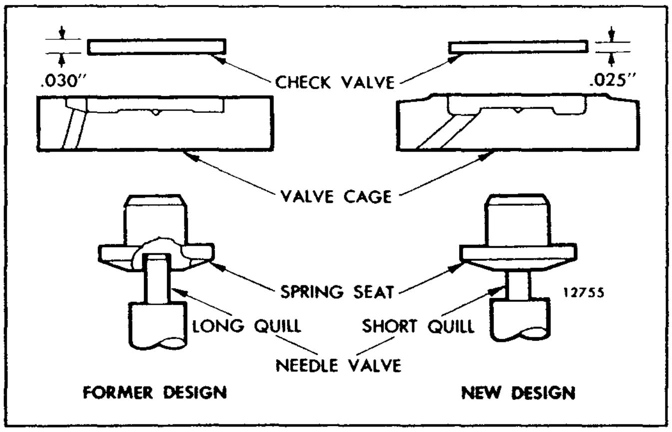


Fig. 30 – Comparison of Former and New Design Injector Parts

The former and new check valve and check valve cage are not separately interchangeable in a former injector (Fig. 30).

17. Insert the spring seat in the valve spring, then insert the assembly into the cage, spring seat first.

18. Place the spring cage, spring seat and valve spring assembly (valve spring down) on top of the check valve cage.

 Do not use new design needle valve spray tip with former design spring seat (Fig. 30).

19. Put the needle, tapered end down, into the spray tip (Fig. 31). Then, place the spray tip assembly on top of the spring cage with the quill end of the needle valve in the hole in the spring cage.

20. 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. 32). 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.

• 21. Use socket J 4983–01 and a torque wrench to tighten the injector nut as follows:

 Non–blued nut on non–blued body . . . . 50 lb–ft (68 N·m) torque

 Blued nut on blued body . . . . 80 lb–ft (108 N·m) torque

 Non–blued nut on blued body or blued nut on non–blued body . . . . 65 lb–ft (88 N·m) torque

22. After assembling a fuel injector, always check the area between the nut and the body. If the seal is still visible after the nut is assembled, try another nut and a new seal which may allow assembly on the body without extruding the seal and forcing it out of the body–nut crevice.

 NOTICE: Do 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.

23. Turn the injector over and push the rack all the way in.

24. Place the follower spring on the injector body.

25. Refer to (Fig. 34) and place the stop pin on the injector body so that the follower spring rests on the narrow flange of the stop pin.

26. Refer to (Fig. 35) and slide the head of the plunger into the follower.

27. Align the slot in the follower with the stop pin hole in the injector body.

28. Align the flat side of the plunger with the flat in the gear.

29. 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 into position. When in place, the spring will hold the stop pin in position.

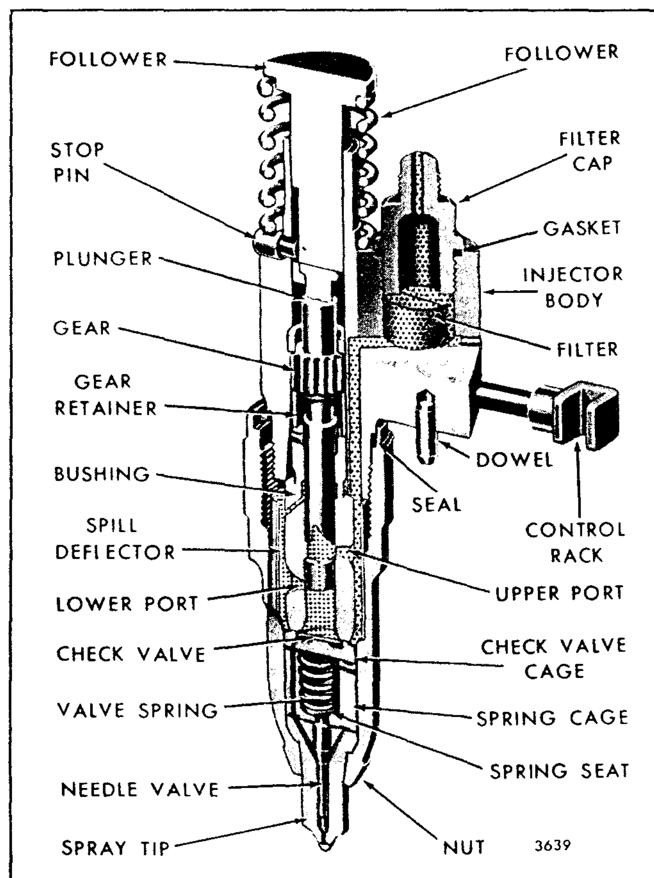


Fig. 31 – Cutaway View of Fuel Injector

2. Rotate the injector 360° and note the total runout as indicated on the dial.

3. If the total runout exceeds .008", remove the injector from the gage. Loosen the injector nut, center the spray tip and tighten the nut to 75–85 lb-ft (102–115 N·m) torque. Recheck the spray tip concentricity. If, after several attempts, the spray tip cannot be positioned satisfactorily, replace the injector nut.

Box and Store Injector

If the reconditioned injector is to be placed in stock, fill it with injector test oil J 26400. *Do not use fuel oil.* Install shipping caps on both filter caps immediately after filling. Store the injector in an *upright* position to prevent test oil leakage.

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 undue stresses from being exerted against the spray tip.

Use injector tube bevel reamer J 5286–9 or a cylindrical wire brush, Section 2.1.4, to clean the carbon from the injector tube. Exercise care to remove ONLY the carbon so that the proper tip protrusion is maintained. Pack the flutes of the reamer with grease to retain the carbon removed from the tube.

Be sure the fuel injector is filled with fuel oil. If necessary, add clean fuel oil at the inlet filter cap until it runs out of the outlet filter cap.

Install the injector in the engine as follows:

1. Refer to (Fig. 5) and insert the injector into the injector tube with the dowel pin in the injector body registering with the locating hole in the cylinder head.

2. Slide the injector rack control lever over so that it registers with the injector rack.

3. Install the injector clamp, special washer (with curved side toward injector clamp) and bolt. Tighten the bolt to 20–25 lb-ft (27–34 N·m) torque. Make sure that the clamp does not interfere with the injector follower spring or the exhaust valve springs.

   NOTICE: Check the injector control rack for free movement. Excess torque can cause the control rack to stick or bind.

4. 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 2.0 – Specifications.

   NOTICE: On four valve cylinder heads, there is a possibility of damaging the exhaust valves if the exhaust valve bridge is not resting on the ends of the exhaust valves when tightening the rocker shaft bracket bolts. Refer to *Install Rocker Arm and Shaft* in Section 1.2.1 and note the position of the exhaust valve bridge before, during and after tightening the rocker shaft bolts.

5. Install fuel pipes:

   - *A. Flared end fuel pipes.* Remove the injector shipping caps. Align the fuel pipes and connect them to the injectors and the fuel connectors.

   NOTICE: DDC recommends that the original fuel pipes not be reused. New flared end fuel pipes should be installed. When installing flared end fuel pipes, use fuel pipe nut wrench J 8932–01 and "clicker" type torque wrench J 24405 (calibrated in inch–pounds) to apply proper torque and avoid damaging the fuel pipes. Refer to the chart for torque specifications. Fuel leakage from damaged or improperly installed fuel pipes can cause lube oil dilution, which may result in serious engine damage.

Fuel Pipe Usage	Torque
Endurion®–coated	130 lb-in. (14.69 N·m)
Uncoated	160 lb-in. (18.3 N·m)
Jacobs Brakes*	120 lb-in. (13.6 N·m)
Load limiting devices	160 lb-in. (18.3 N·m)

**Not serviced. Available from Jacobs Manufacturing Company.*

NOTICE: Because of their low friction surface, Endurion® –coated nuts on fuel jumper lines must be tightened to 130 ***lb-in*** (14.69 N·m) torque, instead of the 160 lb-in (18.3 N·m) required with uncoated nuts. To avoid possible confusion when tightening jumper line nuts, do not mix lines with uncoated and Endurion® –coated nuts on the same cylinder head.

Jacobs brake jumper lines and jumper lines used with load–limiting devices do not have coated nuts. Tighten these to the values shown on the Chart.

NOTICE: 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 (refer to Fuel Jumper Line Maintenance & Pressurize Fuel System – Check for Leaks in Section 2.0 – Shop Notes).

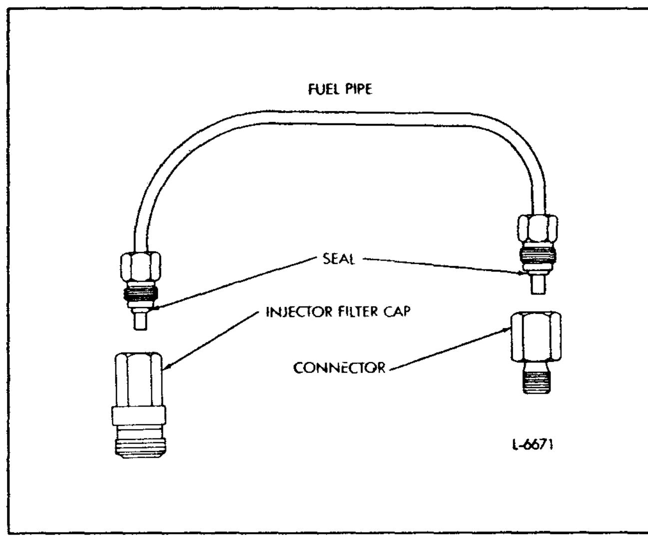
An indication of fuel leakage at the fittings of the fuel injector supply lines and connector nut seals could be either low lubricating oil pressure (dilution) or fuel odor coming from the crankcase breathers or an open oil filler cap. When any of the above are detected, remove the valve rocker cover. A close inspection of the rocker cover, cylinder head, fuel lines and connectors will usually show if there is a fuel leakage problem. Under normal conditions, there should be a coating of lubricating oil throughout the cylinder head area and puddles of oil where the fuel pipes contact the connectors and where the fuel connectors contact the cylinder head. If these areas do not have the normal coating of lubricating oil, it is likely that fuel oil is leaking and washing off the lubricating oil. Remove and replace the leaking fuel pipes and/or connectors. Use a new gasket and reinstall the rocker cover. Then, drain the lubricating oil and change the oil filter elements. Refer to Section 13.3 (Lubrication Specifications) and refill the crankcase to the proper level with the recommended grade of oil.

- *B. O–ring sealed fuel pipes.* Inspect fuel pipes and connectors (Fig. 38) carefully. Fuel pipes may be reused if they are not twisted, bent, distorted or otherwise damaged. O–ring design fuel pipes are not interchangeable with flared tube design fuel pipes on a part–for–part basis. O–ring design fuel pipe connectors and injector filter caps have a 1/2" – 20 female thread to accept the 1/2" – 20 male thread on the fuel pipe nuts. These parts *must* be used together to insure interchangeability.

NOTICE: To avoid fuel leakage, always use new O–ring seals when replacing the fuel pipes on an engine. Do not reuse seals.

Remove the injector shipping caps. Align the fuel pipes and connect them to the injector filter caps and the cylinder head connectors. Using "clicker" type torque wrench J 24405 (calibrated in inch–pounds), tighten the O–ring sealed fuel pipe nuts to 143 ***lb–in*** (16.16 N·m) torque.

6. 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 will only be necessary to adjust the valve clearance and time the injector for the one cylinder, and to position the injector rack control lever.



- Fig. – 38 O–Ring Sealed Fuel Pipes, Connectors, Injector Filter Caps

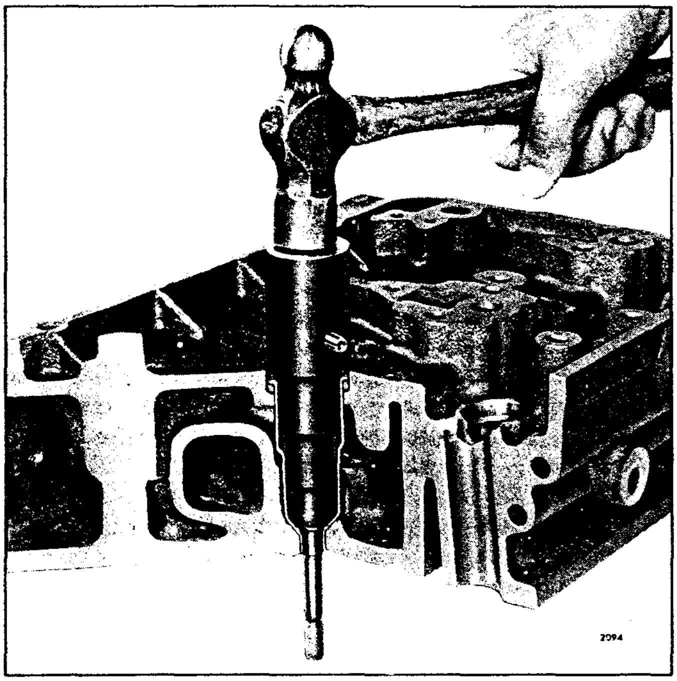


Fig. 2 – Installing Injector Tube Using Tools J 5286–4A and J 5286–5

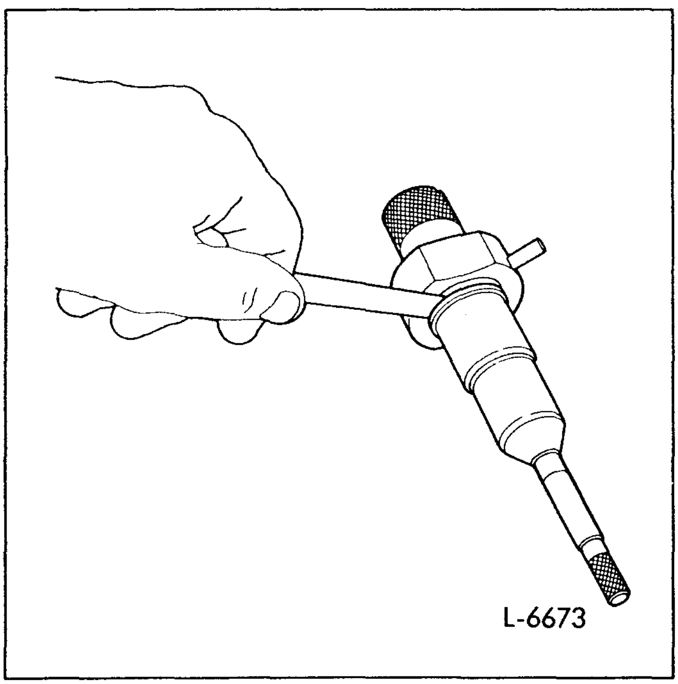


Fig. 3 – Measuring Clearance Between Installation Tool and Top of Hole Tube Flange

• 2. Place the installer J 5286–4C in the injector tube. Then, insert the pilot J 5286–5 through the small opening of the injector tube and thread it into the tapped end of the installer (Fig. 2). For proper installation of any injector hole tube, the tool must contact the tube at the bottom before it touches the flange at the top. The clearance at the top, between the flange and the tool, should be .001" to .010" (Fig. 3).

3. Slip the injector tube into the injector bore and drive it in place (Fig. 2). Sealing is accomplished between the head counterbore (inside diameter) and outside diameter of the injector tube. The tube flange is merely used to retain the seal ring.

• During installation the tube will stretch slightly before the tool contacts the flange, thus allowing the tool to properly install the tube. If there is no clearance at the flange, the tube will buckle slightly during installation until the tool contacts the tube at the lower end. The buckling causes compressive stress which will result in tube cracking during engine operation and subsequent engine damage.

It is permissable for the tube flange at the O–ring seal end to protrude up to .120" above the cylinder head casting without sealing being affected. Sealing is accomplished by compressing the O–ring seal between the head counterbore and the outside diameter of the injector tube. The tube flange is merely used to retain the seal ring in the head counterbore.

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 5286–4C (Fig. 4).

   b. Then, using a socket and torque wrench, apply approximately 30 lb–ft (41 N·m) torque on the upsetting die.

   c. Remove the installing tools and 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 Fig. 5, to receive the injector body nut and spray tip.

Second, *spot–faced* to remove excess stock at the lower end of the injector tube.

Third, *hand reamed,* as shown in Fig. 6, to provide a good seating surface for the bevel or the lower end of the injector nut.

• The new tube takes less time to install than the former tube because the large I.D. (inside diameter) of the new tube does not require reaming. Reaming is only necessary at the small I.D. and the injector nut seat. Reaming must be done carefully and without undue force or speed so as to avoid cutting through the thin wall of the injector tube.

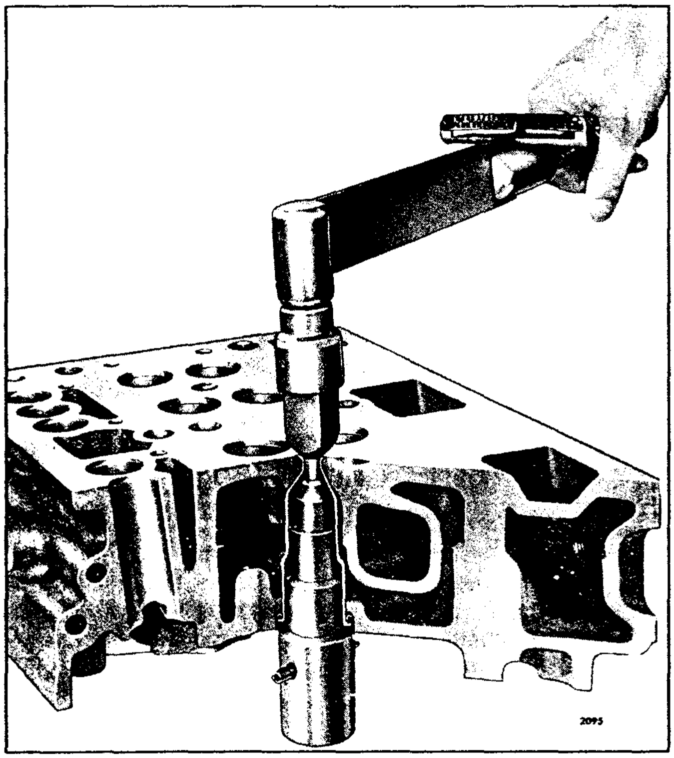


Fig. 4 – Upsetting Injector Tube Using Tools J 5286-4A and J 5286-6

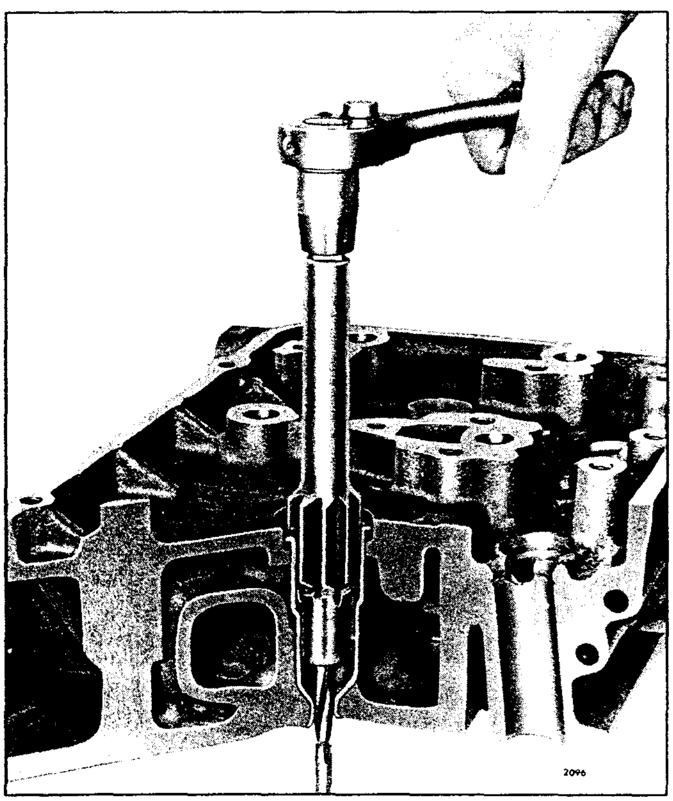


Fig. 5 – Reaming Injector Tube for Injector Body Nut and Spray Tip Using Tool J 22525-1

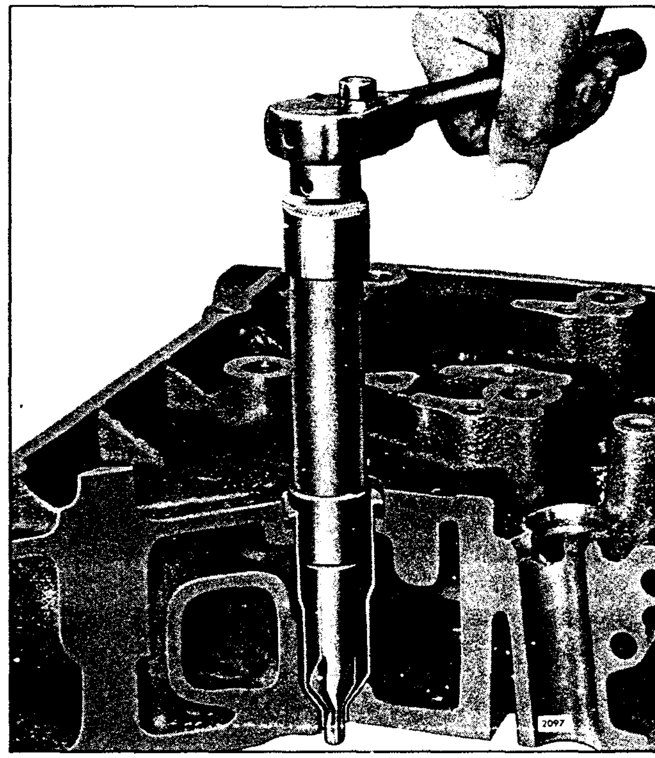


Fig. 6 – Reaming Injector Tube for Injector Nut Using Tool J 5286-9

NOTICE: 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 cutting edges of the flutes.

1. Ream the injector tube for the 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 reamer J 22525-1 in the injector tube.

   b. Turn the reamer in a clockwise direction (withdrawing the reamer frequently for removal of chips) until the lower shoulder of the reamer contacts the injector tube (Fig. 5). Clean out all of the chips.

2. Remove excess stock:

   a. With the cylinder head bottom side up, insert the pilot of cutting tool J 5286-8 into the small hole of the injector tube.

   b. Place a few drops of cutting oil on the tool. Then, using a socket and a speed handle, remove the excess stock so that the lower end of the injector tube is from flush to .005″ below the finished surface of the cylinder head.

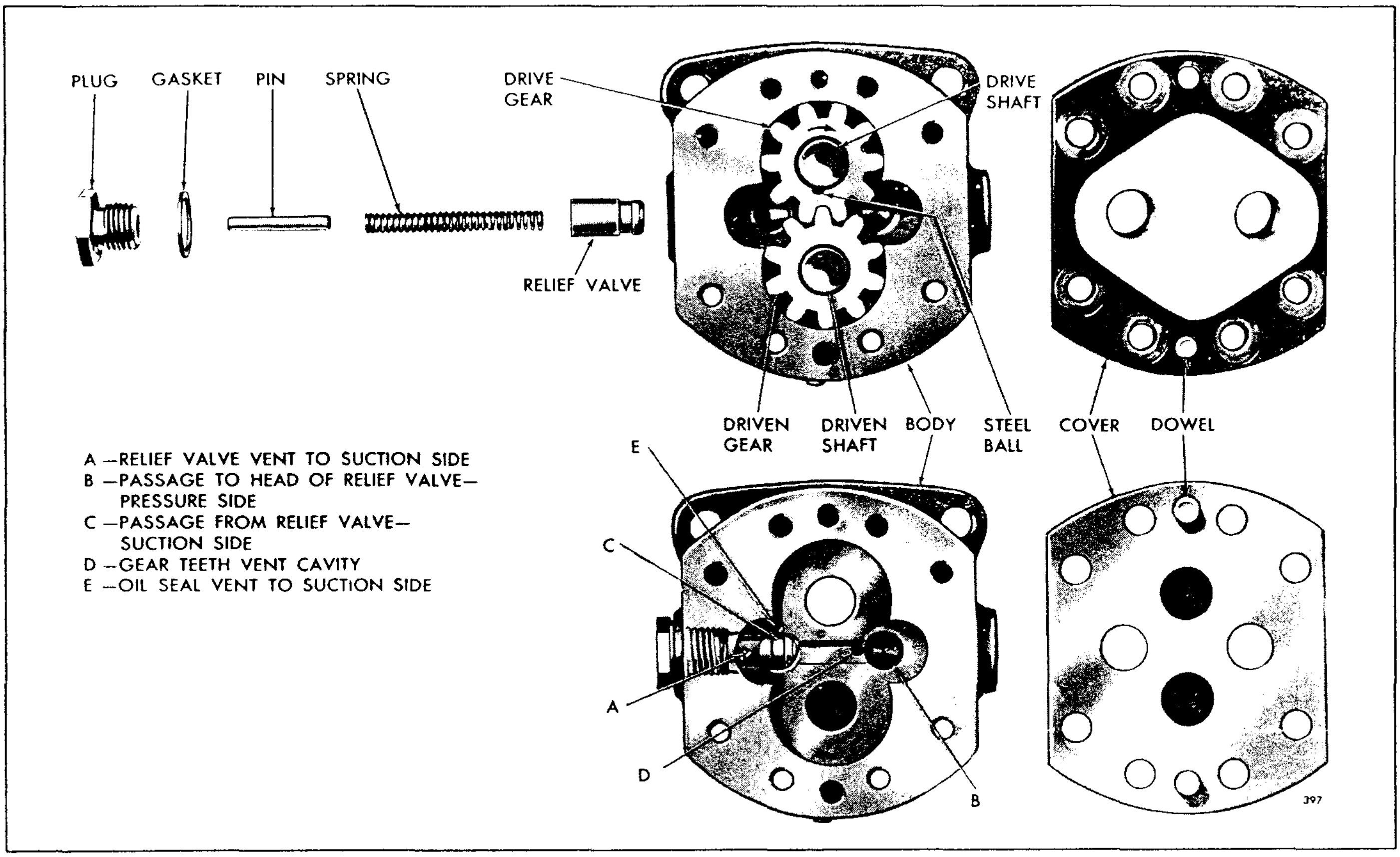


Fig. 2 – Fuel Pump Valving and Rotation (Right Hand Pump Shown)

The drive and driven gears are a line–to–line to a .001" press fit on their shafts. The drive gear is provided with a gear retaining ball to locate the gear on the shaft.

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 the fuel filter) reaches approximately 65 psi (448 kPa).

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 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 (448 to 517 kPa).

The fuel pump should maintain the fuel pressure at the fuel inlet manifold (see Section 13.2).

Remove Fuel Pump

1. Disconnect the fuel lines from the inlet and outlet openings of the fuel pump.
2. Disconnect the drain tube, if used, from the fuel pump.
3. Remove the three pump attaching bolts and withdraw the pump.
4. Check the drive coupling fork and, if broken or worn, replace it with a new coupling.

Disassemble Fuel Pump

With the fuel pump removed from the engine and mounted in holding fixture J 1508–10 as shown in Fig. 4, refer to Figs. 1 and 6 and disassemble the pump as follows:

1. Remove the eight cover bolts and withdraw the pump cover from the pump body. Use care not to damage the finished faces of the pump body and cover.
2. Withdraw the drive shaft, drive gear and gear retaining ball as an assembly from the pump body.

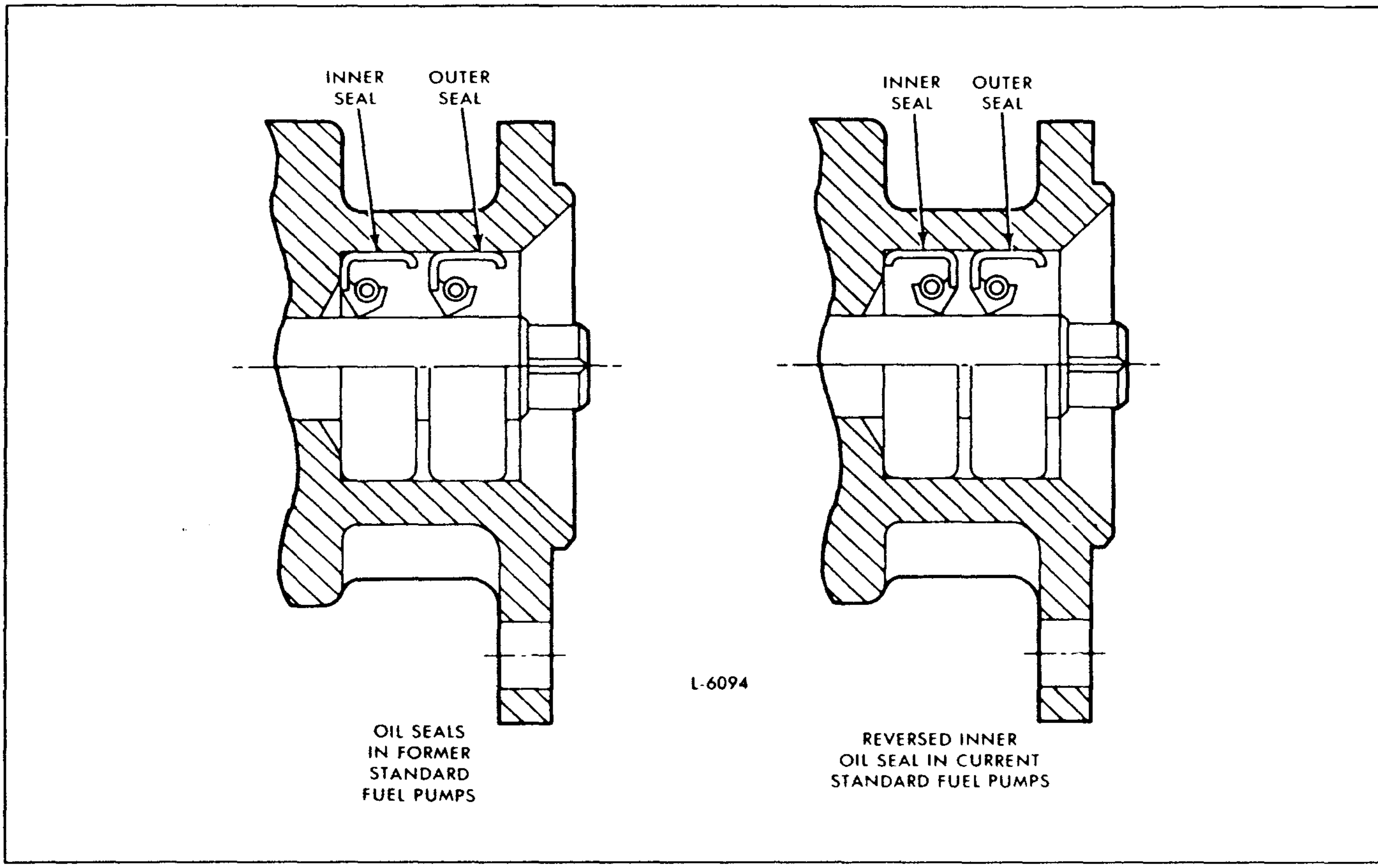


Fig. 3 – Fuel Pump Oil Seal Arrangements

3. Press the drive shaft just far enough to remove the steel locking ball. Then invert the shaft and gear assembly and press the shaft from the 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 only as an assembly.

5. Remove the relief valve plug and copper gasket.

6. Remove the valve spring, pin and relief valve from the valve cavity in the pump body.

7. If the oil seals need replacing, remove them with oil seal remover J 1508–13 (Fig. 5). Clamp the pump body in a bench vise and tap the end of the tool with a hammer to remove the outer and inner seals.

NOTICE: Observe the position of the oil seal lips before removing the old seals to permit installation of the new seals in the same position (Fig. 3).

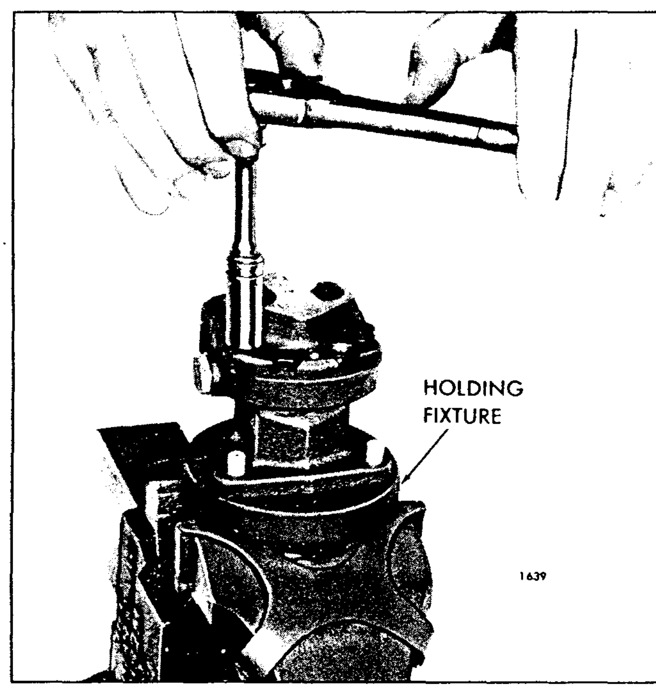


Fig. 4 – Removing Fuel Pump Cover

Inspection

Clean all of the parts in clean fuel oil and dry them with compressed air.

- **CAUTION: To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.**

Oil seals, once removed from the pump body, must be discarded and replaced with new seals.

Check the pump gear teeth for scoring, chipping or wear. Check the ball slot in the drive gear for wear. If necessary, replace the gear.

Inspect the drive and driven shafts for scoring or wear. Replace the shafts if necessary. The driven shaft is serviced as a gear and shaft assembly only.

The mating faces of the pump body and cover must be flat and smooth and fit tightly together. Any scratches or slight damage may result in pressure leaks. Also, check for wear at areas contacted by the gears and shafts. Replace the pump cover or body, if necessary.

The relief valve must be free from score marks and burrs and fit its seat in the pump body. If the valve is scored and cannot be cleaned up with fine emery cloth or crocus cloth, it must be replaced.

Current standard fuel pumps (with 1/4" wide gears) incorporate a 1/8" shorter pump body with three drain holes, a 1/8" shorter drive shaft and a cover with a 3/8" inlet opening. When replacing a former pump, a 3/8" x 1/4" reducing bushing is required for the inlet opening and the unused drain holes must be plugged.

Assemble Fuel Pump

Refer to Figs. 1, 2, 3 and 6 and assemble the pump as follows:

1. Lubricate the lips of the oil seals with a light coat of vegetable shortening, then install the oil seal in the pump body as follows:

   a. Place the inner oil seal on the pilot of the installer handle J 1508-8 so that the lip of the seal will face toward the shoulder on the tool.

   When replacing the former nitrile fuel pump seals with the current polyacrylate seals, install them with the seal lips facing each other (Fig. 3).

   b. With the pump body supported on wood blocks (Fig. 7), insert the pilot of the installer handle in the pump body so the seal starts straight into the pump flange. Then drive the seal in until it bottoms.

   c. Place the shorter end of the adaptor J 1508-9 over the pilot and against the shoulder of the installer handle. Place the outer oil seal on the pilot of the installer handle with the lip of the seal facing the adaptor. Then insert the pilot of the installer handle into the pump body and drive the seal in (Fig. 8) until the shoulder of the adaptor contacts the pump body. Thus the oil seals will be positioned so that the space between them will correspond with the drain holes located in the bottom of the pump body.

2. Clamp the pump body in a bench vise (equipped with soft jaws) with the valve cavity up. Lubricate the outside diameter of the valve and place it in the cavity with the hollow end up. Insert the spring inside of the valve and the pin inside of the spring. With a new gasket in place next to the head of the valve plug, place the plug over the spring and thread it into the pump body. Tighten the 1/2"-20 plug to 18-22 lb-ft (24-30 N·m) torque.

3. Install the pump drive gear over the end of the drive shaft which is not squared (so the slot in the gear will face the plain end of the shaft). This operation is very important, otherwise fine score marks caused by pressing the gear into position from the square end of the shaft may cause rapid wear of the oil seals. Press the gear beyond the gear retaining ball detent. Then place the ball in the detent 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 oil seals as shown in Fig. 9.

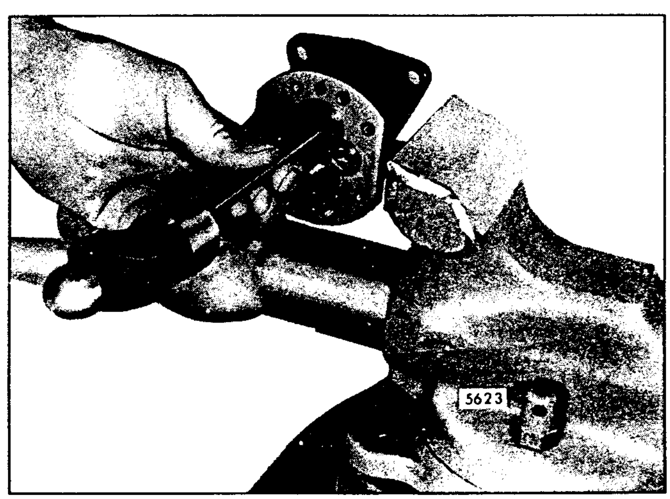


Fig. 5 – Removing Oil Seals Using Tool J 1508-13

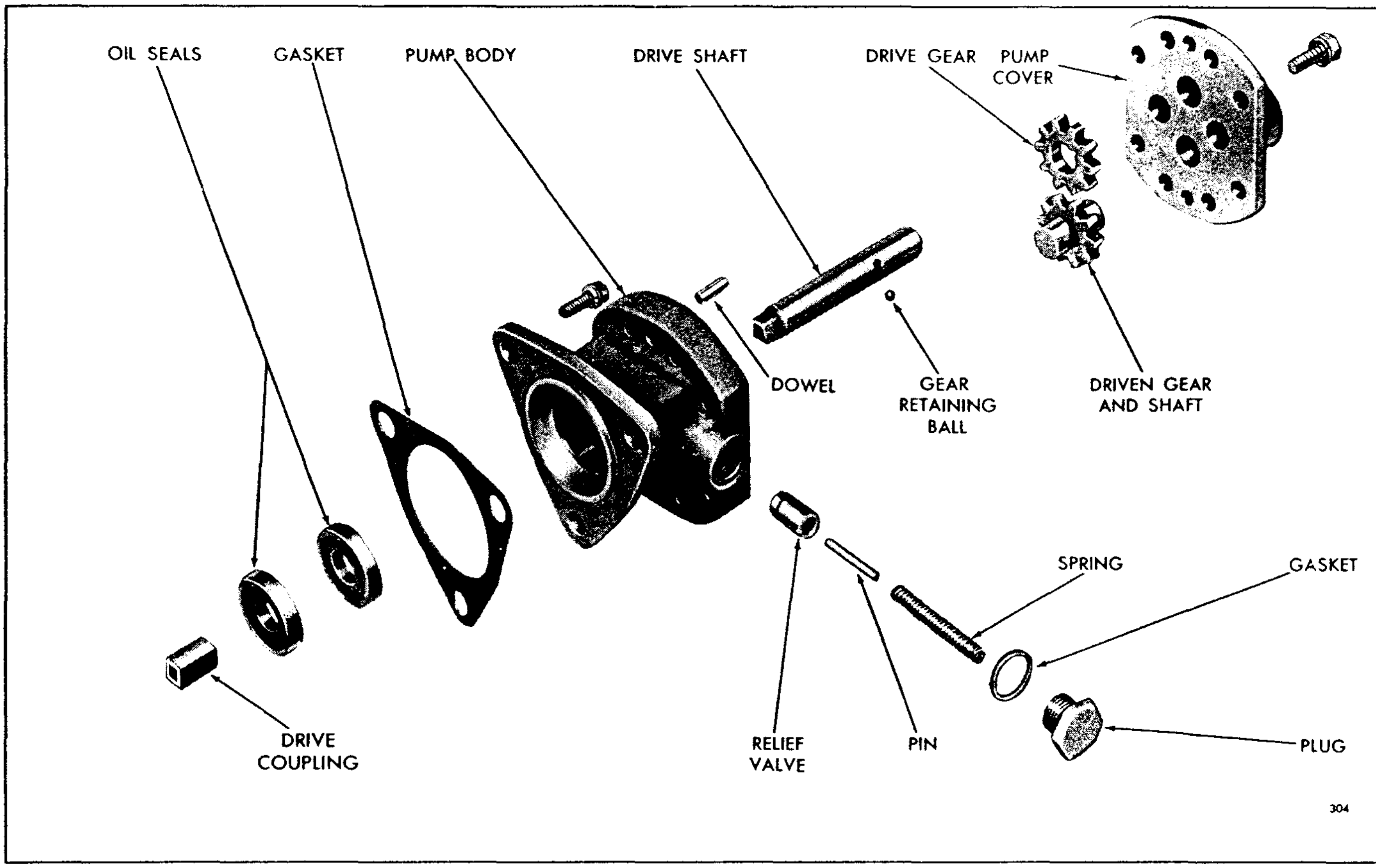


Fig. 6 – Fuel Pump Details and Relative Location of Parts (Right Hand Pump Shown)

5. Place the driven shaft and gear assembly in the pump body.

   NOTICE: The driven gear must be centered on the shaft to give proper end clearance. Also, the chamfered end of the gear teeth of the production gear must face the pump body. If a service replacement gear with a slot is used, the slot must face toward the pump cover.

6. Lubricate the gears and shafts with clean engine oil.

7. Apply a thin coat of quality sealant on the face of the pump cover outside of the gear pocket area.

   Then place the cover against the pump body with the two dowel pins in the cover entering the holes in the pump body. The cover can be installed in only one position over the two shafts.

   NOTICE: 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 much 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 the gears and shafts may result.

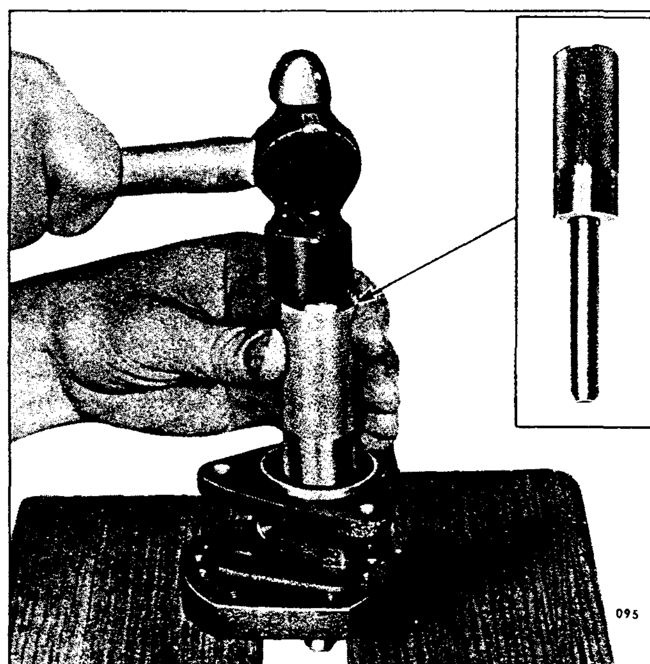


Fig. 7 – Installing Inner Oil Seal Using Tool J 1508–8

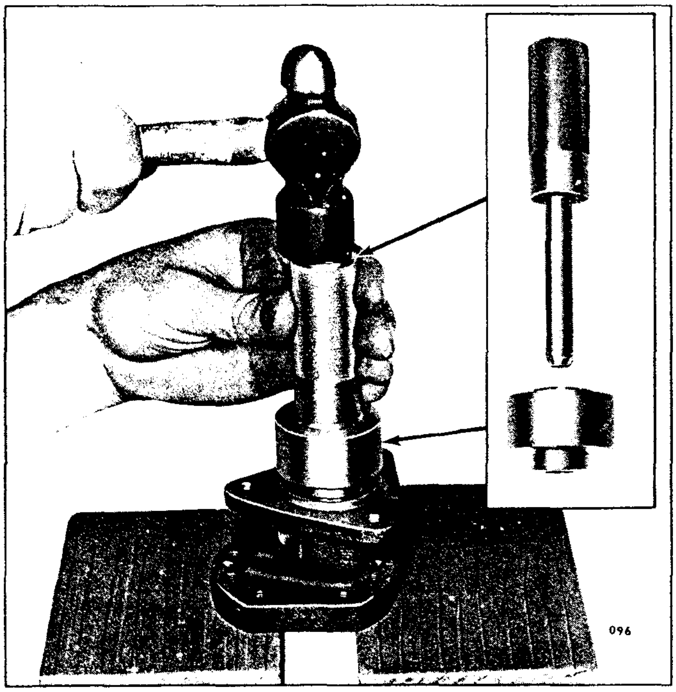


Fig. 8 – Installing Outer Oil Seal Using Tools J 1508-8 and J 1508-9

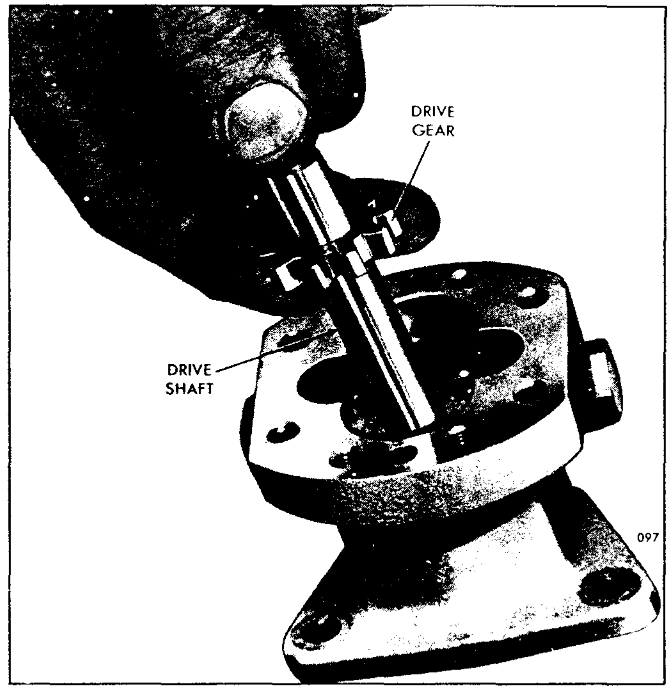


Fig. 9 – Installing Fuel Pump Drive Shaft and Gear Assembly

8. Secure the cover in place with eight bolts and lock washers, tightening the bolts alternately and evenly.
9. After assembly, rotate the pump shaft by hand to make certain that the parts rotate freely. If the shaft does not rotate freely, attempt to free it by tapping a corner of the pump.
10. Install 1/8" pipe plugs in the upper unused drain holes.
11. If the pump is not to be installed immediately, place plastic shipping plugs in the inlet and outlet openings to prevent dirt or other foreign material from entering the pump.

Install Fuel Pump

1. Affix a new gasket to the pump body mounting flange and locate the pump drive coupling over the square end of the fuel pump drive shaft.
2. Install the fuel pump on the engine and secure it with three nylon patch bolts.

   To provide improved sealing against leakage, nylon patch bolts are used in place of the former bolt and seal assemblies.

• 3. If removed, install the inlet and outlet elbows in the pump cover. Before installing, coat the threads lightly with Gasoila, Permatex 2, or an equivalent non-hardening sealant.

- **NOTICE:** Do not use Teflon tape or paste on fittings, since this can result in fuel pump cover damage (cracking) before the required torque is reached.

- To prevent sealant from entering the fuel system, do not apply it to the first two (2) threads of the fittings. Tighten fittings to the low end of the torque. If necessary, continue tightening until alignment is achieved, but do not exceed maximum torque. Tighten fittings to the following values:

Fitting Size	Torque
1/4"	14-16 lb-ft. (19-22 N·m)
3/8"	18-22 lb-ft. (24-30 N·m)
1/2"	20-25 lb-ft. (27-34 N·m)

4. Connect the inlet and outlet fuel lines to the fuel pump.
5. Connect the fuel pump drain tube, if used, to the pump body.
6. If the fuel pump is replaced or rebuilt, prime the fuel system before starting the engine using Primer J 5956. This will prevent the possibility of pump seizure upon initial starting.

FUEL PUMP DRIVE

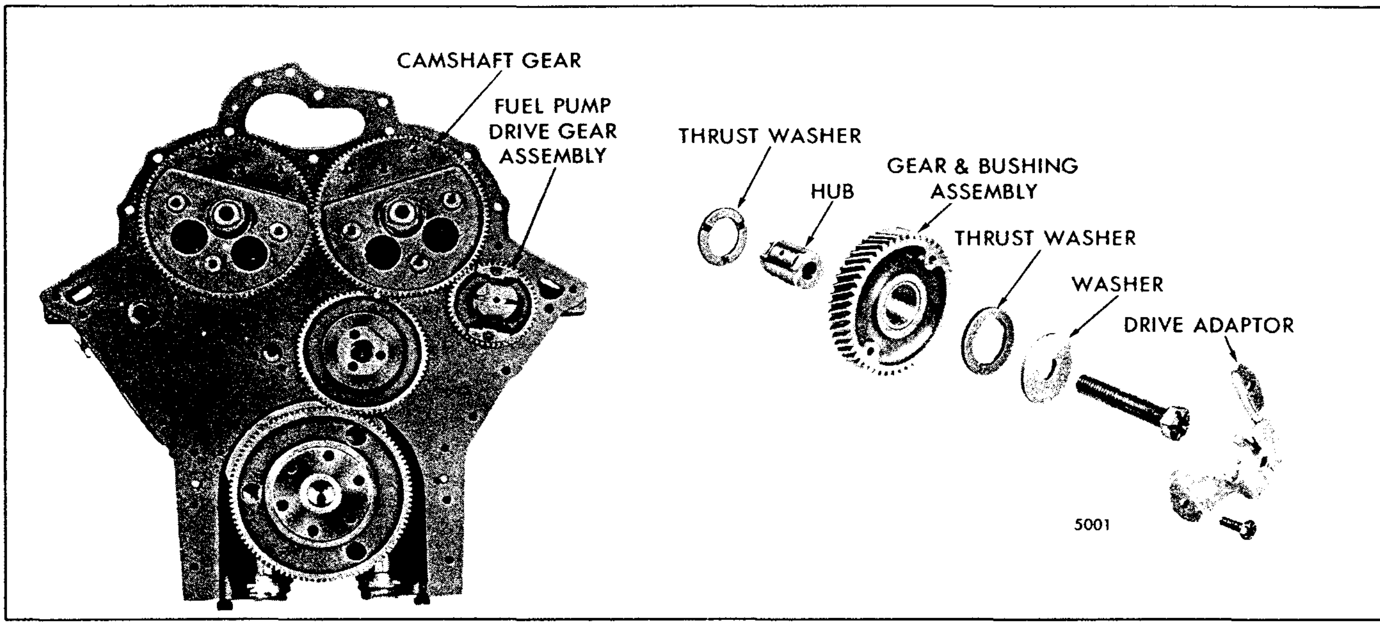


Fig. 1 – Typical Fuel Pump Drive Gear Mounting and Details (V–Type Engine)

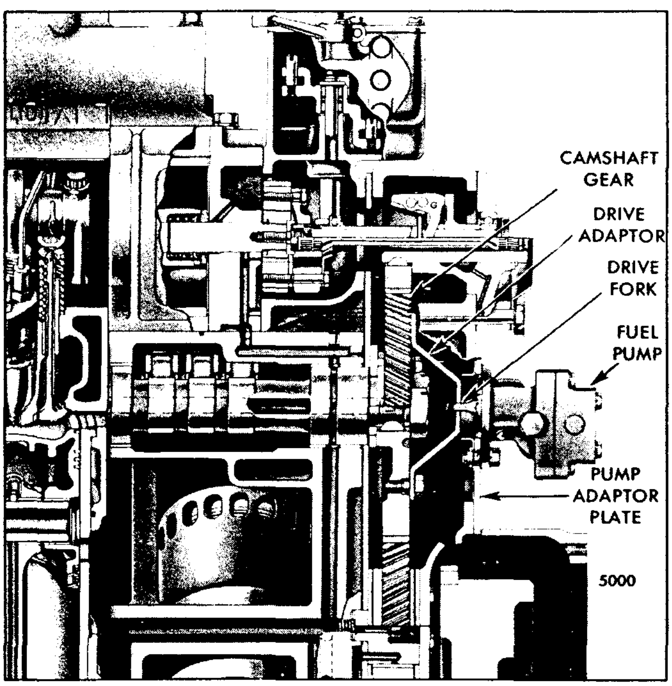


Fig. 2 – Camshaft Drive for Fuel Pump (6V Engine Shown)

On some V–type engines, the fuel pump is mounted on the flywheel housing and is driven by an accessory drive gear. The fuel pump drive consists of a gear, stationary hub and drive adaptor (Fig. 1). The fuel pump drive gear rotates on the stationary hub attached to the cylinder block and is driven at approximately twice the engine speed by the camshaft gear. On other V–type engines, the fuel pump may be driven by either camshaft by means of a drive fork and drive adaptor (Fig. 2), in the same manner as the pump mounted on the flywheel housing of the In–line engines.

The fuel pump on In–line engines is driven by the governor weight shaft by means of a drive coupling. On some engines, the fuel pump is mounted on an adaptor plate attached to the flywheel housing. A drive adaptor attached to the balance shaft gear registers with a drive fork on the fuel pump shaft to provide a drive for the pump. Servicing of the fuel pump and drive on an In–line engine is covered in Section 2.2; the following applies only to a V–type engine.

To reduce the level of engine noise in the Series 53 engines, the pitch and pressure angle of the gear train and accessory drive gears has been changed. Refer to Section 1.7.1.

Lubrication

The fuel pump drive gear bearing (bushing type) is pressure lubricated. Lubricating oil from the oil gallery in the cylinder block flows through a drilled passage in the block, around the gear retaining bolt, and through another drilled hole in the gear hub to the bearing.

Remove Fuel Pump Drive Gear (V–Type Engine)

With the flywheel housing removed, remove the fuel pump drive gear as follows:

1. Remove the bolts and detach the fuel pump drive adaptor from the gear.
2. Loosen the fuel pump drive gear retaining bolt and remove the bolt and washer, gear, thrust washers and hub from the engine.

Inspection

Wash the drive gear and its related parts with fuel oil and dry them with compressed air.

- **CAUTION: To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.**

Inspect the thrust washers, hub and drive gear bearing for wear or scoring. Parts which are excessively worn or scored must be replaced. A pre–finished drive gear bearing (bushing type) is available for service. A new bushing should be pressed in flush to .010" below the gear face (both sides). Examine the gear teeth and, if they are excessively worn, scored or pitted, replace the gear and bushing assembly.

Install Fuel Pump Drive Gear (V–Type Engine)

Install the fuel pump drive gear and its related parts on the engine as outlined below:

1. Lubricate the drive gear bearing, thrust washers and hub with engine oil.
2. Assemble the fuel pump drive gear and thrust washers on the hub. The oil grooves in the thrust washers *must face toward the gear.* Note the position of the oil hole in the hub.

   Do not mix the former and the current hardened gears on the same engine. Mixing the gears will result in the excessive gear wear and may lead to serious engine damage.

   - **NOTICE:** The hardened gears are used on 6V turbocharged automotive engines. This change became effective with engine serial number 6D–229616.
3. Install the hub and gear assembly on the engine with the small diameter of the hub entering the rear end plate and the counterbore in the cylinder block, and the fuel pump drive gear teeth in mesh with the camshaft gear teeth. The oil hole in the hub should be toward the bottom of the engine.
4. Secure the gear and hub assembly in place with the gear retaining bolt and washer. Tighten the 1/2"–13 bolt to 71–75 lb–ft (96–102 N·m) torque.
5. Check the clearance between the gear and the thrust washer. The specified clearance between new parts is between .005" and .018". The maximum clearance between used parts must not exceed .022".
6. Attach the fuel pump drive adaptor to the gear with the two bolts.

FUEL STRAINER AND FUEL FILTER

(BOLT-ON TYPE)

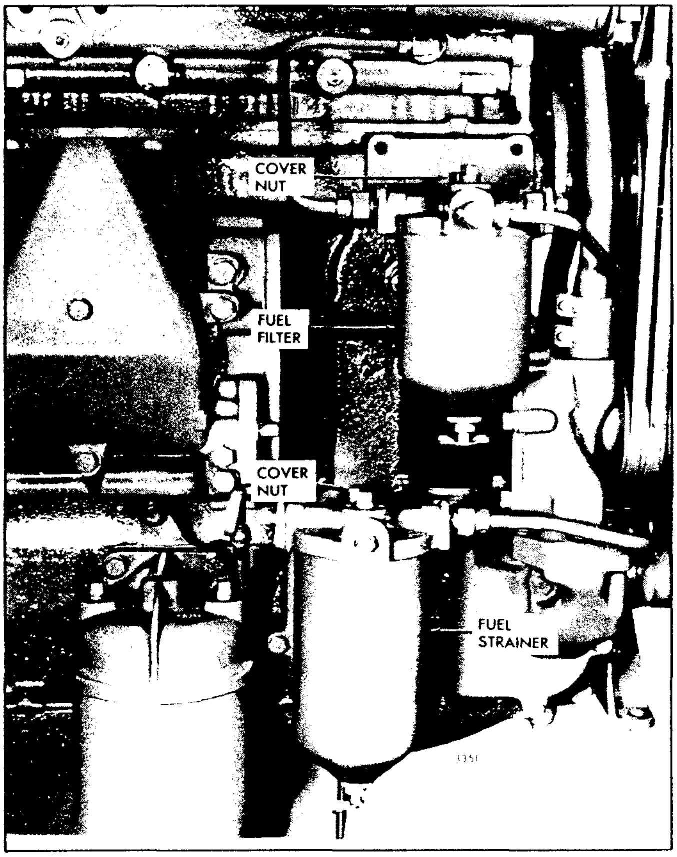


Fig. 1 – Typical Fuel Strainer and Fuel Filter Mounting

- 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 (cellulose) element (Fig. 2) can remove particles as small as 10 microns. Fiberglass elements can remove particles as small as 5 microns.

> **NOTICE:** A fuel tank of galvanized steel should never be used for fuel storage, as the fuel oil reacts chemically with the zinc coating to form powdery flakes which quickly clog the fuel filter and cause damage to the fuel pump and the fuel injectors.

The fuel strainer and fuel filter are essentially the same in construction and operation, and they will be treated as one in this section.

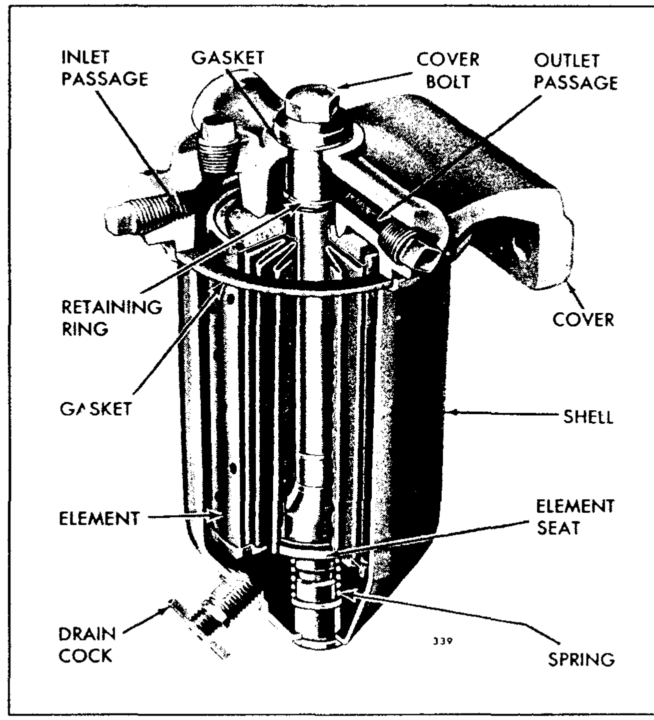


Fig. 2 – Fuel Filter Assembly

The filter and strainer, illustrated in Figs. 3 and 4, consist basically of a shell, a cover, and a replaceable filtering element. The assembly is made oil tight by a shell gasket, a cover nut or bolt, and a cover nut or bolt gasket.

The central stud is a permanent part of the shell and, when the unit is assembled, extends up through the cover where the nut or bolt holds the assembly together.

A filter element sets over the central stud inside the shell and is centered in the shell by the stud.

The former and current cover assemblies are visibly different. The cast letter "P" (primary) has been added to the top of the strainer cover and the letter "S" (secondary) has been added to the top of the filter cover.

Operation

Since the fuel strainer is between the fuel supply tank and the fuel pump, it functions under suction. The fuel filter, placed between the fuel pump and the fuel inlet manifold in the cylinder head, operates under pressure. Fuel enters through the inlet passage in the cover and into the shell surrounding the filter element. Pressure or suction created by the pump causes the fuel to flow through the filter element where dirt particles are removed. Clean fuel flows to the interior of the filter element, up through the central passage in the cover and into the outlet passage, then to the fuel inlet manifold in the cylinder head.

If engine operation is erratic, indicating shortage of fuel or flow obstructions, refer to *Troubleshooting* in Section 15.2 for corrective measures.

Replace Fuel Strainer Or Filter Element

The procedure for replacing an element is the same for the fuel strainer or fuel filter. Refer to Figs. 3 and 4 and replace the element as follows:

NOTICE: Only filter elements designed for fuel oil filtration should be used to filter the fuel.

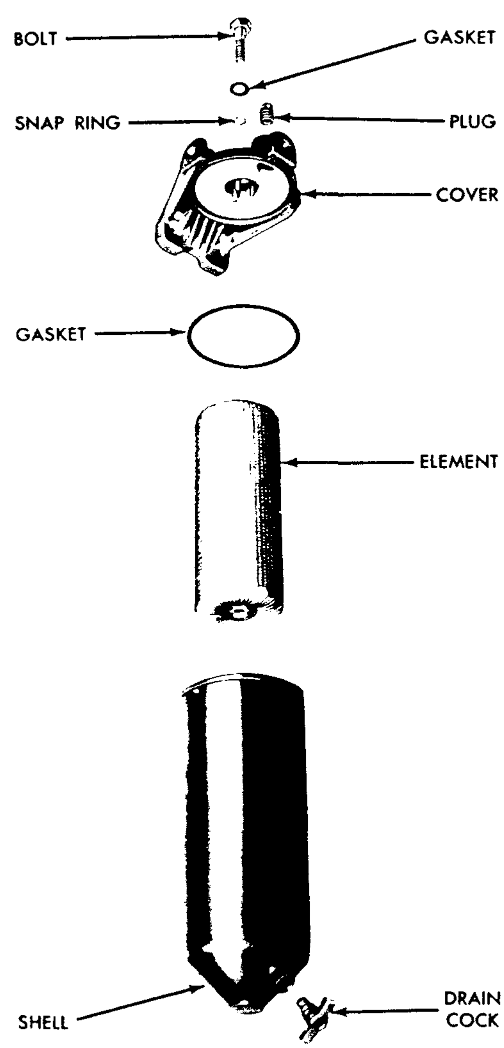


Fig. 3 – Fuel Strainer Details and Relative Location of Parts

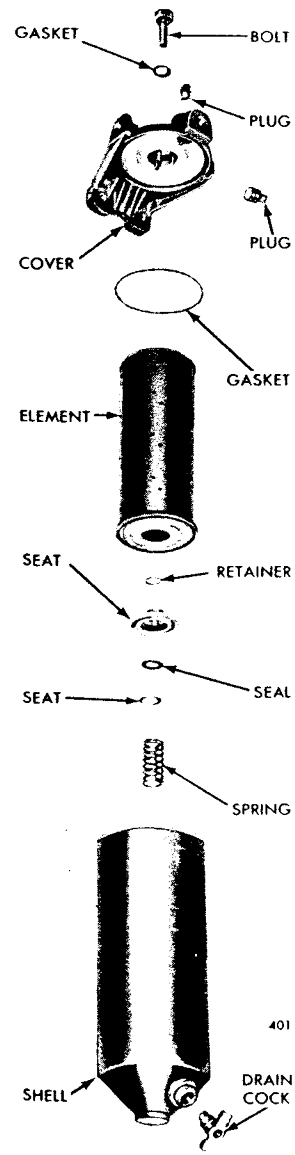


Fig. 4 – Fuel Filter Details and Relative Location of Parts

1. With the engine stopped, place a container under the strainer or filter and open the drain cock. Loosen the cover nut or bolt just enough to allow the fuel oil to drain out freely. Then close the drain cock.

   NOTICE: The wiring harness, starting motor or other electrical equipment 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 element. Also remove and discard the cover nut retaining ring, if used.

3. Remove and discard the filter element and shell gasket, the cover nut or bolt gasket, and, if used, the cover bolt snap ring.

   Current strainers and filters do not incorporate the cover bolt snap ring. This was eliminated to facilitate replacement of the bolt gasket with each element replacement.

4. Wash the shell thoroughly with clean fuel oil and dry it with compressed air.

   CAUTION: To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.

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.

   The element seat, spring, washer and seal can not 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 cracks or hardening. If necessary, replace the seal.

   The current strainer and filter elements include the element, the cover gasket and cover bolt gasket. The strainer element also includes both the former and current bolt gaskets.

6. Place a new element over the center stud and push it down against the element seat. Make sure the drain cock is closed, then fill the shell about two–thirds full with clean fuel oil.

   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. Place a new shell gasket in the recess of the shell; also place a new gasket on the cover nut or bolt.

8. Place the shell and element in position under the cover. Then thread the cover bolt (or nut) in the center stud.

9. With the shell and the gasket properly positioned, tighten the cover bolt or nut just enough to prevent fuel leakage.

10. Remove the pipe plug at the top of the cover and complete filling of the shell with fuel. Fuel system primer J 5956 may be used to prime the entire fuel system.

11. Start the engine and check the fuel system for leaks.

FUEL STRAINER AND FUEL FILTER

(SPIN–ON TYPE)

A spin–on type fuel strainer and fuel filter (Fig. 5) is used on certain engines. The spin–on filter cartridge consists of a shell, element and gasket combined into a unitized replacement assembly (Fig. 6). No separate springs or seats are required to support the filters.

• Replaceable paper type (cellulose) elements can remove particles as small as 10 microns. Fiberglass elements can remove particles as small as 5 microns.

The filter covers incorporate a threaded sleeve to accept the spin–on filter cartridges. The word "Primary" is cast on the fuel strainer cover and the word "Secondary" is cast on the fuel filter cover for identification.

No drain cocks are provided on the spin–on filters. Where water is a problem, it is recommended that a water separator be installed. Otherwise, residue may be drained by removing and inverting the filter. Refill the filter with clean fuel oil before reinstalling it.

Filter Replacement

A 1″ diameter twelve–point nut on the bottom of the filter is provided to facilitate removal and installation.

Replace the filter as follows:

1. Unscrew the filter (or strainer) and discard it.

2. Fill a new filter replacement cartridge about two–thirds full with clean fuel oil. Coat the seal gasket lightly with clean fuel oil.

3. Install the new filter assembly and tighten it to one–half of a turn beyond gasket contact.

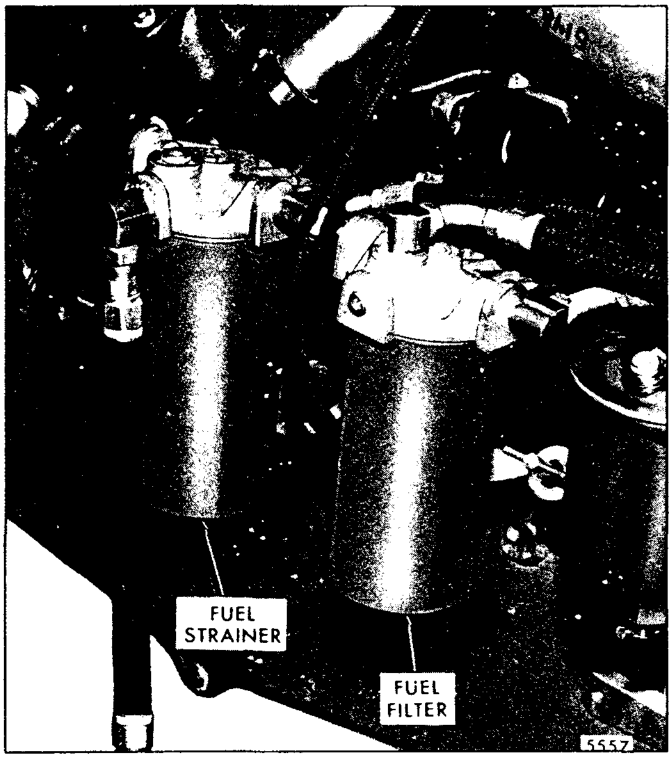


Fig. 5 – Typical Spin-On Filter Mounting

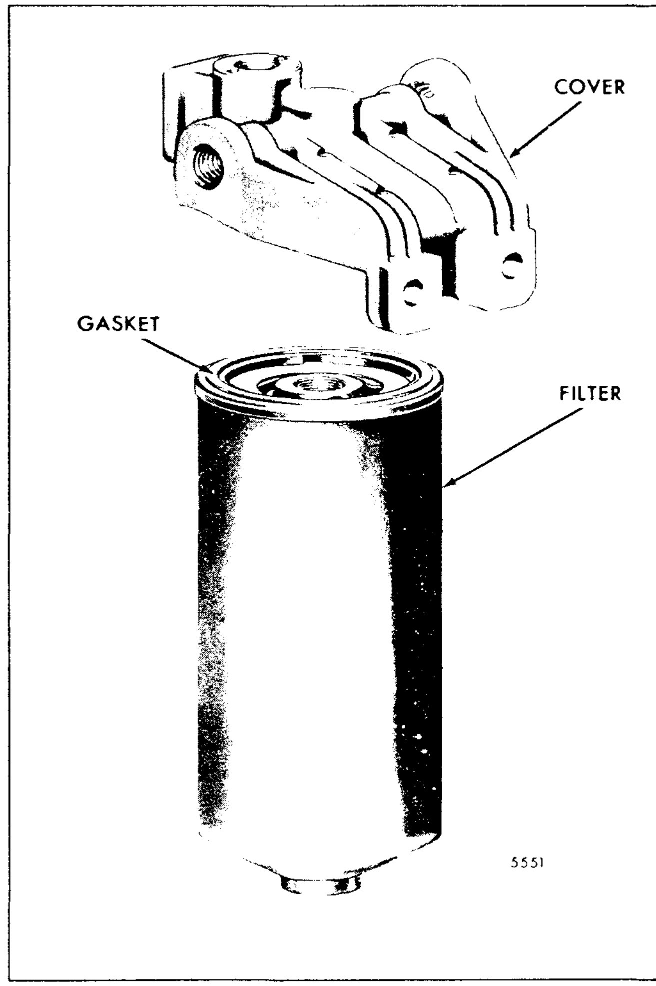


Fig. 6 – Spin-On Filter Details

FUEL COOLER (V Engines)

A fuel cooler may be mounted in the raw water system, between the heat exchanger and the raw water pump, so that the fuel leaving the engine is cooled before it returns to the fuel tank.

Fuel continually cycling through an engine causes the fuel in the tank to become heated after extended operation. Excessive fuel temperatures can affect engine operation. An increase in the fuel inlet temperature above 90°F (32°C) will result in a brake horsepower loss of approximately 2% per 20°F (11°C) increment fuel temperature increase.

Remove Fuel Cooler

1. Disconnect the flexible hoses at the fuel cooler.

2. Loosen the hose clamps and slide the hoses back on the raw water pump tubes.

Clean Fuel Cooler

Clean the oil side of the cooler core first, then immerse it in the following solution: Add 1/2 pound of oxalic acid to each 2–1/2 gallons (9.5 liters) of a solution composed of 1/3 muriatic acid and 2/3 water. The cleaning action is evident by the bubbling and foaming.

Watch the process carefully. When bubbling stops (this usually takes from 30 to 60 seconds), remove the core from the cleaning solution and thoroughly flush it with clean, hot water. After cleaning, dip the core in light oil.

Pressure Test Fuel Cooler

After the fuel cooler has been cleaned, check it for leaks by plugging one of the fuel openings with a 1/4" pipe plug and attaching an air hose to the other opening. Apply approximately 100 psi (689 kPa) air pressure and submerge the cooler in a container of heated water (180°F or 82°C). A leak will be indicated by air bubbles in the water. If leaks are indicated, replace the cooler.

- **CAUTION: To avoid personal injury when making this pressure test, be sure that personnel are adequately protected against any stream of pressurized water from a leak or rupture of the cooler core.**

Install Fuel Cooler

Reverse the procedure for removing the fuel cooler.

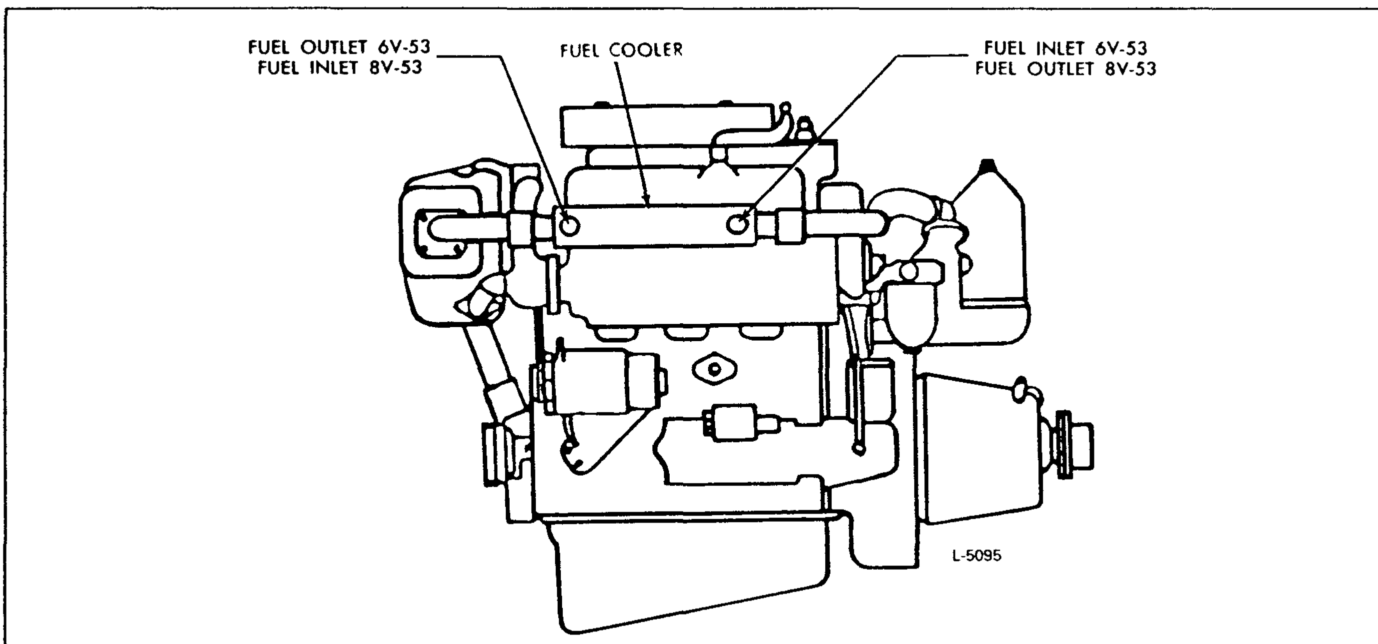


Fig. 1 – Fuel Cooler Mounting (V Engines)

MECHANICAL GOVERNORS

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. The following types of mechanical governors are used:

1. Limiting Speed Mechanical Governor.
2. Variable Speed Mechanical Governor.

Engines requiring a minimum and maximum speed control, together with manually controlled intermediate speeds, are equipped with a limiting speed mechanical governor.

Engines subjected to varying load conditions that require an automatic fuel compensation to maintain a near constant engine speed, which may be changed manually by the operator, are equipped with a variable speed mechanical governor. However, a variable speed governor cannot be used on an engine equipped with an Allison vehicle transmission. Each type of governor has an identification plate located on the control housing, containing the governor assembly number, type, idle speed range and drive ratio. The maximum engine speed, not shown on the identification plate, is stamped on the option plate attached to the valve rocker cover.

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, check the engine as follows:

1. 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 15.2). If any cylinder is not firing properly, remove the injector, test it and, if necessary, recondition it as outlined in Section 2.1 or 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 clamp 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 (27–34 N·m) torque.
2. An injector which is not functioning properly may have 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 rack control lever adjusting screws. If this relieves the bind, 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, remove and recondition the governor.

LIMITING SPEED MECHANICAL GOVERNOR

In–Line Engine

The limiting speed mechanical governor performs the following functions (Fig. 1):

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 and is driven by a gear that extends through the end plate and meshes with either the camshaft gear or the balance shaft gear, depending upon the engine model.

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 the 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 speed control lever.

In the low speed range, the centrifugal force of the low and high speed weights together operate 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 spring 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 the injector control tube lever, provides a means for the governor to change the fuel settings of the injector rack control levers.

The engine idle speed is determined by the force exerted by the governor low speed spring. When the governor speed 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 speed adjusting screw. Refer to the tune–up section for idle speed adjustment.

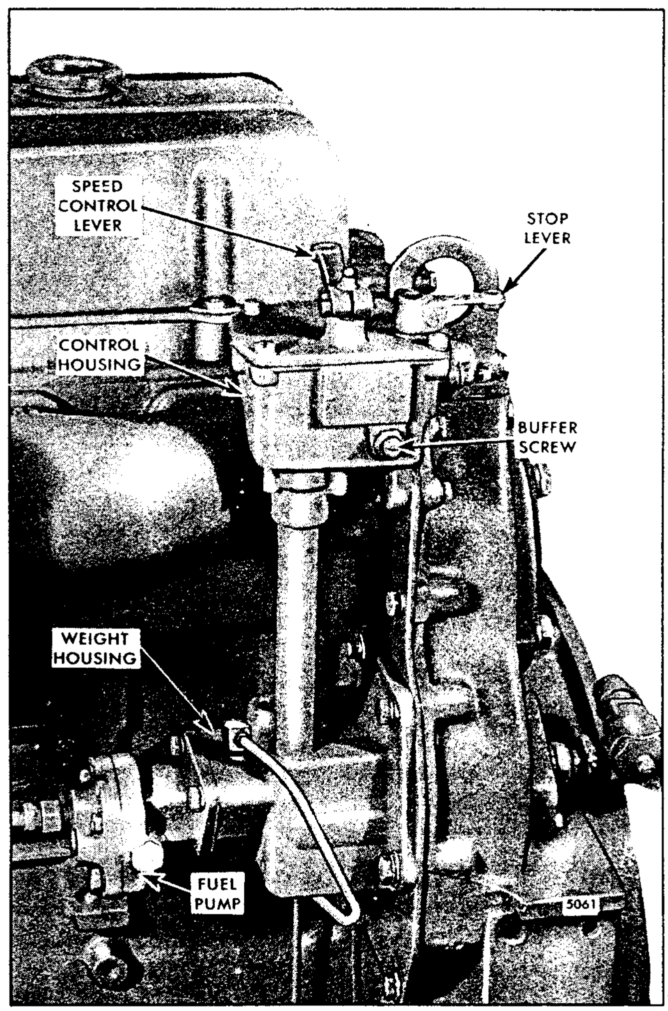


Fig. 1 – Governor Mounting

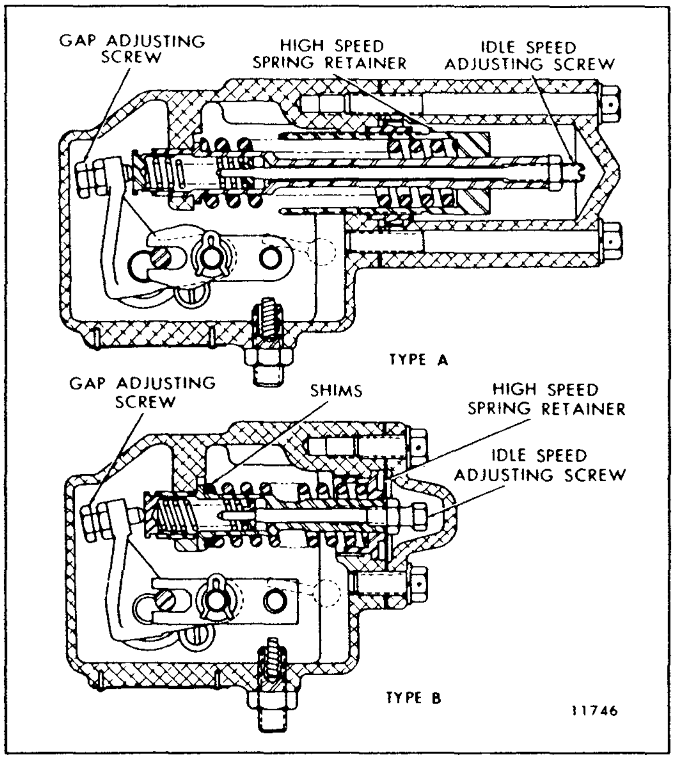


Fig. 2 – Differences Between Industrial and Vehicle Type Governor Assemblies

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 a pressure line on current engine models. 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

Before removing the governor from the engine, the operation should be checked as outlined in Section 2.7. If the governor fails to control the engine properly after performing these checks, remove and recondition it.

1. Disconnect the linkage to the governor control levers.
2. Remove the governor cover and gasket.
3. Detach the spring housing from the governor housing by removing the two bolts and lock washers.
4. Loosen the high speed spring retainer locknut with spanner wrench J 5895 and remove the spring assembly (Fig. 2).
5. Loosen the fuel rod cover hose clamps.
6. Clean and remove the rocker cover from the cylinder head.
7. Disconnect the fuel rod from the injector control tube lever. Remove the clip that holds the fuel rod to the differential lever and lift the fuel rod from the lever.
8. Detach the fuel pump by disconnecting the fuel lines and removing the three bolts. Also, disconnect the lubricating oil line, if used.
9. Remove the five bolts from the governor weight housing and the two bolts from the governor control housing.
10. Detach the governor and gasket from the engine.

Disassemble Governor Cover

1. Remove the return spring and clip from a single lever cover only, then loosen the governor speed control lever retaining bolt and lift the control lever from the speed control shaft (Fig. 3).
2. Remove the retaining ring and washer. Withdraw the speed control shaft from the cover.
3. Remove the seal ring from the cover. 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.

Disassemble Governor Weight Housing

1. Remove the gear retaining nut from the shaft, then remove the gear, key and spacer from the 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.

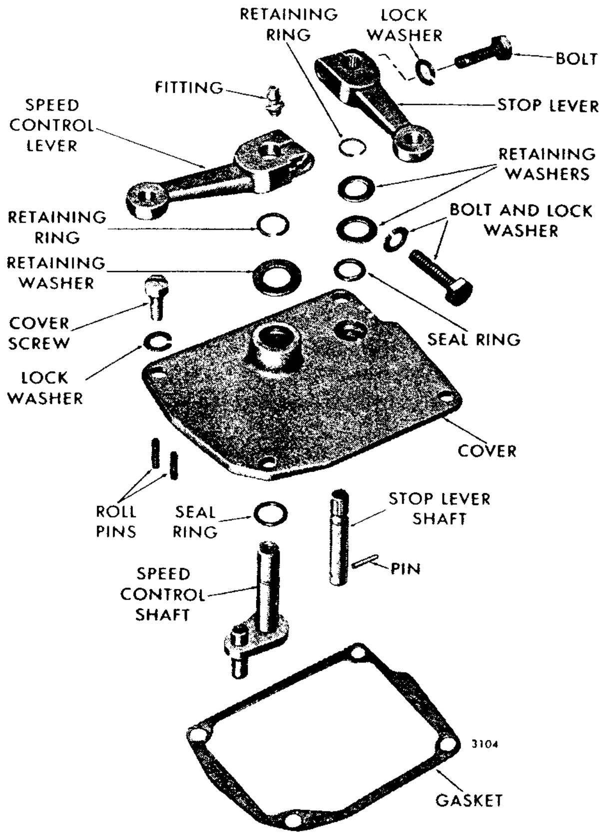


Fig.3 – Governor Cover Details and Relative Location of Parts

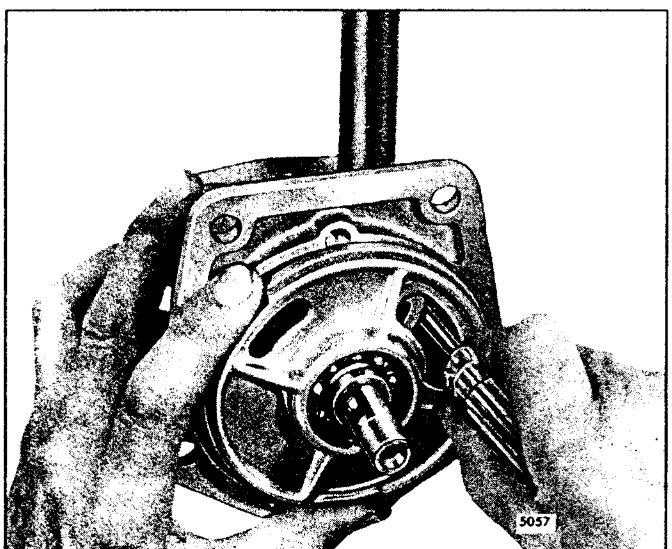


Fig. 4 – Removing Fork from Operating Shaft

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 clip and washer from the governor operating shaft lever and remove the governor differential lever.

10. Press the bearing and 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. *Drive the pins out of the carrier from the weight pin retainer end.*

   Remove the governor weights. 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

Immerse all of the governor parts in a suitable cleaning fluid to loosen and remove all foreign material. Use a bristle brush and compressed air as necessary to ensure cleanliness of all parts.

- **CAUTION: To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.**

Examine the bearings for any indications of corrosion or pitting. Lubricate each bearing with light engine oil; then, while holding the bearing inner race from turning, revolve the outer race slowly by hand and check for rough spots. Replace the bearings if rough or tight spots are detected.

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 assemblly, 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. Examine the weight carrier pins for wear and replace them if necessary.

Inspect the weight carrier, weights and retaining pins for wear. The current single–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 governor operation.

Assemble Governor Cover

New mechanical governor cover assemblies with serrated shafts are being used on In–line 53 engines.

The limiting speed governor cover assemblies include a new, longer 7/16" diameter speed control shaft and a new 3/8" diameter serrated stop lever shaft (Fig. 3). The serrations on the shafts ensure positive clamping between the serrated levers and the shafts and prevent any slippage. Four serrations on the stop lever shaft of the limiting speed governor are eliminated. This allows certain customers to design a mating lever with missing serrations which will provide a *fixed position* for particular requirements. Levers with missing serrations are not provided. The former and new cover and shaft assemblies are interchangeable on a governor, and only the new assemblies will be serviced. Since the new serrated shafts can be used with the former covers, only the new serrated shafts will be serviced.

1. Place a new seal ring in the counterbore of the cover (Fig. 2). 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 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 stop lever shaft with engine oil, then slide the shaft through the cover.
5. Place the seal ring in the counterbore of the shaft opening, then install the washers 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 1/8" pipe plug in the tapped hole 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 bearing, numbered side out, in the weight housing. Install the snap ring to secure the bearing (Fig. 5).
4. Apply a quality sealant around the edge of a new plug and tap it in place.
5. Start the governor operating shaft upper bearing 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 bearing until it contacts the shoulder of the operating shaft.
6. 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 bearing on the shaft.
7. Lubricate both bearings with engine lubricating oil. Insert the lever and operating shaft assembly in the control housing. Guide the lower end into the bearing.
8. Secure the upper operating shaft bearing with the round head retaining screw and washers.
9. Place the fork on the operating shaft with the two cam faces facing the fuel pump.
10. Secure the fork to the operating shaft with two screws and lock washers.
11. Place the differential lever over the operating shaft lever pin and secure it in place with a washer and spring pin.

Assemble Governor Weight and Shaft Assembly

1. If the 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 carrier.
2. Press the governor weight shaft bearing into the bearing retainer by pressing on the outer race of the bearing (Fig. 6).

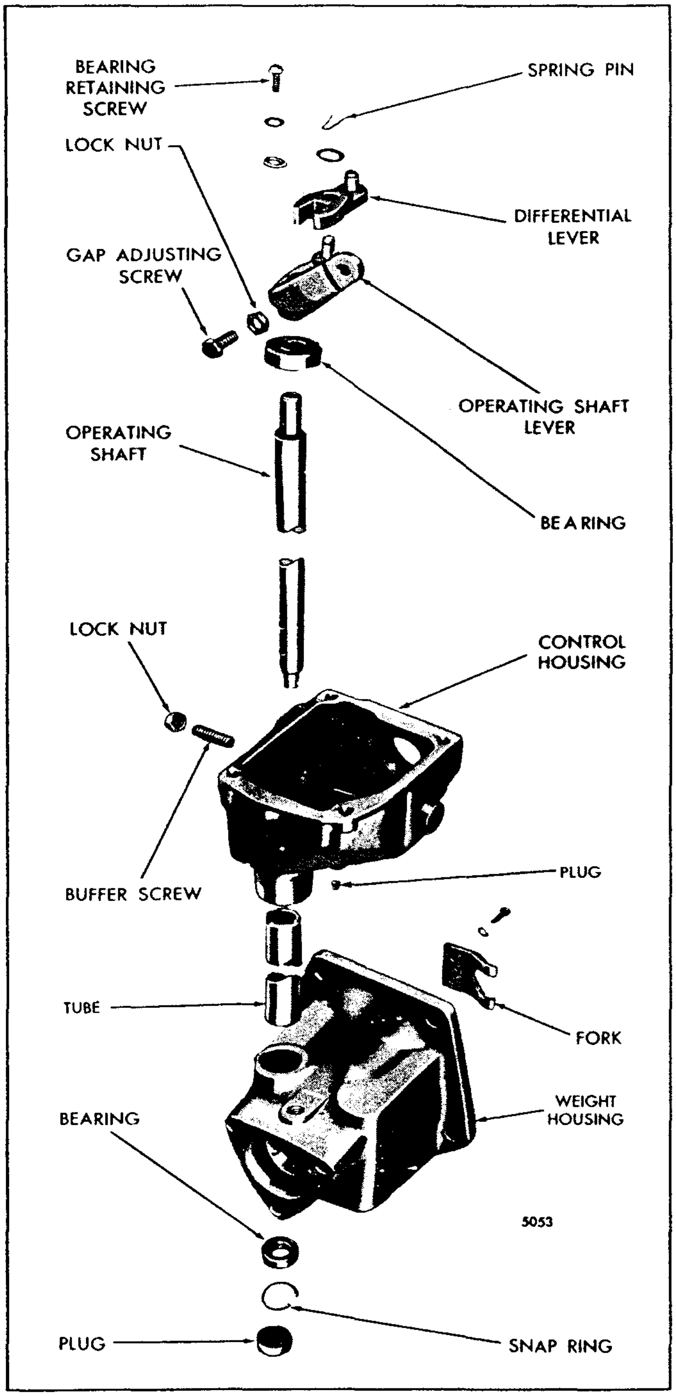


Fig. 5 – Governor Housings and Relative Location of Parts

3. Install the snap ring in the retainer with the flat side of the ring facing the bearing.

4. Press the bearing retainer on the weight shaft until the bearing is against the shoulder on the shaft.

NOTICE: 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 the weight pin retainers.

7. Install the high speed weights in the same way. The high speed weights are identified by the long cam arm and three center laminations; the middle lamination is 3/16" thick and the outer ones are 1/8" thick.

   The weight pins must be reinstalled in the same positions from which they were 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 bearing. Install the drive gear retaining nut and tighten it to 125–135 lb-ft (170–183 N·m) torque.

13. Check the backlash between the governor drive gear and the camshaft or balance shaft gear. The backlash should be .0030" to .0050" between new gears and should not exceed .0070" between used gears. If necessary, loosen and readjust the rear end plate to bring gear lash within specifications.

Install Governor

Refer to Fig. 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. Refer to Section 1.0 for allowable backlash.

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 (47 N·m) torque.

5. Install the two governor control housing attaching bolts and lock washers. Tighten the bolts to 10–12 lb–ft (14–16 N·m) torque.
6. On current engines, install the lubricating oil line and fittings to the weight housing and 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 industrial governor spring mechanism as follows:
   a. Thread the spring retainer locknut on the retainer.
   b. Thread the idle speed adjusting screw on the governor spring plunger.
   c. Place the high speed spring over the governor spring plunger.
   d. Lubricate and install the spring plunger assembly in the spring retainer and secure it with a locknut so that approximately 1/4" of the idle speed adjusting screw extends beyond the nut.
   e. Lubricate and insert the spring seat, low speed spring and the spring cap in the open end of the spring plunger.
10. Thread the spring retainer and spring assembly into the governor housing and tighten the locknut finger tight until an engine tune–up is performed.
11. Assemble the vehicle governor spring mechanism as follows:
    a. Back off the locknut 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 over 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 into the control housing and tighten the retainer nut with spanner wrench J 5895.
12. Thread the spring retainer and spring assembly into the governor; the locknut should be finger tight until an engine tune–up is performed.
13. Use a new gasket when installing the governor cover and lever assembly. Be sure the speed control shaft pin engages the slot in the differential lever and the stop lever is in the correct position. Secure the cover with four screws and lock washers.

- **CAUTION: Before starting an engine after an engine speed control adjustment or after removal of the engine governor cover and lever assembly, the technician must determine that the injector racks move to the *no–fuel* position when the governor stop lever is placed in the stop position. Engine overspeed will result if the injector racks cannot be positioned at no fuel with the governor stop lever. An overspeeding engine can result in engine damage which could cause personal injury.**

14. Install the return spring and spring clip (single lever cover only).
15. Add all purpose grease to the speed control shaft through the grease fitting on top of the shaft. *At temperatures above 30°F (1°C) use a No. 2 grade grease and a No. 1 grade grease below this temperature.*
16. Connect the linkage to the governor control levers.
17. Install the fuel pump and fuel lines.
18. Perform an engine tune–up as outlined in Section 14.

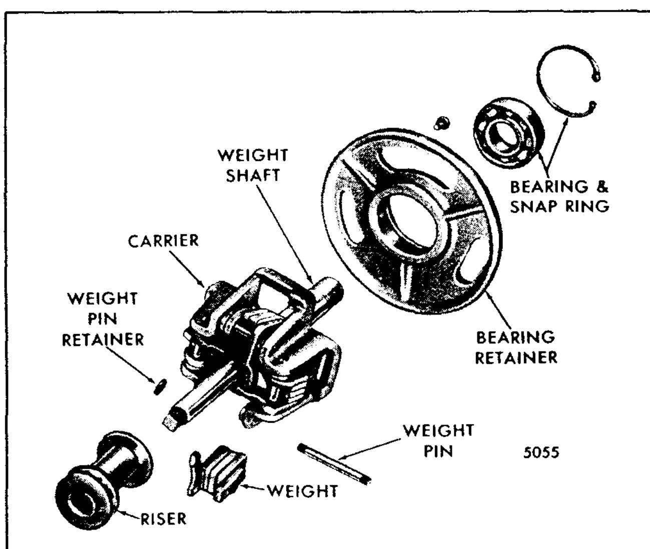


Fig. 6 – Governor Weight Details and Relative Location of Parts

LIMITING SPEED MECHANICAL GOVERNOR

6V Engine

The limiting speed mechanical governor, illustrated in Fig. 1, performs the following functions:

1. Controls the engine idle speed.

2. Limits the maximum operating speed of the engine.

The double-weight governor, identified by the letters D.W.-L.S. stamped on the governor name plate, is mounted between the engine blower and the flywheel housing (Fig. 2). One end of the governor weight shaft is splined to a drive plate attached to the driven blower timing gear to provide a means of driving the governor. The other end of the shaft is supported by a bearing in the blower drive support (Fig. 1).

The governor consists of four basic sub-assemblies: a cover and lever assembly, governor housing, spring housing, and a weight and shaft assembly.

Operation

Two manual controls are provided on the governor: a stop lever and a speed control lever. In the RUN position, the stop lever holds the fuel injector racks near the full-fuel position. When the engine is started, the governor moves the injector racks toward the idle speed position. The engine speed is then controlled manually by moving the speed control lever.

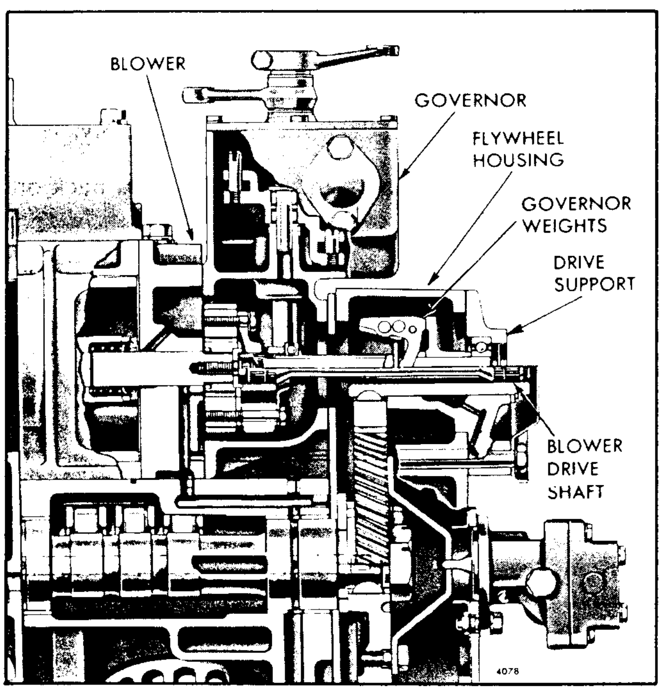


Fig. 1 - Limiting Speed Governor and Drive on 6V-53 Engine

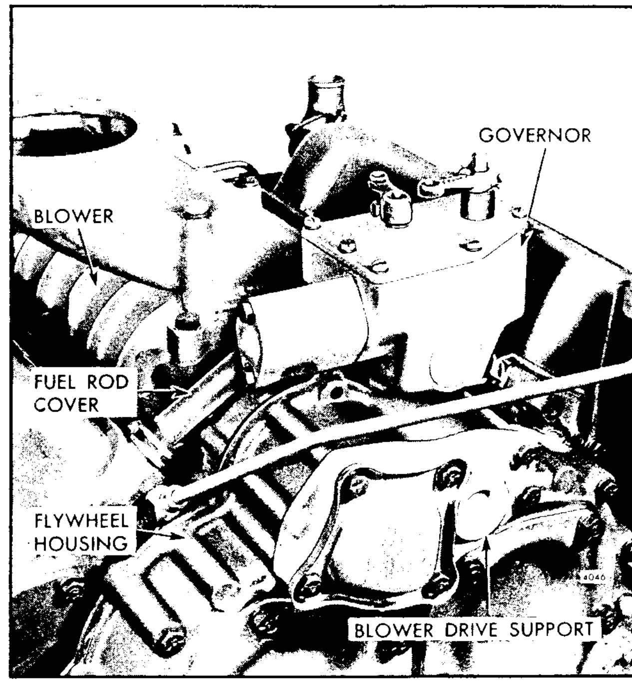


Fig. 2 - Governor Mounting on 6V-53 Engine

The centrifugal force of the revolving governor 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 bears against the governor spring cap while the other end provides a moving fulcrum on which the differential lever pivots.

The centrifugal force of the governor weights is opposed by the governor springs. Load changes or movement of the speed control lever momentarily creates an unbalanced force between the revolving weights and the tension on the high speed spring or low speed spring (depending on the speed range). When the forces reach a balanced condition again, the engine speed will be stabilized for the new speed setting or new load.

In the low speed range, the centrifugal force of the low speed weights and the high speed weights operates against the low speed spring. As the engine speed increases, the centrifugal force of both pairs of weights compresses the low speed spring until the low speed weights have reached the limit of their travel, at which time the low speed spring is fully compressed

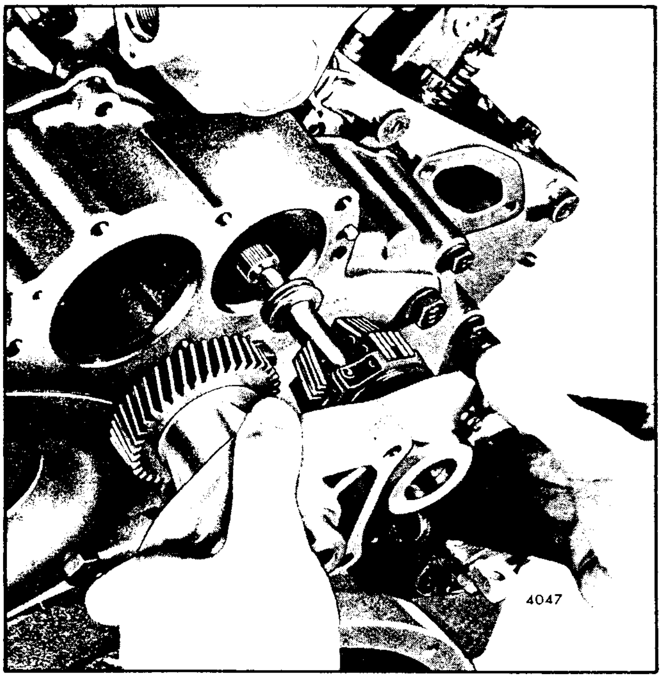


Fig. 3 - Removing or Installing Blower Drive Support

and the spring cap is within .0015" of the high speed spring plunger.

Throughout the intermediate speed range, the operator has complete control of the engine because both the low speed spring 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 engine speed continues to increase, the centrifugal force of the high speed weights increases until this force overcomes the high speed spring and the governor again takes control of the engine, limiting the maximum engine speed.

Fuel rods are connected to the differential lever and the injector control tube levers through the control link lever. This arrangement provides a means for the governor to change the fuel settings of the injector control racks.

To stop the engine, the speed control lever is moved to the idle speed position and the stop lever is moved to the no-fuel position and held there until the engine stops.

Adjustment of the governor is covered in Section 14.

Lubrication

The governor is lubricated by a spray of pressurized lubricating oil from the blower rear end plate to the blower timing gears which distribute this oil to various parts of the governor. Oil splash from the gear train provides lubrication for the governor weights and shaft. Excess oil overflows into the gear train compartment and returns to the crankcase.

Remove Governor From Engine

Check the governor as outlined in Section 2.7 and, if it fails to control the engine properly, remove and disassemble it for further inspection.

Since the governor is mounted between the blower and the flywheel housing, the blower and blower drive support assemblies must also be removed. Remove the governor as follows:

1. Disconnect the linkage to the governor control levers.

2. Remove the seven attaching screws and lock washers and detach the governor cover and lever assembly from the governor housing. Remove the cover gasket.

3. Take out the two bolts and copper washers and remove the spring housing (or cover) and gasket from the governor housing.

4. Loosen the high speed spring retainer lock nut (type "A" governor, Fig. 6) with a spanner wrench. Remove the spring retainer and withdraw the spring retainer, idle speed adjusting screw, high speed spring, spring plunger, low speed spring, spring seat and spring cap as a unit.

On engines equipped with the type "B" governor (Fig. 6), remove the spring retainer with spanner wrench J 5895 and withdraw the spring assembly.

5. Loosen the hose clamps and slide the hoses back on the fuel rod covers.

6. Remove the valve rocker covers from the cylinder heads.

7. Disconnect the lower fuel rods from the injector control tube levers and from the lower (threaded) ends of the upper fuel rods.

8. Remove the threaded pins that connect the fuel rods to the control link lever and remove the upper fuel rods.

9. Remove the blower drive support (Fig. 3) as outlined in Section 3.4. The governor weight and shaft assembly will be removed with the blower drive support.

10. Check the clearance between the gear and each of the fully extended weights (Fig. 18). If this clearance

is less than .100", the weights or carrier are worn and must be replaced.

NOTE: The current weight carrier is hardened in the weight stop areas and the stop area on the low speed weights has been increased with the use of new center laminations to prevent wear which could allow the weights to open beyond limits and strike the blower drive gear.

11. Remove the governor weight shaft and carrier assembly from the blower drive support, using pry bars if necessary.

12. Remove the blower and governor housing assembly as outlined in Section 3.4.

13. Remove the six attaching bolts and lock washers and detach the governor housing from the blower rear end plate. Remove the gasket.

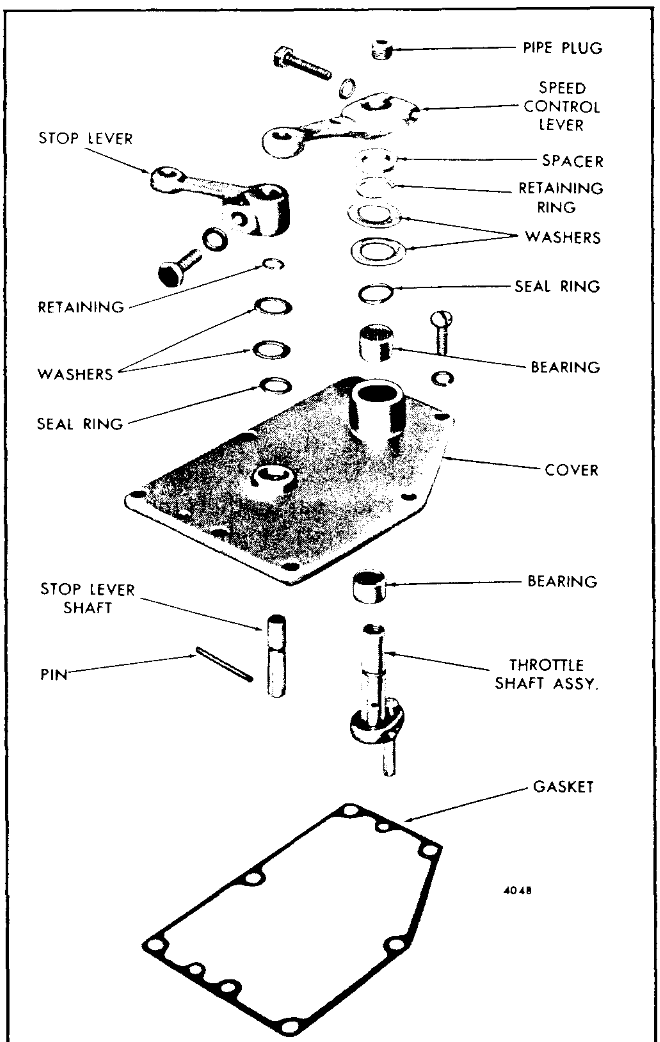


Fig. 4 - Governor Cover Details and Relative Location of Parts

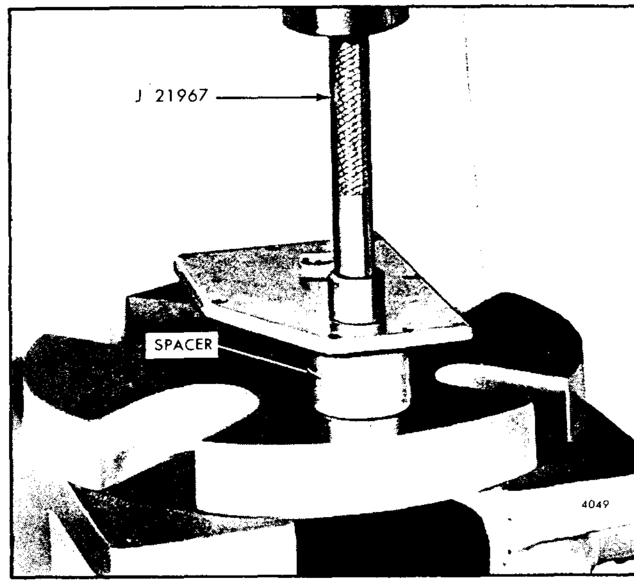


Fig. 5 - Removing Governor Cover Bearing

Disassemble Governor Cover

Refer to Fig. 4 and disassemble the governor cover as follows:

1. Remove the pipe plug from the throttle shaft.

2. Loosen the clamping bolt and remove the speed control lever.

3. Remove the spacer from the throttle shaft.

4. Remove the retaining ring and two seal retaining washers and withdraw the throttle shaft assembly from the cover.

5. Remove the seal ring from the cover.

6. Loosen the clamping bolt and remove the stop lever.

7. Remove the retaining ring and two seal retaining washers and withdraw the stop lever shaft from the cover.

8. Remove the seal ring from the cover.

9. Wash the governor cover with clean fuel oil and inspect the needle bearings for wear or damage. If the bearings are satisfactory, removal is unnecessary.

10. If the bearings are to be removed, place the governor cover on an arbor press and press them out with bearing remover J 21967 (Fig. 5).

Disassemble Governor Springs

Refer to Fig. 6 and disassemble the governor spring assembly as follows:

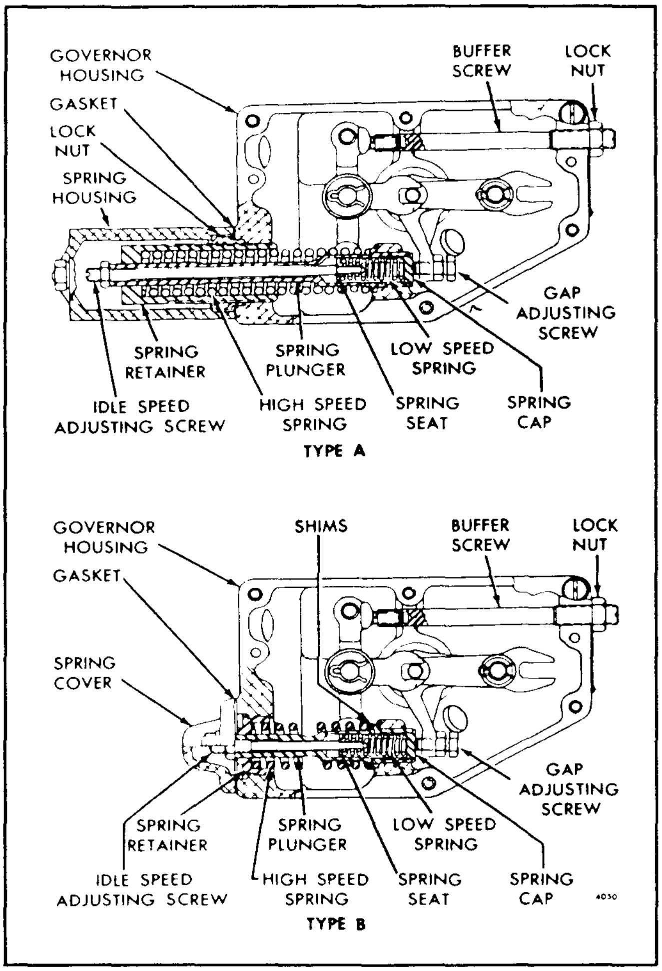


Fig. 6 - Governor Spring Assemblies

1. Remove the low speed spring cap, spring, and spring seat from the spring plunger.

2. Depress the high speed spring by hand and remove the idle speed adjusting screw lock nut. The spring retainer and high speed spring (and shims) may then be withdrawn. Remove the idle speed adjusting screw from the spring plunger.

Disassemble Governor Housing

1. Remove the governor buffer screw and spring.

2. Remove the spring pin and washer from the control link lever pin (Fig. 7) and withdraw the control link lever and washer.

3. If the bearings require replacement, support the control link lever on a sleeve placed on the bed of an arbor press. Then, press the bearings out of the lever with tool J 8985 (Fig. 8).

4. Remove the spring pin and washer from the pin in the operating shaft lever and remove the differential lever.

5. Remove the plug at the bottom of the governor housing.

6. Remove the set screws, if used, from the governor operating fork.

7. Remove the operating shaft upper bearing retaining screw and washer.

8. Remove the operating shaft lower bearing by placing the inverted governor housing on the bed of an arbor press; use wood block(s) to prevent damage to the dowel pins in the housing. Press on the shaft, using a rod small enough to pass through the bearing, until the bearing is free of the shaft. Then, withdraw the bearing.

9. Place an end wrench between the operating fork and the governor housing; also place a rod on the end of the operating shaft and press the shaft out of the fork (Fig. 9).

10. Withdraw the operating shaft, operating shaft lever and bearings.

11. Press the shaft from the operating shaft lever and the upper bearing.

Disassemble Governor Weights and Shaft

1. Remove the retaining rings from the governor weight pins (Fig. 10). Then, drive the pins out by tapping on a punch held against the grooved end of the pins. Remove the governor weights.

2. Press the shaft from the governor weight carrier (Fig. 11).

3. Slide the governor riser and bearing assembly from the shaft. Do not remove the bearing since the bearing and riser are serviced only as an assembly.

Disassemble Blower Drive

1. Remove the snap ring and the thrust washer from the blower drive gear shaft (Fig. 12). Slide the shaft and gear from the blower drive support.

2. Press the drive gear from the shaft and remove the key.

3. Tap the governor weight shaft bearing from the blower drive support. If the bearing is a tight fit, drive

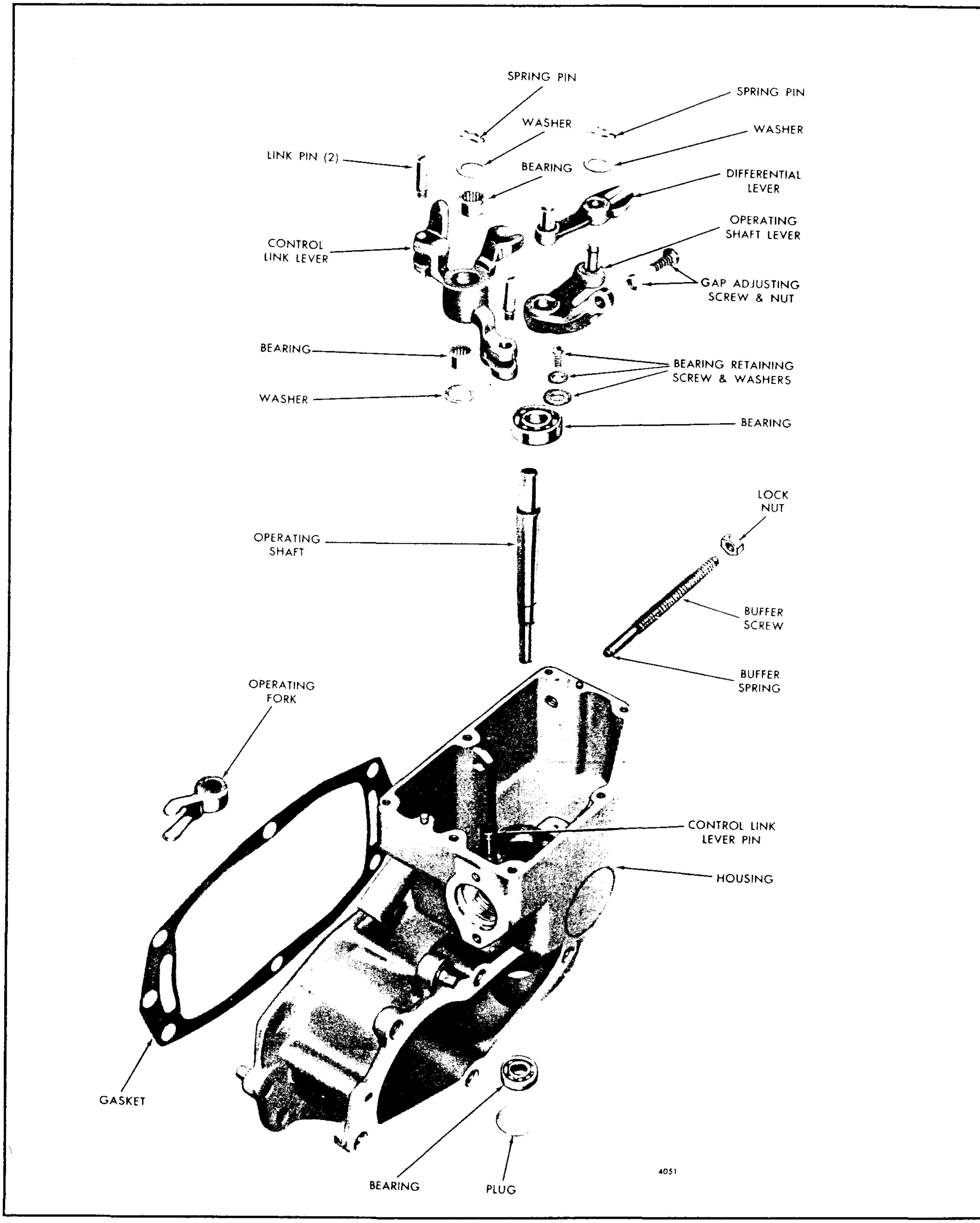


Fig. 7 - Governor Housing Details and Relative Location of Parts

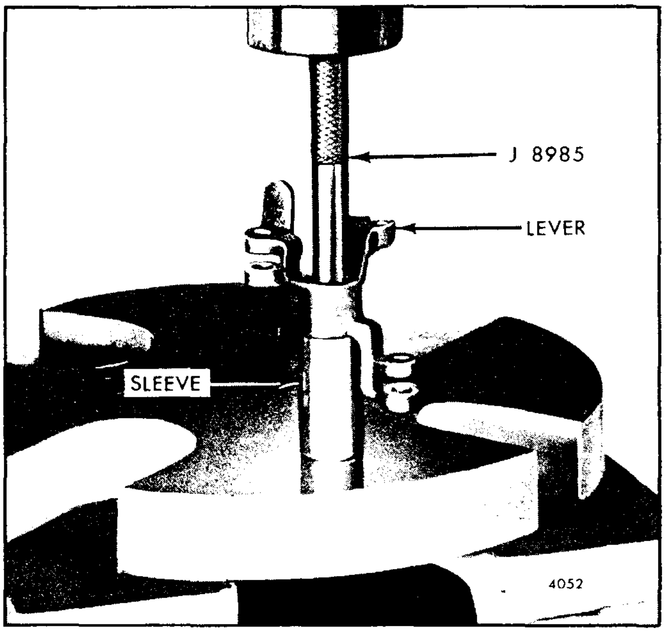


Fig. 8 - Removing Bearings from Control Link Lever

the plug from the support and, using a spacer against the outer race of the bearing, press or tap the bearing from the support.

Inspection

Clean all of the parts with fuel oil and dry them with compressed air.

Inspect all of the bearings. Replace corroded or pitted

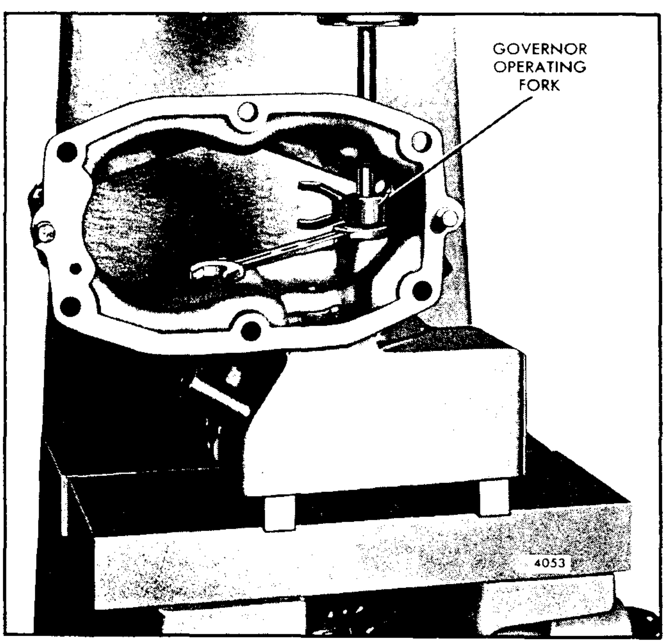


Fig. 9 - Removing Governor Operating Fork

bearings. Revolve ball bearings slowly by hand. Replace bearings which indicate rough or tight spots.

Examine the riser thrust bearing for excessive wear, flat spots or corrosion. If any of these conditions exist, install a new riser and thrust bearing assembly.

Inspect the control link lever, needle bearings and control link lever pin for wear. Replace worn parts. If a new control link lever pin is required, remove the old pin and press the new pin in the governor housing; the pin must project 1.055" to 1.060" above the boss in the housing.

Examine the weight carrier, weights and pins. Replace worn parts. The current weight carrier is hardened in the weight stop areas and the stop area on the low speed weights has been increased with the use of new center laminations.

Inspect the governor springs, spring seat, spring cap, plunger, spring retainer, adjusting screws and other parts of the governor housing for wear.

Check the serrations on the governor weight shaft and the drive plate on the blower timing gear for wear. Replace worn parts.

Assemble Governor Cover

Refer to Fig. 4 and assemble the governor cover as follows:

1. Place the cover, with the inner face down, on the bed of an arbor press. Start a needle bearing straight into the bearing bore of the cover, with the number side of the bearing up. Then, insert bearing installer J 21068 in the bearing and press the bearing in until the shoulder on the tool contacts the cover (Fig. 13).

2. Turn the cover over and start the second bearing, number side up, in the bearing bore. Press the bearing in flush with the cover with tool J 21068.

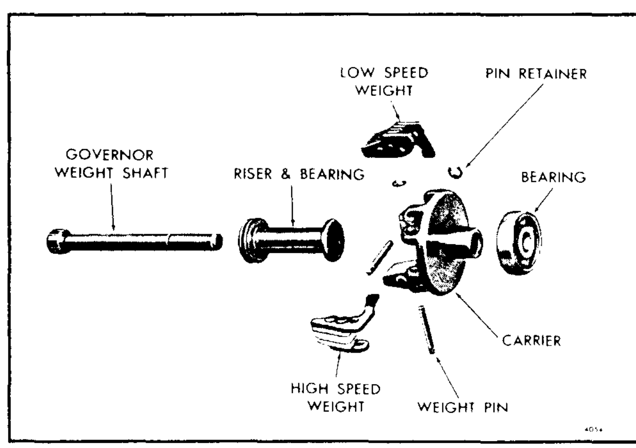


Fig. 10 - Governor Weight Details and Relative Location of Parts

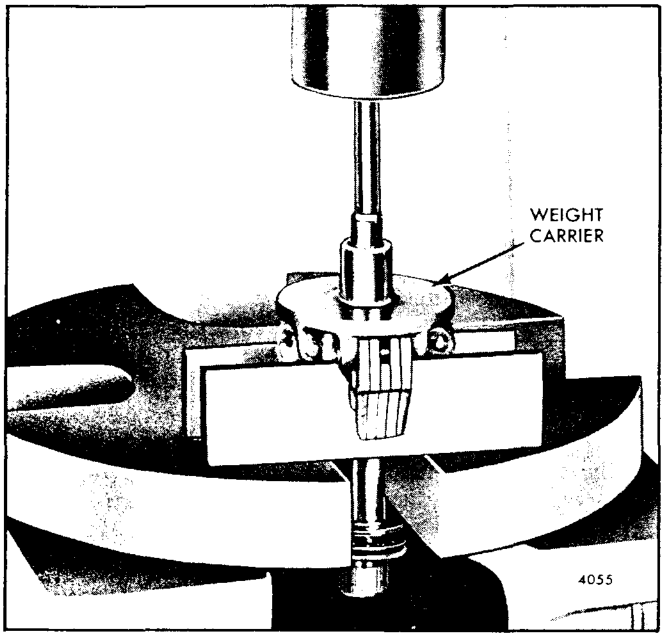


Fig. 11 - Removing Shaft from Weight Carrier

NOTE: Do not use impact tools to install needle bearings.

3. Install the pipe plug in the tapped hole in the throttle shaft.

4. Pack the needle bearings with grease. Then, slide the throttle shaft assembly through the bearings, with the fulcrum lever pin seated in the slot on the underside of the cover.

5. Install a new seal ring on top of the upper bearing. Then, install the two seal retaining washers and the retaining ring.

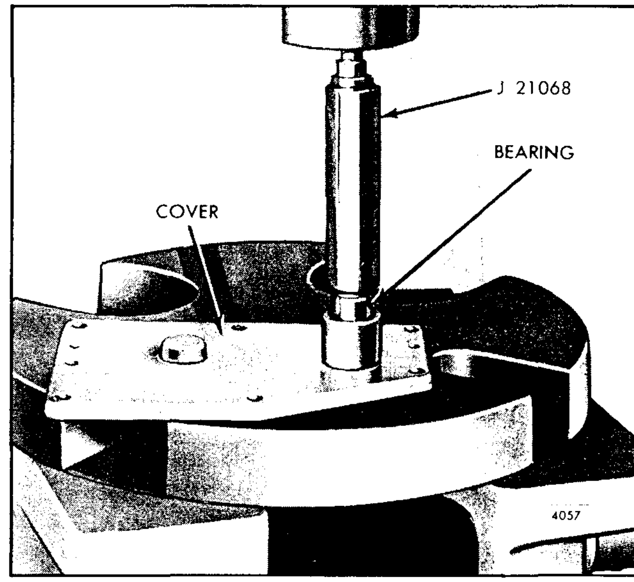


Fig. 13 - Installing Governor Cover Bearings

NOTE: A .0329" thick, 33/64" I.D. x 43/64" O.D. seal ring back-up washer is used in place of the lower washer on certain governor covers.

6. Lubricate the stop lever shaft with engine oil. Then, slide the shaft through the cover.

7. Install a new seal ring over the shaft. Then, install the two seal retaining washers and the retaining ring.

NOTE: A .0329" thick, 25/64" I.D. x 17/32" O.D. seal ring back-up washer is used in place of the lower washer on certain governor covers.

8. Install the .078" thick spacer over the speed control shaft and against the retaining ring.

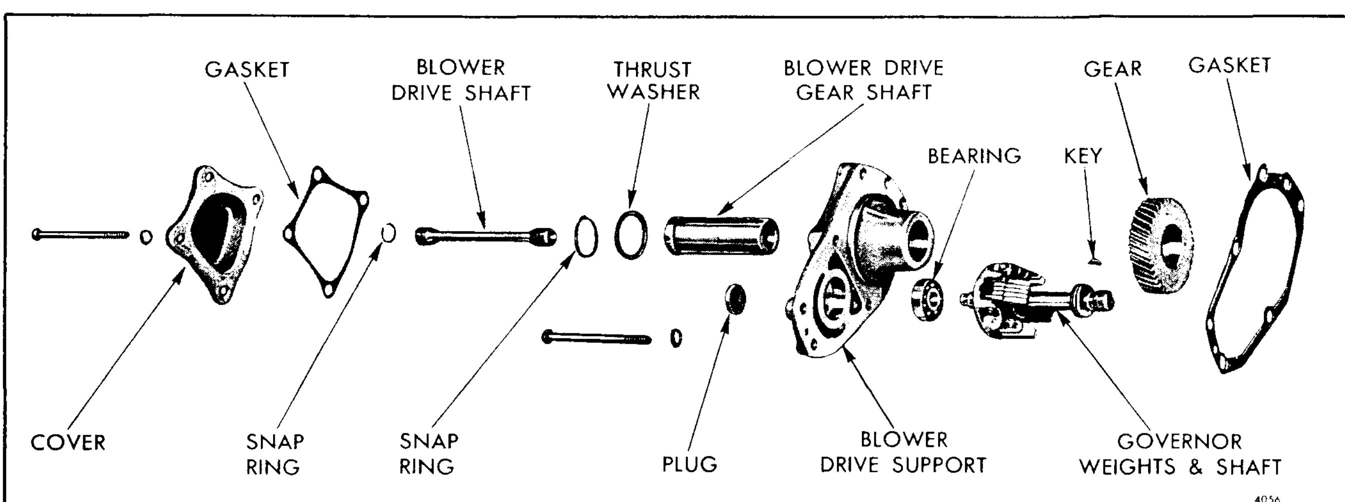


Fig. 12 - Blower Drive Support Assembly Details and Relative Location of Parts

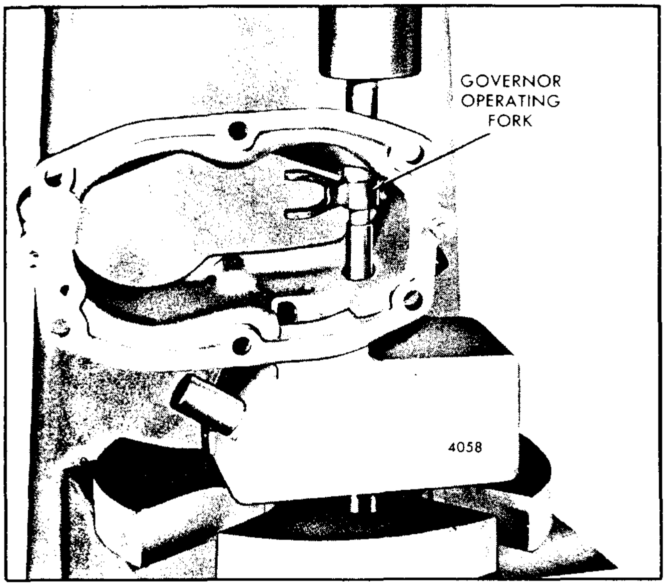


Fig. 14 - Installing Governor Operating Fork on Shaft

9. Install the stop lever and speed control lever, then tighten the clamping bolts. Be sure the speed control lever contacts the spacer.

Assemble Governor Housing

Refer to Fig. 7 and assemble the governor housing as follows:

1. Start the upper operating shaft bearing, number side up, on the end of the shaft. Support the lower end of the shaft on an arbor press. Place a sleeve on the inner race and press the bearing against the shoulder on the shaft.

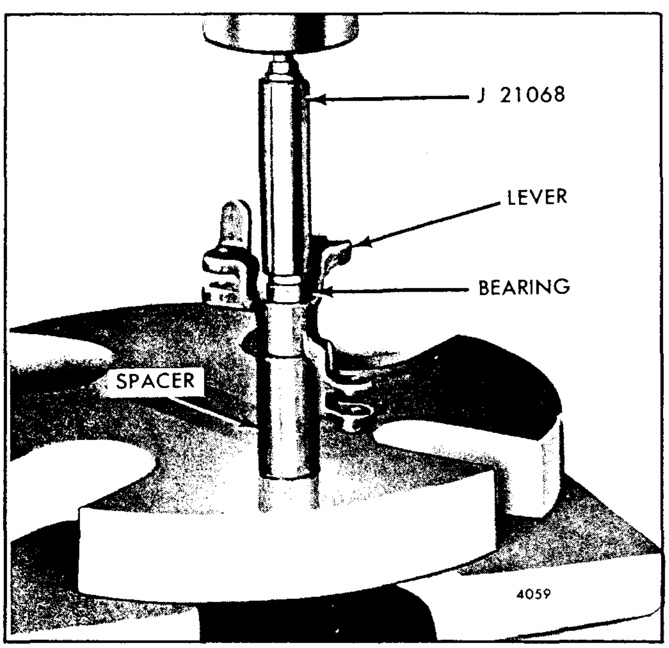


Fig. 15 - Installing Bearings in Control Link Lever

2. Start the operating shaft lever, with the pivot pin up, on the end of the shaft with the flat on the shaft registering with the flat in the lever bore. Use a sleeve to press the lever tight against the bearing.

3. Insert the lever and shaft assembly through the top of the governor housing. Position the operating fork over the lower end of the shaft, with the finished cam surfaces facing toward the rear of the governor (toward the governor drive).

4. Support the operating shaft and governor housing on the bed of an arbor press with the upper end of the shaft resting on a steel block (Fig. 14). Align the flat in the fork with the flat on the shaft, then place a sleeve over the shaft and against the fork. Press the fork tight against the shoulder on the shaft. Install the set screw and lock screw, if used, in the fork.

5. Start the lower operating shaft bearing, number side up, on the end of the shaft. Place a sleeve on the inner race and press the bearing against the shoulder in the housing.

6. Lubricate both bearings with engine oil.

7. Apply a good quality sealant around the edge of a new expansion plug and tap it in place in the housing.

8. Secure the upper operating shaft bearing in place with a retaining screw and flat washer.

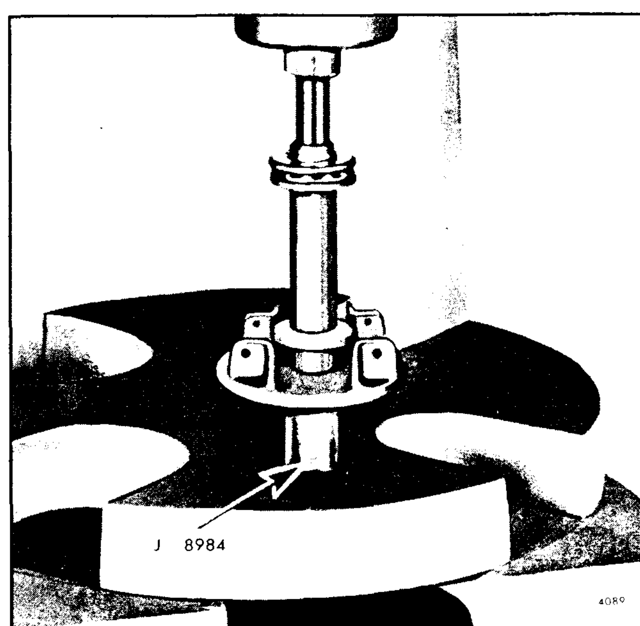


Fig. 16 - Installing Weight Carrier on Shaft

9. Place the differential lever (Fig. 7) over the pivot pin in the operating shaft lever. Secure the lever with a washer and spring pin.

10. If previously removed, install the gap adjusting screw and lock nut in the tapped hole in the operating shaft lever.

11. Support the control link lever on a steel spacer on the bed of an arbor press. Start one bearing, number side up, in the lever and press it flush with the lever with tool J 21068 (Fig. 15). Invert the lever and install the second bearing in the same manner.

12. Place the washer on the control link lever pin in the housing. Pack the needle bearings with grease and install the lever, with the tapped end of the link pin holes down, over the pin in the governor housing (Fig. 7). Secure the lever with the washer and spring pin.

13. Thread the buffer screw into the governor housing until it extends 9/16" to 5/8" beyond the governor housing and install the lock nut.

> **NOTE:** The buffer screw on early governors threaded into a splined lock nut which was installed (inside the housing) in a drilled hole in the governor housing. The current buffer screw threads into a tapped hole in the housing and is secured with a lock nut which is installed from the outer side of the housing.

Assemble Governor Weights and Shaft

Refer to Fig. 10 and assemble the governor weights and shaft as follows:

1. Lubricate the governor weight shaft with clean engine oil and slide the riser assembly over the shaft, with the bearing end toward the serrated end of the shaft. Pack the bearing with grease.

2. Use installer J 8984 as illustrated in Fig. 16 and press the shaft into the weight carrier. The tool will properly position the carrier on the shaft.

3. Position the low speed weights, identified by the long cam arm, on opposite sides of the weight carrier. Drive the weight pins in place and install the retaining rings. To install a weight pin correctly, push the grooved end through the smaller hole in the carrier and through the weight. Then, drive the knurled end in just enough so the retaining ring can be installed on the pin.

4. Install the high speed weights in a similar manner. The high speed weights are identified by the short cam arm.

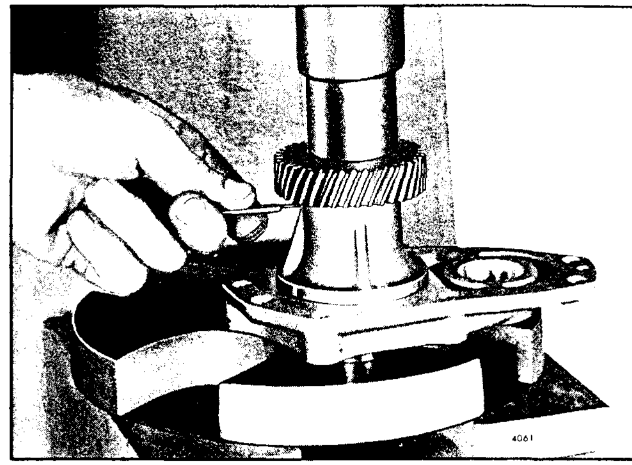


Fig. 17 - Installing Blower Drive Gear on Shaft

Assemble Blower Drive

Refer to Fig. 12 and assemble the blower drive as follows:

1. Place the blower drive support, with the inner face up, on the bed of an arbor press. Start the governor weight shaft bearing, numbered side up, into the bore of the support. Place a suitable sleeve against the outer race and press the bearing against the shoulder of the blower drive support.

2. Place the steel thrust washer on the end of the blower drive gear shaft and secure it in place with the snap ring.

3. Lubricate the blower drive gear shaft with engine oil and install it in the blower drive support.

4. Install the key in the shaft, then place the blower drive support on an arbor press. Lubricate the inner diameter of the blower drive gear and start it straight on the shaft, with the keyway in the gear aligned with the key in the shaft. Place a spacer over the gear and press the gear on the shaft until a .005" feeler gage may just be withdrawn (Fig. 17).

5. Place a support under the inner race of the bearing in the blower drive support and start the weight end of the governor weight shaft into the bearing. Press the shaft in until the shoulder on the shaft contacts the inner race of the bearing. Press the shaft in straight to avoid brinelling the bearing.

6. Apply a good quality sealant on the edge of the cup plug and press the plug in flush with the blower drive support.

7. Check the clearance between the fully extended governor weights and the blower drive gear. This clearance must not be less than .100" (Fig. 18).

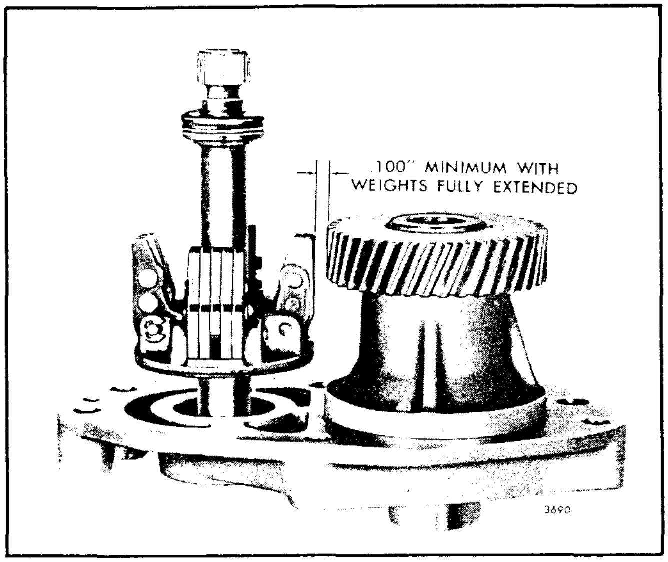


Fig. 18 - Minimum Clearance Between Blower Drive Gear and Governor Weights

Install Governor

Install the governor on the engine as follows:

1. Attach a new gasket to the governor housing and place the housing against the blower rear end plate. Secure the governor housing to the blower with six bolts and lock washers.

2. Install the blower and governor assembly on the engine as outlined in Section 3.4.

3. Install the blower drive support assembly as outlined in Section 3.4 under *Install Blower in 6V Engine.*

4. Insert the upper fuel rods through the fuel rod covers, hoses and clamps and attach the fuel rods to the governor control link lever. Then, thread the link pins into the lever.

5. Attach the lower fuel rods to the injector control tube levers and to the upper fuel rods.

6. Slide the fuel rod cover hoses in place and secure them with the hose clamps.

7. Assemble the governor springs as follows:

TYPE A (Fig. 6):

a. Thread the lock nut on the spring retainer.

b. Thread the idle speed adjusting screw into the spring plunger.

c. Place the high speed spring over the spring plunger (with the close wound coils toward the idle screw end of the plunger).

d. Lubricate the spring and plunger assembly with engine oil. Then, install the spring and plunger assembly in the spring retainer and secure it in place with a lock nut. Approximately 1/4" of the idle speed adjusting screw should extend beyond the lock nut.

e. Lubricate and insert the spring seat, low speed spring, and spring cap in the open end of the spring plunger.

f. Place a new gasket over the spring retainer and thread the retainer and spring assembly into the governor housing. Tighten the lock nut finger-tight until the engine tune-up is performed.

TYPE B (Fig. 6):

a. Thread the idle speed adjusting screw into the spring plunger.

b. Reinstall the original shims over the spring plunger.

c. Place the high speed spring over the spring plunger.

d. Lubricate the spring and plunger assembly with engine oil. Then, place the spring retainer over the plunger and secure it with a lock nut. Approximately 1/4" of the idle speed adjusting screw should extend beyond the lock nut.

e. Lubricate and insert the spring seat, low speed spring and spring cap in the open end of the spring plunger.

f. Thread the retainer and spring assembly into the governor housing. The cover and gasket are to be installed after the engine tune-up is performed.

8. Place a new gasket on the governor housing and install the cover and lever assembly. Make sure the control link lever engages the pin on the differential lever. Also, be sure the pin in the speed control shaft enters the slot in the differential lever and that the pin in the stop lever shaft is engaged between the stop on the underside of the cover and the vertical extension of the control link lever. Then, secure the cover with seven screws and lock washers.

9. Connect the linkage to the governor control levers after the engine tune-up is performed.

10. Perform an engine tune-up as outlined in Section 14.

LIMITING SPEED MECHANICAL GOVERNOR

8V ENGINE

The limiting speed mechanical governor, illustrated in Fig. 1, performs the following functions:

1. Controls the engine idling speed.

2. Limits the maximum operating speed of the engine.

The double-weight governor, identified by the letters D.W.-L.S. stamped on the governor name plate, is mounted on the front end of the blower and is driven by the left-hand helix blower rotor shaft (Fig. 2).

The governor consists of four basic sub-assemblies: a cover and lever assembly, governor housing, spring housing, and a weight and shaft assembly.

Operation

Two manual controls are provided on the governor: a stop lever and a speed control lever. In the RUN position, the stop lever holds the fuel injector racks near the full-fuel position. When the engine is started, the governor moves the injector racks toward the idle speed position. The engine speed is then controlled manually by moving the speed control lever.

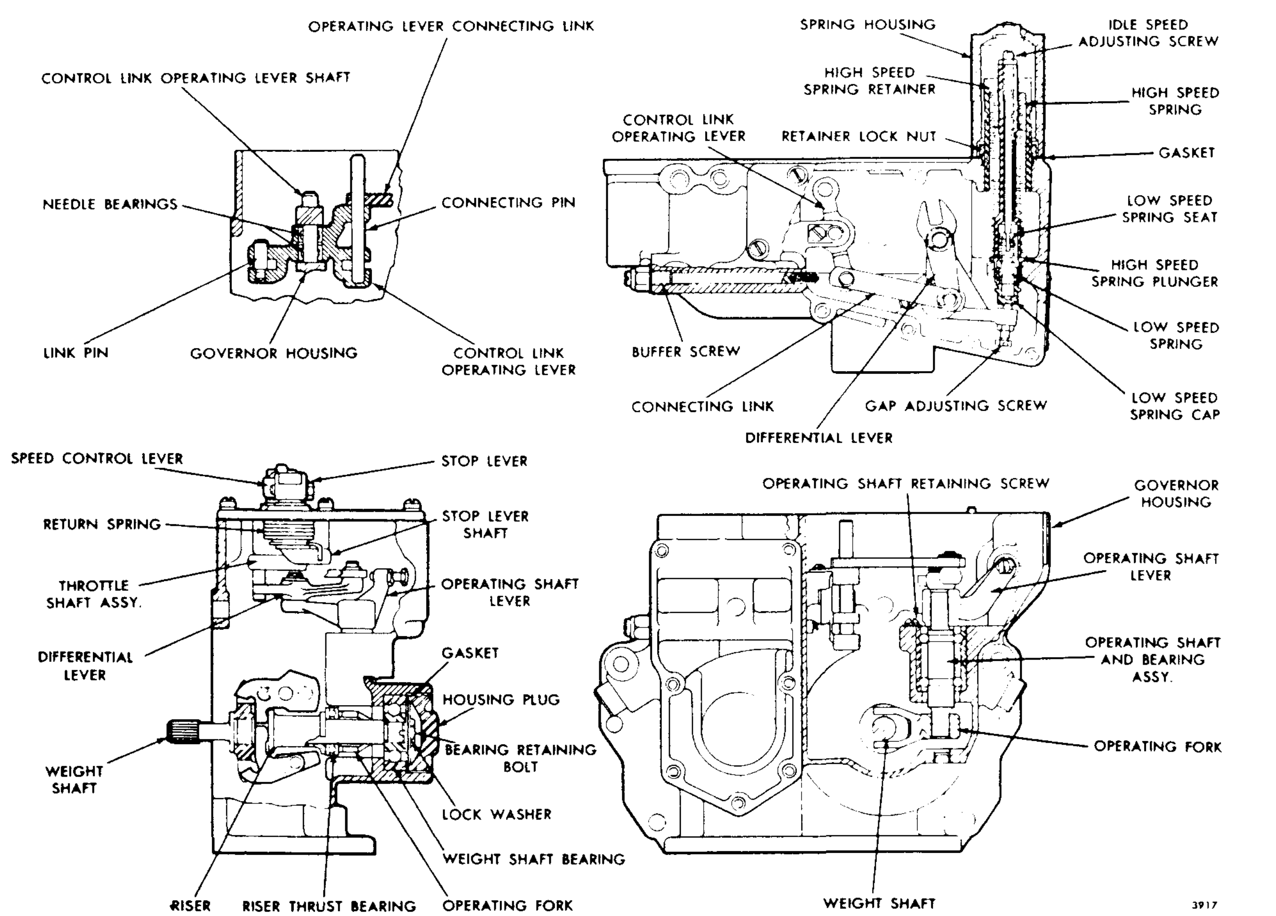


Fig. 1 - Limiting Speed Governor for 8V-53 Engine

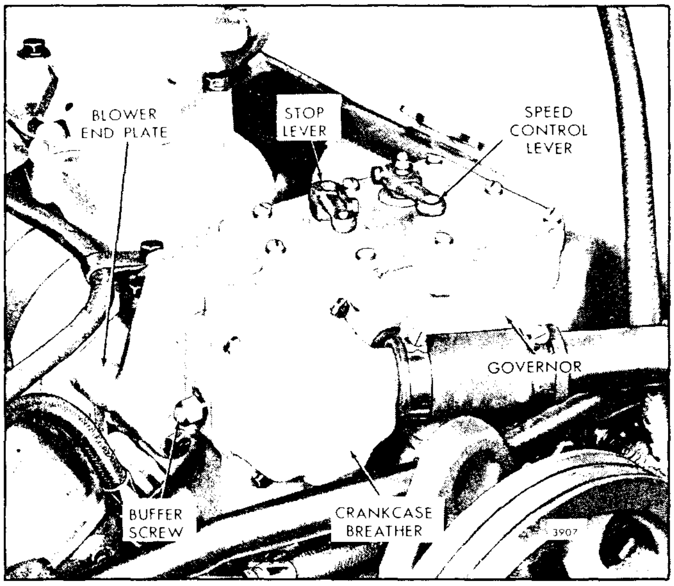


Fig. 2 - Governor Mounting

The centrifugal force of the revolving governor 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 bears against the governor spring cap while the other end provides a moving fulcrum on which the differential lever pivots.

The centrifugal force of the governor weights is opposed by the governor springs. Load changes or movement of the speed control lever momentarily creates an unbalanced force between the revolving weights and the tension on the high speed spring or low speed spring (depending on the speed range). When the forces reach a balanced condition again, the engine speed will be stabilized for the new speed setting or new load.

In the low speed range, the centrifugal force of the low speed weights and the high speed weights operates against the low speed spring. As the engine speed increases, the centrifugal force of both pairs of weights compresses the low speed spring until the low speed weights have reached the limit of their travel at which time the low speed spring is fully compressed and the spring cap is within .0015 " of the high speed spring plunger.

Throughout the intermediate speed range, the operator has complete control of the engine because both the low speed spring 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 engine speed continues to increase, the

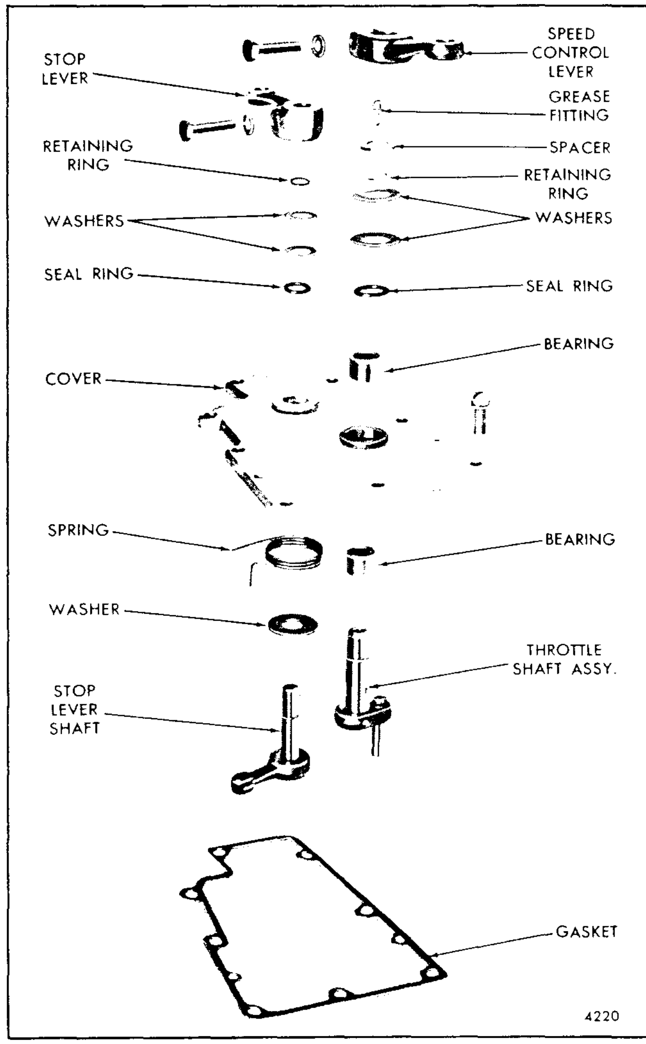


Fig. 3 - Governor Cover Details and Relative Location of Parts

centrifugal force of the high speed weights increases until this force overcomes the high speed spring and the governor again takes control of the engine, limiting the maximum engine speed.

Fuel rods are connected to the differential lever and the injector control tube levers through the control link operating lever and the connecting link (Fig. 1). This arrangement provides a means for the governor to change the fuel settings of the injector control racks.

To stop the engine, the speed control lever is moved to the idle speed position and the stop lever is moved to the no-fuel position and held there until the engine stops.

Adjustment of the governor is covered in Section 14.

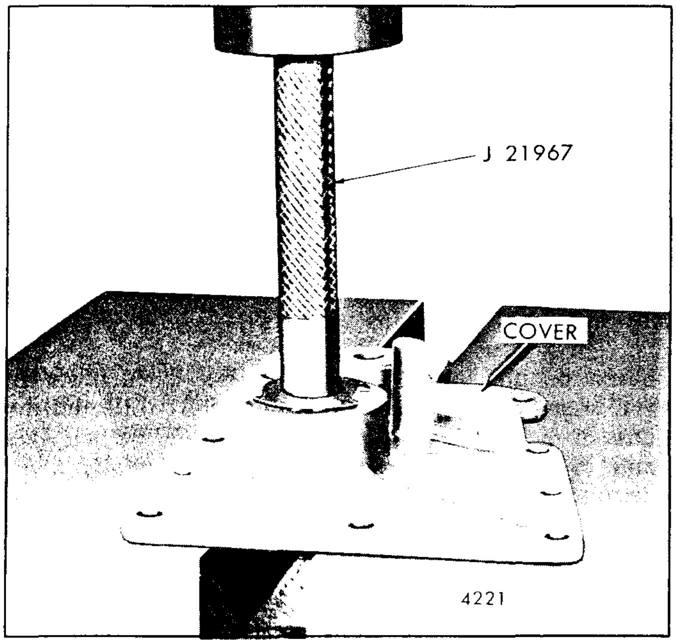


Fig. 4 - Removing Governor Cover Bearings

Lubrication

The governor is lubricated by a spray of oil from a passage in the blower end plate. The revolving governor weights distribute this oil to all parts of the governor which require lubrication. Excess oil returns to the engine crankcase through passages in the blower end plate and the cylinder block.

Remove Governor From Engine

Check the operation of the governor as outlined in Section 2.7 and if it fails to control the engine properly, remove and disassemble it for further inspection.

The blower and governor must be removed together as outlined under *Remove Blower (8V-53)* in Section 3.4.1. Then remove the governor from the blower as outlined under *Remove Accessories from Blower (8V-53)* in Section 3.4.1.

Disassemble Governor

Before removing any parts from the governor, wash the entire unit in clean fuel oil, dry it with compressed air and inspect for worn or damaged parts which may be repaired or replaced without complete disassembly.

Disassemble Governor Cover

Refer to Fig. 3 and disassemble the governor cover as follows:

1. Loosen the clamping bolt and remove the stop lever.

2. Remove the retaining ring and withdraw the two washers from the stop lever shaft assembly.

3. Note the position of the stop lever shaft assembly and the lever return spring. Then withdraw the shaft, washer and spring.

4. Remove the seal ring.

5. Loosen the clamping bolt and remove the speed control lever.

6. Remove the spacer from the throttle shaft.

7. Remove the retaining ring and withdraw the two washers from the throttle shaft assembly.

8. Withdraw the throttle shaft assembly. Remove the grease fitting from the shaft.

9. Remove the seal ring.

10. Wash the governor cover with clean fuel oil and inspect the needle bearings for wear or damage. If the bearings are satisfactory, removal is unnecessary.

11. If the bearings are to be removed, place the governor cover on an arbor press and press them out with bearing remover J 21967 (Fig. 4).

Disassemble Governor Springs

Refer to Fig. 5 and disassemble the governor spring housing as follows:

1. Remove the two retaining bolts and copper washers and withdraw the spring housing from the governor.

2. Loosen the spring retainer lock nut with a spanner wrench. Remove the spring and retainer assembly from the governor. Remove the gasket.

3. Remove the spring cap and low speed spring.

4. Loosen the lock nut and remove the idle speed adjusting screw. Then withdraw the high speed spring and plunger from the spring retainer.

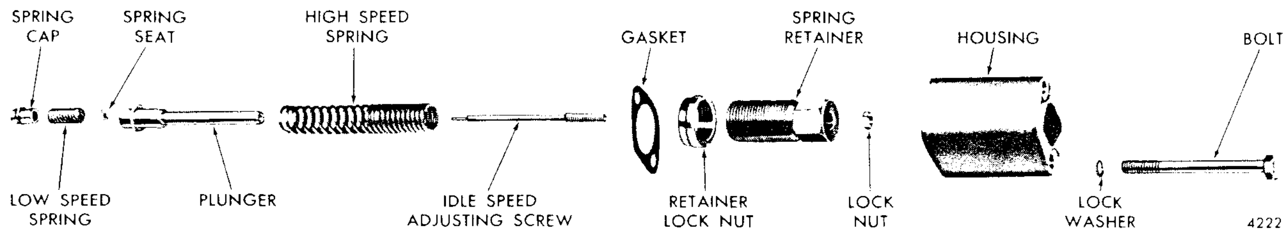


Fig. 5 - Governor Spring Assembly Details and Relative Location of Parts

Disassemble Governor Housing

Refer to Figs. 6 and 9 and disassemble the governor housing as follows:

1. Remove the large plug and gasket from the governor housing to provide access to the weight shaft bearing.

2. Straighten the tang on the lock washer and remove the weight shaft bearing retaining bolt, washer and lock washer.

3. Withdraw the weight, riser and shaft assembly.

4. Remove the weight shaft bearing from the governor housing.

5. Loosen the lock nut and remove the buffer screw.

6. Remove the two link pins from the control link lever.

7. Remove the spring pin and washer and remove the connecting link.

8. Remove the spring pin and washer and remove the differential lever.

9. Remove the control link lever shaft retainer and screw. Then withdraw the control link lever, shaft and two washers from the governor housing.

10. Examine the needle bearings. If they are satisfactory for further use, removal is unnecessary.

11. If the bearings require replacement, support the control link lever on a sleeve placed on the bed of an arbor press. Then press the bearings out of the lever with bearing remover J 8985 (Fig. 7).

12. Remove the operating shaft bearing retaining screw and washer.

13. Tap the small cup plug out of the housing.

14. Place the governor housing, upside down, on wood blocks on the bed of an arbor press. Then place an end wrench between the operating shaft fork and the boss in the housing. Insert a rod through the cup plug hole in the housing and against the end of the shaft, then press the shaft out of the fork (Fig. 8).

15. Withdraw the operating shaft, bearing and lever assembly.

16. If the operating shaft bearing requires replacement, use a small puller to remove the lever from the shaft.

Disassemble Governor Weights and Shaft

Refer to Fig. 9 and disassemble the governor weights as follows:

1. Remove the riser thrust bearing and riser tube from the weight shaft.

2. Remove the retaining rings from the weight pins. Then drive the pins out of the carrier and the weights by tapping on the grooved end of the pins. Remove the governor weights.

Inspection

Clean all of the parts (except the operating shaft bearing) with fuel oil and dry them with compressed air.

> **NOTE:** The operating shaft bearing is sealed and must not be cleaned with fuel oil or other cleaning agent.

Inspect all bearings. Replace corroded or pitted bearings. Revolve ball bearings slowly by hand; replace bearings which indicate rough or tight spots. The operating shaft and bearing are serviced only as an assembly.

Examine the riser thrust bearing for excessive wear, flat spots or corrosion.

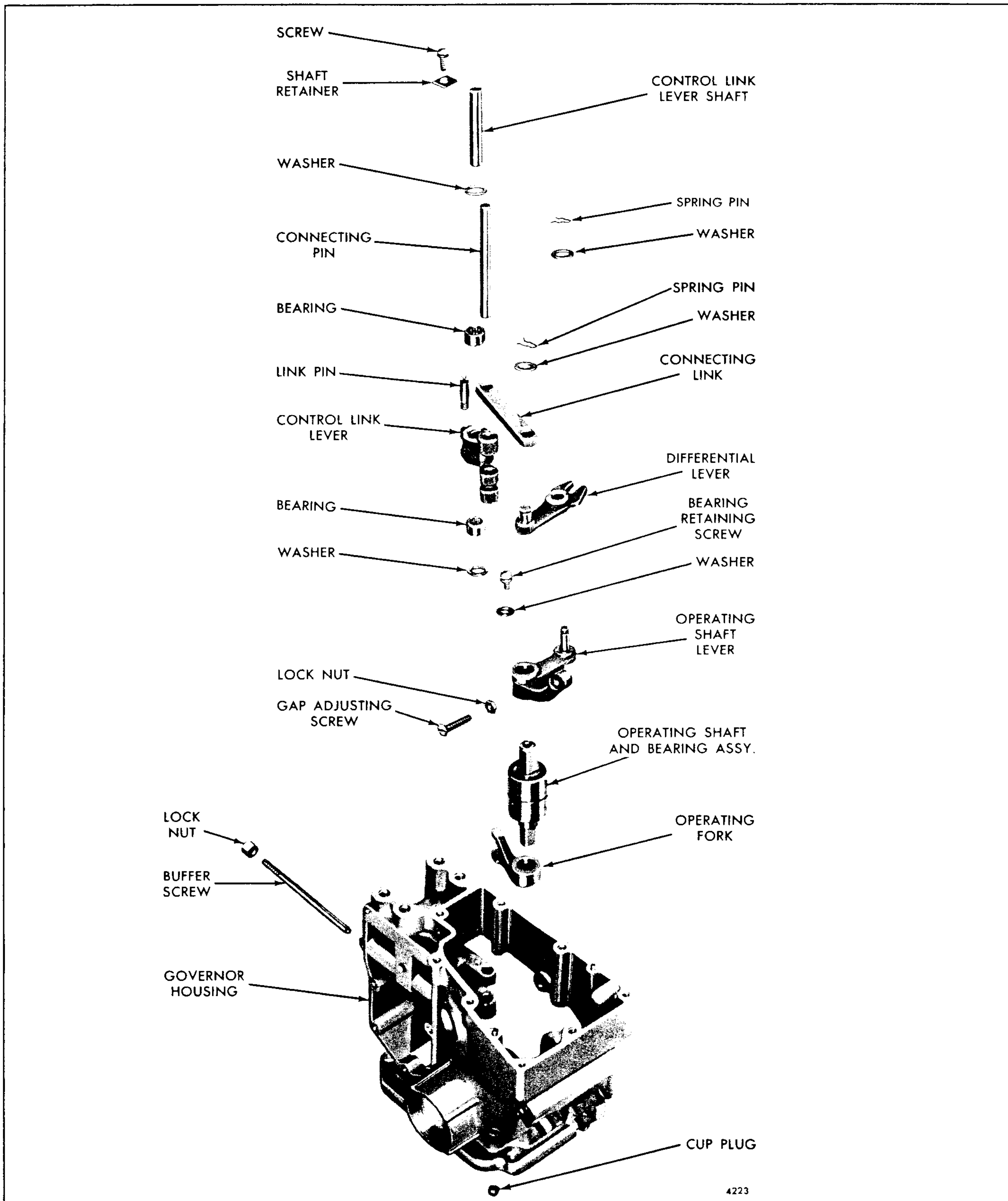


Fig. 6 - Governor Housing Details and Relative Location of Parts

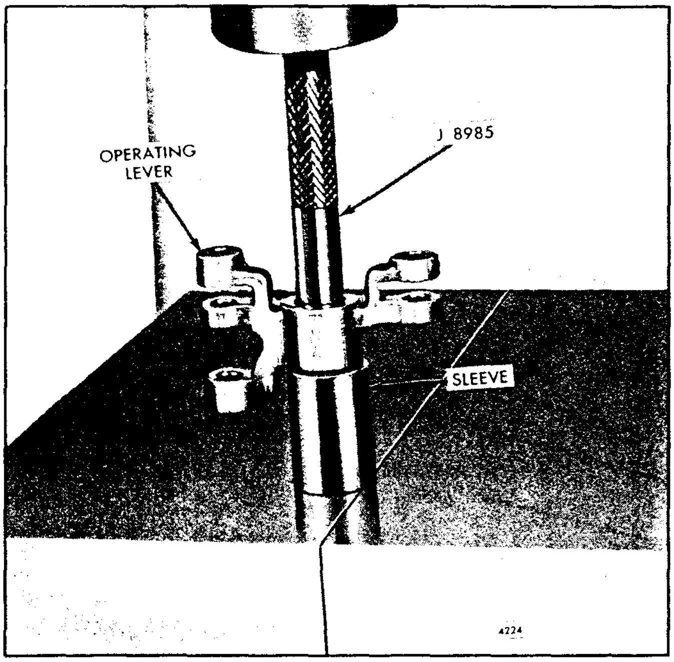


Fig. 7 - Removing Control Link Lever Bearings

Inspect all of the levers, pins, shafts, governor weights and springs. Replace worn or damaged parts.

Assemble Governor Cover

Refer to Fig. 3 and assemble the governor cover as follows:

1. Place the cover, with the inner face down, on a spacer on the bed of an arbor press. Start a needle bearing straight into the bearing bore of the cover, with the number side of the bearing up. Then insert bearing installer J 21068 in the bearing and press the bearing in until the shoulder on the tool contacts the cover (Fig. 10).

2. Turn the cover over and start the second bearing, number side up, in the bearing bore. Press the bearing in flush with the cover with tool J 21068.

NOTE: Do not use impact tools to install needle bearings.

3. Install the grease fitting in the throttle shaft.

4. Pack the needle bearings with grease. Then slide the throttle shaft assembly through the bearings, with the fulcrum lever pin seated in the slot on the underside of the cover.

5. Install a new seal ring on top of the upper bearing.

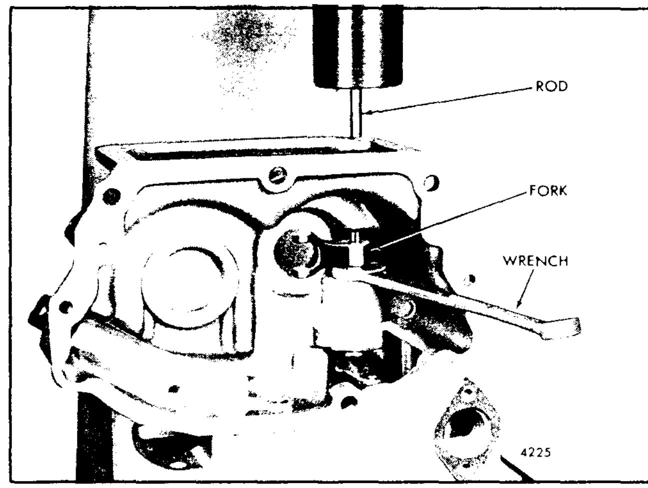


Fig. 8 - Removing Governor Operating Fork

Then install the two seal retaining washers and the retaining ring.

6. Place the large washer over the stop lever shaft. Then place the spring, with the hook end down, over the shaft. Insert the shaft in the cover with the lever against the stop in the cover; position the spring with the hook behind the lever and the upper extended end of the spring located between the lever stop and the shaft boss in the cover.

7. Install a new seal ring over the shaft. Then install the two seal retaining washers and the retaining ring.

8. Install the .078 " thick spacer over the speed control shaft and against the retaining ring.

9. Install the stop lever and the speed control lever; tighten the clamping bolts. Be sure the speed control lever contacts the spacer.

Assemble Governor Housing

Refer to Fig. 6 and assemble the governor housing as follows:

1. Start the operating shaft lever on the shaft with the flat surfaces aligned and press the lever flush with the top of the shaft.

2. Insert the shaft, bearing and lever assembly in the governor housing.

3. Place the housing right side up on the bed of an arbor press.

4. Align the flat surfaces and start the operating shaft fork on the shaft with the finished cam surfaces of the fork facing toward the rear of the governor. Insert the

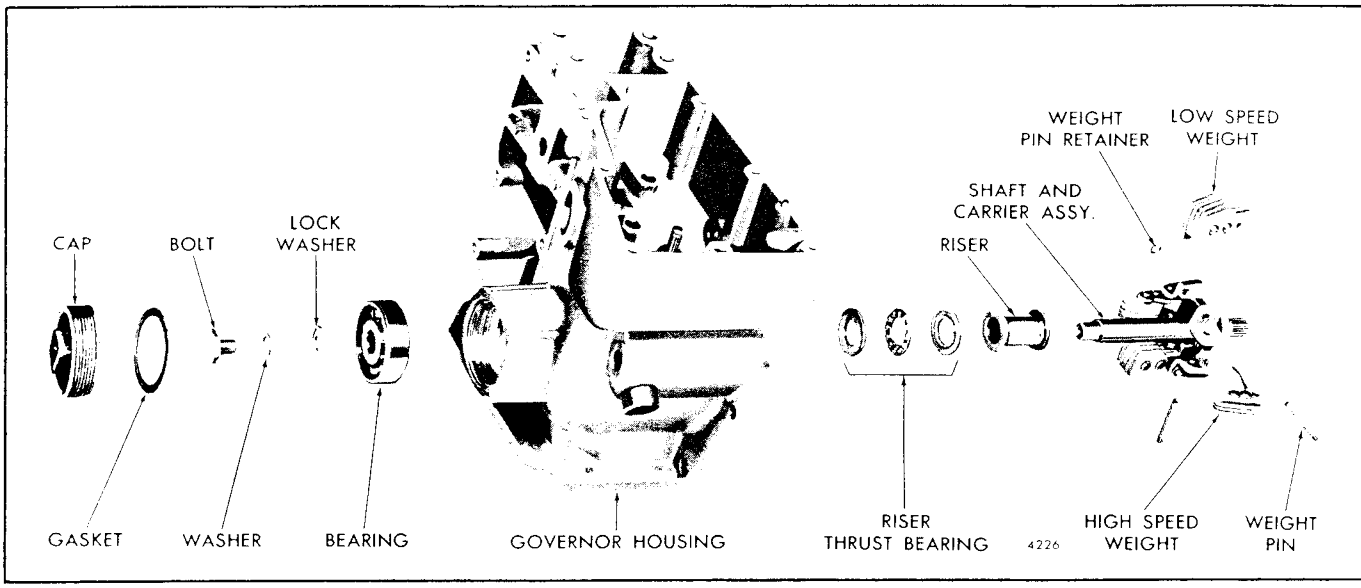


Fig. 9 - Governor Weight Details and Relative Location of Parts

threaded end of tool J 21995-2 through the cup plug hole in the housing. Then thread the knurled nut J 21995-1 on the end of the tool so the fork rests on the nut. Use a rod of suitable length and diameter and press the shaft into the fork until the fork is flush with the end of the shaft (Fig. 11). Remove the tools.

5. Install the operating shaft bearing retaining screw and washer.

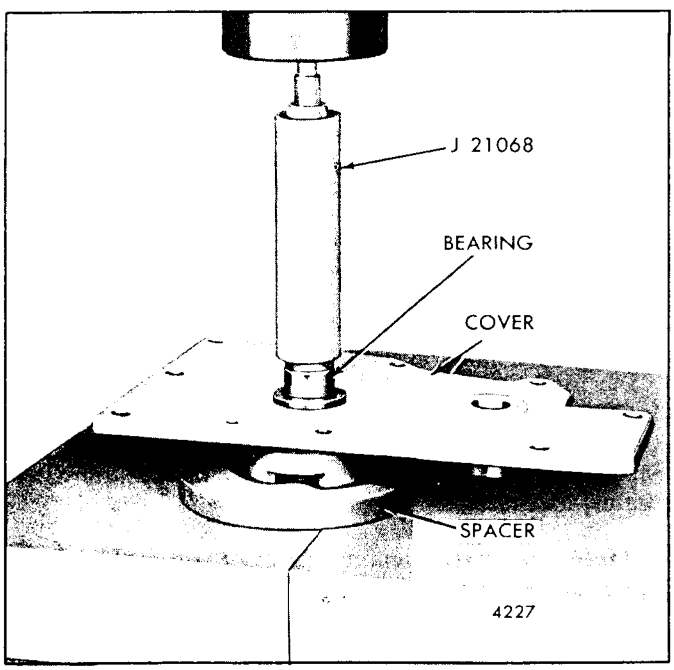


Fig. 10 - Installing Governor Cover Bearings

6. Apply a good quality sealant to a new cup plug and press the plug in the governor housing.

7. Place the differential lever over the pin in the operating shaft lever and secure it with a washer and spring pin.

8. If previously removed, install the gap adjusting screw and lock nut in the tapped hole in the operating shaft lever.

9. Support the control link lever on a steel spacer on

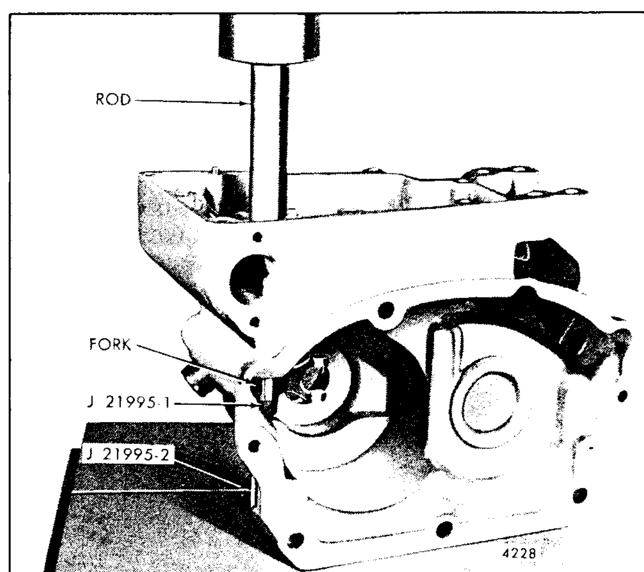


Fig. 11 - Installing Governor Operating Fork

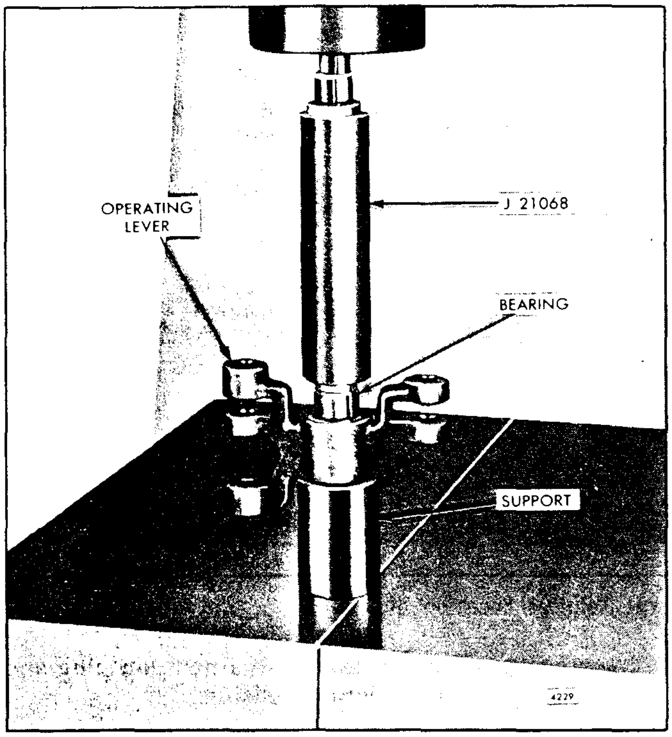


Fig. 12 · Installing Control Link Lever Bearings

the bed of an arbor press. Start one bearing, number side up, in the lever and press it flush with the lever with tool J 21068 (Fig. 12). Invert the lever and install the second bearing in the same manner.

NOTE: Do not use impact tools to install needle bearings.

10. Pack the needle bearings with grease, place a washer over each bearing and insert the control link lever between the two bosses in the housing (Fig. 1). Insert the control link lever shaft, then insert the shaft retainer in the notch of the shaft and fasten it to the housing with the retaining screw.

11. Place the connecting pin in the control link lever, then place the connecting link over the connecting pin and the pin in the differential lever. Secure the link to the differential lever with a washer and spring pin.

12. Thread the short link pin into the control link lever.

13. Install the buffer screw and lock nut.

Assemble Governor Springs

Refer to Fig. 5 and assemble the governor springs as follows:

1. Thread the lock nut on the high speed spring retainer approximately 1-1/2 ". Place the high speed spring over the spring plunger with the loosely wound end of the spring against the shoulder of the plunger.

2. Insert the plunger and spring assembly in the spring retainer. Thread the idle speed adjusting screw approximately 1/2 " into the tapped end of the plunger. Thread the lock nut on the idle speed adjusting screw.

3. Insert the spring cap in one end of the low speed spring and the small end of the spring seat in the other end of the spring.

4. Insert the spring seat end of the spring, cap and seat assembly in the spring plunger, with the spring seat against the shoulder on the idle screw.

5. Place the spring housing gasket over the springs and against the shoulder on the spring retainer lock nut. Then thread the spring retainer in the governor housing, with the spring cap against the gap adjusting screw in the operating shaft lever. Tighten the lock nut.

6. The spring housing may be installed after the engine tune-up (Section 14) is performed.

Assemble Governor Weights

Refer to Fig. 9 and assemble the weights, shaft and riser as follows:

1. Position the low speed weights, identified by the short cam arm, on opposite sides of the weight carrier. Drive the weight pins in place and install the retaining rings. To install a weight pin correctly, push the grooved end through the smaller hole in the carrier and through the weight. Then drive the knurled end in just enough so the retaining ring can be installed on the pin.

2. Install the high speed weights in a similar manner.

3. Lubricate the weight shaft with clean engine oil and slide the riser tube on the shaft.

4. Pack the riser thrust bearing with grease. Then assemble the bearing on the weight shaft, with the bearing race having the smaller inside diameter against the riser.

5. Insert the shaft, weight and riser assembly in the governor housing.

6. Support the splined end of the shaft on the bed of an arbor press. Start the weight shaft bearing in the governor housing and over the end of the shaft. Place

a sleeve against the inner race and press the bearing in the housing and against the shoulder on the shaft.

7. Place a flat washer and lock washer over the bearing retainer bolt. Thread the bolt into the tapped end of the shaft and tighten it. Bend the tang on the lock washer against the flat on the head of the bolt.

8. Place a gasket against the weight shaft bearing. Apply a sealant such as Loctite grade H, HV or HVW, or equivalent on the threads of the governor housing and the plug and thread the plug into the housing. Clean the plug with solvent to remove any oil or grease before applying the sealant. Tighten the plug to 45 lb-ft torque.

Install Governor

1. Refer to Section 3.4.1 and attach the governor to the blower as outlined under *Attach Accessories to Blower (8V-53)*.

2. Install the blower and governor assembly as outlined under *Install Blower (8V-53)* in Section 3.4.1.

3. Install the crankcase breather assembly as outlined in *Ventilating System*, Section 4.8.

4. Perform an engine tune-up as outlined in Section 14.

LIMITING SPEED MECHANICAL GOVERNOR

(Variable Low-Speed)

The variable low-speed limiting speed mechanical governor used on highway vehicle engines is of the double-weight type and is used where the same engine powers both the vehicle and auxiliary equipment and a 500 to 1200 rpm idle speed range is desired during the auxiliary operation.

Governor identification is provided by a name plate attached to the governor housing. The letters V.L.S.L.S. stamped on the name plate denote a variable low-speed limiting speed mechanical governor.

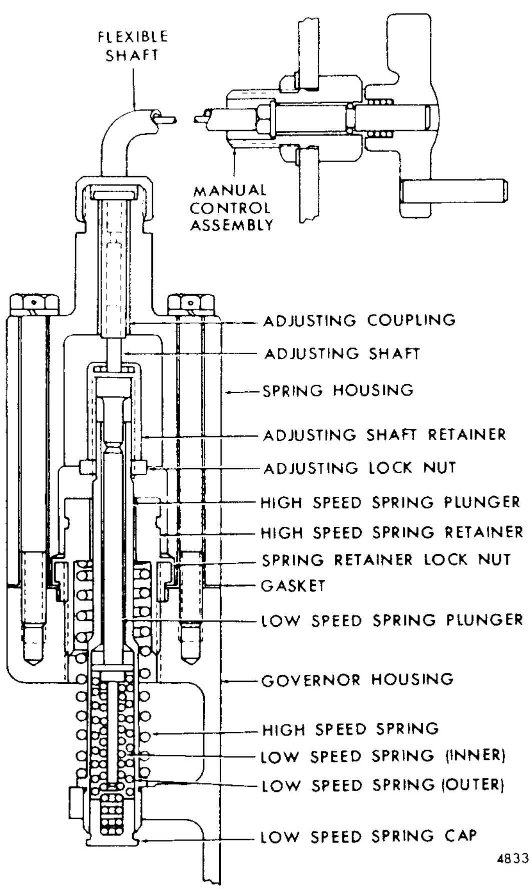


Fig. 1 - Governor Spring Housing and Components

Operation

During highway operation the governor functions as a limiting speed governor, controlling the engine idling speed and limiting the maximum operating speed. At the unloading area, the throttle is left in the idle speed position and the remote control knob is turned to the speed required within the above range to operate the auxiliary equipment. The governor then functions as a variable speed governor, maintaining a constant speed when the load is continuously changing during the unloading operation. Before resuming highway operation, the remote control knob must be turned all the way back.

Lubrication

The governor is lubricated in the same manner as the limiting speed governor (Section 2.7.1.1).

Check Governor Operation

Governor difficulties should be checked out in the same manner as outlined in Section 2.7. If, after making the checks, the governor fails to control the engine or auxiliary equipment properly, it should be removed and reconditioned.

Remove Governor From Engine

1. Disconnect the manual control flexible shaft from the governor spring housing.

2. Remove the governor following the same procedures outlined in Section 2.7.1.1.

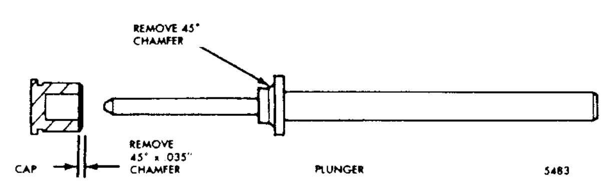


Fig. 2 - Rework Former Plunger and Cap

Disassemble Governor

The variable low-speed limiting speed governor is similar to the limiting speed governor with the exception of the spring housing and its components. Therefore, disassemble the governor as outlined in Section 2.7.1.1, then disassemble the spring housing and its components (Fig. 1) as follows:

1. Clamp the flange of the governor housing in a vise equipped with soft jaws.

2. Remove the two bolts and lock washers securing the spring housing to the governor housing and withdraw the spring housing and gasket.

3. Remove the adjusting coupling from the adjusting shaft.

4. Hold the adjusting lock nut with a wrench and back off the retainer and adjusting shaft.

5. Unscrew the adjusting shaft from the retainer.

6. Unscrew the idle adjusting lock nut from the end of the high-speed spring plunger.

7. Unscrew the high-speed spring retainer lock nut and remove the high-speed spring retainer, plunger and spring along with the low-speed spring plunger, inner and outer springs and low-speed spring cap as an assembly from the governor housing.

8. Remove the high-speed spring retainer and spacer assembly and spring from the high-speed spring plunger. Remove the low-speed spring cap from the opposite end of the high-speed spring plunger and remove the low-speed spring plunger along with the inner and outer low-speed springs.

> **NOTE:** The high-speed spring retainer on early engines did not include a spacer. If the shaft sticks in the retainer, replace it with the current retainer and spacer assembly.

Inspect Governor Parts

Wash all of the parts in clean fuel oil and dry them with compressed air, then inspect them as outlined in Section 2.7.1.1.

Assemble Governor

> **NOTE:** During assembly, lubricate all spring housing components and needle bearing assemblies with MIL. G3278A, Aero Shell 7A grease, or equivalent (special grease for high and low temperature operations).

Assemble the governor as outlined in Section 2.7.1.1, then assemble the spring housing and components (Fig. 1).

To assure a 500 rpm idle speed, the spring seat chamfer has been removed from the low low-speed spring plunger and cap. The internal chamfer has been removed from both ends of the coil of the outer low-speed spring. A high idle condition could be the result if an unchamfered spring did not seat properly due to the chamfer on the former plunger and cap. To correct this condition, install a current (modified) plunger and cap, or remove the 45° chamfer from the spring seat area of the plunger and also the 45° x .035 " chamfer on the cap (shaded area, Fig. 2).

> **CAUTION:** A chamfered spring should not be used with an unchamfered plunger and cap, because a severe wear condition will result.

1. Thread the spring retainer lock nut on the high-speed spring retainer approximately 1-1/2 ".

2. Place the high-speed spring on the high-speed spring plunger.

3. Insert the high-speed spring and plunger assembly in the high-speed spring retainer.

4. Insert the low-speed spring plunger into the high-speed spring plunger.

5. Place the inner and outer springs in the lower end of the high-speed spring plunger, over the low-speed spring plunger.

6. Install the low-speed spring cap over the end of the inner low-speed spring and into the end of the high-speed spring plunger and install the assembly in the governor housing.

> **CAUTION:** Place the spring housing gasket in position before installing the assembly.

7. Thread the idle speed adjusting lock nut on the threaded end of the high-speed spring plunger approximately 1/2 ".

8. Screw the adjusting shaft into the adjusting shaft retainer all the way in as shown in Fig. 1.

9. Install the adjusting retainer and shaft onto the high-speed spring plunger. Turn down the adjusting retainer against the idle speed adjusting lock nut.

10. Install the adjusting coupling and spring housing

after the governor adjustments (Section 14.3.3) have been performed.

Install Governor

Install the governor as outlined in Section 2.7.1.1, then connect the manual control flexible shaft to the governor spring housing (Fig. 1).

Adjust the governor as outlined in Section 14.3.3.

LIMITING SPEED MECHANICAL GOVERNOR

(FAST IDLE CYLINDER)

6V-53 VEHICLE ENGINE

The double-weight limiting speed governor equipped with a fast idle air cylinder is used on vehicle engines where the engine powers both the vehicle and auxiliary equipment.

The fast idle system consists of a fast idle air cylinder installed in place of the buffer screw and a throttle locking air cylinder mounted on a bracket fastened to the governor cover (Fig. 1). An engine shutdown air

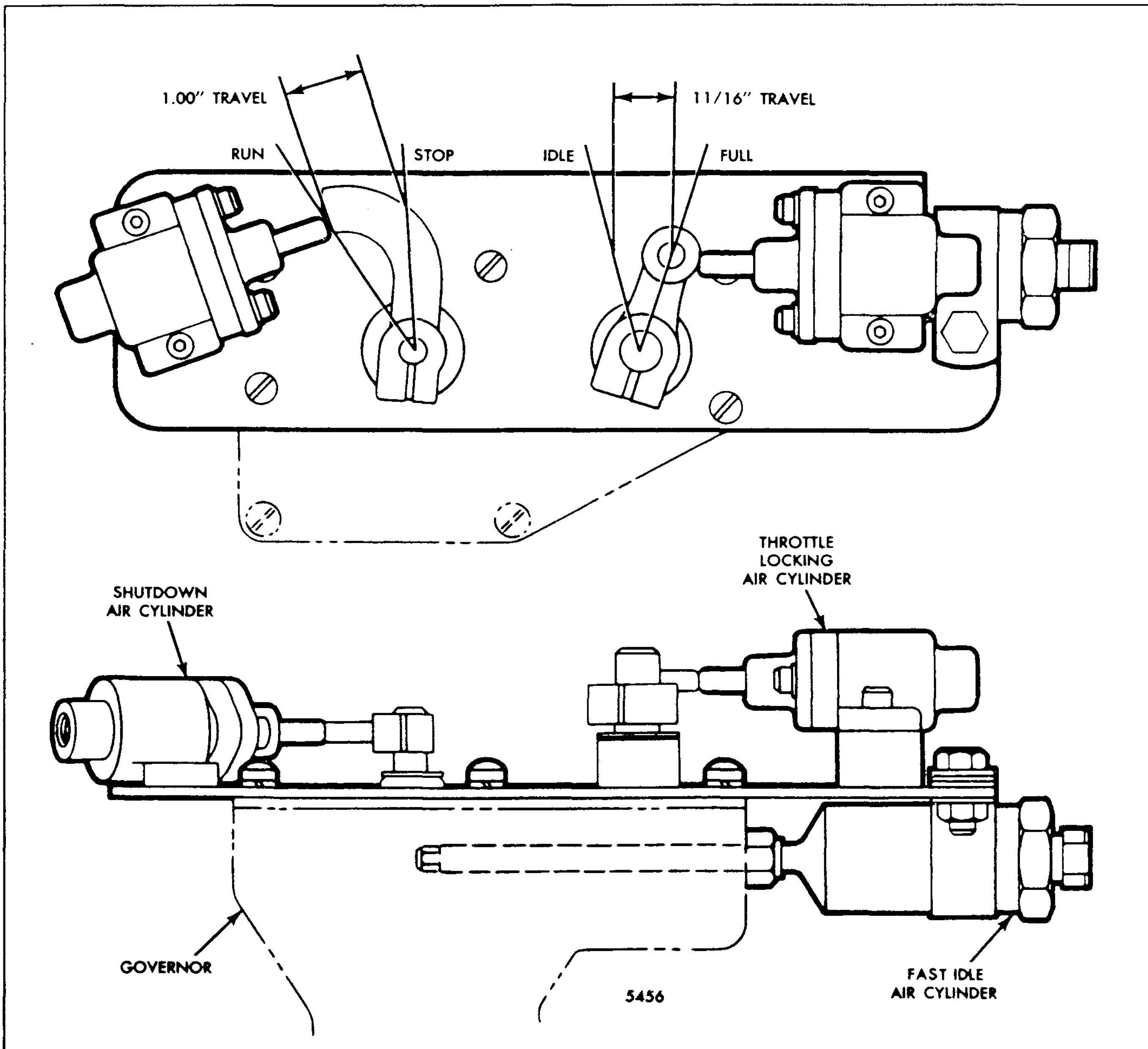


Fig. 1 - Governor with Fast Idle Cylinder

cylinder, if used, is also mounted on the governor cover.

For operation and adjustment of the fast idle air cylinder, refer to Section 14.3.4.

Lubrication

The governor is lubricated in the same manner as the limiting speed governor (Section 2.7.1.1).

Check Governor Operation

Governor difficulties should be checked in the manner outlined in Section 2.7. If, after making the checks, the governor fails to control the engine or auxiliary equipment properly, it should be removed and reconditioned.

Remove Governor

1. Release any air in the system and disconnect the air hoses from the air cylinders.

2. Remove the governor by following the procedure outlined in Section 2.7.1.1.

Disassemble Governor

1. Disassemble the governor as outlined in Section 2.7.1.1.

2. Refer to Fig. 2 and disassemble the fast idle cylinder as follows:

a. Pull the plunger out of the buffer spring and cylinder.

b. Clamp the air cylinder in a vise equipped with soft jaws.

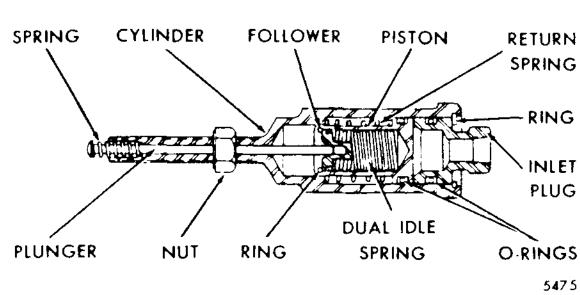


Fig. 2 - Fast Idle Air Cylinder

c. Apply pressure on the end of the air inlet plug and remove the plug retaining ring from the groove in the air cylinder.

d. Pull the air inlet plug and seal ring assembly from the air cylinder. Remove the seal ring from the groove in the plug.

e. Insert a 3/32 " diameter steel rod in the plunger opening in the air cylinder and push the piston, seal ring, dual idle spring and spring follower out of the air cylinder as an assembly. Then remove the air cylinder spring from the cylinder.

f. Remove the seal ring from the groove in the piston. Apply pressure on the spring follower and remove the follower retaining ring from the groove in the piston. Remove the follower and spring.

Inspection

Wash all of the governor components in clean fuel oil and dry them with compressed air. Then inspect them as outlined in Section 2.7.1.1.

Examine the fast idle air cylinder components for wear or any defects. Replace worn or damaged parts.

Assemble Governor

1. Assemble the governor as outlined in Section 2.7.1.1.

2. Assemble the fast idle cylinder as follows:

a. Refer to Fig. 2 and insert the dual idle spring inside of the fast idle air cylinder. Place the spring follower, with the small diameter end down, inside of the spring. Apply pressure on the spring follower and compress the spring enough to expose the retaining groove. Then install the retaining ring in the groove.

b. Install a new seal ring in the groove in the piston. Then install the air cylinder spring over the small diameter end of the piston.

c. Lubricate the seal ring on the piston with engine oil. Then insert the piston and spring assembly, with the small diameter end of the piston first, straight into the air cylinder spring seats on the shoulder in the cylinder.

d. Install a new seal ring in the groove of the air cylinder air inlet plug.

e. Lubricate the seal ring with engine oil. Then insert the air inlet plug straight into the air cylinder and against the piston.

f. Clamp the air cylinder in a vise equipped with soft jaws. Apply pressure on the end of the air inlet plug and compress the spring enough to expose the retaining ring groove. Then install the retaining ring.

g. If removed, thread the lock nut on the air cylinder. Then insert the plunger through the buffer spring and into the air cylinder.

3. Install the fast idle air cylinder assembly in the governor housing buffer screw hole.

Install Governor

1. Install the governor on the engine as outlined in Section 2.7.1.1.

2. Install the throttle locking and engine shutdown air cylinders.

3. Connect the air hoses to the air cylinders.

4. Adjust the governor as outlined in Section 14.3.4.

VARIABLE SPEED MECHANICAL GOVERNOR (PIERCE)

In-Line Fan-To-Flywheel Industrial Engines

The variable speed mechanical governor, illustrated in Fig. 1, performs three functions:

1. Controls the engine idle speed.

2. Limits the maximum no-load speed.

3. Holds the engine at any constant speed, between idle and maximum, as desired by the operator.

The governor is mounted on the rear end plate of the engine and is driven by a gear that extends through the end plate and meshes with either the camshaft gear or balance shaft gear, depending upon the engine model.

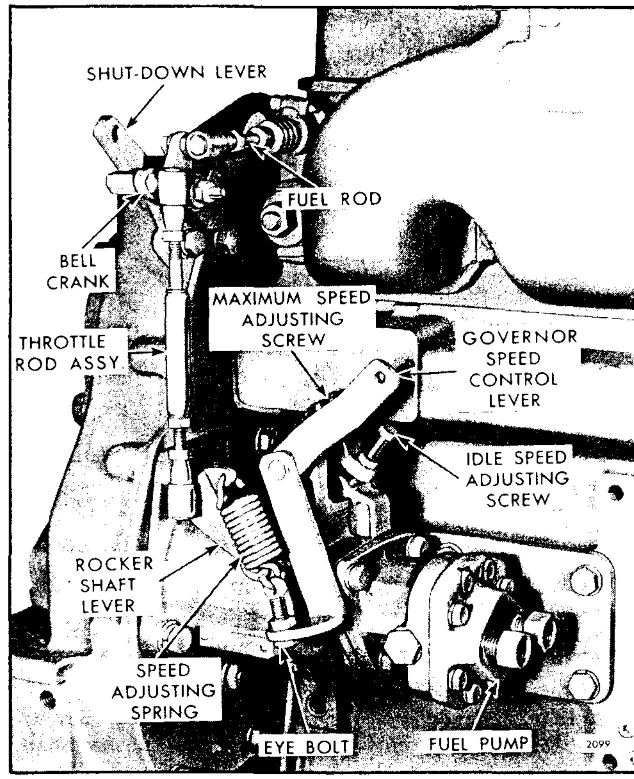


Fig. 1 - Governor Mounting

Lubrication

The governor is lubricated by oil splash, from the engine gear train, that passes through the bearing housing to the governor flyweight assembly. The oil is distributed to the various moving parts within the governor by the revolving flyweights.

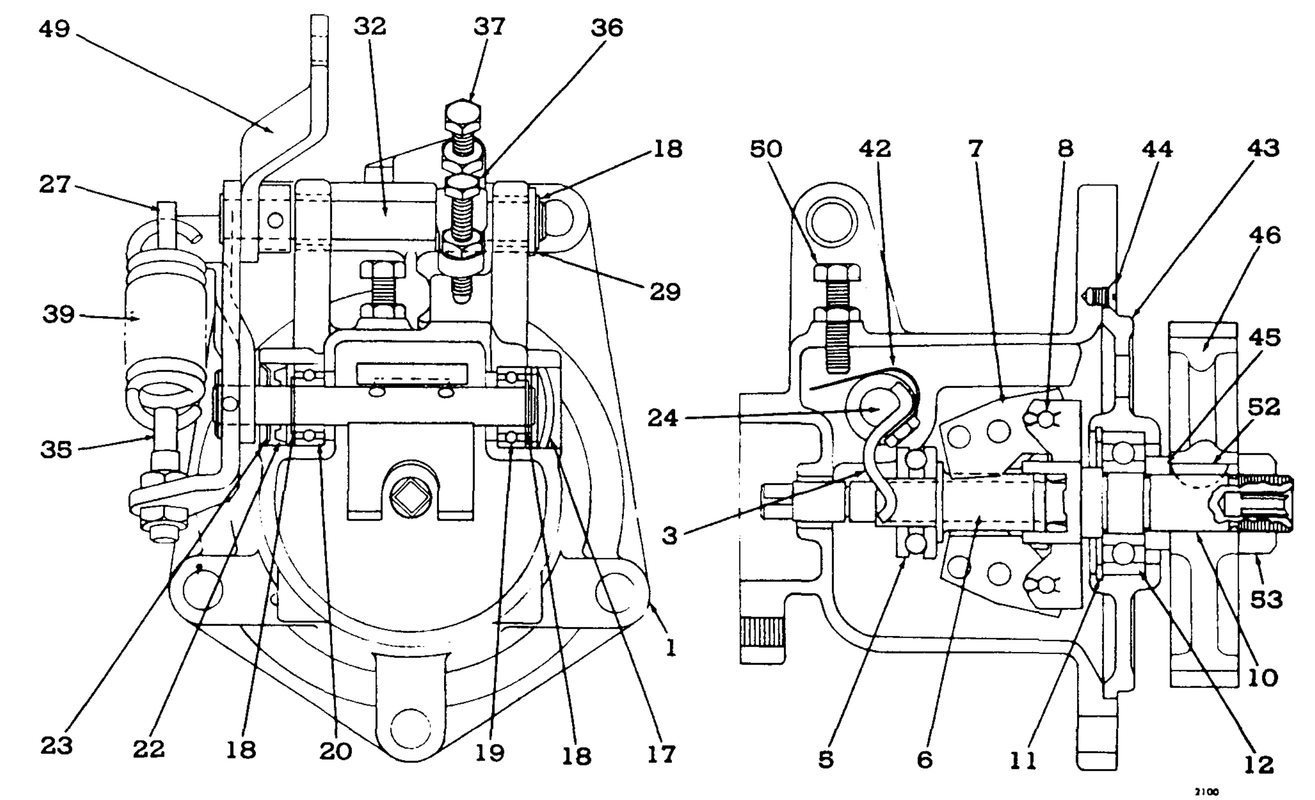
Surplus oil drains from the governor through holes in the governor bearing housing back to the engine crankcase.

Operation

The governor flyweights (7), shown in Fig. 2, are mounted on the spider and shaft assembly (10) and driven by the governor drive gear (46). This gear is pressed on the spider and shaft assembly and is driven by the engine gear train. A shoulder on the flyweights bears against the riser (6) that transmits the motion of the flyweights through the riser thrust bearing (5) to the operating fork (3). The operating fork is attached to the rocker shaft (24) that rides in ball bearings (19 and 20), and transmits the motion of the flyweights to the rocker shaft lever (27). The rocker shaft lever is pinned to the rocker shaft. The rocker shaft lever is connected to the speed adjusting spring (39) that is, in turn, connected through an eyebolt (35) to the governor speed control lever (49). The governor speed control lever is mounted on the speed adjusting shaft (32) and is controlled by the engine operator when establishing the desired speed of the unit. The idle (36) and maximum (37) speed adjusting screws limit the travel of the governor speed adjusting shaft and thus the minimum and maximum engine speed settings. The linkage operating the injector fuel racks is attached to the rocker shaft lever. Movement of the rocker shaft lever increases or decreases the amount of fuel delivered by the injectors to the engine. A governor buffer spring (42) is mounted, with the operating fork, on the rocker shaft. The spring bears against the screw (50), extending inside the governor body, that is used to stablize the engine operation at idle speed.

When the governor speed control lever is moved to an increased speed position, the tension on the speed adjusting spring is increased. The force resulting from the increased spring tension is transmitted to the rocker shaft lever and control linkage which advances the injector racks. Engine speed increases, as a result of the increased fuel, until the governor flyweight force is sufficient to balance the increased spring tension. The flyweights then move against the spring and reduce the injector rack fuel setting to an amount sufficient to maintain the higher engine speed setting.

If the governor speed control lever is moved to a decreased speed position, the tension on the speed



1. Body--Governor	17. Plug--Oil Seal	29. Washer	44. Screw--Bearing Housing Retaining
3. Fork--Operating	18. Ring--Snap (External)	32. Shaft--Speed Adjusting	45. Spacer--Drive Gear
5. Bearing--Riser Thrust	19. Bearing--Rocker Shaft (Inner)	35. Eyebolt	46. Gear--Drive
6. Riser	20. Bearing--Rocker Shaft (Outer)	36. Screw--Idle Speed Adjusting	49. Lever--Governor Speed Control
7. Flyweights	22. Seal--Rubber Oil	37. Screw--Maximum Speed Adjusting	50. Screw--Buffer
8. Pins--Weight Supporting	23. Retainer--Oil	39. Spring--Speed Adjusting	52. Key--Drive
10. Spider and Shaft Assembly--Operating	24. Shaft--Rocker	42. Spring--Buffer	53. Nut--Drive Gear Retaining
11. Ring--Snap (Internal)	27. Lever--Rocker Shaft	43. Housing--Bearing	
12. Bearing--Shaft			

Fig. 2 - Governor Cross-Section

adjusting spring will decrease and the governor flyweights will overcome the spring tension and move the rocker shaft lever to a decreased fuel position. The engine speed will be reduced until the force of the governor flyweights equals the tension of the speed-adjusting spring. The engine will then operate at the desired reduced speed.

Remove Governor from Engine

The governor is mounted on the engine rear end plate and is retained by five bolts. The engine fuel pump is driven by the governor. After removing the dirt from around the governor and engine end plate, remove the governor as follows:

1. Disconnect the linkage to the governor speed control lever.

2. Disconnect the throttle rod assembly from the rocker shaft lever.

3. Disconnect the fuel lines from the fuel pump.

4. Remove the fuel pump from the governor.

5. Remove the fuel pump gasket and the pump drive coupling.

6. Remove the attaching bolts and withdraw the governor from the engine.

7. Remove the end plate-to-governor gasket.

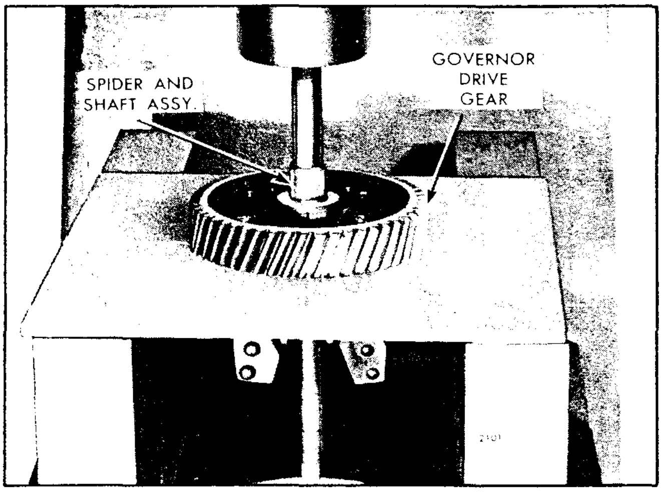


Fig. 3 - Removing Drive Gear from Spider and Shaft Assembly

Disassemble Governor

Before removing any parts from the governor, wash the entire unit in clean fuel oil and dry it with compressed air. Then inspect for worn or damaged parts that can be repaired or replaced without complete disassembly. Refer to Figs. 2 and 4 and disassemble the governor as follows:

1. Remove the countersunk screw (44) retaining the bearing housing (43) to the governor body (1) and withdraw the bearing housing from the governor. The governor drive gear (46), spider and shaft assembly (10), riser (6) and three piece thrust bearing (5) will be removed with the bearing housing.

2. Remove the outer race and the ball assembly (5) from the riser (6).

3. Remove the riser (6) from the spider and shaft assembly (10).

4. If necessary, carefully support the lower side of the inner race of the thrust bearing (5) in an arbor press and gently press the riser (6) from the inner race.

5. If required, remove the hair pin clips or retainer rings (9) that secure the flyweights (7) on the supporting pins (8). Then gently tap out the supporting pins with a 1/8" punch and remove the flyweights.

6. Remove the drive gear retaining nut (53) from the shaft and place the drive gear (46), bearing housing (43), and spider and shaft assembly (10) in an arbor press, using split plates as illustrated in Fig. 3. Then press the drive gear from the shaft with a brass rod. Remove the drive key (52) from the shaft.

7. Remove the gear spacer (45) from the shaft (10).

8. Remove the internal snap ring (11) which retains the bearing (12) in the bearing housing (43). Then separate the bearing housing from the bearing.

9. Support the inner race of the bearing (12) on split plates in an arbor press, with the drive gear end of the spider and shaft assembly (10) up. Then press the shaft from the bearing.

10. Remove the speed adjusting spring (39) by removing the eyebolt (35) from the governor speed control lever (49). The spring can then be slipped from the eyebolt and the rocker shaft lever (27).

11. Remove the roll pin (25) retaining the speed adjusting bracket (30) to the governor speed adjusting shaft (32).

12. Remove the snap ring (18) retaining the speed adjusting shaft (32) to the governor body. Then remove the speed adjusting shaft, tapping the shaft, if necessary, to remove it from the speed adjusting bracket (30).

13. If desired, remove the idle (36) and maximum (37) speed adjusting screws from the speed adjusting bracket.

14. Remove the speed control lever (49) by driving out the roll pin and tapping the shaft from the lever.

15. If desired, remove the buffer screw (50) from the governor body.

16. Remove the operating fork (3) and the buffer spring (42) by removing the two retaining bolts (4) and lock washers.

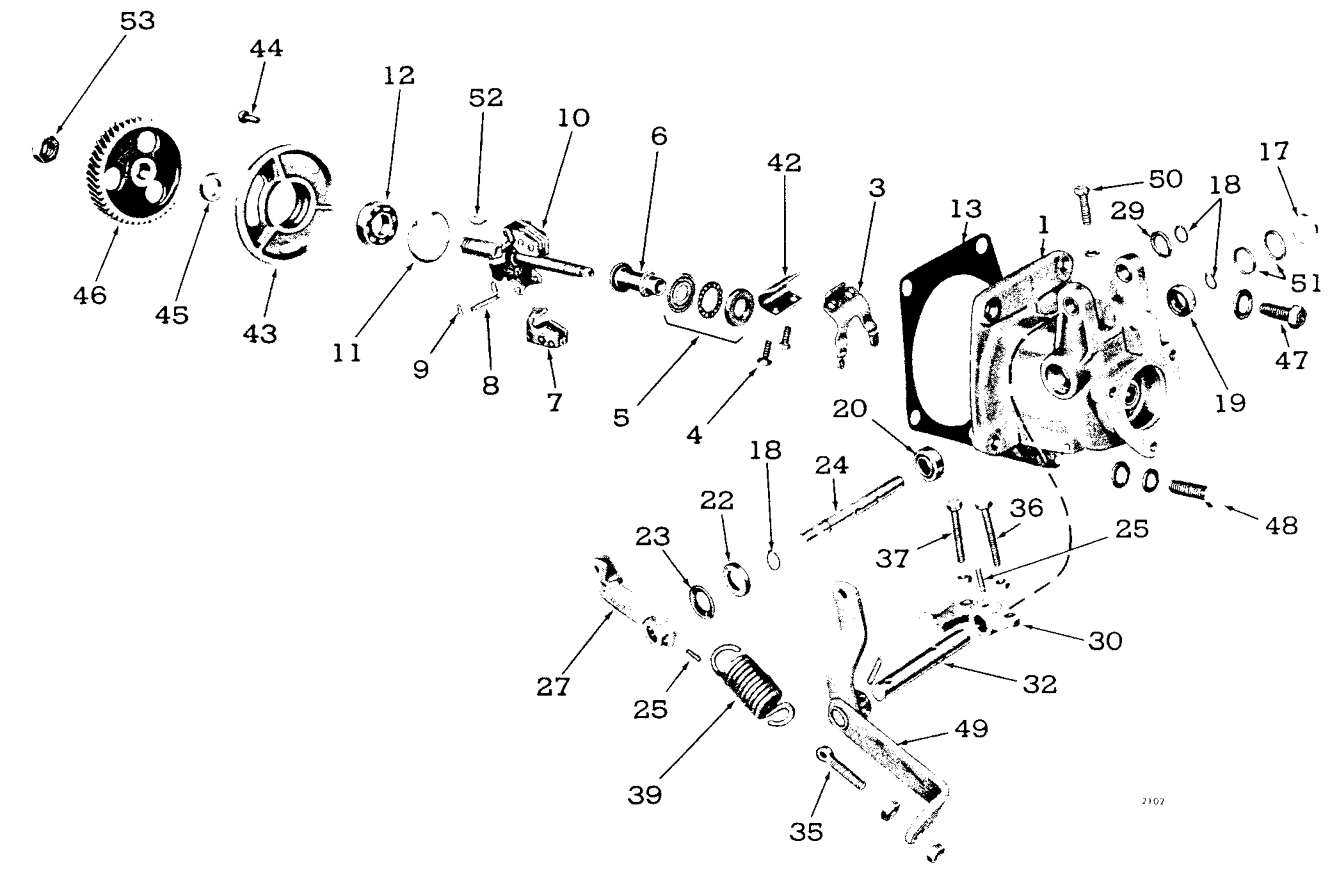
17. Remove the oil seal plug (17) by driving lightly with a small punch at the lower edge of the plug, thus forcing the upper edge outward. Then place a screw driver behind the plug and remove it from the governor body. Remove the gaskets (51).

18. Remove the bearing retaining snap ring (18) from the rocker shaft (24). Then tap the rocker shaft lightly to withdraw it from the governor body.

19. Remove the bearing (19) from the governor body.

20. Remove the oil seal retainer (23) and the oil seal (22) from the rocker shaft (24).

21. Remove the rocker shaft lever (27) from the rocker shaft (24) by driving out the roll pin (25) and tapping the shaft gently to facilitate removal.



1. Body--Governor
3. Fork--Operating
4. Bolts--Operating Fork
5. Bearing--Riser Thrust
6. Riser
7. Flyweights
8. Pins--Weight Supporting
9. Ring--Retainer
10. Spider and Shaft Assy.--Operating
11. Ring--Snap (Internal)
12. Bearing--Shaft
13. Gasket--Body Mounting
17. Plug--Oil Seal
18. Ring--Snap (External)
19. Bearing--Rocker Shaft (Inner)
20. Bearing--Rocker Shaft (Outer)
22. Seal--Rubber Oil
23. Retainer--Oil
24. Shaft--Rocker
25. Pin--Roll (5/32")
27. Lever--Rocker Shaft
29. Washer
30. Bracket--Speed Adjusting Shaft
32. Shaft--Speed Adjusting
35. Eyebolt
36. Screw--Idle Speed Adjusting
37. Screw--Maximum Speed Adjusting
39. Spring--Speed Adjusting
42. Spring--Buffer
43. Housing--Bearing
44. Screw--Bearing Housing Retaining
45. Spacer--Drive Gear
46. Gear--Drive
47. Bolt--Body Mounting (3/8"-24 x 1")
48. Bolt--Body Mounting (3/8"-16 x 1-1/4")
49. Lever--Governor Speed Control
50. Screw--Buffer
51. Gasket--Oil Seal Plug
52. Key--Drive
53. Nut--Drive Gear Retaining

Fig. 4 - Governor Details and Relative Location of Parts

Inspection

After the governor has been disassembled, clean the parts thoroughly with fuel oil and dry them with compressed air.

Inspect the rocker shaft bearings for excessive wear. Replace the bearings, if necessary.

Inspect the bushings in the governor housing for wear. If badly worn, replace the bushings.

Inspect the rubber oil seal on the rocker shaft. The slightest wear on this part can cause oil leakage. When overhauling a governor, it is recommended that a new oil seal be installed.

Inspect all of the retaining snap rings to determine if they have been damaged at time of disassembly. Replace them if necessary.

Inspect the riser bearing surface of the flyweights for excessive wear or flat spots. If either condition exists, new flyweights must be installed. The flyweights must work freely on the supporting pins for satisfactory governor operation.

Inspect the governor operating fork and the buffer spring for excessive wear or distortion. If either condition exists, replace the defective part.

Inspect the teeth of the governor drive gear for wear. Also examine the engine gear train. Replace any defective gears.

Inspect the spider and shaft assembly at the bushing and bearing surfaces and at the drive gear surface. Replace the shaft if it is damaged or worn.

Assemble Governor

After all of the parts have been cleaned and inspected, refer to Figs. 2 and 4 and assembly the governor as follows:

1. Install the outer bearing (20) on the rocker shaft (24) and retain it in place with a snap ring (18).

2. Slide the rocker shaft and bearing into the governor body.

3. Support the lever end of the rocker shaft and install the inner bearing (19) in the governor body and on the rocker shaft. Retain the bearing and shaft with a snap ring (18).

4. Install two new gaskets (51) and the oil retaining plug (17) in the rocker shaft bore.

5. Install the rocker shaft oil seal (22), with the lip of the seal facing the bearing, and the oil seal retainer (23).

6. Install the operating fork (3) and the buffer spring (42) on the rocker shaft (24) with two bolts (4) and lock washers. Tighten the bolts.

7. Install the rocker shaft lever (27) on the rocker shaft (24) and secure it with a roll pin (25).

8. Install the buffer screw (50) and the lock nut.

9. Install the governor speed control lever (49) on the speed adjusting shaft (32) and secure it with a roll pin (25).

10. Slide the speed adjusting shaft (32) through one governor body bushing and the speed adjusting bracket (30), and then through the opposite body bushing. The shaft is secured to the governor body, after installing a flat washer (29), by a snap ring (18) inserted into the groove in the shaft.

11. Position the speed adjusting bracket (30) on the speed adjusting shaft (32) and secure it with a roll pin (25).

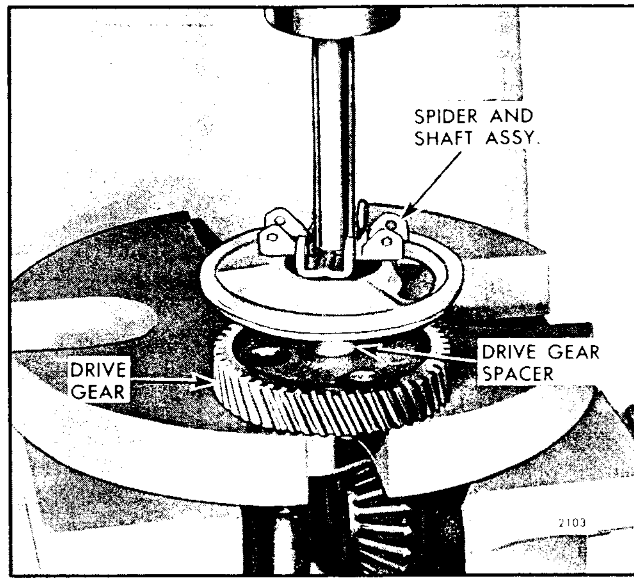


Fig. 5 - Installing Drive Gear on Spider and Shaft Assembly

12. Install the speed adjusting spring (39) on the rocker shaft lever (27) and then, using eyebolt (35), attach the spring to the governor speed control lever (49).

13. Install the idle (36) and maximum (37) speed adjusting screws and lock nuts.

14. If the spider was removed from the weight shaft, press the spider on the shaft so as to allow a clearance of .001" to .006" between the shaft shoulder and the rear face of the spider.

15. Support the inner race of the shaft bearing (12) on an arbor press. Then press the gear end of the spider and shaft assembly (10) through the bearing until the bearing seats on the shoulder of the shaft.

16. Install the bearing housing (43) on the bearing (12) and retain it with an internal snap ring (11).

17. Support the governor drive gear on an arbor press. Then, with the drive gear spacer (45) on the shaft and the key (52) installed in the keyway, press the spider and shaft assembly (10) into the gear (46) until the gear bottoms against the spacer and bearing (12), as shown in Fig. 5. Install the drive gear retaining nut (53) and tighten it to 125-135 lb-ft torque.

18. Install the flyweights (7) on the spider and shaft assembly with supporting pins (8). Retain the pins in place with hair pin clips or retainer rings (9) at the unknurled ends.

19. Support the inner race of the three-piece thrust bearing (5) on an arbor press and press the riser (6)

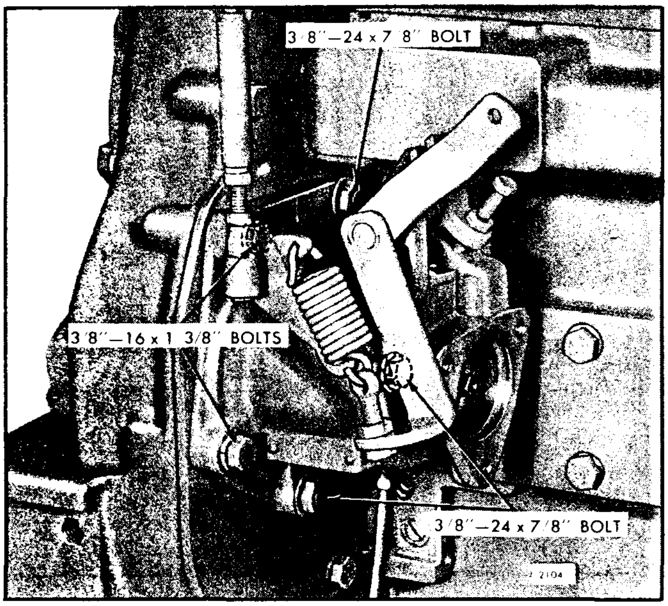


Fig. 6 - Location of Governor Retaining Bolts

into the bearing race until the shoulder on the riser contacts the bearing race.

20. Slide the riser (6) on the spider and shaft assembly (10).

21. Install the ball assembly and outer race of the three-piece bearing (5) on the riser (6).

22. Turn the bearing housing (48) around to align the attaching screw hole with the tapped hole in the governor housing. Then slide the shaft and bearing housing assembly into the governor body. The fuel pump end of the shaft extends through the bushing in the governor body. Install the countersunk screw (44) to retain the bearing housing to the governor body.

Install Governor on Engine

Mount the governor on the engine rear end plate as follows:

1. Attach a new governor-to-end plate gasket on the governor body mounting flange.

2. Install the governor against the engine end plate, so the teeth of the governor drive gear mesh with the teeth of the balance shaft gear or camshaft gear. Install and tighten the three bolts with plain copper washers (only) and two bolts with plain steel washers and lock washers (Fig. 6).

3. Install the fuel pump drive coupling and a new gasket on the fuel pump.

4. Mount the fuel pump, coupling and gasket on the governor housing (Fig. 1), turning the pump shaft until the coupling engages the drive end of the governor operating shaft. Secure the pump to the governor with three 5/16" - 18 x 7/8" bolts.

5. Reconnect the fuel lines to the fuel pump.

6. Reconnect the throttle rod assembly to the rocker shaft lever.

7. Perform an engine tune-up as outlined in Section 14.4.1.

VARIABLE SPEED MECHANICAL GOVERNOR

6V ENGINE

The variable speed mechanical governor, illustrated in Fig. 1, performs the following functions:

1. Controls the engine idling speed.

2. Limits the maximum no-load speed.

3. Holds the engine at any constant speed, between idle and maximum, as desired by the operator.

The governor is mounted between the engine blower and the flywheel housing. One end of the governor weight shaft is splined to a drive plate attached to the driven blower timing gear to provide a means of driving the governor. The other end of the governor weight shaft is supported on a bearing in the blower drive support (Fig. 2).

The governor consists of a cover and lever assembly, governor control housing, variable speed spring housing and shaft, and governor weight and shaft assembly with a single pair of weights.

For certain applications, a heavy-duty governor is provided. This governor has two pair of weights, one high speed spring (former governor has two high speed springs), a heavier operating shaft and related components, larger bearings and a blower drive support which has a larger bore to admit the larger weight shaft bearing.

Operation

Two manual controls are provided on the governor; a stop lever and a speed control lever. In its normal position, the stop lever holds the fuel injector racks near the full-fuel position. When the engine is started, the governor moves the injector racks toward the idle speed position. The engine speed is then controlled manually by moving the speed control lever.

The centrifugal force of the revolving governor 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 bears against the variable speed spring plunger, while the other end provides a moving fulcrum on which the differential lever pivots.

The centrifugal force of the governor weights is opposed by the variable speed spring. Load changes or movement of the speed control lever momentarily creates an unbalanced force between the revolving weights and the tension on the spring. When the forces reach a balanced condition again, the engine speed will be stabilized for the new speed setting or new load.

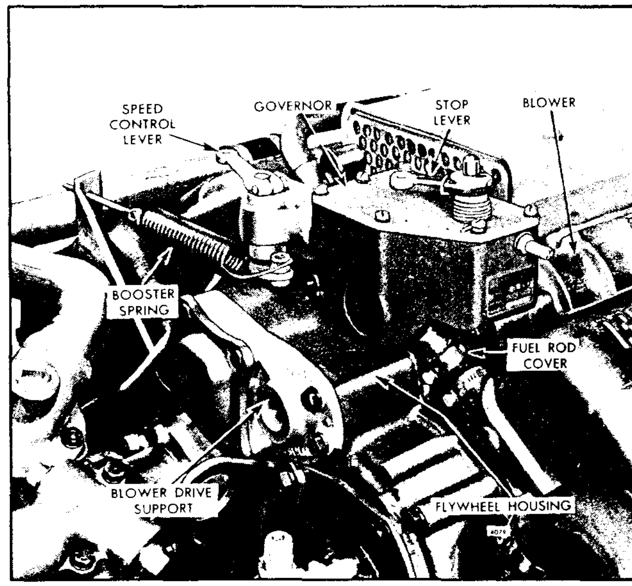


Fig. 1 - Governor Mounting

Fuel rods are connected between the control link operating lever and each injector control tube lever. A vertical pin in the differential lever engages the slot in

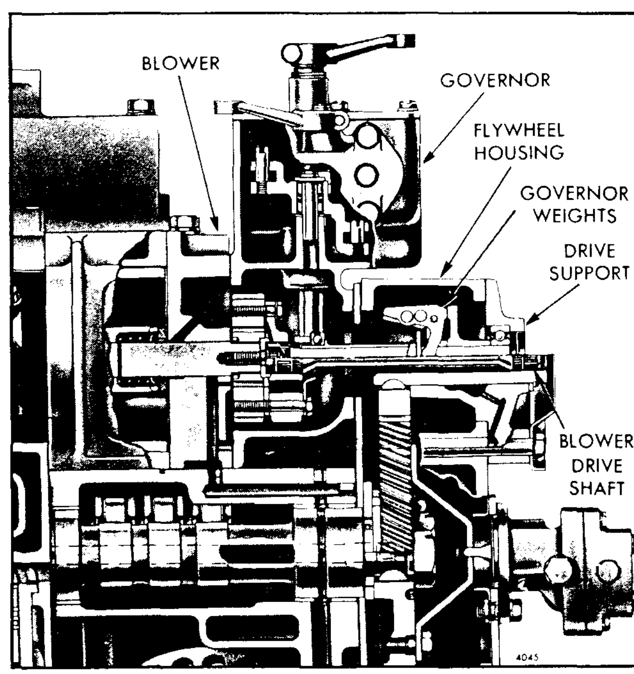


Fig. 2 - Governor and Drive

Fig. 3 - Removing or Installing Blower Drive Support

the control link lever fork. This arrangement provides a means for the governor to change the fuel settings of the injector control racks.

The engine idle speed is determined by the centrifugal force required to balance out the tension on the variable speed spring in the low speed range.

To stop the engine, the speed control lever is moved to the idle speed position and the stop lever is moved to the no-fuel position and held there until the engine stops.

Adjustment of the governor is covered in the *Engine Tune-Up* Section.

Lubrication

The governor is lubricated by a spray of pressurized lubricating oil from the blower rear end plate to the blower timing gears which distribute this oil to various parts of the governor. Oil splash from the gear train provides lubrication of the governor weights and shaft. Excess oil overflows into the gear train compartment and returns to the crankcase.

The governor weight shaft bearing, in the heavy-duty governor, is lubricated by oil flowing under pressure through a drilled passage from the cavity surrounding the blower gear drive shaft to the bearing bore in the blower drive support.

Remove Governor From Engine

Governor operation should be checked as outlined in Section 2.7 before the governor is removed from the engine. If, after performing these checks, the governor fails to control the engine properly, it should be removed and reconditioned.

Since the governor is mounted between the blower and the flywheel housing, it must be removed along with the blower as outlined below.

1. Disconnect the throttle control rod and the booster spring (Fig. 1) from the speed control lever.

2. Disconnect the retracting spring from the stop lever or cover screw.

3. Remove the attaching screws and lock washers and lift the cover and lever assembly and the gasket from the governor housing.

4. Loosen the two attaching bolts and lock washers and withdraw the variable speed spring housing and lever assembly and gasket from the governor.

5. Remove the spring retainer, shims, variable speed spring(s), stops and spring plunger.

6. Loosen the hose clamps and slide the hoses back on the fuel rod covers.

7. Remove the valve rocker cover from each cylinder head.

8. Disconnect the lower fuel rod from each injector control tube lever and also from each upper fuel rod.

9. Remove the threaded pins which connect the upper fuel rods to the control link lever. Remove the fuel rods.

10. Remove the blower drive support assembly (Fig. 3) and the blower drive shaft as outlined in Section 3.4. The governor weights, carrier, riser tube and bearing assembly, and weight shaft will be removed with the blower drive support.

11. Remove the governor weight shaft and carrier assembly from the blower drive support, using pry bars if necessary.

12. Remove the blower and governor housing assembly as outlined in Section 3.4.

13. Remove the six bolts and lock washers which attach the governor housing to the blower rear end plate. Studs and nuts were used in place of one or two of the bolts on early units. Remove the governor housing and gasket.

Disassemble Governor Cover

1. Loosen the governor stop lever retaining bolt and remove the lever from the shaft. Remove the lever retracting spring.

2. Remove the retaining ring and the two seal retaining washers. Withdraw the throttle shaft from the cover (Fig. 4).

3. Remove the seal ring from the cover.

4. At this stage of disassembly, wash the cover assembly thoroughly in clean fuel oil and inspect the bearings or bushing for wear or damage. If the

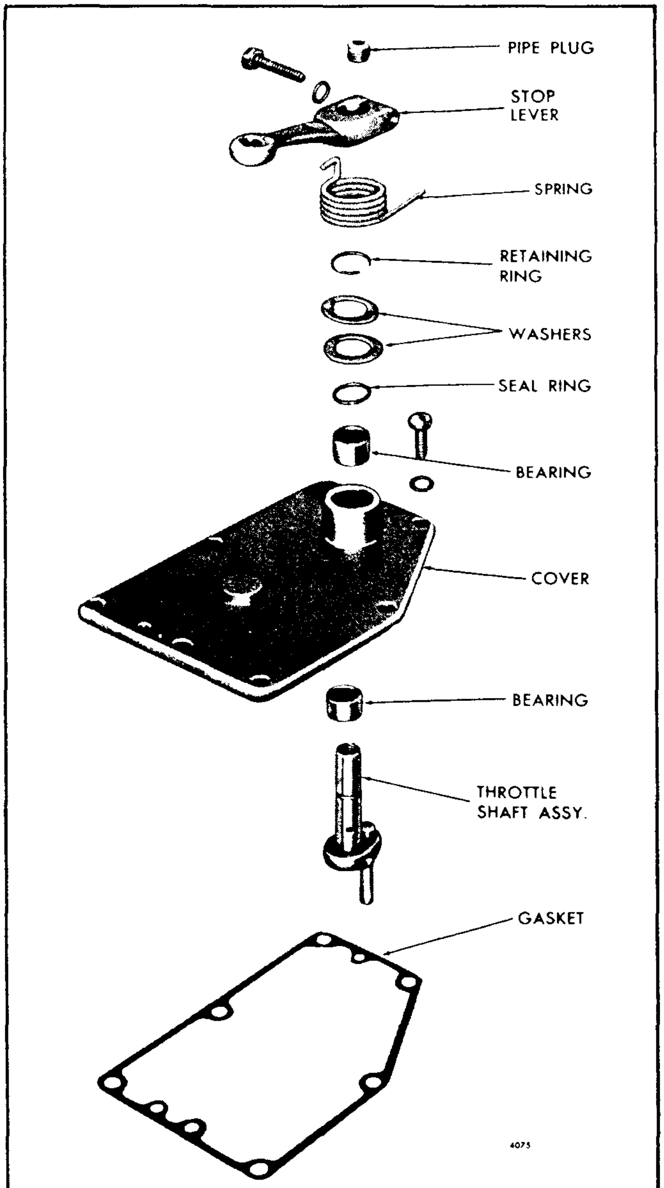


Fig. 4 - Governor Cover Details and Relative Location of Parts

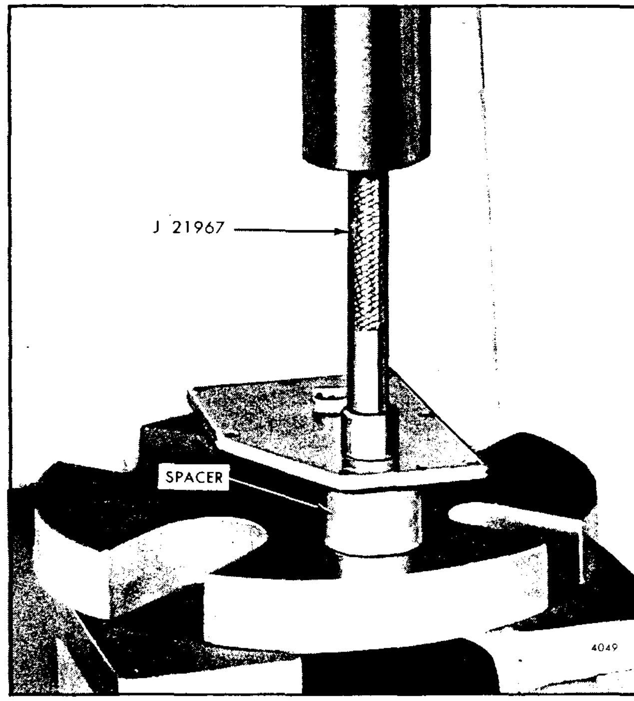


Fig. 5 - Removing Governor Cover Bearings

bearings (or bushing) are satisfactory for further use, removal is unnecessary.

5. If the bearings (or bushing) are to be removed, place the governor cover with the inner face down on an arbor press. Place a hollow spacer between the cover and the bed of the press (Fig. 5). Place the bearing remover J 21967 on top of the upper bearing (or bushing) and press both bearings (or bushing) out of the cover.

Disassemble Governor Spring Housing

If the bearings or lever require replacement, disassemble the spring housing as follows:

1. Loosen the clamp bolt and remove the speed control lever from the shaft. Remove the Woodruff key.

2. Loosen the clamp bolt and remove the booster spring lever, if used. Remove the Woodruff key.

3. Remove the plain washer and seal ring. If a booster spring lever is used, a washer and seal ring is used at each end of the shaft (Fig. 6).

4. On current governors, remove one screw and lock washer and remove the spring housing cover and gasket. Then remove the set screw from the spring lever.

On former governors, remove the pipe plug from the housing and, working through the opening, remove the set screw from the spring lever.

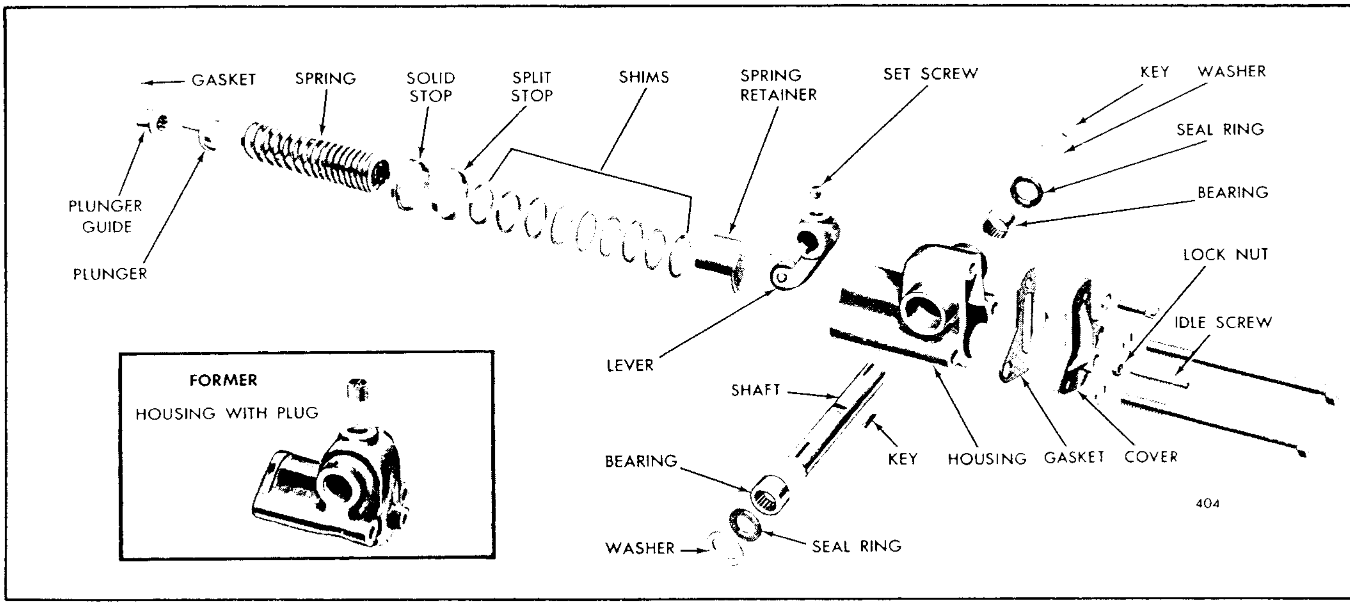


Fig. 6 - Variable Speed Spring Housing Assembly

5. Support the spring housing in an arbor press. Use a brass rod to press the shaft, bearing and plug (if used) from the housing.

6. Remove the spring lever assembly.

7. Press the second bearing from the housing.

Disassemble Governor Housing

1. Remove the governor buffer screw and spring.

2. Remove the spring pin and washer from the control link lever pin (Fig. 7) and withdraw the control link lever and washer.

3. If the bearings require replacement, support the control link lever on a sleeve placed on the bed of an arbor press. Then press the bearings out of the lever with tool J 8985 (Fig. 8).

4. Remove the spring pin and washer from the pin in the operating shaft lever and remove the differential lever.

5. Remove the plug at the bottom of the governor housing.

6. Remove the set screws, if used, from the governor operating fork.

7. Remove the operating shaft upper bearing retaining screw and washer.

8. Remove the operating shaft lower bearing by placing the inverted governor housing on the bed of an arbor press; use wood blocks to prevent damage to the dowel pins in the housing. Press on the shaft, using a rod small enough to pass through the bearing, until the bearing is free of the shaft. Then withdraw the bearing.

9. Place an end wrench between the operating fork and the governor housing and a rod on the end of the operating shaft. Then press the shaft out of the fork (Fig. 9).

10. Withdraw the operating shaft, operating shaft lever and bearings. Also withdraw the fork spacer, if a heavy-duty governor is being disassembled.

11. Press the upper bearing and operating shaft lever from the shaft.

Disassemble Governor Weights and Shaft

1. Remove the retaining rings from the governor weight pins (Fig. 10). Then drive the pins out of the carrier and the weights. Remove the governor weights.

2. Press the governor weight carrier from the shaft (Fig. 11).

3. Slide the governor riser and bearing assembly from the shaft. Do not remove the bearing since the bearing and riser are serviced only as an assembly.

Disassemble Blower Drive

1. Remove the snap ring and the thrust washer from the blower drive gear shaft (Fig. 12). Slide the shaft and gear from the blower drive support.

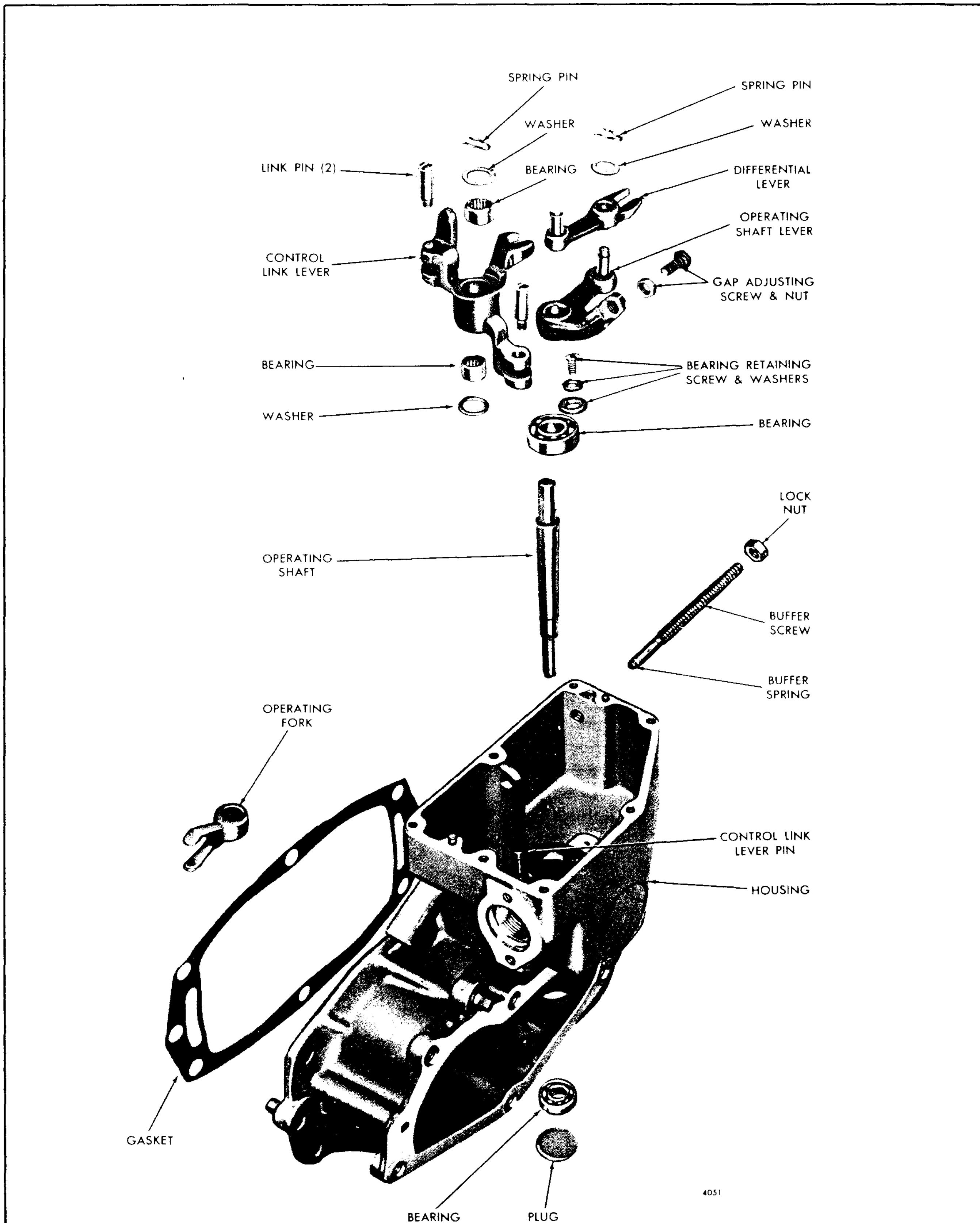


Fig. 7 - Governor Housing Details and Relative Location of Parts

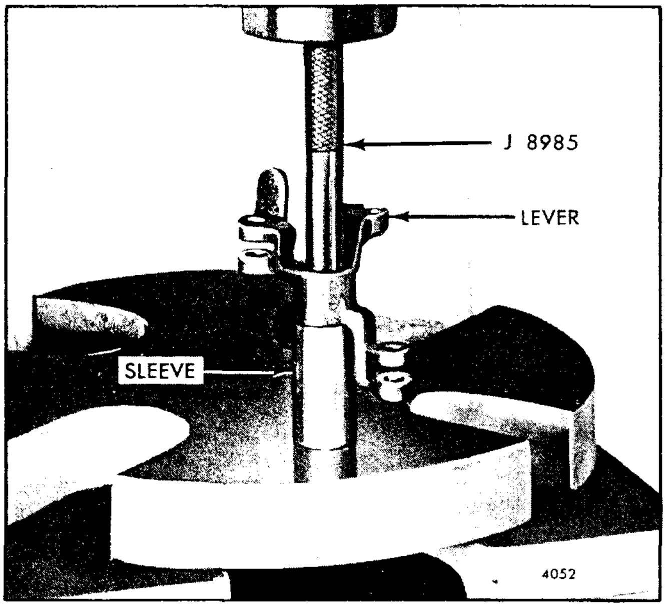


Fig. 8 - Removing or Installing Control Link Lever Bearings

2. Press the drive gear from the shaft and remove the key.

3. Tap the governor weight shaft bearing from the blower drive support. If the bearing is a tight fit, drive the plug from the support and, using a spacer against the outer race of the bearing, press or tap the bearing from the support.

Inspection

Clean all of the parts with fuel oil and dry them with compressed air.

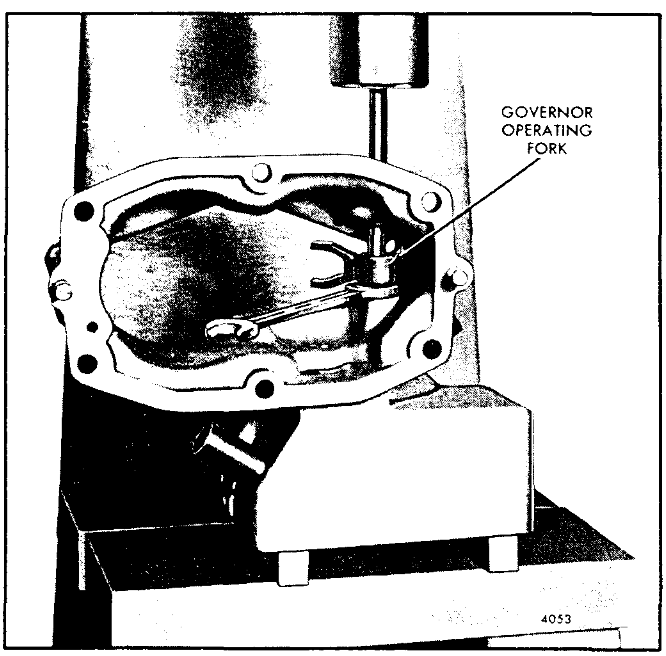


Fig. 9 - Removing Governor Operating Fork

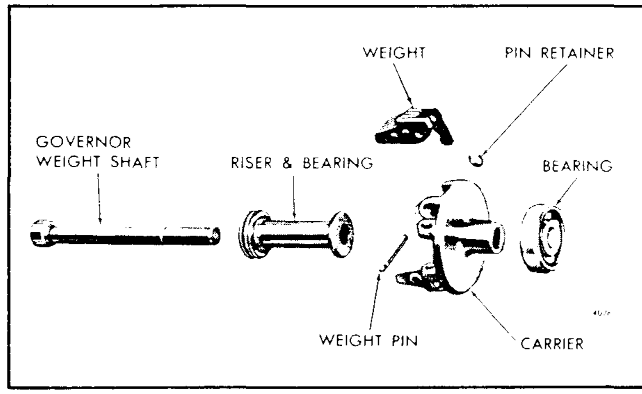


Fig. 10 - Governor Weight Details and Relative Location of Parts

Inspect all bearings. Replace corroded or pitted bearings. Revolve ball bearings slowly by hand. Replace bearings which indicate rough or tight spots.

Examine the riser thrust bearing for excessive wear, flat spots or corrosion. If any of these conditions exist, install a new riser and thrust bearing assembly.

Inspect the control link lever, needle bearings and control link lever pin for wear. Replace worn parts. If a new control link lever pin is required, remove the old pin and press the new pin in the governor housing; the pin must project 1.055" to 1.060" above the boss in the housing.

Examine the governor weight carrier pins for wear.

Examine the variable speed spring lever roller and pin for excessive wear. The current roller type bearing rides on a hardened bearing pin which is a press fit in the spring lever and is staked at three places on both

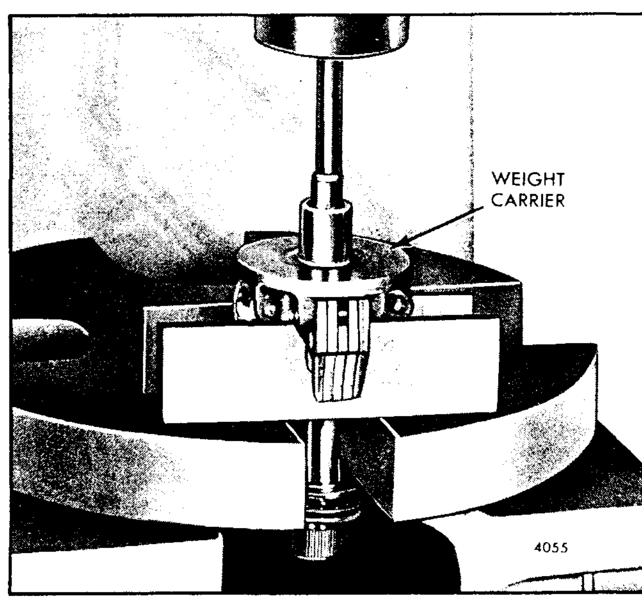


Fig. 11 - Removing Shaft from Weight Carrier

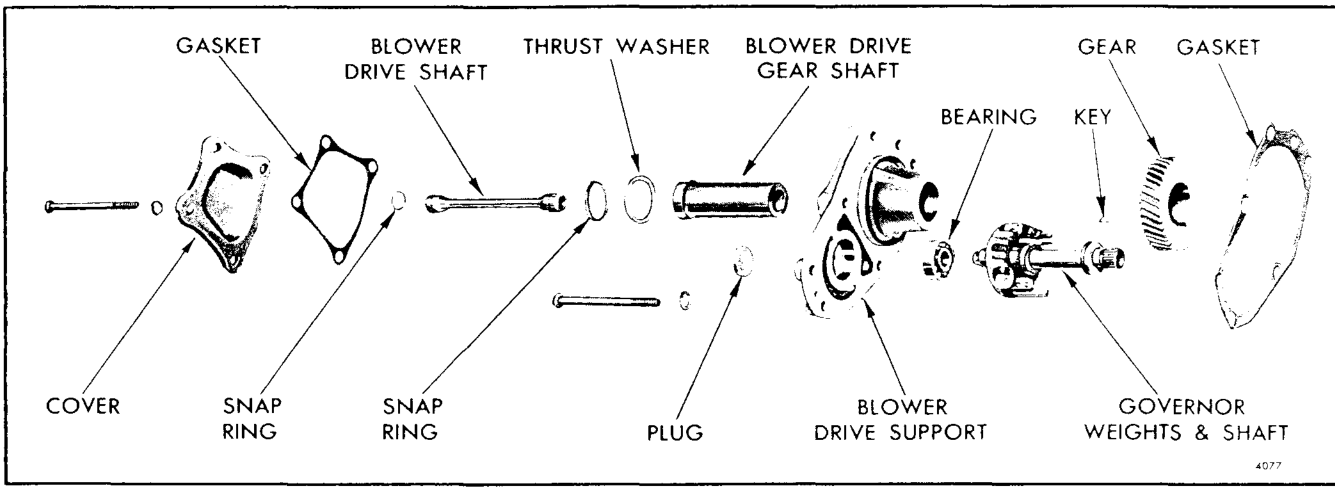


Fig. 12 - Blower Drive Support Details and Relative Location of Parts

sides. The former ball type bearing (with two washers) rides on a soft bearing pin that is swagged at both ends to retain the bearing in the spring lever.

Examine the variable speed spring plunger, guide and spring retainer for wear or score marks. If the retainer or plunger are scored slightly, clean them up with crocus cloth. Replace the retainer, plunger and guide if scored excessively.

Check the serrations on the governor weight shaft and the drive plate on the blower timing gear for wear. Replace worn parts.

Assemble Governor Cover

Refer to Figs. 4 and 13 and assemble the governor cover as follows:

1. Place the cover, with the inner face down, on the bed of an arbor press. Start a needle bearing straight into the bearing bore of the cover, with the number side of the bearing up. Then insert the installer J 21068 in the bearing and press the bearing in until the shoulder on the tool contacts the cover.

2. Turn the cover over and start the second bearing, number side up, in the bearing bore. Place a flat washer over the pilot end of tool J 4647 and insert the tool in the bearing. Press the bearing in until the washer contacts the cover.

NOTE: The bushing, used in certain governor covers, is not serviced. For service, install two needle bearings. Do not use impact tools to install needle bearings.

3. Pack the needle bearings with grease. Then slide the governor throttle shaft assembly through the bearings, with the fulcrum lever pin seated in the slot on the underside of the cover.

4. Install a new seal ring on top of the upper bearing. Then install two seal retaining washers and lock them in place with the retaining ring.

NOTE: A .0329" thick, .312" I.D. x .672" O.D. seal ring back-up washer is used in place of the lower washer on certain governor covers.

5. If a torsion-type stop lever retracting spring (Fig. 4) is used, place it over the cover hub with the hooked end up. Then place the governor stop lever on the shaft and secure it with a bolt and lock washer.

Assemble Governor Spring Housing

1. Lubricate the speed control lever shaft needle bearings with Shell Alvania No. 2 grease, or equivalent. Then start one of the bearings, numbered end up, straight in the bearing bore in the right hand side of the spring housing as viewed in Fig. 6.

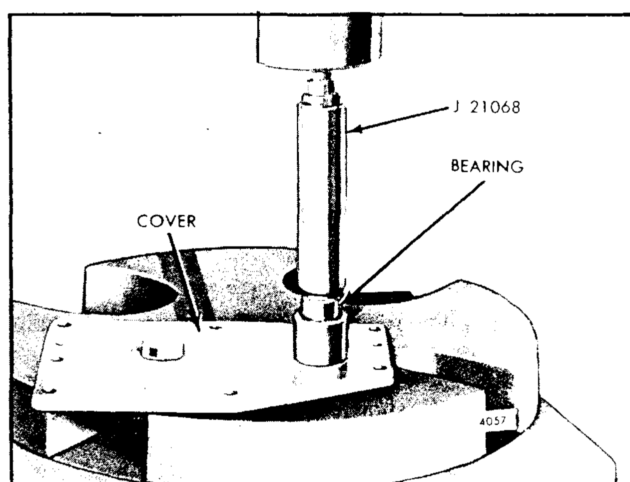


Fig. 13 - Installing Governor Cover Bearings

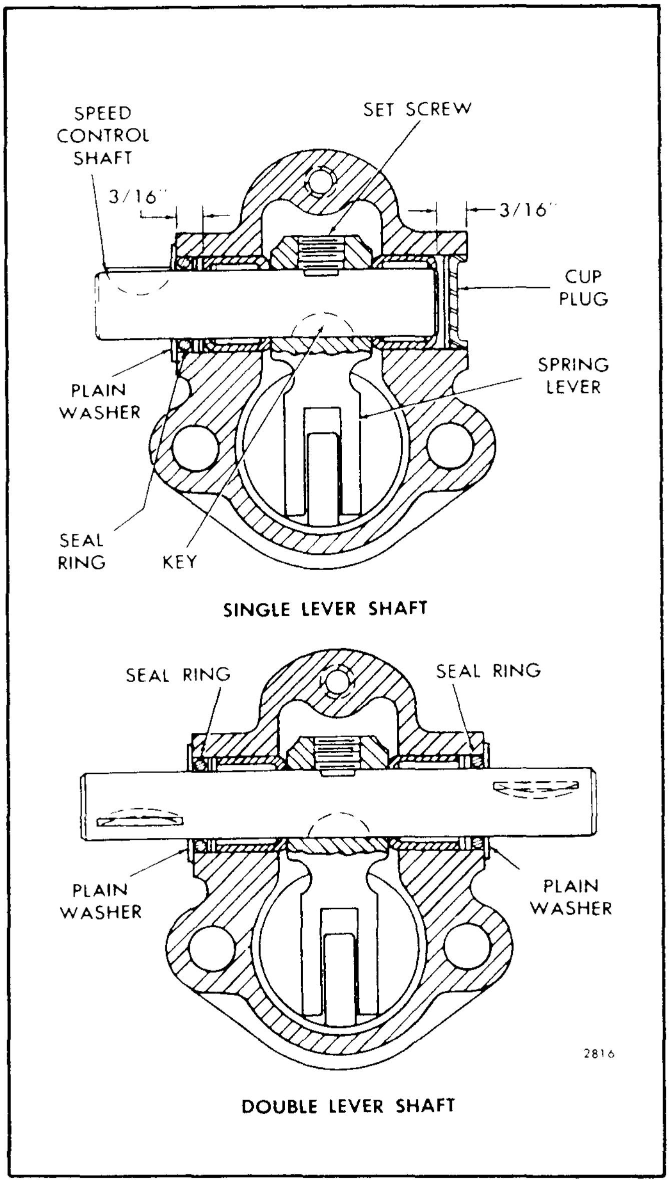


Fig. 14 - Governor Variable Speed Spring Housing

2. Install the needle bearing pilot rod J 9196-2 in the installer body J 9196-1 and secure it in place with the retaining screw.

NOTE: Do not use impact tools to install needle bearings.

3. Place the pilot rod end of the bearing installer assembly in the bearing. Support the spring housing, bearing and installer on a short sleeve on the bed of an arbor press as shown in Fig. 15, then press the bearing in the housing until the shoulder on the installer contacts the housing.

NOTE: When the shoulder on the installer body contacts the housing, the bearing will be properly positioned in the housing.

4. Install the current roller type bearing and pin in the spring lever. Press the pin below the surface of the lever and stake at three places on both sides of the lever. The former ball type bearing (with two washers) is swagged at both ends to retain the bearing in the spring lever.

5. If removed, install the spring lever Woodruff key in the center keyway in the speed control lever shaft.

6. Place the spring lever assembly between the bearing bores inside the spring housing with the arm (roller end) of the lever facing out.

7. Insert the correct end of the (single or double lever type) speed control lever shaft, Fig. 6, through the bearing bore in the side of the spring housing, opposite the bearing previously installed. Align the key in the shaft with the keyway in the spring lever and push the shaft through the lever and in the bearing until the flat on the top of the shaft is centered under the set screw hole in the lever.

8. Thread the set screw into the spring lever, making sure the point of the screw is seated in the flat on the shaft.

9. Place the second shaft needle bearing, numbered end up, over the protruding end of the shaft and start it straight in the bore of the housing.

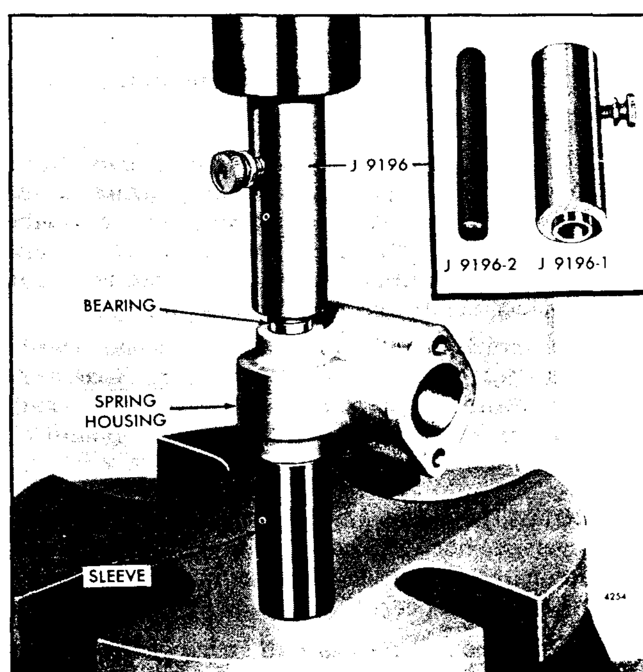


Fig. 15 - Installing Speed Control Shaft Bearings In Spring Housing

10. Remove the bearing pilot rod J 9196-2 from the installer body J 9196-1 and place the installer body over the end of the shaft and against the bearing. Support the spring housing, bearings and installer on a short sleeve on the bed of an arbor press as shown in Fig. 15, then press the bearing in the housing until the shoulder on the installer contacts the housing.

11. If a single lever shaft was installed in the spring housing, apply a thin coat of sealing compound to the outside diameter of the cup plug. Start the cup plug straight in the bearing bore in the housing, then support the spring housing, bearings and shaft assembly on a sleeve on the bed of an arbor press and press the cup plug in flush with the outside face of the housing.

12. Clamp the spring housing assembly in a bench vise equipped with soft jaws. Then tighten the spring lever retaining set screw to 12-15 lb-ft torque.

13. Stake the edge of the set screw hole with a small center punch and hammer to retain the set screw in the lever. Then install the plug in the spring housing.

14. On a single lever shaft, place a seal ring over the end of the shaft and push it into the bearing bore and against the bearing. Place the plain washer over the shaft and against the housing, then install the Woodruff key in the keyway in the shaft.

15. On a double lever shaft, place a seal ring over each end of the shaft and push them into the bearing bores and against the bearings. Place a plain washer over each end of the shaft and against the housing, then install a Woodruff key in the keyway at each end of the shaft.

16. Place the speed control lever(s) on the shaft in its original position. Align the keyway in the lever with the key in the shaft and push the lever in against the plain washer and secure it in place with the retaining bolt and lock washer.

Assemble Governor Housing

Refer to Fig. 7 and assemble the governor housing as follows:

1. Start the upper operating shaft bearing, number side up, on the end of the shaft. Support the lower end of the shaft on an arbor press. Place a sleeve on the inner race and press the bearing against the shoulder on the shaft. The shaft on the heavy-duty governor has no shoulder; press the bearing approximately .562" from the end of the shaft.

2. Start the operating shaft lever, with the pivot pin up, on the end of the shaft with the flat on the shaft registering with the flat in the lever bore. Use a sleeve to press the lever tight against the bearing. On the heavy-duty shaft, use a rod to press the lever against the bearing until the lever is flush with the end of the shaft.

3. Insert the lever and shaft assembly through the top of the governor housing. On the heavy-duty governor, slide the 2.50" long governor fork spacer on the shaft. Position the operating fork over the lower end of the shaft, with the finished cam surfaces facing toward the rear of the governor (toward the governor drive).

4. Support the operating shaft and governor housing on the bed of an arbor press with the upper end of the shaft resting on a steel block (Fig. 16). Align the flat in the fork with the flat on the shaft, then place a sleeve over the shaft and against the fork. Press the fork tight against the shoulder on the shaft or against the fork spacer. Install the set screw and lock screw, if used, in the fork.

5. Start the lower operating shaft bearing, number side up, on the end of the shaft. Place a sleeve on the outer race and press the bearing against the shoulder in the housing.

6. Lubricate both bearings with engine oil.

7. Apply a good quality sealant around the edge of a new expansion plug and drive it securely in place in the housing.

CAUTION: Do not break the housing.

8. Secure the upper operating shaft bearing in place with a retaining screw and flat washer.

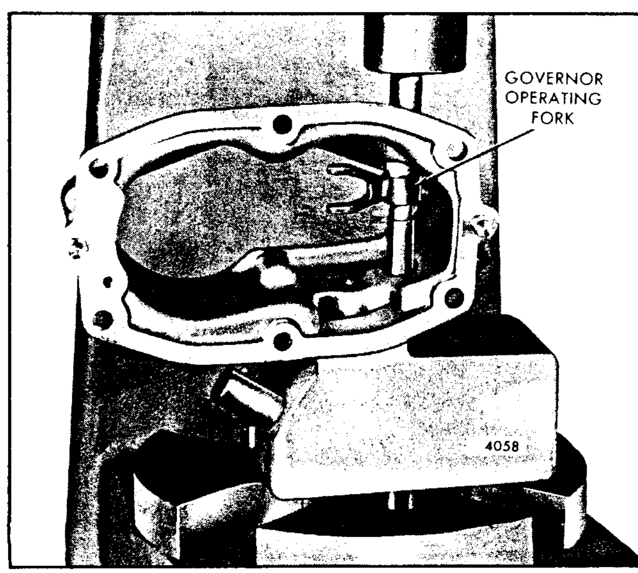


Fig. 16 - Installing Governor Operating Fork on Shaft

9. Place the differential lever (Fig. 7) over the pivot pin in the operating shaft lever. Secure the lever with a washer and spring pin.

10. If previously removed, install the gap adjusting screw and lock nut in the tapped hole in the operating shaft lever.

11. Support the control link lever on a steel spacer as shown in Fig. 8. Start one bearing, number side up, in the lever. Insert the pilot end of installer J 8985 in the bearing and press the bearing in the lever. Reverse the lever and install the second bearing in the same manner.

12. Place a washer over the end of the control link lever pin in the governor housing. Pack the needle bearings with grease and place the lever, with the tapped ends of the link pin holes down, over the pin in the housing. Secure the lever with a washer and spring pin.

13. Install the buffer screw and lock nut, leaving approximately .750" of the screw extending from the governor housing.

> **NOTE:** The buffer screw lock nut on some earlier governors was an integral part of the governor housing.

Assemble Governor Weights and Shaft

1. Lubricate the governor weight shaft with engine oil, then slide the riser assembly over the shaft with the bearing end toward the serrated end of the shaft. Pack the bearing with grease.

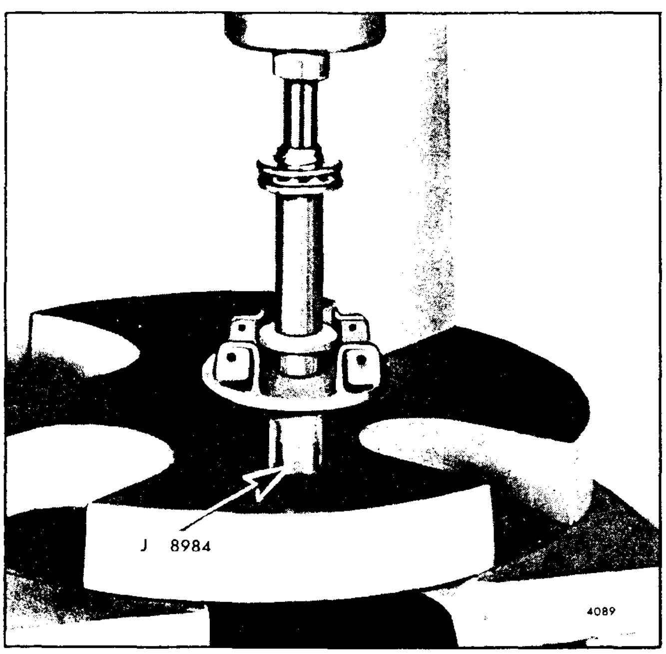


Fig. 17 - Installing Weight Carrier on Shaft

2. Press the shaft into the weight carrier, using tool J 8984 as illustrated in Fig. 17. The tool will properly position the weight carrier on the shaft. However, if a four-weight assembly is used, press the shaft in until it extends .555" to .559" from the weight carrier.

3. Position the weights on the carrier and drive the weight pins in place. Install the retaining rings.

Assemble Blower Drive Support

1. Place the blower drive support, with the inner face up, on the bed of an arbor press. Start the governor weight shaft bearing, number side up, in the bearing bore of the support. Place a sleeve against the outer race and press the bearing firmly against the shoulder in the bearing bore. Attach the bearing retainer (four-weight governor only) with two bolts, nuts and copper washers.

2. Place the steel thrust washer on the end of the blower drive shaft and secure it in place with a snap ring.

3. Lubricate the shaft with engine oil and install it in the drive support.

4. Install the key in the shaft, then place the blower drive support on an arbor press. Lubricate the inner diameter of the blower drive gear and start it straight on the shaft, with the keyway in the gear aligned with the key in the shaft. Place a spacer over the gear and press the gear on the shaft until a .005" feeler gage may just be withdrawn (Fig. 18).

5. Place a support under the inner race of the bearing in the blower drive support and start the weight end of the governor weight shaft into the bearing. Press the shaft in until the shoulder on the shaft contacts the inner race of the bearing. Press the shaft in straight to avoid brinelling the bearing.

6. Apply a good quality sealant on the edge of the cup plug and press the plug in flush with the blower drive support.

7. Check the clearance between the fully extended governor weights and the blower drive gear. This clearance must not be less than .100" (Fig. 19).

Install Governor

Install the governor on the engine as follows:

1. Attach a new gasket to the governor housing and place the housing against the blower rear end plate. Secure the governor housing to the blower with six bolts and lock washers.

2. Install the blower and governor assembly on the engine as outlined in Section 3.4.

3. Install the blower drive support assembly as outlined in Section 3.4 under *Install Blower on 6V Engine.*

4. Insert the upper fuel rods through the fuel rod covers and hoses and attach the rods to the governor control link lever with link pins which thread into the lever.

5. Attach the lower fuel rods to the injector control tube levers and to the upper fuel rods.

6. Slide the fuel rod cover hoses in place and secure them with hose clamps.

7. Refer to Fig. 6 and install the variable speed spring and housing to the governor as follows:

a. On current governors, use a new gasket and attach the spring housing cover to the spring housing with a screw and lock washer.

b. Install the spring plunger guide in the governor housing.

c. Insert the spring plunger in the plunger guide.

d. Insert the solid stop in the governor housing.

e. Place the spring retainer in the spring housing, with the closed end of the retainer against the spring lever. If shims were used, place them inside of the spring retainer. Insert the split stop in the housing and against the spring retainer.

NOTE: Be sure to use shims with a .343" inside diameter and a spring retainer with three bleed holes when a two-spring assembly is used. On the one-spring assembly, either spring retainer may be used with shims which have a .750" I.D. However, do not use the .343" I.D. shims with a spring retainer which has only one air bleed hole.

f. Insert the variable speed spring in the spring retainer with the tightly wound end of the spring against the shims. If a two-spring assembly is used, insert the inner spring inside of the outer spring.

g. On former governors, insert two bolts with lock

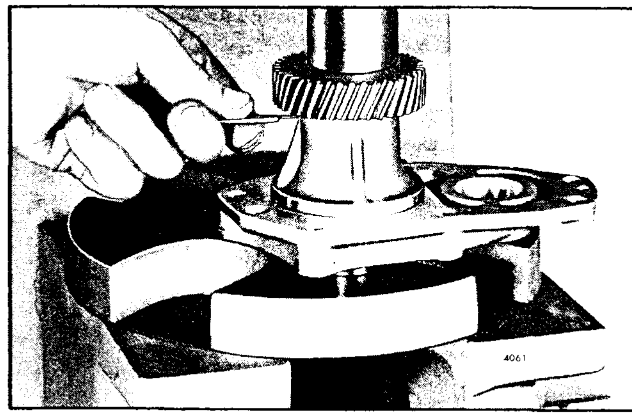


Fig. 18 - Installing Blower Drive Gear on Shaft

washers through the spring housing (through the spring housing cover and spring housing on current governors) and place a new gasket over the bolts and against the housing. On current governors, use copper washers with the two attaching bolts.

h. Place the spring housing in position against the governor housing, with the spring plunger engaged in the end of the spring (inner spring of the two-spring assembly). Thread the bolts into the governor housing and tighten them.

i. Install the idle speed adjusting screw and lock nut in the spring housing (former governors) and in the spring housing cover (current governors).

8. Place a new gasket on the governor, then install the governor cover and lever assembly. Be sure the governor control lever assembly enters the slot in the

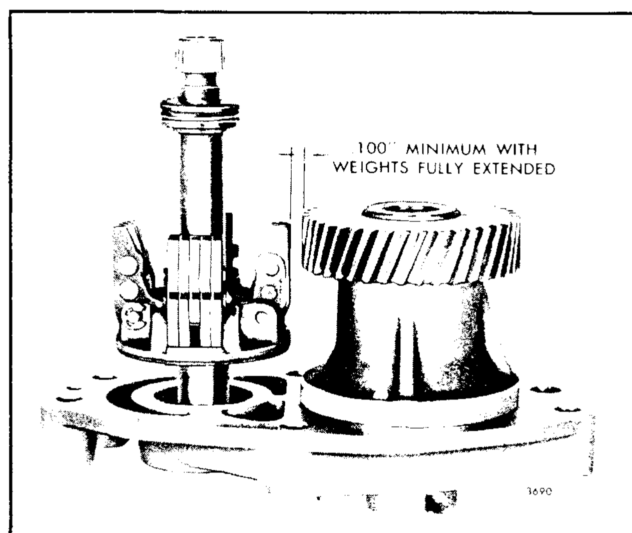


Fig. 19 - Minimum Clearance Between Blower Drive Gear and Governor Weights

differential lever. Secure the cover to the governor with seven screws and lock washers.

NOTE: If a torsion-type stop lever spring is used, a special cover screw is used to hold the spring in place. If a long coil spring is used, the spring retaining bracket is held in place by one of the standard cover retaining screws.

9. Hook the stop lever spring to the lever and to the spring retaining bracket or the special cover screw.

10. Perform an engine tune-up as outlined in Section 14.

VARIABLE SPEED MECHANICAL GOVERNOR (ENCLOSED LINKAGE)

IN-LINE ENGINES

The variable speed mechanical governor, illustrated in Fig. 1, performs the following functions:

1. Controls the engine idle speed.

2. Limits the maximum no-load speed.

3. Holds the engine at any constant speed, between idle and maximum, as desired by the operator.

The single-weight governor is mounted on the rear end plate of the engine and is driven by a gear that extends through the end plate and meshes with either the camshaft gear or the balance shaft gear, depending upon the engine model.

Operation

Two manual controls are provided on the governor; a stop lever and a speed control lever. In its normal position, the stop lever holds the fuel injector racks near the full-fuel position. When the engine is started, the governor moves the injector racks toward the idle speed position. The engine speed is then controlled manually by moving the speed control lever.

The centrifugal force of the revolving governor 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 bears against the variable speed spring plunger, while the other end provides a moving fulcrum on which the differential lever pivots.

The centrifugal force of the governor weights is opposed by the variable speed spring. Load changes or movement of the speed control lever momentarily creates an unbalanced force between the revolving weights and the tension on the spring. When the forces reach a balanced condition again, the engine speed will be stabilized for the new speed setting or new load.

A fuel rod, connected to the differential lever and injector control tube lever, provides a means for the governor to change the fuel settings of the injector control racks.

The engine idle speed is determined by the centrifugal force required to balance out the tension on the variable speed spring in the low speed range.

To stop the engine, the speed control lever is moved to the idle speed position and the stop lever is moved to the no-fuel position and held there until the engine stops.

Adjustment of the governor is covered in Section 14.

Lubrication

The governor is lubricated by oil splash from the engine gear train and by an oil line on current engines. Also, to provide increased lubrication to the governor, an oil line has been added between the control housing and the weight housing on current engines. The oil passes through the governor weight

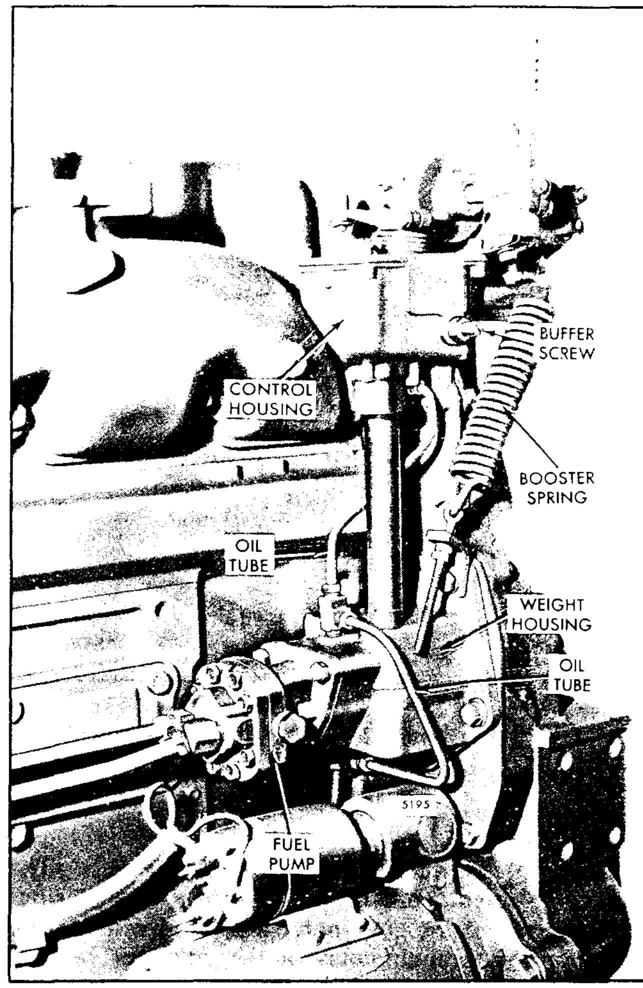


Fig. 1 - Governor Mounting

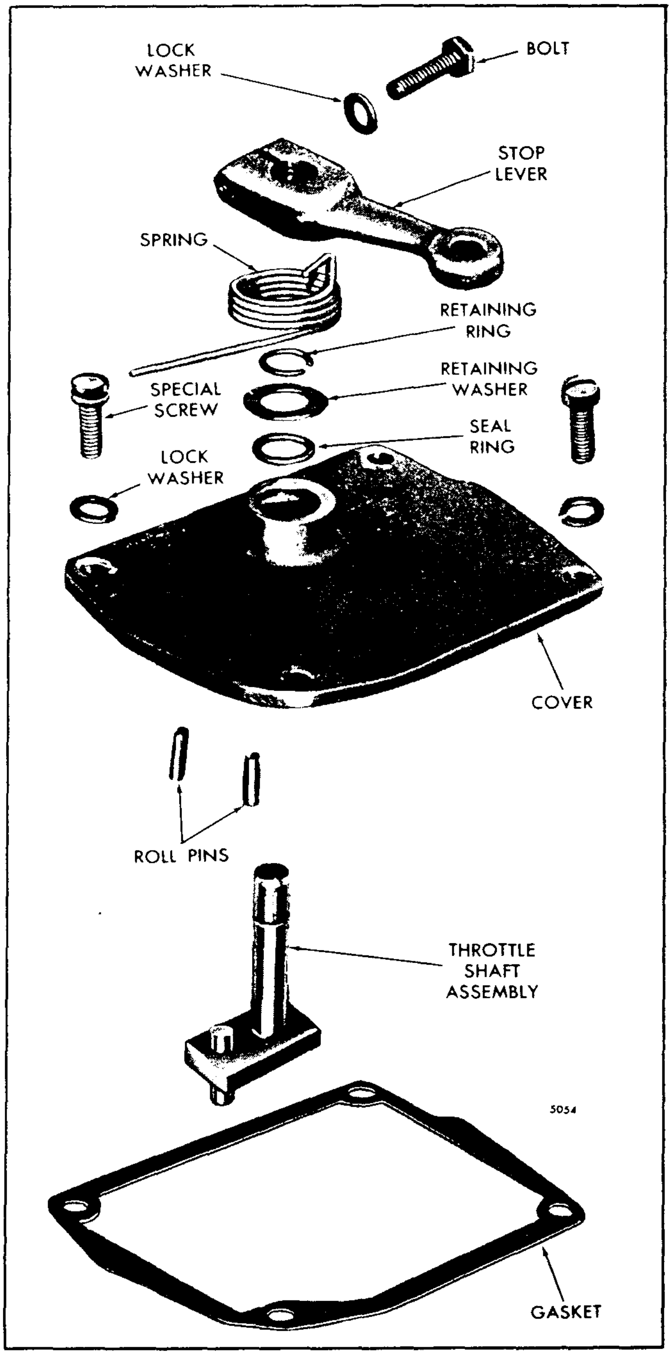


Fig. 2 - Governor Cover Details and Relative Location of Parts

housing to the shaft and weight assembly. The revolving weights distribute the oil to the various moving parts of the governor. Surplus oil drains from the governor through holes in the governor bearing retainer back to the engine gear train.

Remove Governor From Engine

Check the operation of the governor as outlined in Section 2.7 before removing it from the engine. If the governor fails to control the engine properly after performing these checks, it should be removed and reconditioned.

Refer to Fig. 1 and remove the governor as follows:

1. Disconnect the throttle rod and the booster spring from the speed control lever.

2. Disconnect the retaining spring from the stop lever. Also disconnect any linkage attached to the stop lever.

3. Remove the lever retaining spring, governor cover and gasket from the governor housing.

4. Withdraw the two retaining bolts and lock washers and remove the variable speed spring housing and lever assembly and the gasket.

5. Remove the spring plunger, variable speed spring, stops, shims and spring retainer.

6. Loosen the hose clamps between the governor and the cylinder head.

7. Clean and remove the valve rocker cover.

8. Disconnect the fuel rod from the injector control tube lever.

9. Disconnect the fuel lines from the fuel pump. Then remove the fuel pump from the governor weight housing.

10. Disconnect the lubricating oil tube, if used, from the cylinder block and the governor weight housing.

11. Withdraw the five bolts from the weight housing and the two bolts from the control housing, then remove the governor and the gaskets from the engine.

12. Remove the fuel rod from the differential lever.

Disassemble Governor Cover

1. Loosen the clamping bolt and remove the stop lever from the shaft. Remove the lever retracting spring.

2. Remove the return spring from the underside of the cover (early governors).

3. Remove the retaining ring and seal retaining washer. Withdraw the throttle shaft (Fig. 2) from the cover.

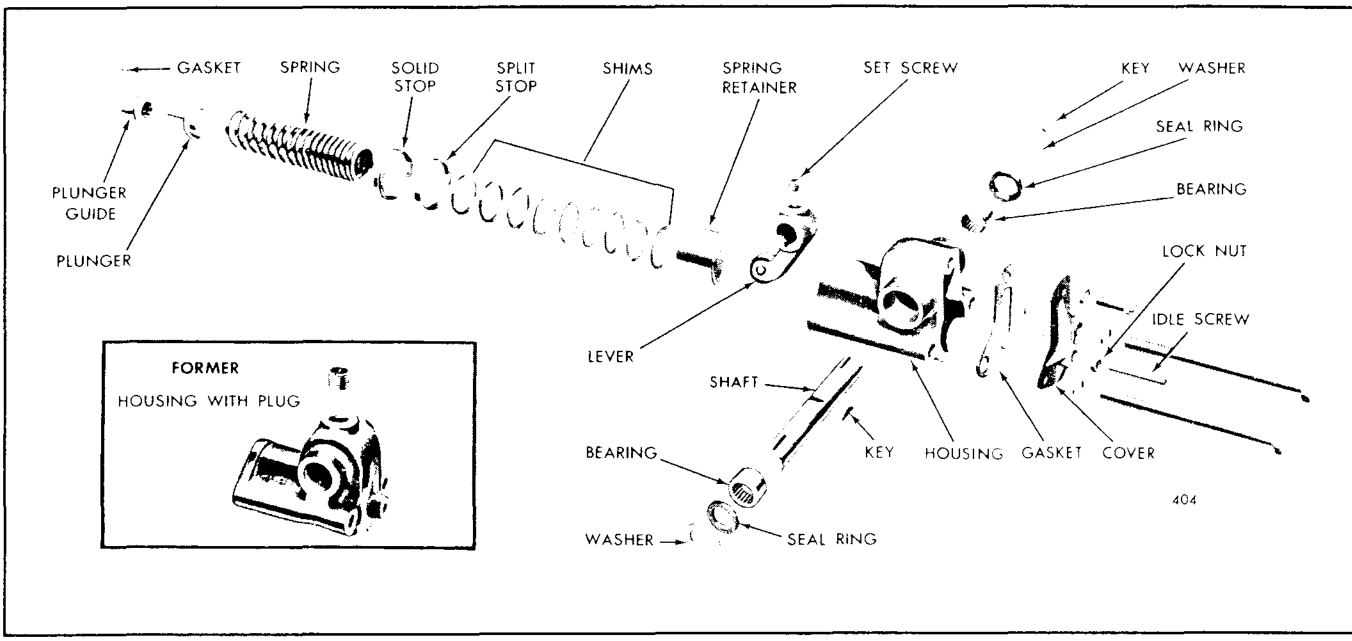


Fig. 3 - Variable Speed Spring Housing and Relative Location of Parts

4. Remove the seal ring from the cover.

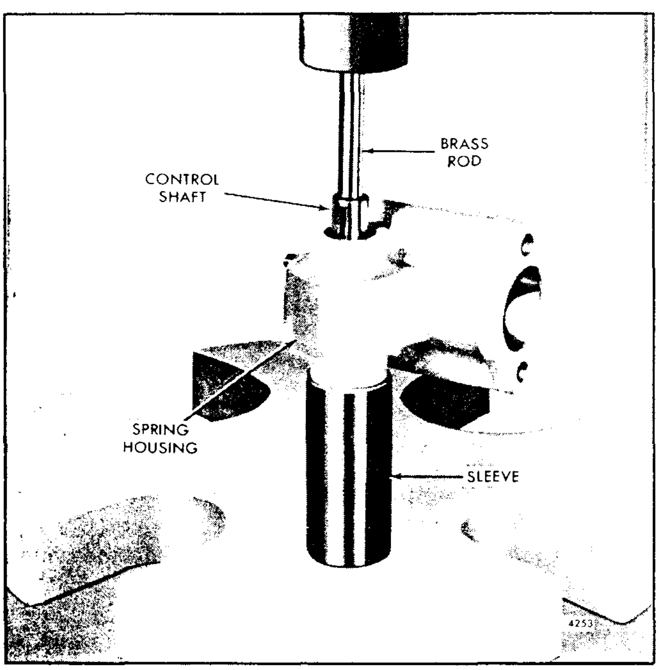


Fig. 4 - Removing Shaft and Bearing from Spring Housing

Disassemble Governor Spring Housing

If the bearings or lever require replacement, disassemble the spring housing as follows:

1. Loosen the clamp bolt and remove the speed control lever from the shaft. Remove the Woodruff key.

2. Loosen the clamp bolt and remove the booster spring lever, if used. Remove the Woodruff key.

3. Remove the plain washer and seal ring. If a booster

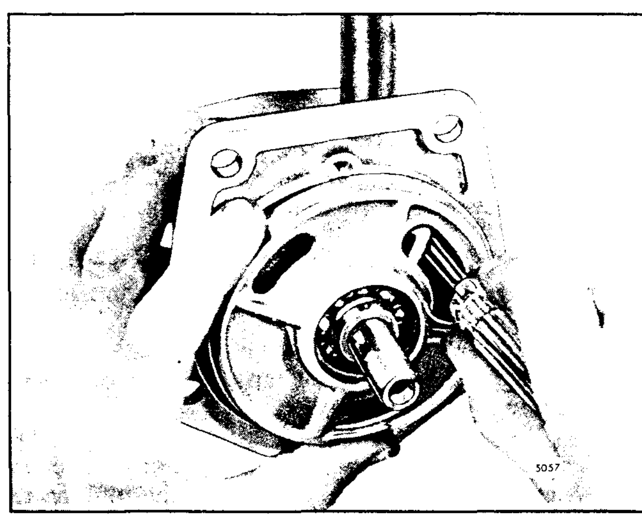


Fig. 5 - Removing or Installing Operating Shaft Fork

spring lever is used, a washer and seal ring is used at each end of the shaft (Fig. 3).

4. On current governors, remove one screw and lock washer and remove the spring housing cover and gasket. Then remove the set screw from the spring lever.

On former governors, remove the pipe plug from the housing and, working through the opening, remove the set screw from the spring lever.

5. Support the spring housing in an arbor press. Use a brass rod to press the shaft, bearing and plug (if used) from the housing (Fig. 4).

6. Remove the spring lever.

7. Press the second bearing from the housing.

Disassemble Control Housing

1. Remove the governor drive gear retaining nut. Then remove the gear, key and spacer from the shaft.

2. Remove the small flat head screw (Fig. 7) which holds the bearing retainer in place.

3. Turn the bearing retainer until the large opening is centered over the fork on the governor operating shaft (Fig. 5).

4. Lift up on the weight shaft to provide clearance for a 5/16 " electrician's socket wrench. Then remove the two retaining screws and washers and withdraw the governor operating fork.

5. Remove the shaft and weight assembly from the governor weight housing.

6. Remove the buffer screw and lock nut.

7. Remove the upper bearing retaining screw and washer and withdraw the operating shaft and lever assembly from the governor control housing.

8. Insert a rod (approximately 18 " long) in the control housing and knock the plug from the bottom of the weight housing.

9. Remove the snap ring and tap the lower operating shaft bearing from the housing.

10. Remove the spring pin and washer from the pin in the operating shaft lever, then remove the differential lever.

11. If necessary, press the bearing and operating shaft lever from the operating shaft.

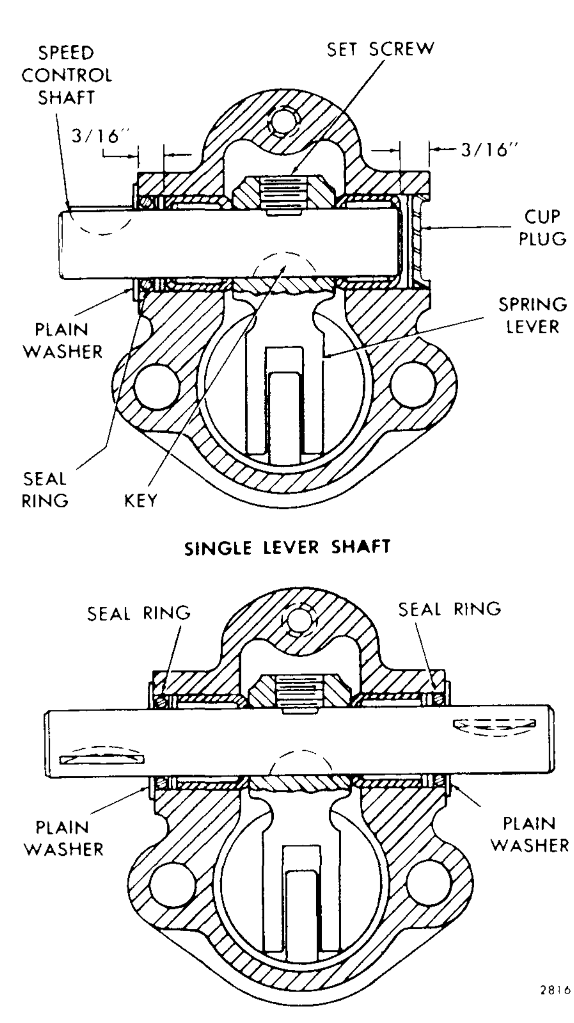


Fig. 6 - Governor Variable Speed Spring Housing

12. If necessary, disassemble the control housing from the weight housing.

Disassemble Weight Shaft Assembly

1. Press the bearing retainer (Fig. 7) from the weight shaft.

2. If necessary, remove the snap ring and press the bearing from the retainer.

3. Remove the weight pin retainers and drive the pins out of the carrier and weights. Remove the weights.

NOTE: The weight pin hole in the carrier is larger at the side where the pin retainers are located.

4. Slide the riser and bearing assembly from the shaft. Do not attempt to remove 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.

The governor cover and throttle shaft have been revised to eliminate the shaft return spring formerly located beneath the cover. An external stop lever retracting spring is used on current governor assemblies. If the cover is to be replaced, install a new current cover and lever assembly and the new spring.

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 tube 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 tube must be installed to provide adequate lubrication.

Current engines have an oil line extending from the weight housing to the control housing to provide increased lubrication for the governor components. When replacing a control housing on a former governor, it will be necessary to include the oil line and fittings or the tapped hole in the housing must be plugged. Also the buffer screw assembly with the "Perma-tite" lock nut and the copper washers for the spring housing attaching bolts must be used.

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 single-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.

Examine the variable speed spring lever roller and pin for excessive wear. The current roller type bearing rides on a hardened bearing pin which is a press fit in the spring lever and is staked at three places on both sides. The former ball type bearing (with two washers) rides on a soft bearing pin that is swaged at both ends to retain the bearing in the spring lever.

Examine the variable speed spring plunger, guide and spring retainer for wear or score marks. If the retainer or plunger are scored slightly, clean them up with crocus sloth. Replace the retainer, plunger and guide if scored excessively.

The current variable speed spring plunger guide incorporates a replaceable bushing.

Assemble Governor Cover

1. Lubricate the throttle shaft with engine oil and slide the shaft through the cover, with the pin in the shaft located between the roll pins in the underside of the cover.

2. Install a new seal ring in the counterbore at the top of the cover. Place the seal retaining washer (Fig. 2) over the shaft and lock the shaft in place with the retaining ring.

3. If a torsion-type stop lever retracting spring (Fig. 2) is used, place it over the cover hub with the hooked end up. Then place the stop lever on the shaft and tighten the clamping bolt.

NOTE: The lever retracting spring on early governors was located on the underside of the governor cover and worked against a pin in the throttle shaft assembly. On later governors, the retracting spring is located on top of the cover, connected between the stop lever and a bracket on the cover.

Assemble Governor Spring Housing

1. Lubricate the speed control lever shaft needle bearings with Shell Alvania No. 2 grease, or equivalent. Then start one of the bearings, numbered end up, straight in the bearing bore in the right-hand side of the spring housing as viewed in Fig. 6.

2. Install the needle bearing pilot rod J 9196-2 in the installer body J 9196-1 and secure it in place with the retaining screw.

NOTE: Do not use impact tools to install needle bearings.

3. Place the pilot rod end of the bearing installer assembly in the bearing. Support the spring housing, bearing and installer on a short sleeve on the bed of an arbor press as shown in Fig. 8, then press the bearing in the housing until the shoulder on the installer contacts the housing.

NOTE: When the shoulder on the installer body contacts the housing, the bearing will be properly positioned in the housing.

4. Install the current roller type bearing and pin in the spring lever. Press the pin below the surface of the lever and stake it at three places on both sides of the lever. The former ball-type bearing (with two washers) is swaged at both ends to retain the bearing in the spring lever.

5. If removed, install the spring lever Woodruff key in the center keyway in the speed control lever shaft.

6. Place the spring lever assembly between the bearing bores inside the spring housing with the arm (roller end) of the lever facing out.

7. Insert the correct end of the, single or double lever type, speed control lever shaft (Fig. 6) through the bearing bore in the side of the spring housing opposite the bearing previously installed. Align the key in the shaft with the keyway in the spring lever and push the shaft through the lever and in the bearing until the flat on the top of the shaft is centered under the set screw hole in the lever.

8. Thread the set screw into the spring lever, making sure the point of the screw is seated in the flat on the shaft.

9. Place the second needle bearing, numbered end up, over the protruding end of the shaft and start it straight in the bore of the housing.

10. Remove the bearing pilot rod J 9196-2 from the installer body J 9196-1 and place the installer body over the end of the shaft and against the bearing. Support the spring housing, bearings and installer on a short sleeve on the bed of an arbor press as shown in Fig. 8, then press the bearing in the housing until the shoulder on the installer contacts the housing.

11. If a single lever shaft was installed in the spring housing, apply a thin coat of sealing compound to the outside diameter of a new cup plug. Start the plug straight in the bearing bore in the housing, then support the spring housing, bearings and shaft assembly on a sleeve on the bed of an arbor press and press the plug in flush with the outside face of the housing.

12. Clamp the spring housing assembly in a bench vise equipped with soft jaws. Then tighten the spring lever retaining set screw to 12-15 lb-ft torque.

13. Stake the edge of the set screw hole with a small center punch and hammer to retain the set screw in the lever. Then install the plug in the spring housing on former governors.

14. On a single lever shaft, place a seal ring over the end of the shaft and push it into the bearing bore and against the bearing. Place the plain washer over the shaft and against the housing, then install the Woodruff key in the keyway in the shaft.

15. On a double lever shaft, place a seal ring over each end of the shaft and push them into the bearing bores and against the bearings. Place a plain washer over each end of the shaft and against the housing, then install a Woodruff key in the keyway at each end of the shaft.

16. Place the speed control lever on the shaft in its original position. Align the keyway in the lever with the key in the shaft and push the lever in against the plain washer and secure it in place with the retaining bolt and lock washer.

Assemble Control Housing

1. If necessary, assemble the control housing to the weight housing using a good quality sealant between the tube and the housings.

2. Install the lower governor operating shaft bearing, with the number side facing out, in the weight housing (Fig. 9). Install the snap ring to secure the bearing. Lubricate the bearing with engine oil.

3. Apply a good quality sealant around the edge of a new plug and tap it in place in the weight housing.

4. Start the upper bearing, number side up, on the upper end of the governor operating shaft. Support the shaft on the bed of an arbor press. Place a sleeve against the inner race and press the bearing against the shoulder on the shaft.

5. Place the operating shaft lever on the shaft with the flat on the shaft registering with the flat in the lever. Press the lever tight against the bearing.

6. Lubricate the bearing with engine oil. Insert the lever and shaft assembly in the control housing and guide the lower end of the shaft into the bearing in the weight housing.

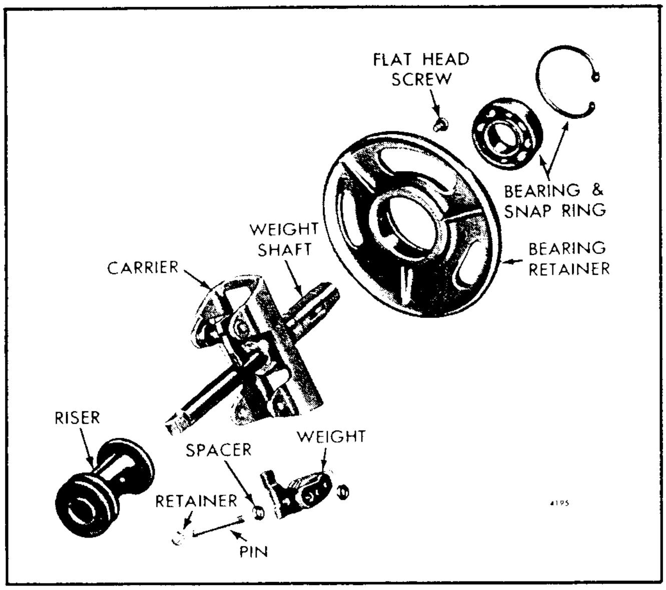


Fig. 7 - Governor Weight Details and Relative Location of Parts

7. Install the upper bearing retaining screw and washers.

8. Place the fork against the operating shaft, with the two cam faces of the fork facing away from the governor weights. Thread the fork attaching screws in approximately two or three turns. The screws are to be tightened after the weight and shaft assembly is installed.

9. Place the differential lever (Fig. 9) over the pin in the governor operating shaft lever. Secure the lever in place with a washer and spring pin.

10. Install the buffer screw and lock nut, leaving approximately .750 " of the screw extending from the governor housing.

11. If previously removed, install the gap adjusting screw and lock nut in the operating shaft lever.

Assemble 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 bearing (Fig. 7) in the retainer (press on the outer race). Then install the snap ring, with the flat side of the ring facing the bearing.

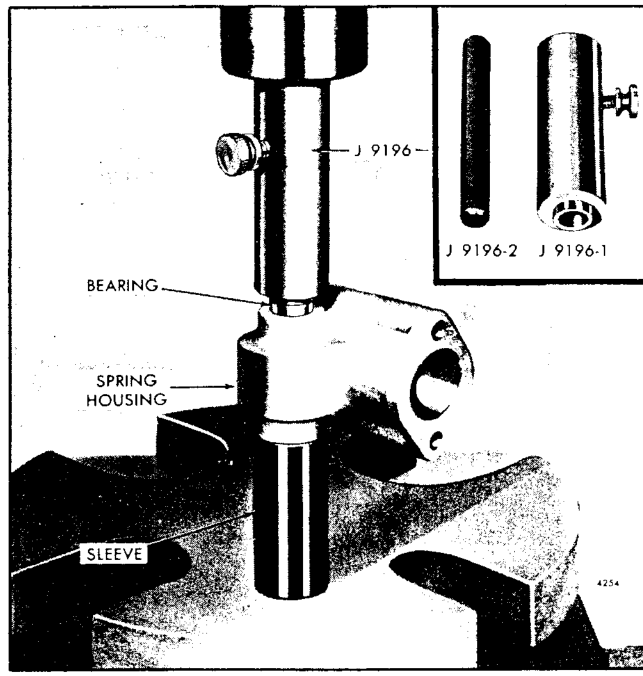


Fig. 8 - Installing Speed Control Shaft Bearings in Spring Housing

3. Press the bearing and retainer assembly on the shaft until the bearing contacts the shoulder on the shaft.

NOTE: Press on the inner race of the bearing.

4. Lubricate the shaft with clean engine oil. Then slide the riser and bearing assembly on the shaft.

5. Secure the weights to the carrier as follows:

a. Position one of the weights in the carrier. If the current steel carrier is used, place a spacer on each side of the weight.

b. Insert the serrated end of the weight pin through the larger opening in the carrier and through the weight and spacers. Then drive the pin into the smaller opening in the carrier.

c. Install a retainer in the groove of the pin.

d. Install the second weight in the same manner.

6. Slide the shaft and weight assembly into the weight housing, with the riser bearing positioned behind the operating fork.

7. Turn the bearing retainer until the large opening is over the fork on the operating shaft. Then tighten the two fork attaching screws with a 5/16 " electrician's socket wrench (Fig. 5).

d. Insert the solid stop in the counterbore of the governor housing.

e. Lubricate the outside diameter of the spring retainer with engine oil and insert it, solid end first, in the spring housing and against the spring lever.

f. Place the same amount of shims in the spring retainer that were removed, thin shims first. Then insert the split stop in the spring housing approximately 1/16 " from the finished face of the housing.

NOTE: Do not use shims with an 11/32 " I.D. with a spring retainer which has only one air bleed hole. Shims with a 3/4 " I.D. may be used with a spring retainer which has either one or three air bleed holes (provided only one spring is used).

g. Insert the variable speed spring in the spring retainer with the tightly wound end of the spring against the shims.

h. On former governors, insert two bolts (with lock washers) through the spring housing (through the spring housing cover and spring housing on current governors) and place a new gasket over the bolts and against the housing. On current governors, use copper washers with the two attaching bolts.

i. Place the spring housing in position against the governor housing, with the spring over the end of the spring plunger inside of the governor housing.

j. Thread the two spring housing retaining bolts into the governor housing and tighten them to 13-17 lb-ft torque.

k. Install the idle speed adjusting screw and lock nut in the spring housing (former governors) or in the spring housing cover (current governors). Then thread the idle speed adjusting screw in approximately 1 ".

10. Place a new gasket on the governor housing, then install the governor cover and lever assembly. Be sure the pin in the throttle shaft enters the slot in the differential lever. Secure the cover to the governor with four screws and lock washers.

NOTE: If a torsion-type stop lever spring (Fig. 2) is used, a special cover screw is used to hold the spring in place. If a long coil spring is used, the spring retaining bracket is held in place by one of the standard cover retaining screws.

11. Hook the stop lever spring to the lever and to the spring retaining bracket or the special cover screw.

12. Install the fuel pump and fuel lines.

13. Perform an engine tune-up as outlined in Section 14.

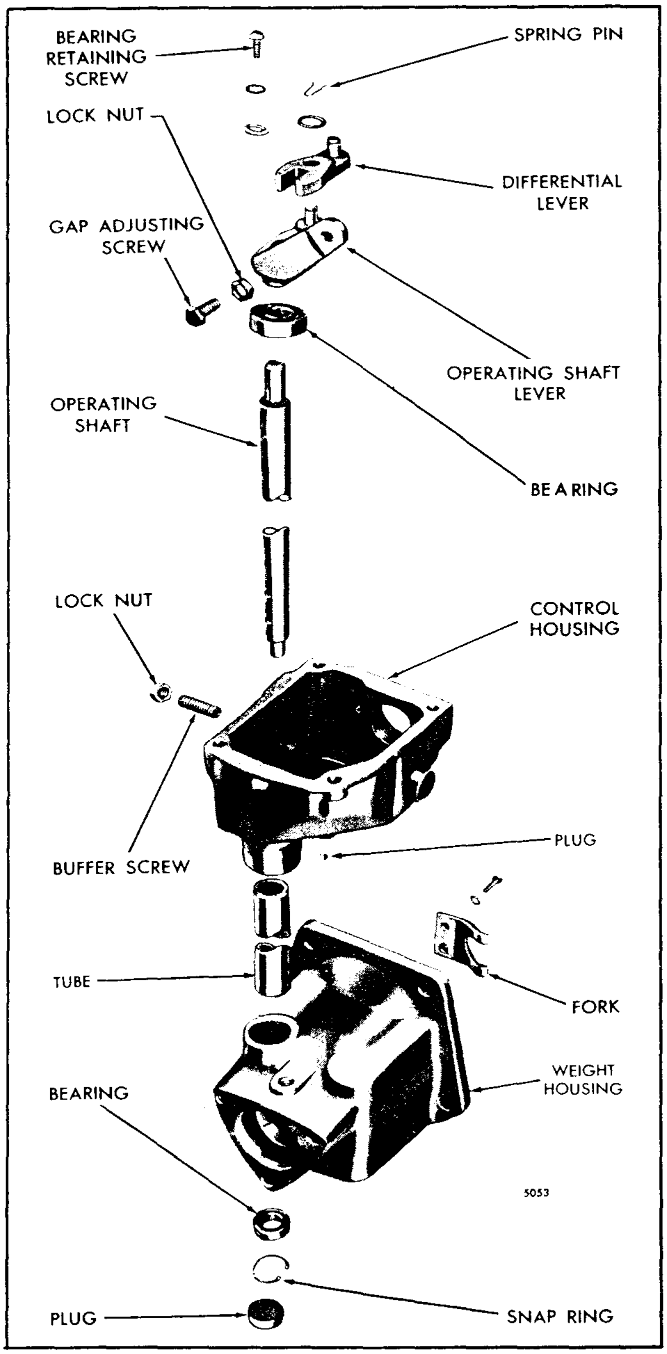


Fig. 9 - Governor Housing and Relative Location of Parts

8. Turn the bearing retainer until the counterbored notch above the large opening in the retainer and the tapped hole in the housing are aligned. Secure the bearing retainer to the housing with a flat head screw.

9. Place the governor drive gear spacer on the shaft. Install the key and start the gear on the shaft.

10. Tap the gear until the gear and spacer contact the inner race of the weight shaft bearing.

11. Install the gear retaining nut and tighten it to 125-135 lb-ft torque.

Install Governor

Refer to Fig. 1 and install the governor 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 lines and fittings from the weight housing to the cylinder block and the control housing.

7. Align and tighten the hose clamps on the fuel rod cover.

8. Attach the fuel rod to the injector control tube lever with a pin and cotter pin.

9. Refer to Fig. 3 and attach the variable speed spring and housing to the governor as follows:

   a. On current governors, use a new gasket and attach the spring housing cover to the spring housing with a screw and a lock washer.

   b. If removed, start the variable speed spring plunger guide straight in the boss inside the governor housing and tap it into place with a small brass rod and hammer.

   c. Lubricate the small end of the variable speed spring plunger with engine oil. Then insert the plunger in the plunger guide inside the governor housing.

VARIABLE SPEED MECHANICAL GOVERNOR (Pierce)

IN-LINE TRACTOR ENGINE

The variable speed mechanical governor (Fig. 1) performs three functions:

1. Controls the engine idle speed.

2. Limits the maximum no-load speed.

3. Holds the engine at any constant speed, between idle and maximum, as desired by the operator.

The governor is mounted on the rear end plate of the engine and is driven by a gear that extends through the end plate and meshes with the balance shaft gear.

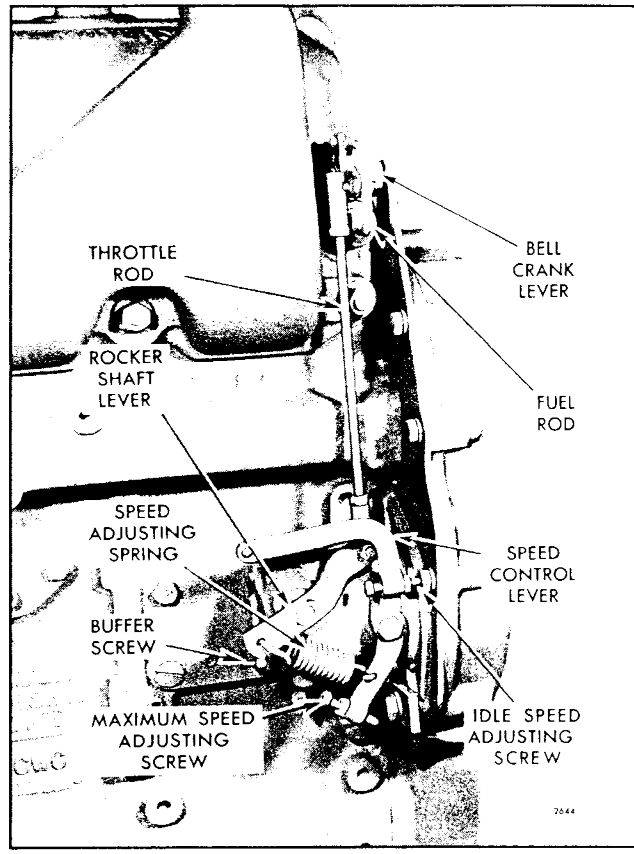


Fig. 1 - Governor Mounted on Engine

Lubrication

The governor is lubricated by oil splash, from the engine gear train, that passes through the bearing housing to the governor flyweight assembly. The oil is distributed to the various moving parts within the governor by the revolving flyweights.

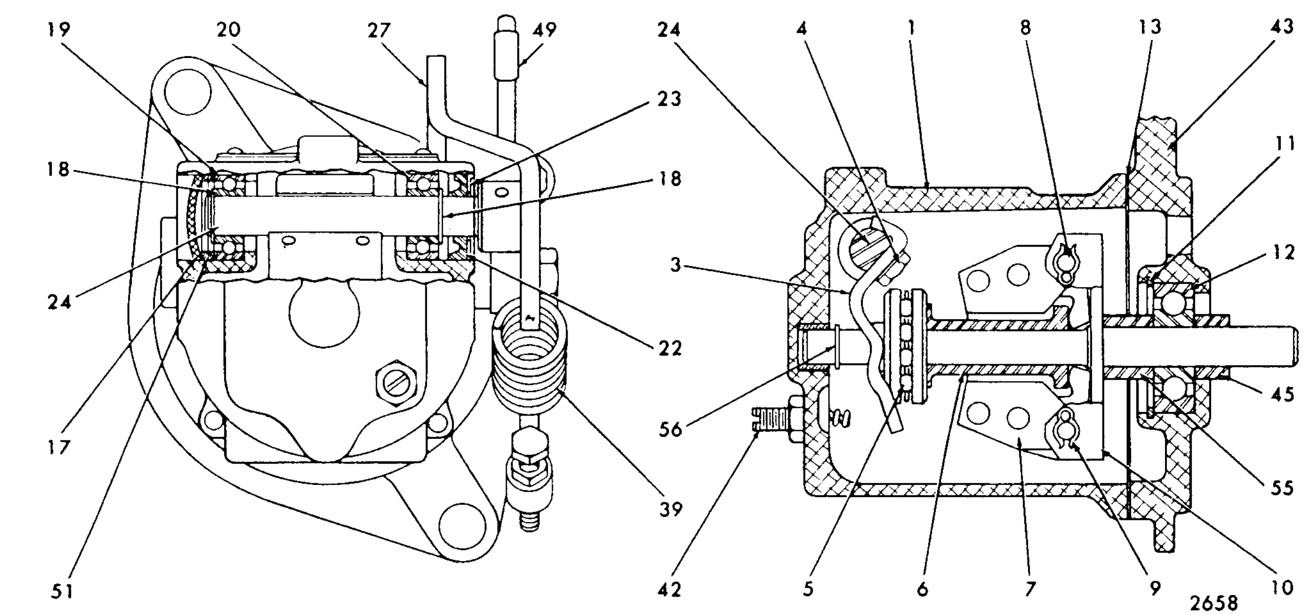
Surplus oil drains from the governor assembly through holes in the governor bearing housing, back to the engine crankcase.

Operation

The governor flyweights (7), shown in Fig. 2, are mounted on the spider and shaft assembly (10) and driven by the governor drive gear (46). This gear is pressed on the spider and shaft assembly and is driven by the engine gear train. A shoulder on the flyweights bears against the riser (6), that transmits the motion of the flyweights through the riser thrust bearing (5) to the operating fork (3). The operating fork is attached to the rocker shaft (24), that rides in ball bearings (19 and 20), and transmits the motion of the flyweights to the rocker shaft lever (27). The rocker shaft lever is pinned to the rocker shaft. The rocker shaft lever is connected to the speed adjusting spring (39) that is, in turn, connected to the governor speed control lever (49). The governor speed control lever is bolted to the governor and is controlled by the engine operator when establishing the desired speed of the unit. The idle (36) and maximum (37) speed adjusting screws limit the travel of the governor speed control lever and thus the minimum and maximum engine speed settings. The linkage operating the injector fuel racks is attached to the rocker shaft lever. Movement of the rocker shaft lever increases or decreases the amount of fuel delivered by the injectors to the engine. A governor buffer screw and spring assembly (42) is mounted in the governor body. The buffer screw and spring assembly bears against the operating fork and is used to stabliize engine operation at idle speed.

When the governor speed control lever is moved to an increased speed position, the tension on the speed adjusting spring is increased. The force resulting from the increased spring tension is transmitted to the rocker shaft lever and control linkage which advances the injector racks. Engine speed increases, as a result of the increased fuel, until the governor flyweight force is sufficient to balance the increased spring tension. The flyweights then move against the spring and reduce the injector rack fuel setting to an amount sufficient to maintain the higher engine speed setting.

If the governor speed control lever is moved to a decreased speed position, the tension on the speed adjusting spring will decrease and the governor



1. Body--Governor	Assembly--Operating	22. Seal--Rocker Shaft	49. Lever--Governor Speed Control
3. Fork--Operating	11. Snap Ring--Internal	23. Retainer--Oil Seal	51. Gaskets--Oil Seal Plug
4. Bolt--Special	12. Bearing	24. Shaft--Rocker	55. Spacer--Spider and Shaft Assembly
5. Bearing--Riser Thrust	13. Gasket--Body-to-Bearing Housing	27. Lever--Rocker Shaft	56. Snap Ring--External
6. Riser	17. Plug--Oil Seal	39. Spring--Speed Adjusting	
7. Flyweights	18. Snap Ring	42. Screw and Spring Assembly--Buffer	
8. Pin--Weight Supporting	19. Bearing--Ball (Inner)	43. Housing--Bearing	
9. Retainer Ring	20. Bearing--Ball (Outer)	45. Spacer--Gear	
10. Spider and Shaft			

Fig. 2 - Cross-Section of Governor

flyweights will overcome the spring tension and move the rocker shaft lever to a decreased fuel position. The engine speed will be reduced until the force of the governor flyweights equals the tension of the speed adjusting spring. The engine will then operate at the desired reduced speed.

Remove Governor from Engine

The governor is mounted on the engine rear end plate as shown in Fig. 1 and is retained by two bolts. After removing the dirt from around the governor and the engine end plate, remove the governor as follows:

1. Disconnect the linkage to the governor speed control lever.

2. Disconnect the throttle rod at the rocker shaft lever.

3. Remove the two retaining bolts and withdraw the governor from the engine.

Disassemble Governor

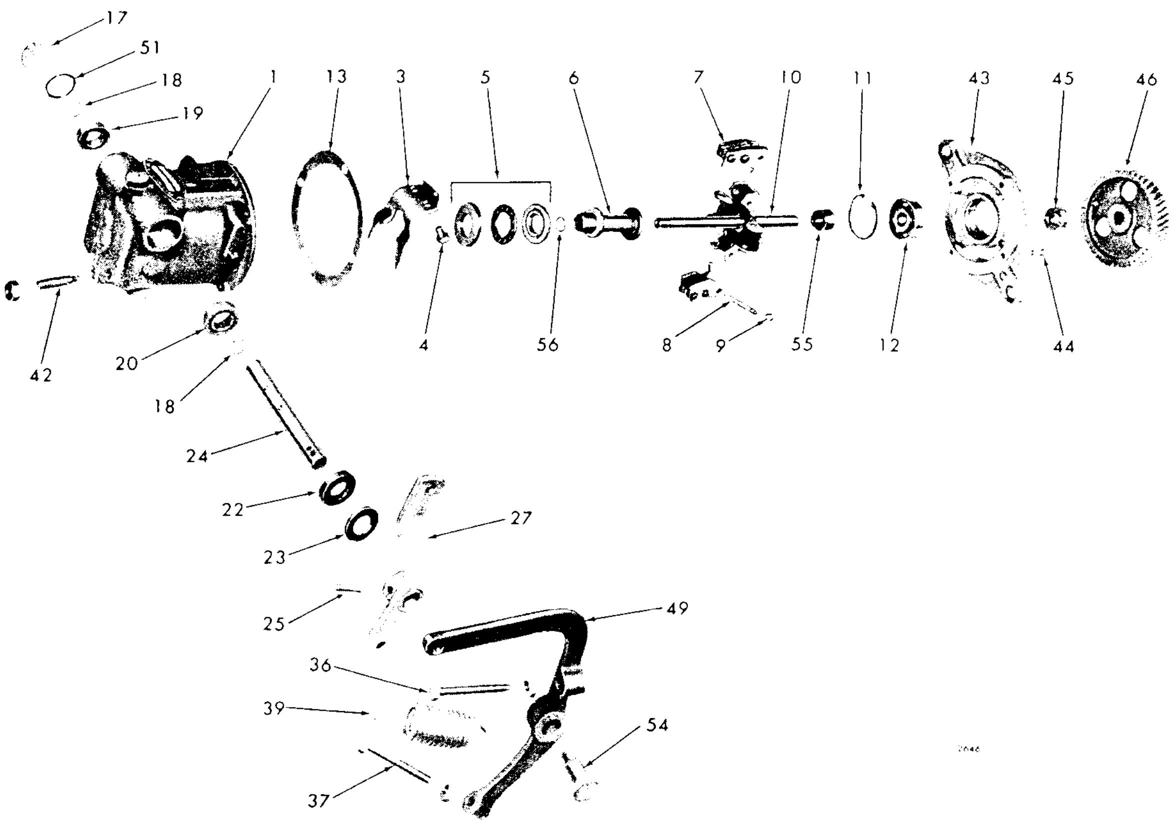
Before removing any parts from the governor, wash the entire unit in clean fuel oil and dry it with compressed air.

Inspect for worn or damaged parts that can be repaired or replaced without complete disassembly. Refer to Fig. 2 and 3 and disassemble the governor as follows:

1. Remove the four countersunk screws (44) which retain the bearing housing (43) to the governor body and withdraw the housing. Remove the bearing housing gasket (13). The governor drive gear (46), spider and shaft assembly (10), riser (6) and three-piece thrust bearing (5) will be removed with the bearing housing.

2. Remove the thrust bearing outer race and the ball assembly (5) from the riser (6).

3. Remove the external snap ring (56) and riser (6) from the spider and shaft assembly (10).



1. Body--Governor
3. Fork--Operating
4. Bolt--Special
5. Bearing--Riser Thrust
6. Riser
7. Flyweights
8. Pin--Weight Supporting
9. Retainer Ring
10. Spider and Shaft Assembly--Operating
11. Snap Ring--Internal
12. Bearing
13. Gasket--Body to Bearing Housing
17. Plug--Oil Seal
18. Snap Ring
19. Bearing--Ball (Inner)
20. Bearing--Ball (Outer)
22. Seal--Rocker Shaft
23. Retainer--Oil Seal
24. Shaft--Rocker
25. Pin--Roll
27. Lever--Rocker Shaft
36. Screw--Idle Speed Adjusting
37. Screw--Maximum Speed Adjusting
39. Spring--Speed Adjusting
42. Screw and Spring Assembly--Buffer
43. Housing--Bearing
44. Screws--Bearing Housing
45. Spacer--Gear
46. Gear--Governor Drive
49. Lever--Governor Speed Control
51. Gasket--Oil Seal Plug
54. Bolt--Governor Speed Control Lever
55. Spacer--Spider and Shaft Assembly
56. Snap Ring--External

Fig. 3 - Governor Details and Relative Location of Parts

4. Carefully support the thrust bearing inner race (5) in an arbor press and gently press the riser (6) from the inner race.

5. Remove the hair pin clips or retaining rings (9) which secure the flyweights (7) on the supporting pins (8). Then gently tap out the supporting pins with a suitable punch and remove the flyweights.

6. Place the drive gear (46), bearing housing (43) and the spider and shaft assembly (10) in an arbor press, using split plates under the gear. Then press the drive gear from the shaft, using a brass rod between the ram and the shaft.

7. Remove the gear spacer (45) from the spider and shaft assembly (10).

8. Remove the spider and shaft assembly (10) from the bearing (12) and bearing housing (43); then, remove the spacer (55).

9. Remove the internal snap ring (11) which retains the bearing (12) in the bearing housing (43). Then separate the bearing from the bearing housing.

NOTE: The bearing is a light press fit in the housing.

10. Remove the bolt (54) which retains the governor speed control lever (49) to the governor body. Remove the speed adjusting spring (39) and the speed control lever.

11. If desired, the idle (36) and maximum (37) speed adjusting screws can be removed from the speed control lever at this time.

12. If desired, remove the buffer screw and spring assembly (42).

13. Remove the operating fork (3) by removing the two special bolts (4) and lock washers which retain it to the rocker shaft (24).

14. Remove the oil seal plug (17) by driving lightly with a small punch at the lower edge of the plug, thus forcing the upper edge outward. Then place a screw driver behind the plug and remove the plug. Remove the two oil seal plug gaskets (51).

> **NOTE:** If necessary, use a chisel and cut a slot in the center of the plug; then, using a screw driver, pry the plug from the housing.

15. Remove the bearing retaining snap ring (18) from the rocker shaft (24). Then tap the rocker shaft lightly to withdraw it from the governor body.

16. Remove the inner bearing (19) from the governor body.

17. Remove the outer bearing (20) from the rocker shaft.

18. Remove the external snap ring from the rocker shaft and remove the oil seal (22) and oil seal retainer (23).

19. If desired, remove the rocker shaft lever (27) from the rocker shaft by driving out the roll pin (25) and tapping the shaft gently to facilitate removal.

Inspection

After the governor has been disassembled, thoroughly clean all of the parts in fuel oil and dry them with compressed air.

Inspect the rocker shaft bearings for excessive wear. Replace the bearings if necessary.

Inspect the bushings in the governor housing for wear. Replace the bushings if they are worn.

Inspect the rubber oil seal on the governor rocker shaft. The slightest wear on this part can cause oil leakage. It is recommended that a new oil seal be installed when the governor is overhauled.

Inspect all of the retaining snap rings to determine if they have been damaged at the time of disassembly. Replace them if necessary.

Inspect the riser bearing surface of the flyweights for excessive wear or flat spots. If either conditon exists, new flyweights must be installed. The flyweights must work freely on the supporting pins for satisfactory governor operation.

Inspect the governor operating fork for excessive wear or distortion. If either condition exists, replace the fork.

Inspect the teeth of the drive gear for signs of wear. Also examine the engine gear train. Replace any defective gears.

Inspect the spider and shaft assembly at the bushing and bearing surfaces and at the drive gear surface. Replace the shaft if it is damaged or worn.

Assemble Governor

After all of the parts have been cleaned and inspected, refer to Figs. 2 and 3 and assemble the governor as follows:

1. If removed, install the rocker shaft lever (27) on the rocker shaft (24) and secure it in place with a roll pin (25).

2. Install the oil seal retainer (23) with the lip of the retainer facing the rocker shaft lever. Install the oil seal (22) with the lip of the seal facing away from the lever.

3. Install the external snap ring (18) on the rocker shaft. Then install the outer bearing (20) with the numbered side facing the rocker shaft.

4. Slide the rocker shaft, bearing and oil seal assembly into the governor body and tap the seal retainer in flush with the bearing bore.

> **NOTE:** Carefully slide the outer edge of the rocker shaft oil seal into the governor body.

5. Install the inner bearing (19) in the bearing bore of the governor body and onto the rocker shaft (24). Secure the inner bearing with an external snap ring (18).

6. Install two new gaskets (51) and the oil retaining plug (17).

7. Install the operating fork (3) on the rocker shaft and secure it with two special bolts (4) and lock washers.

8. Install the buffer screw and spring assembly (42) and the lock nut.

9. Attach the speed adjusting spring (39) to the rocker shaft lever (27) and to the governor speed control lever (49). Then install the speed control lever on the governor with a bolt (54).

10. Install the speed adjusting screws (36) and (37) and lock nuts.

11. Install the bearing (12) in the bearing housing (43). Press against the outer race only. Secure the bearing in place with a snap ring (11).

12. If the spider was removed from the weight shaft, press the spider on the shaft so as to allow a clearance of .001" to .006" between the shaft shoulder and the rear face of the spider.

13. Slide the spacer (55), bearing (12) and gear spacer (45) on the spider and shaft assembly.

14. Support the governor drive gear on an arbor press; then, press the spider and shaft assembly (10) into the drive gear (46) until the gear bottoms the spacer against the bearing (12).

15. Install the flyweights (7) on the spider and shaft assembly with supporting pins (8). Install the hair pin clips or retainer rings (9) in the grooves of the supporting pins.

> **NOTE:** When viewing the spider and shaft assembly from the gear end, the right support pin hole has a smaller inside diameter. The serrated end of the supporting pin is inserted through the larger diameter hole, through the weight, and driven into the smaller hole.

16. Support the inner race of the three-piece thrust bearing (5) on an arbor press and press the riser (6) into the bearing race until the race seats on the shoulder of the riser.

17. Slide the riser (6) on the spider and shaft assembly (10) until it rests against the shoulder of the flyweights (7) and install an external snap ring (56) on the shaft.

18. Install the ball assembly and outer race of the three-piece bearing (5) on the riser.

19. Install a new gasket (13) on the bearing housing and slide the shaft assembly and bearing housing into the governor body. The end of the shaft extends into the bushing in the governor body. Align the bearing housing with the governor body so the three slotted holes in the housing are toward the top of the governor. Install the counter sunk screws (44) to secure the bearing housing to the governor body.

Install Governor on Engine

1. Attach a new gasket to the governor mounting flange.

2. Install the governor against the end plate, so the teeth of the governor drive gear mesh with the teeth of the balance shaft gear. Install the two governor attaching bolts and lock washers. Tighten the 3/8" -24 bolt to 35-39 lb-ft torque and the 7/16" -14 bolt to 46-50 lb-ft torque.

3. Connect the throttle rod to the rocker shaft lever.

4. Perform an engine tune-up as outlined in Section 14.4.4.

VARIABLE SPEED MECHANICAL GOVERNOR (Open Linkage)

IN-LINE ENGINES

The variable speed open linkage governor (Fig. 1) performs the following functions:

1. Controls the engine idle speed.

2. Limits the maximum no-load speed.

3. Holds the engine at any constant speed, between idle and maximum, as desired by the operator.

The single-weight governor is mounted on the rear end plate of the engine and is driven by a gear that extends through the end plate and meshes with either the camshaft gear or the balance shaft gear, depending upon the engine model.

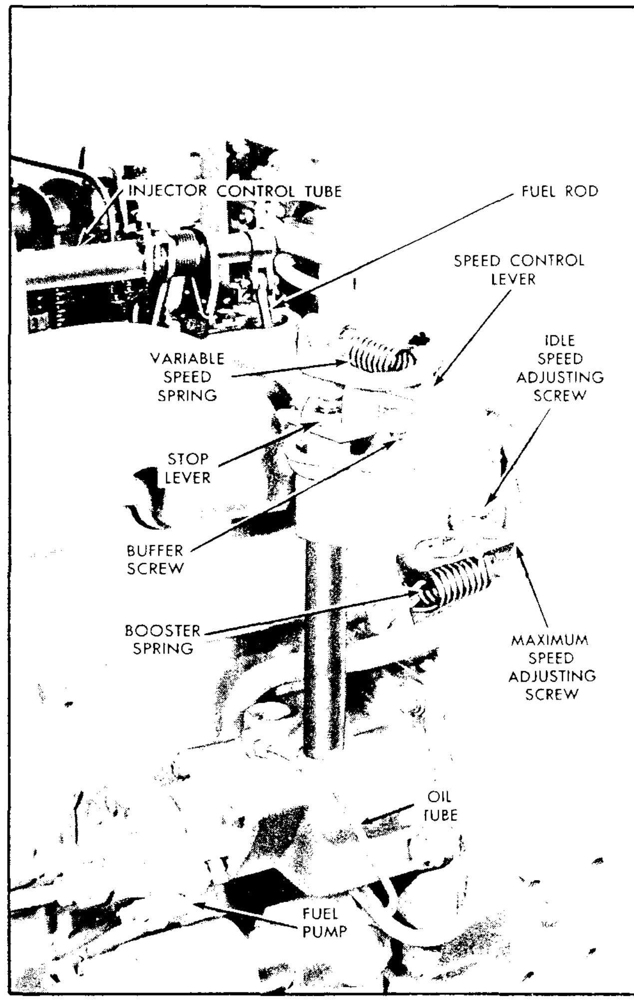


Fig. 1 - Variable Speed Open Linkage Governor Mounted on Engine

Operation

Two manual controls are provided on the governor: a stop lever and a speed control lever. In its normal position, the stop lever holds the fuel injector racks near the full-fuel position. When the engine is started, the governor moves the injector racks toward the idle speed position. The engine speed is then controlled manually by moving the speed control lever.

The centrifugal force of the revolving governor weights is converted into linear motion which is transmitted through the riser and the operating shaft to the operating shaft lever. Movement of this lever is transmitted to the stop lever which changes the fuel setting of the injector racks, since the fuel rod is connected between the stop lever and the injector control tube.

The centrifugal force of the governor weights is opposed by the variable speed spring which is fastened to the end of the operating shaft lever. Load changes or movement of the speed control lever momentarily creates an unbalanced force between the revolving weights and the tension on the spring. When the forces reach a balanced condition again, the engine speed will be stabilized for the new speed setting or new load.

To stop the engine, the speed control lever is moved to the idle speed position and the stop lever is moved to the no-fuel position and held there until the engine stops.

Adjustment of the governor is covered in Section 14.4.2.

Lubrication

The governor is lubricated by oil splashed from the engine gear train. The oil passes through the governor weight housing to the shaft and weight assembly. The revolving weights distribute the oil to the various moving parts of the governor. The surplus oil drains back to the engine crankcase through holes in the governor bearing retainer.

The clearance between the riser tube and the weight shaft has been reduced with the use of current governor assemblies. To ensure adequate lubrication of the riser tube, an oil tube has been added between the oil gallery in the cylinder block and the top of the weight housing to supply oil under pressure.

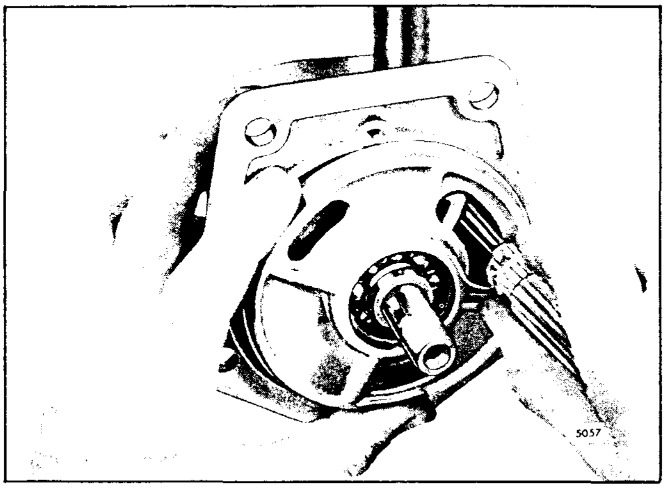


Fig. 2 - Removing or Installing Operating Shaft Fork

Remove Governor From Engine

Check the operation of the governor as outlined in Section 2.7 before removing it from the engine. If the governor fails to control the engine properly after performing these checks, it should be removed and reconditioned.

Refer to Fig. 1 and remove the governor as follows:

1. Disconnect the fuel rod from the stop lever.

2. Disconnect the throttle control rod from the speed control lever.

3. Disconnect the fuel lines and remove the fuel pump from the governor weight housing.

4. Remove the governor lubricating oil tube, if used.

5. Withdraw the five bolts from the weight housing and the two bolts from the control housing; then, remove the governor and gasket from the engine.

Disassemble Weight Housing

1. Remove the governor drive gear retaining nut. Then remove the gear, key and spacer from the shaft.

2. Remove the small flat head screw (Fig. 3) which holds the bearing retainer in place.

3. Turn the bearing retainer until the large opening is centered over the fork on the governor operating shaft (Fig. 2).

4. Lift up on the weight shaft to provide clearance for a 5/16" electrician's socket wrench. Then remove the two retaining screws and washers and withdraw the governor operating fork.

5. Remove the shaft and weight assembly from the governor weight housing.

6. Inspect the bushing in the weight housing. If the bushing is worn or pitted, press it out of the housing and install a new bushing.

Disassemble Weight Shaft Assembly

1. Press the bearing retainer (Fig. 3) from the weight shaft.

2. If necessary, remove the snap ring and press the bearing from the retainer.

3. Remove the weight pin retainers and drive the pins out of the carrier and weights. Remove the weights.

> **NOTE:** The weight pin hole in the carrier is larger at the side where the pin retainers are located.

4. Slide the riser and bearing assembly from the shaft. Do not attempt to remove the bearing since the riser and bearing are serviced only as an assembly.

Disassemble Control Housing

1. Remove the outer nut on the variable speed spring eye bolt. Then remove the spring and eye bolt.

2. Pry the plug from the bottom of the weight housing.

3. Remove the snap ring from the lower end of the operating shaft and tap the shaft and lever assembly out of the control housing.

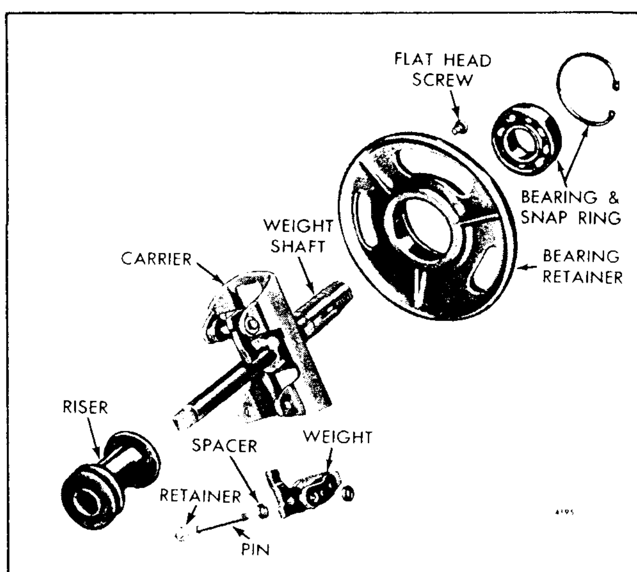


Fig. 3 - Governor Weight Details and Relative Location of Parts

4. Remove the snap ring and press the lower operating shaft bearing out of the weight housing.

5. Withdraw the outer nut and remove the booster spring and eye bolt.

6. Drive the pin from the speed control lever and remove the lever from the shaft.

7. Slide the shaft and booster spring bracket from the housing.

8. Remove the buffer screw.

9. Disengage the small spring between the operating shaft lever and the stop lever.

10. Remove the retaining ring and washer and lift the stop lever from the operating shaft.

11. Drive the pin from the operating shaft lever and remove the lever from the shaft.

12. Slide the bearing shield from the operating shaft.

13. Press the bearing from the operating shaft.

Inspection

Clean all of the parts (except the shielded upper operating shaft bearing) with fuel oil and dry them with compressed air.

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 tube 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 tube 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.

Examine the fuel pump drive end of the weight shaft. Replace the shaft if the end is worn or rounded.

Inspect the bushings in the control housing. If they are worn, drive the bushings out and install new ones.

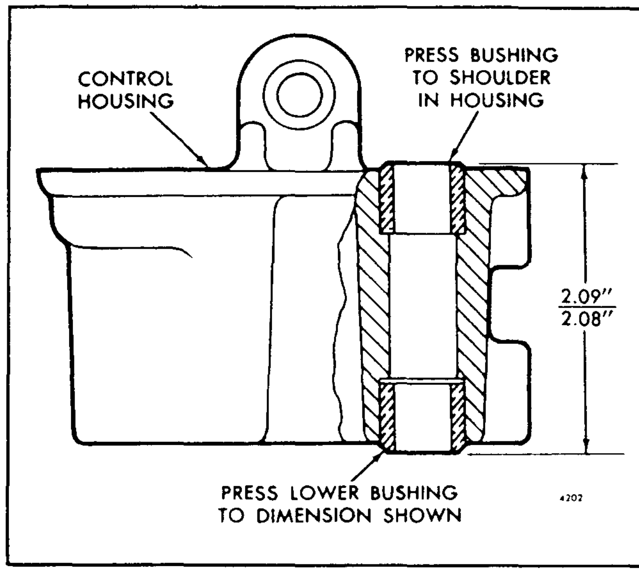


Fig. 4 - Bushings in Control Housing

Press the upper bushing in until it contacts the shoulder in the housing. Press the lower bushing to the dimension shown in Fig. 4.

Assemble Control Housing

Refer to Fig. 5 and assemble the control housing as follows:

1. Start the upper bearing, number side up, on the governor operating shaft. Support the shaft on the bed of an arbor press. Place a sleeve against the inner race and press the bearing against the shoulder on the shaft.

2. Slide the bearing shield on the shaft.

3. Place the operating shaft lever on the shaft and align the retaining pin holes. Then drive the retaining pin in place to secure the lever to the shaft.

4. Place the stop lever on the operating shaft and secure it in place with the washer and retaining ring. Then hook the small spring to the stop lever and operating shaft lever.

5. Install the lower operating shaft bearing, number side out, in the weight housing. Install the snap ring to secure the bearing. Lubricate the bearing with engine oil.

6. Insert the operating shaft and lever assembly in the control housing. Tap the shaft into the lower bearing and install a snap ring on the end of the shaft.

7. Apply a good quality sealant around the edge of the plug and tap it in place in the weight housing.

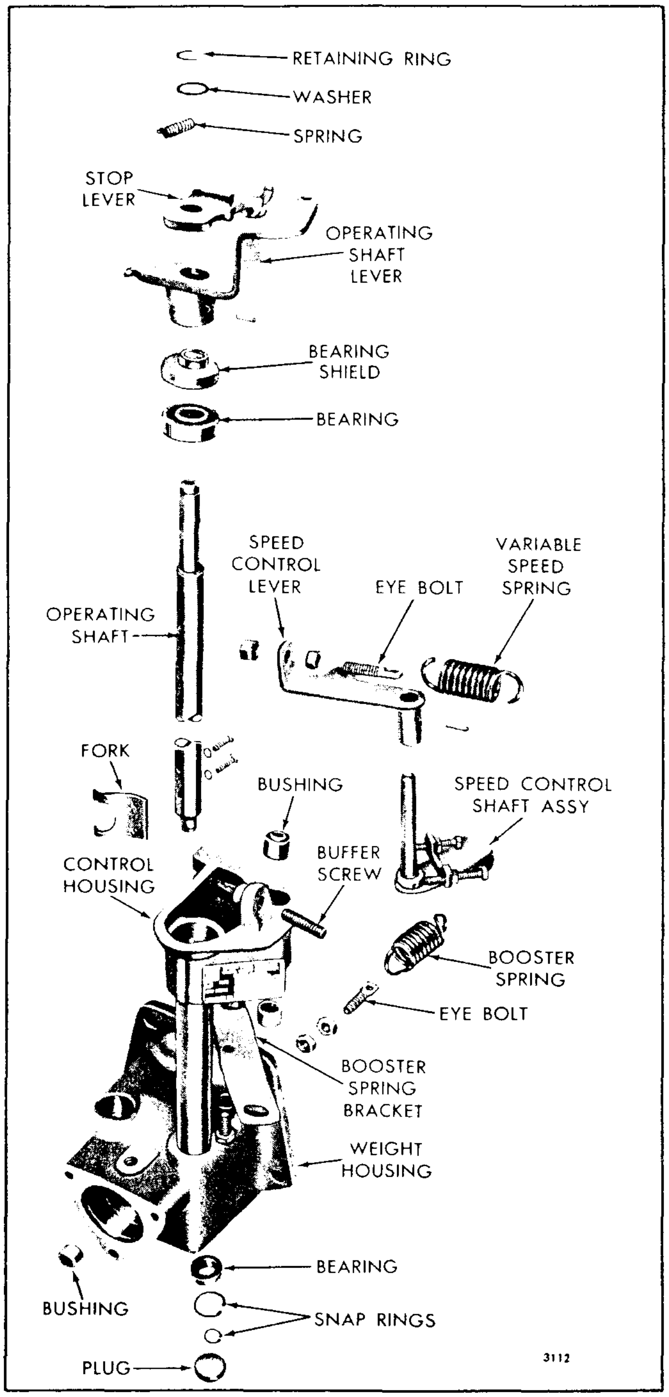


Fig. 5 - Governor Housing Details and Relative Location of Parts

8. Place the fork against the operating shaft, with the two cam faces of the fork facing away from the governor weights. Thread the fork attaching screws in approximately two or three turns. The screws are tightened after the weight and shaft assembly is installed.

9. Install the booster spring bracket.

10. Slide the speed control shaft assembly in the control housing. Then place the speed control lever on the shaft and tap the pin in place to secure the lever.

11. Install the booster spring and the variable speed spring.

12. Install the buffer screw.

Assemble 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 bearing (Fig. 3) in the retainer (press on the outer race). Then install the snap ring with the flat side of the ring facing the bearing.

3. Press the bearing and retainer assembly on the shaft until the bearing contacts the shoulder on the shaft.

NOTE: Press on the inner race of the bearing.

4. Lubricate the shaft with clean engine oil. Then slide the riser and bearing assembly on the shaft.

5. Secure the weights to the carrier as follows:

a. Position one of the weights, with a spacer on each side, in the carrier.

b. Insert the serrated end of the weight pin through the larger opening in the carrier and through the weight and spacers. Then drive the pin into the smaller opening in the carrier.

c. Install a retainer in the groove of the pin.

d. Install the second weight in the same manner.

6. Slide the shaft and weight assembly into the weight housing, with the riser bearing positioned behind the operating fork.

7. Turn the bearing retainer until the large opening is over the fork on the operating shaft. Then tighten the two fork attaching screws with a 5/16" electrician's socket wrench.

8. Turn the bearing retainer until the counterbored notch above the large opening in the retainer and the tapped hole in the housing are aligned. Secure the bearing retainer to the housing with a flat head screw.

9. Place the governor drive gear spacer on the shaft. Install the key and start the gear on the shaft.

10. Tap the gear until the gear and spacer contact the inner race of the weight shaft bearing.

11. Install the gear retaining nut and tighten it to 125-135 lb-ft torque.

Install Governor

Refer to Fig. 1 and install the governor as follows:

1. Attach a new gasket to the governor weight housing.

2. Position the governor 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.

3. 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.

4. Install the two governor control housing attaching bolts and lock washers. Tighten the bolts to 35 lb-ft torque.

5. Attach the fuel rod to the stud on the stop lever.

6. Install the fuel pump and fuel lines.

7. If required, install the governor lubricating oil tube and fittings.

8. Perform an engine tune-up as outlined in Section 14.4.2.

VARIABLE SPEED MECHANICAL GOVERNOR

8V ENGINE

The variable speed mechanical governor, illustrated in Fig. 1, performs three functions:

1. Controls the engine idle speed.

2. Limits the maximum no-load speed.

3. Holds the engine at any constant speed, between idle and maximum, as desired by the operator.

The governor is identified by a name plate attached to the governor housing. The letters S-W.-V.S. stamped on the name plate denote a single-weight variable speed governor.

As shown in Fig. 2, the governor is mounted on the front end of the blower and driven by one of the blower rotors. The governor assembly consists of three subassemblies:

1. Control housing cover.

2. Variable speed spring housing and shaft.

3. Control and weight housing.

Operation

Two manual controls are provided on the governor: a governor stop lever and a speed control lever. For starting, the governor stop lever is moved to the RUN position; this moves the injector control racks to the full-fuel position. Upon starting, the governor moves the injector racks out to the position required for idling. The engine speed is then controlled manually by movement of the speed control lever.

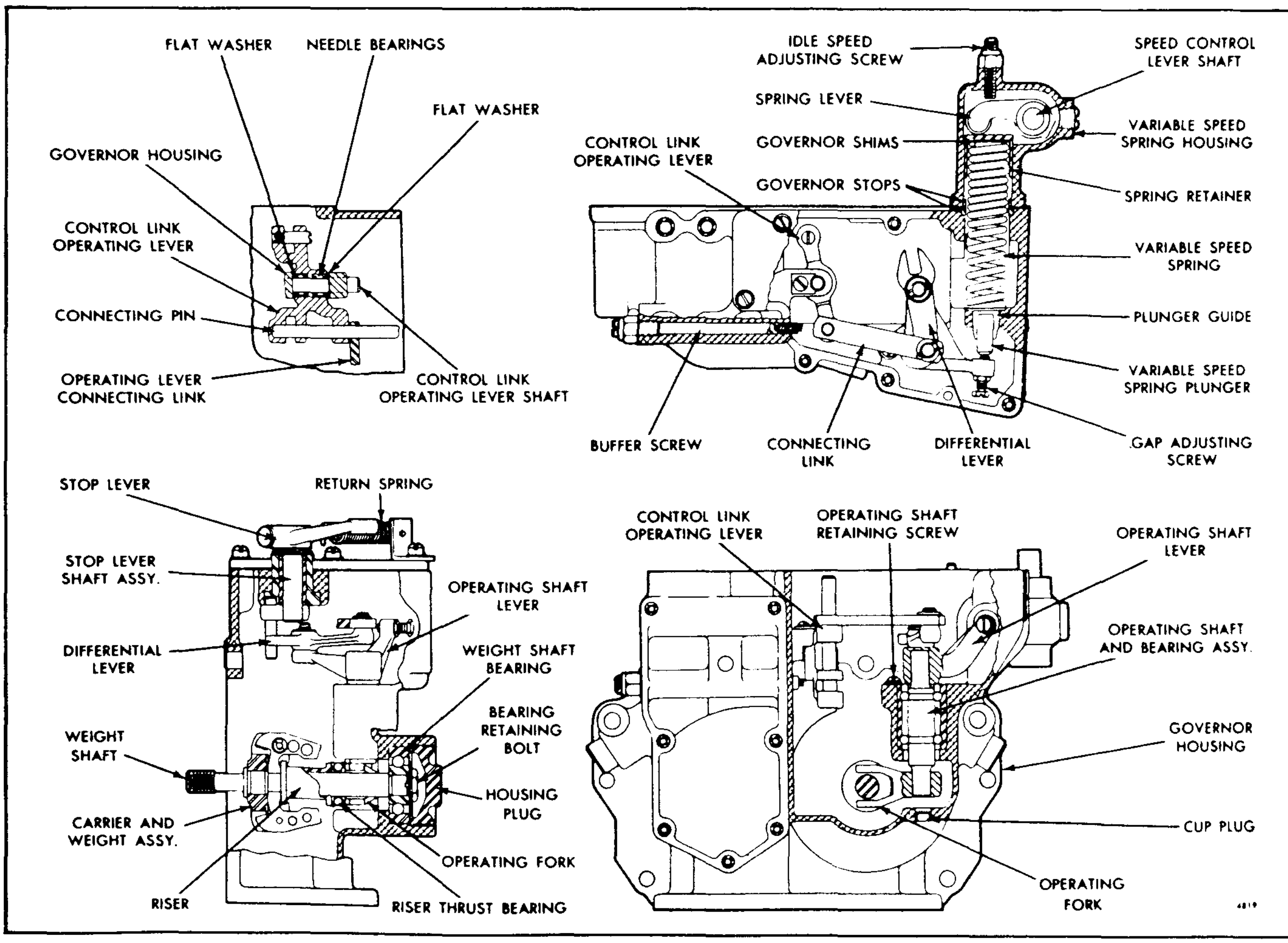


Fig. 1 - Cross Sections of Variable Speed Mechanical Governor

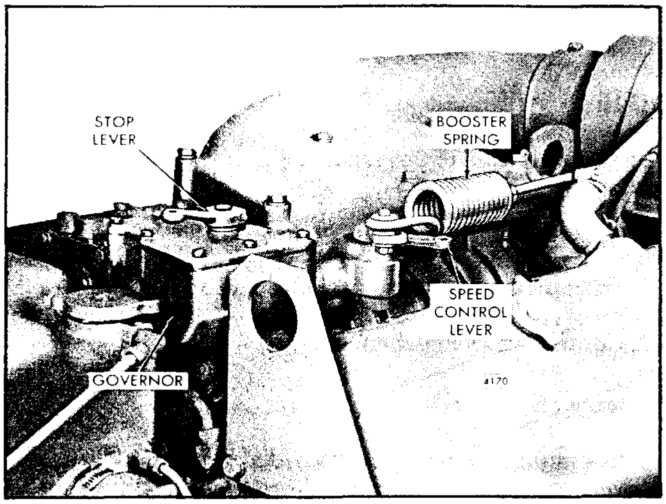


Fig. 2 - Variable Speed Governor Mounting

The centrifugal force of the revolving governor weights is converted into linear motion which is transmitted through the riser (Fig. 1) and operating shaft to the operating shaft lever. One end of the operating shaft lever bears against the variable speed spring plunger, while the other end provides a changing fulcrum on which the differential lever pivots.

The centrifugal force of the governor weights is opposed by the variable speed spring. Load changes or movement of the speed control lever create an unbalanced force between the revolving governor weights and tension on the variable speed spring. When the two forces are equal, the engine speed stabilizes for a setting of the speed control lever.

Fuel rods connected to the injector control tube levers and the control link operating lever assembly are operated by the differential lever, through the operating lever connecting link. This arrangement provides a means for the governor to change the fuel settings of the injector rack control levers.

The engine idle speed is determined by the centrifugal force required to balance out the tension on the variable speed spring in the low speed range.

To stop the engine, the speed control lever is moved to the idle speed position and the stop lever is moved to the no-fuel position and held there until the engine stops.

Adjustment of the governor is covered in the *Engine Tune-Up* section of this manual.

Lubrication

The governor is lubricated by a spray of oil from a passage in the blower end plate. The revolving governor weights distribute this oil to all parts of the governor which require lubrication. Excess oil returns to the engine crankcase through passages in the blower end plate and the cylinder block.

Remove Governor From Engine

Governor operation should be checked as outlined in Section 2.7 before the governor is removed from the engine. If, after performing these checks, the governor fails to control the engine properly, it should be removed and reconditioned.

The blower and governor must be removed together as outlined under *Remove Blower* in Section 3.4.1. Then remove the governor from the blower as outlined under *Remove Accessories from Blower* in Section 3.4.1.

Disassemble Governor

Before removing any of the parts from the governor, wash the entire unit in clean fuel oil, dry it with compressed air and inspect it for worn or damaged parts which may be repaired or replaced without complete disassembly.

With the governor cover removed from the governor housing, refer to Fig. 1 and disassemble the cover as follows:

1. Disassemble the governor cover:

   a. Clamp the cover assembly in a vise equipped with soft jaws.

   b. Loosen the stop lever retaining bolt and pull the lever from the shaft.

   c. Remove the snap ring from the groove in the stop lever shaft and remove the two seal ring retainers.

   d. Pull the stop lever shaft out of the cover and remove the seal ring (on top of the bushing) from the cover.

   e. At this stage of disassembly, wash the cover assembly thoroughly in clean fuel oil and inspect the bushing for wear and damage. If the bushing is satisfactory for further use, removal is unnecessary. If worn excessively or damaged, replace the bushing.

   f. If bushing removal is necessary, support the inner face of the cover over the opening in the bed of an arbor press. Place the remover J 21967 on top of the stop shaft bushing and under the ram of the press, then press the bushing out of the cover (Fig. 3).

2. Remove the variable speed spring, spring plunger and spring housing assembly from the governor housing:

a. Clamp the flange of the governor housing in a vise equipped with soft jaws.

b. Remove the two bolts and lock washers securing the variable speed spring housing to the governor housing. Then withdraw the spring housing, spring retainer, shims, stop and spring as an assembly from the governor housing. Remove the spring housing gasket.

c. Remove the variable speed spring, split stop, shims and spring retainer from the spring housing. Then remove the spring plunger from the plunger guide.

d. Remove the spring retainer solid stop from the governor housing.

e. If necessary, remove the variable speed spring plunger guide from the governor housing with a small brass rod and hammer.

3. Disassemble the variable speed spring housing:

a. Loosen the bolt securing the speed control lever to the speed control shaft and pull the lever from the shaft.

b. Remove the Woodruff key and flat washer from the speed control shaft.

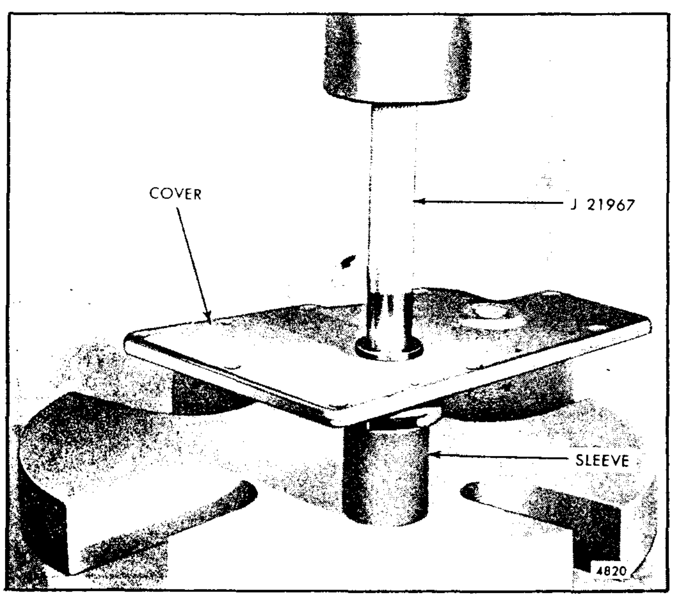


Fig. 3 - Removing Stop Lever Shaft Bushing from Governor Cover

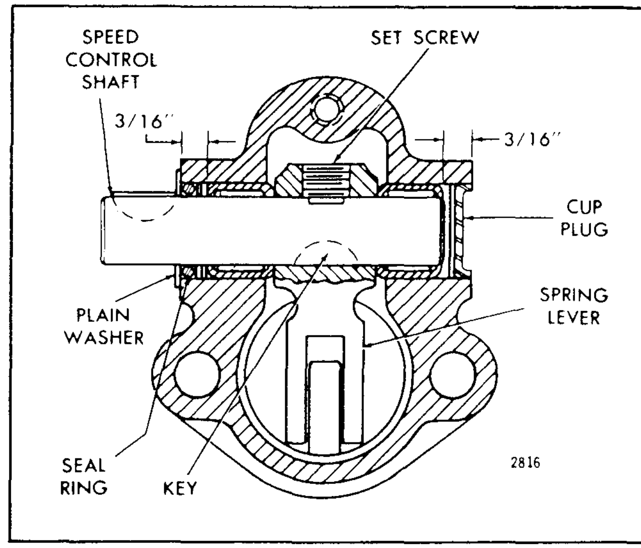


Fig. 4 - Cross Section of Governor Spring Housing and Lever Assembly

c. On the former spring housing, remove the pipe plug in the top of the spring housing. On the current spring housing, remove one screw and lock washer and remove the spring housing cover and gasket. Then remove the set screw from the spring lever (Fig. 4).

d. Place a 3/4" inside diameter sleeve approximately 1-1/2" long on the bed of an arbor press. Support the spring housing assembly on top of the sleeve with the cup plug in the side of the housing over the opening of the sleeve.

e. Place a small brass rod on the end of the shaft and under the ram of the press as shown in Fig. 5 and press the plug and bearing out of the spring housing.

f. Remove the spring lever from the spring housing and the bearing from the speed control shaft. If necessary, remove the Woodruff key from the shaft.

NOTE: Due to the Woodruff key in the speed control shaft, the inner end of the needle bearing will be damaged when pressing the bearing and cup plug out of the spring housing. Do not reuse the bearing.

g. At this stage of disassembly, wash the spring housing (containing the remaining bearing) thoroughly in clean fuel oil and inspect the needle bearing for wear and damage. If the bearing is satisfactory for further use, removal is unnecessary.

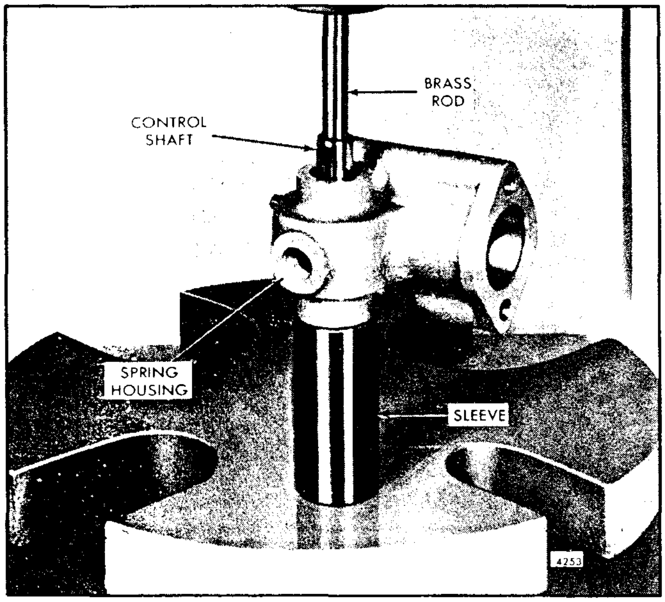


Fig. 5 - Removing Speed Control Shaft, Bearing and Cup plug from Governor Spring Housing

h. If removal of the needle bearing is necessary, support the spring housing, bearing side down, on top of the 3/4" inside diameter sleeve on the bed of the arbor press. Insert the bearing remover J 21967 through the housing and rest it on top of the bearing, then press the bearing out of the housing.

4. Remove the governor weight and shaft assembly from the governor housing as follows:

a. Clamp the flange of the governor housing in a vise equipped with soft jaws.

b. Remove the governor weight housing plug and gasket (Fig. 1).

c. Bend the tang on the lock washer away from the head of the bolt. Then, while holding the weight carrier from turning, remove the bearing retaining bolt, flat washer and lock washer.

d. Place a 1/4" brass rod in the bearing retainer bolt hole in the weight carrier shaft, then tap the shaft out of the weight shaft bearing with a hammer. Catch the shaft and weight carrier assembly by hand to prevent it from falling and being damaged.

e. Slide the governor riser thrust bearing and riser from the weight shaft.

NOTE: The thrust bearing is specially designed to absorb thrust load; therefore, looseness between the mating parts does not indicate excessive wear.

f. Remove the weight shaft bearing from the governor housing. If necessary, use a small brass rod and hammer and tap the bearing out of the housing.

5. Disassemble the governor weights and shaft assembly as follows:

a. If removal of the weight carrier assembly from the shaft is necessary, support the shaft, weight carrier and sleeve on the bed of an arbor press as shown in Fig. 6 and press the shaft out of the weight carrier assembly.

b. Remove the weight pin retainer from each weight pin (Fig. 12). Clamp the weight carrier assembly in a vise equipped with soft jaws, then drive the pin out of the carrier and weights by tapping on the grooved end of the pins with a small punch and hammer. Remove the weights from the carrier.

6. Remove the governor linkage and operating shaft from the governor housing as follows:

a. Remove the spring retainer and plain washer securing the connecting link to the differential lever and remove the connecting link.

b. Remove the spring retainer and plain washer securing the differential lever to the operating shaft lever and remove the differential lever.

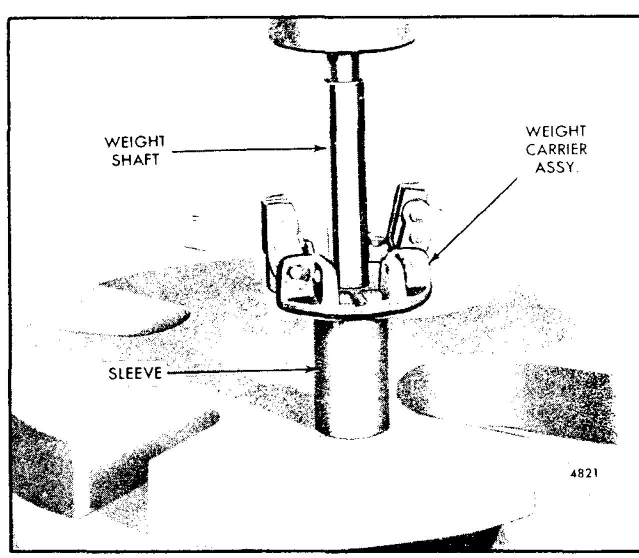


Fig. 6 - Removing Governor Weight Shaft from Weight Carrier Assembly

c. Remove the screw, lock washer and lock clip securing the control link operating lever shaft in the housing. Lift the shaft out of the housing and remove the operating lever and two flat washers at each side of the operating lever.

NOTE: Do not lose the two flat washers located between the top and bottom of the lever assembly and the governor housing.

d. Remove the cup plug in the bottom of the governor housing by tapping it out of the housing, toward the operating fork, with a 1/4" rod and hammer.

e. Remove the operating shaft and bearing assembly retaining screw, lock washer and flat washer securing the shaft and bearing assembly in the governor housing.

f. Support the governor housing, bottom side up, on two wood blocks on the bed of an arbor press as shown in Fig. 7. Place a 9/16" open end wrench under the operating fork and the boss of the housing, then insert a rod through the cup plug hole in the housing and against the end of the operating shaft and press the shaft and bearing assembly out of the operating fork.

g. Remove the governor operating shaft lever, shaft and bearing assembly from the governor housing.

h. Examine the operating shaft bearing for wear and rough spots and, if replacement is necessary, remove the operating shaft lever from the shaft with a small puller.

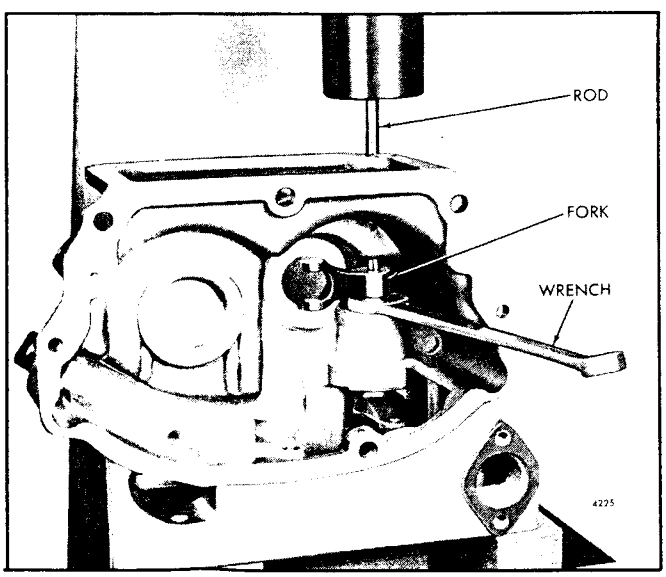


Fig. 7 - Removing Governor Operating Fork from Operating Shaft and Bearing Assembly

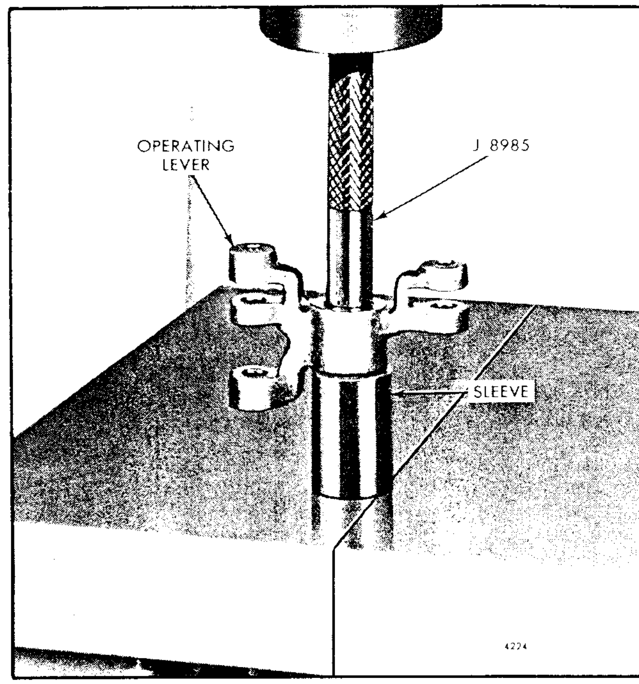


Fig. 8 - Removing Control Link Operating Lever Bearings

i. Remove the buffer screw from the governor housing and, if desired, remove the lock nut from the screw.

j. Remove the bolts, lock washers and plain washers securing the breather hole cover to the governor housing, then remove the cover and gasket.

k. Wash the control link operating lever (containing the bearings) thoroughly in clean fuel oil and inspect the needle bearings for wear or damage. If the needle bearings are satisfactory for further use, removal is unnecessary.

l. If removal of the needle bearing is necessary, support the control link operating lever on a sleeve and rest the sleeve on the bed of an arbor press. Place tool J 8985 on top of the bearing and under the ram of the press, then press both bearings out of the lever as shown in Fig. 8.

Inspection

Wash all of the governor parts (except the operating shaft bearing) in clean fuel oil and dry them with compressed air.

NOTE: The operating shaft bearing is sealed and must not be cleaned with fuel oil or other cleaning agent.

Examine the governor weight shaft bearing for any indications of corrosion or pitting. Lubricate the

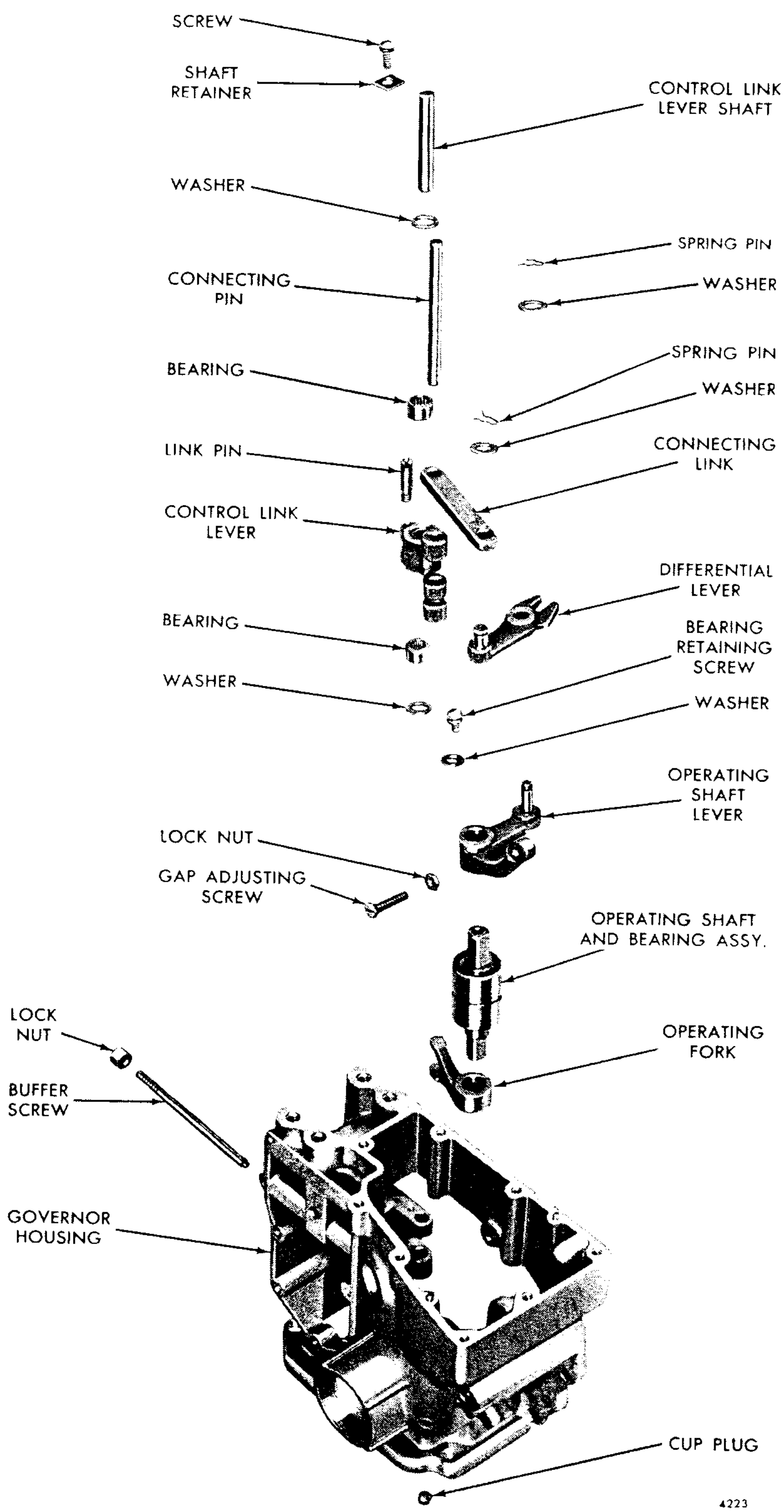


Fig. 9 - Governor Housing and Operating Shaft Details and Relative Location of Parts

bearing with light engine oil; then, while holding the bearing inner race from turning, revolve the outer race by hand and check for rough spots.

Examine the riser thrust bearing for excessive wear, flat spots or corrosion.

Examine the stop lever shaft and bushing in the governor cover for wear.

> **NOTE:** The stop lever shaft bushing is not serviced. When replacement of the bushing becomes necessary, it must be replaced with two needle bearings.

Examine the weight carrier pins and pin holes in the weights for wear.

Examine the speed control shaft and needle bearing in the spring housing for excessive wear.

Inspect the variable speed spring roller bearing and pin for wear.

Inspect the serration on the end of the governor weight shaft and in the blower rotor shaft for wear.

Examine the variable speed spring lever roller and pin for excessive wear. The current roller type bearing rides on a hardened bearing pin which is a press fit in the spring lever and is staked at three places on both sides. The former ball type bearing (with two washers) rides on a soft bearing pin that is swagged at both ends to retain the bearing in the spring lever.

Examine the variable speed spring plunger, guide and spring retainer for wear or score marks. If the retainer or plunger are scored slightly, clean them up with crocus cloth. Replace the retainer, plunger and guide if scored excessively.

Inspect the adjusting screw, lock nut, pins, seal rings and any other parts in the governor housing for wear or defects that might affect the governor operation.

Replace all of the governor parts that are excessively worn or damaged.

Assemble Governor

With all of the governor parts cleaned and inspected and the necessary new parts on hand, the governor may be assembled.

Refer to Figs. 1, 9, 12, 14 and 16 for the location of the various parts and assemble the governor as follows:

1. Install the operating shaft and governor linkage in the governor housing as follows:

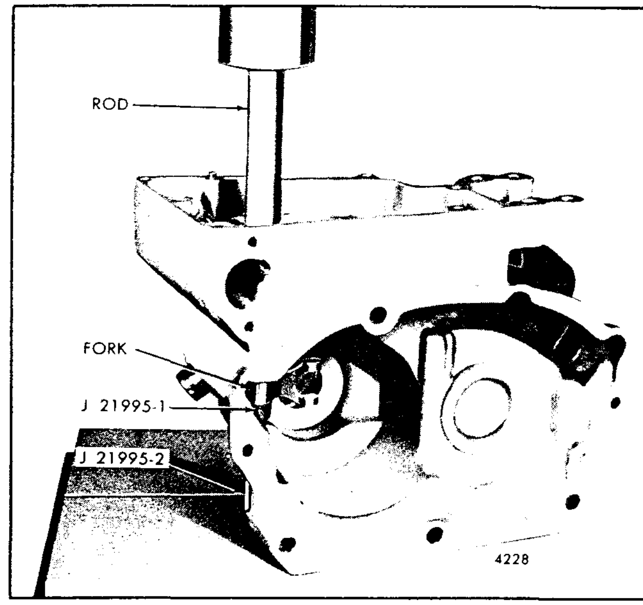


Fig. 10 - Installing Governor Operating Shaft Fork on Operating Shaft and Bearing Assembly

a. If removed, lubricate the inside diameter of the operating shaft lever with engine oil, then start the lever on the upper end (short protruding end) of the shaft with the flat surface in the lever in alignment with the flat surface of the shaft. Support the lever, shaft and bearing assembly on the bed of an arbor press and press the lever flush with the top end of the shaft.

b. Lubricate the outside diameter of the shaft bearing with engine oil, then insert the shaft, bearing and lever assembly in the bearing bore in the governor housing.

c. Lubricate the inside diameter of the governor operating fork with engine oil, then start the fork on the lower end of the shaft with the flat surface in the fork in alignment with the flat surface on the shaft, and the finished cam surface of the fork facing toward the rear face of the governor housing.

d. Insert the threaded end of the governor fork installing pin J 21995-1 through the cup plug hole in the bottom of the housing, then thread the knurled disc J 21995-2 on the end of the rod.

e. Support the housing, lever, shaft, fork and installer, right side up, on the bed of an arbor press as shown in Fig. 10, with the end of the installer pin resting on the bed of the press and the disc centered under the bottom of the operating fork. Then place a short rod on the top end of the operating shaft and under the ram of the press and press the shaft into the fork until

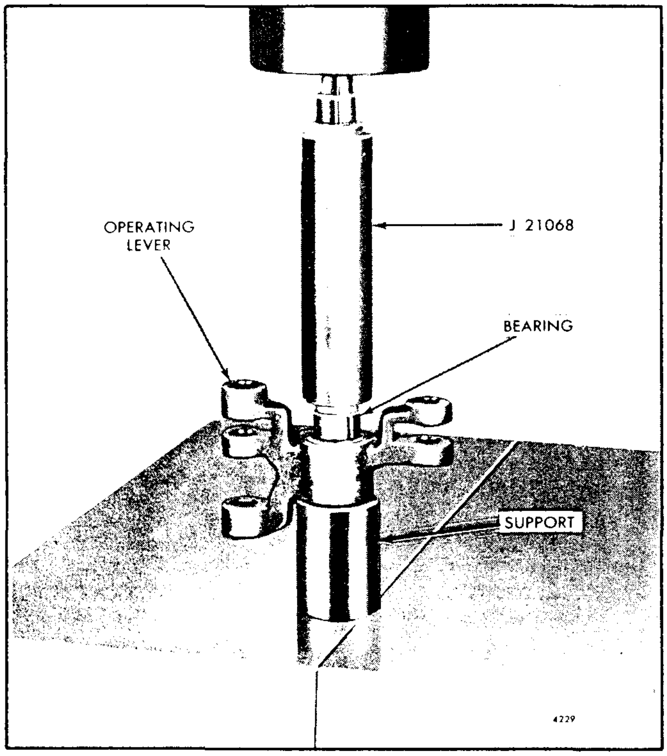


Fig. 11 - Installing Control Link Operating Lever Bearings in Lever

the fork is flush with the end of the shaft. Remove the fork installer disc and rod from the housing.

f. Install the operating shaft and bearing assembly retaining flat washer, lock washer and screw in the governor housing and tighten the screw securely.

g. Apply a good sealant to the outside diameter of a new cup plug. Start the cup plug, solid end first, straight in the plug hole in the bottom of the housing, then support the governor housing on the bed of an arbor press and press the plug in flush with the bottom face of the housing (Fig. 1).

h. Place the differential lever over the pivot pin in the operating lever, pin in lever up, and secure it in place with a plain washer and spring retainer.

i. If previously removed, install the governor gap adjusting screw and lock nut in the tapped hole in the operating shaft lever.

j. If removed, place the control link operating lever on the bed of an arbor press with a steel support under the bearing bore. Lubricate the bearing with engine oil and start the bearing, numbered end up, straight into the bore of the lever. Insert the pilot end of installer J 21068 (Fig. 11) in the bearing and under the ram of the press. Then press the bearing into the lever until it is flush with the top surface of the lever. Reverse the lever on the press and install the second bearing in the same manner.

k. Lubricate the control link operating lever needle bearings with Shell Alvania No. 2 grease, or equivalent. Place the operating lever in position between the two bosses inside the governor housing. Insert a flat washer on each side of the lever (Fig. 1). Then install the operating lever shaft with the slot in the side at one end of the shaft up.

l. Align the slot in the operating lever shaft with the lock clip screw hole in the boss next to the shaft. Install the lock clip, lock washer and screw and tighten it securely.

m. Place one end of the connecting link over the differential lever pin and secure it in place with a plain washer and spring retainer (Fig. 1). Place the opposite end of the connecting link on top of the control link operating lever and install the connecting pin.

n. If removed, thread the lock nut on the buffer screw and thread the buffer screw into the governor housing.

o. Affix a new gasket to the breather hole cover, then attach the cover to the governor housing with bolts, lock washers and plain washers.

2. Assemble the governor weight and shaft assembly as follows:

If the governor weight carrier assembly was removed from the weight shaft, the weights must be removed from the carrier before attempting to install the carrier on the shaft.

a. Support the weight carrier, rear face up, on a sleeve on the bed of an arbor press as shown in Fig. 13.

b. Lubricate the weight carrier surface of the weight shaft with engine oil. Insert the non-splined end of the shaft through the carrier and into the sleeve, then press the shaft straight into the carrier until the shoulder on the shaft is tight against the carrier.

c. Clamp the weight carrier and shaft assembly in a vise equipped with soft jaws.

d. Place a governor weight in position in the carrier, then insert a weight pin, grooved end first, into the smallest pin hole in the carrier, through the weight and into the opposite hole in the carrier, then tap the knurled end of the pin into the carrier just enough to permit the pin retaining ring to be installed in the pin groove. Install the retaining ring.

e. Install the remaining governor weight in the weight carrier in the same manner as described in Step "d".

3. Install the governor weight and shaft assembly in the governor housing as follows:

a. Lubricate the weight shaft with engine oil, then slide the governor riser over the end of the shaft and against the fingers of the weight.

b. Lubricate the governor riser thrust bearing with engine oil, then place the thrust bearing over the end of the weight shaft with the bearing race which has the smallest inside diameter against the riser.

c. Insert the weight carrier and shaft assembly in the governor housing. Then support the splined end of the shaft and the governor housing on the bed of an arbor press with the upper end of the shaft under the ram of the press.

d. Lubricate the weight shaft bearing with engine oil, then place the bearing in the governor housing (numbered side up) and start it straight on the end of the weight carrier shaft. Place a sleeve with a 1/2" inside diameter on top of the bearing

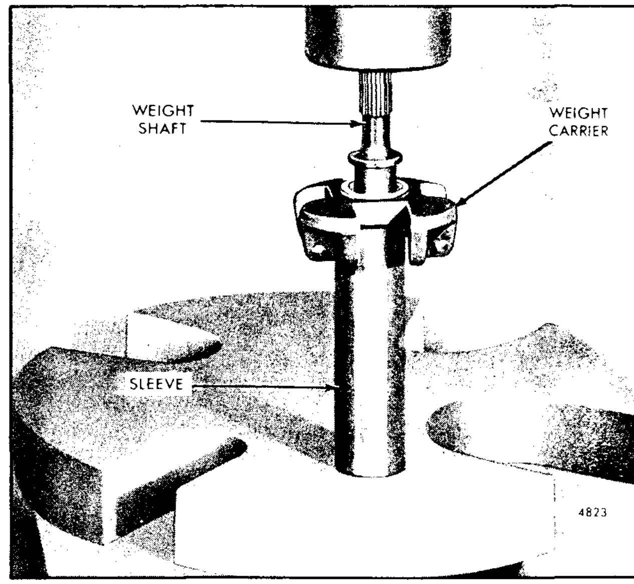


Fig. 13 - Installing Governor Weight Shaft in Weight Carrier

inner race. Bring the ram of the press down on the sleeve and press the bearing into the housing and against the shoulder on the shaft.

e. Place the special lock washer on the end of the weight carrier shaft with the tang on the inner diameter of the washer in the notch in the end of the shaft.

f. Place the flat washer on the bearing retainer bolt and thread the bolt into the shaft. Clamp the splined end of the weight carrier shaft in the soft jaws of a bench vise and tighten the bearing

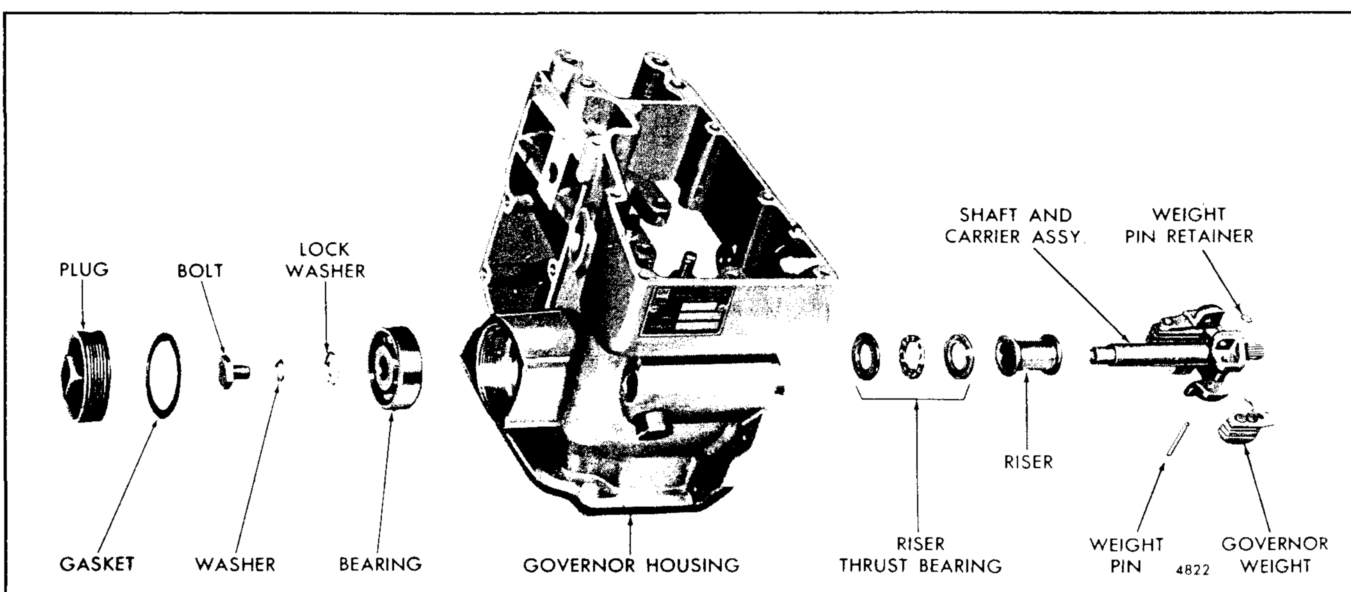


Fig. 12 - Governor Housing and Weight Details and Relative Location of Parts

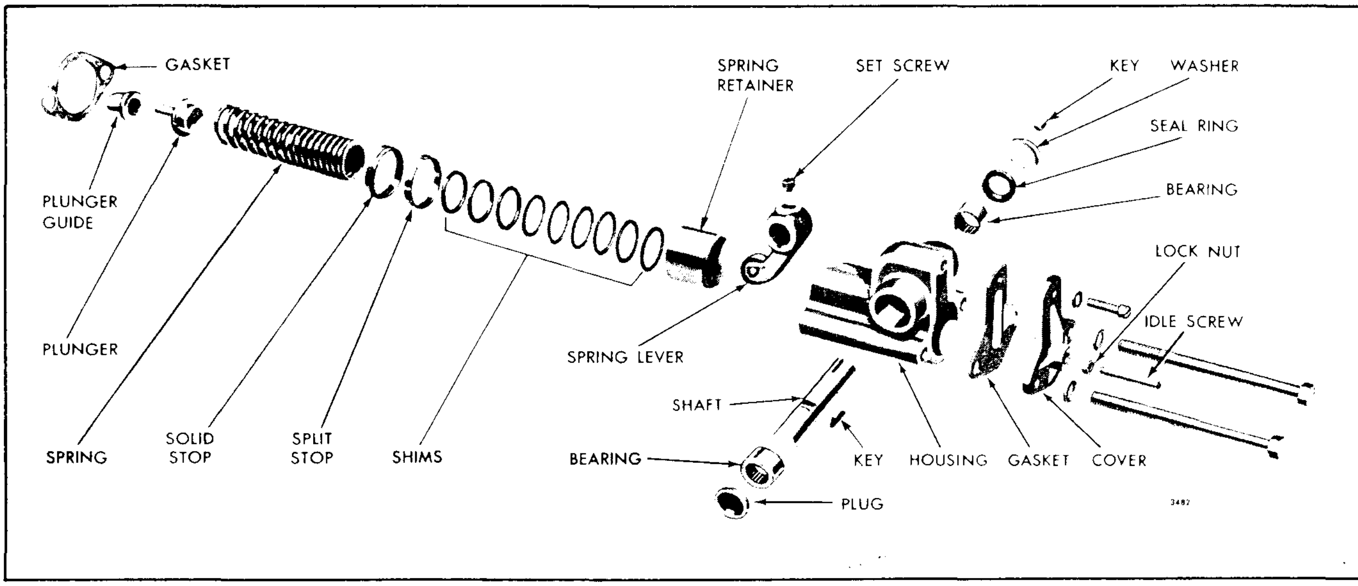


Fig. 14 - Variable Speed Spring Housing and Shaft Details and Relative Location of Parts

retainer bolt to 15-19 lb-ft torque. Bend the tang on the lock washer against the head of the bolt.

g. Place a gasket against the weight shaft bearing. Apply a good quality sealant such as Loctite grade H, HV or HVW, or equivalent, on the threads of the governor housing and the plug and thread the plug into the housing. Clean the plug with solvent to remove any oil or grease before applying the sealant. Tighten the plug to 45 lb-ft torque.

NOTE: Rotate the governor weight assembly to see that there is no bind. If a bind exists, remove the housing plug and check to see if the weight shaft bearing is fully seated in the governor housing.

4. Refer to Figs. 4 and 14 for the location of the parts and assemble the variable speed spring housing as follows:

a. Lubricate the speed control lever shaft needle bearings with Shell Alvania No. 2 grease, or equivalent. Then start one of the bearings, numbered end up, straight in the bearing bore in the right-hand side of the spring housing as viewed in Fig. 4.

b. Install the needle bearing pilot rod J 9196-2 in the installer body J 9196-1 and secure it in place with the retaining screw.

NOTE: Do not use impact tools to install needle bearings.

c. Place the pilot rod end of the bearing installer assembly in the bearing. Support the spring housing, bearing and installer on a short sleeve on the bed of an arbor press as shown in Fig. 15, then press the bearing in the housing until the shoulder on the installer contacts the housing.

NOTE: When the shoulder on the installer body contacts the housing, the bearing will be properly positioned in the housing.

d. Install the current roller type bearing and pin in

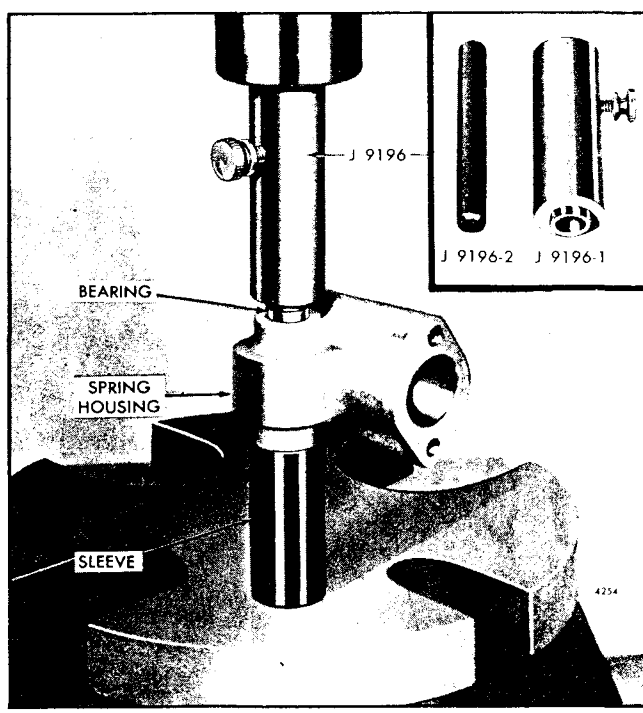


Fig. 15 - Installing Speed Control Shaft Bearing in Spring Housing

the spring lever. Press the pin below the surface of the lever and stake at three places on both sides of the lever. The former ball type bearing (with two washers) is swagged at both ends to retain the bearing in the spring lever.

e. If removed, install the spring lever Woodruff key in the center keyway in the speed control lever shaft.

f. Place the spring lever assembly between the bearing bores inside the spring housing with the arm (roller end) of the lever facing out.

g. Insert the correct end of the speed control lever shaft (Fig. 4) through the bearing bore in the side of the spring housing, opposite the bearing previously installed. Align the key in the shaft with the keyway in the spring lever and push the shaft through the lever and in the bearing until the flat on the top of the shaft is centered under the set screw hole in the lever.

h. Thread the set screw into the spring lever, making sure the point of the screw is seated on the flat on the shaft.

i. Place the second speed control lever shaft needle bearing, numbered end up, over the protruding end of the shaft and start it straight in the bore of the housing.

j. Remove the bearing pilot rod J 9196-2 from the installer body J 9196-1 and place the installer body over the end of the shaft and against the bearing. Support the spring housing, bearings and installer on a short sleeve on the bed of an arbor press as shown in Fig. 15, then press the bearing in the housing until the shoulder on the installer contacts the housing.

k. Apply a thin coat of sealing compound to the outside diameter of the cup plug. Start the cup plug, solid end first, straight in the bearing bore in the housing. Then support the spring housing, bearings and shaft assembly on a sleeve on the bed of an arbor press and press the cup plug in flush with the outside face of the housing.

l. Clamp the spring housing assembly in a bench vise equipped with soft jaws. Then tighten the spring lever retaining set screw to 12-15 lb-ft torque.

m. Stake the edge of the spring lever set screw hole with a small center punch and hammer to retain the set screw in the lever. Then install the plug in the former spring housing.

n. Place a seal ring over the end of the shaft and push it into the bearing bore and against the bearing. Place the plain washer over the shaft and against the housing, then install the Woodruff key in the keyway in the shaft.

o. Place the speed control lever on the shaft in its original position. Align the keyway in the lever with the key in the shaft and push the lever in against the plain washer and secure it in place with the retaining bolt and lock washer.

p. If removed, thread the lock nut on the idle speed adjusting screw. Then thread the idle speed adjusting screw into the spring housing or spring housing cover approximately 1".

5. Refer to Figs. 1 and and 14 and attach the variable speed spring plunger guide, plunger retainer, shims, spring, stops and spring housing assembly to the governor housing as follows:

a. On current governors, use a new gasket and attach the spring housing cover to the spring housing with a screw and lock washer.

b. Clamp the flange of the governor housing in a vise equipped with soft jaws.

c. If removed, start the variable speed spring plunger guide straight in the boss inside the governor housing and tap it into place with a small brass rod and hammer.

d. Lubricate the small end of the variable speed spring plunger with engine oil. Then insert the plunger in the plunger guide inside the governor housing (Fig. 1).

e. Place the spring retainer solid stop in the counterbore of the governor housing.

f. Lubricate the outside diameter of the variable speed spring retainer with engine oil. Insert the spring retainer, solid end first, into the spring housing and against the spring lever.

g. Place the same amount of shims in the spring retainer that were removed, thin shims first. Then insert the spring retainer split stop in the spring housing approximately 1/16" from the finished face of the housing.

h. Affix a new gasket to the forward face of the spring housing. Then insert the variable speed spring into the spring housing and spring retainer with the tightly wound end of the spring against the shims in the retainer.

i. Place the variable speed spring housing into position against the governor housing, with the

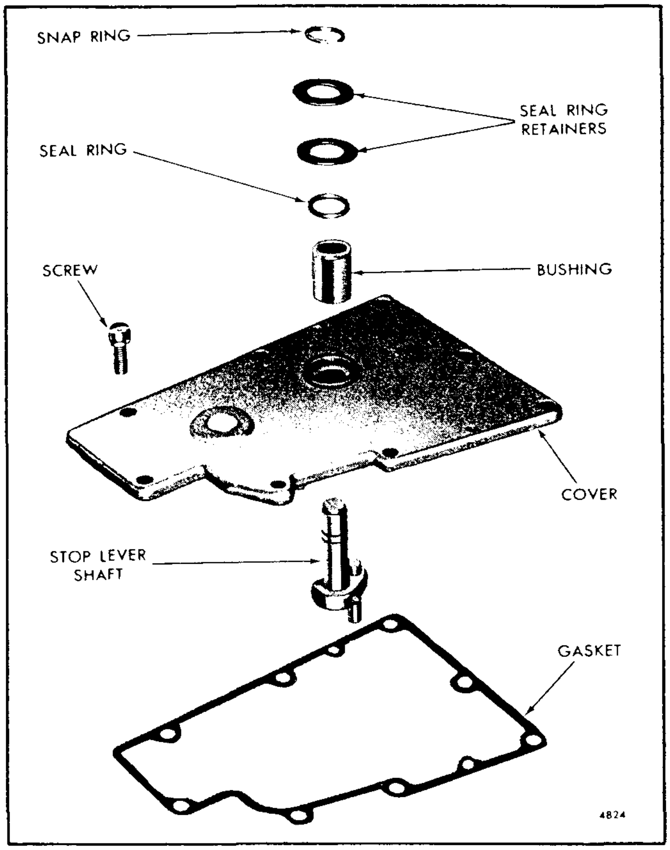


Fig. 16 - Governor Cover Details and Relative Location of Parts

speed control lever facing the top of the governor (Fig. 2) and the variable speed spring over the end of the spring plunger (Fig. 1) inside the governor housing.

j. On former governors, insert two bolts with lock washers through the spring housing. On current governors, insert two bolts with copper washers through the spring housing cover and spring housing. Tighten the bolts to 13-17 lb-ft torque.

6. Refer to Fig. 16 for the location of the various parts and assemble the governor cover as follows:

a. If the stop lever bushing (Fig. 16) was removed from the cover, place the cover, inner face down, on the bed of an arbor press as shown in Fig. 17. Refer to "NOTE" under *Inspection*, then lubricate the new needle bearing with engine oil and start the bearing, numbered end up, straight in the bearing bore in the cover boss.

b. Place the correct end of the installer J 21068 in the bearing and under the ram of the press. Then press the bearing into the cover until the stop on the installer contacts the boss on the cover.

c. Reverse the cover, inner face up, on the bed of an arbor press. Lubricate the second bearing with engine oil and start the bearing, numbered end up, straight in the bore in the cover boss.

d. Place the bearing installer J 21068 in the bearing and under the ram of the press. Then press the bearing in the bore until it is flush with the face of the boss.

e. Lubricate the stop lever shaft needle bearings with Shell Alvania No. 2 grease, or equivalent. Then insert the stop shaft through the bearings in the cover.

f. Place the seal ring over the shaft and push it into the bearing bore and against the bearing. Place the two seal ring retainer washers on the shaft and against the cover boss, then install the snap ring in the groove in the shaft.

g. Install the stop lever on the shaft and secure it in place with the retaining bolt and lock washer.

Install Governor on Engine

1. Refer to Section 3.4.1 and attach the governor to the blower as outlined under *Attach Accessories to Blower*.

2. Install the blower and governor assembly as outlined under *Install Blower* in Section 3.4.1.

3. Perform an engine tune-up as outlined in Section 14.

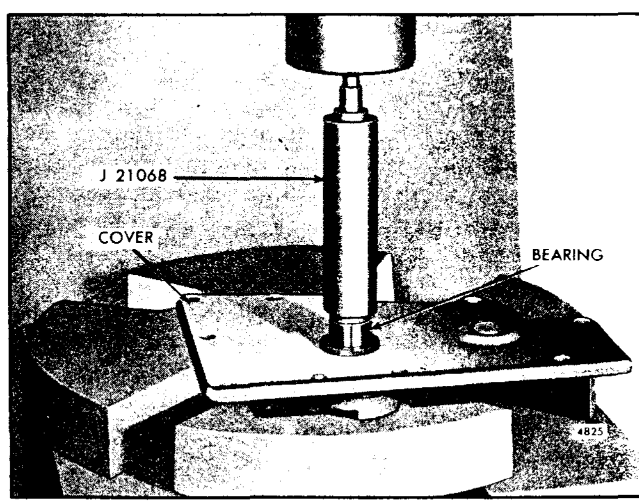


Fig. 17 - Installing Bearings in Governor Cover

CONSTANT SPEED MECHANICAL GOVERNOR

In-Line Engine

The horsepower requirements of an engine vary continually due to fluctuating loads; therefore, some means must be provided to control the amount of fuel required to hold the engine speed reasonably constant during such fluctuations. To accomplish this control, a mechanical governor of the constant speed type has been provided.

Upon starting, the engine will automatically attain approximately 50 rpm more than the predetermined speed.

As the load is applied the engine speed drops until it reaches the desired speed at full load. This speed can be adjusted by the use of shims behind the governor spring.

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 either the camshaft or the balance shaft gear, depending upon the engine model.

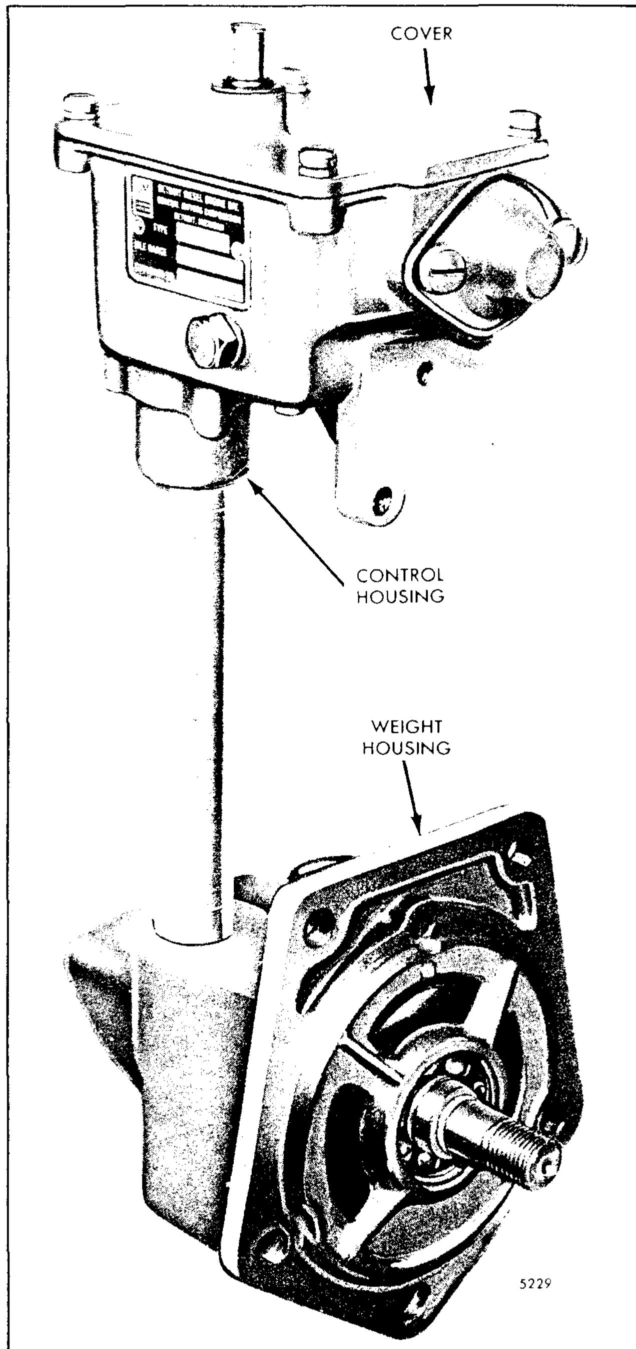


Fig. 1 - Constant Speed Governor

Operation

A spring on top of the governor holds the governor control lever in the *run* position. A cable from the instrument panel, when pulled, overcomes the spring and draws the injector racks to the no-fuel position (through the governor), thus stopping the engine.

The centrifugal force of the revolving flyweights is converted into linear motion which is transmitted through the riser, operating shaft, the operating shaft lever, the low speed gap screw and the plunger to the spring. The other arm of the operating lever provides a changing fulcrum on which the differential lever pivots. A fuel rod, connected to the differential lever and injector control tube lever, provides a means for the governor to change the fuel settings of the injector control racks.

The centrifugal force of the governor weights is opposed by the governor spring. Load changes create an unbalanced force between the revolving governor weights and the tension of the spring. When the two forces are equal, the engine speed stabilizes. Whenever the centrifugal force of the revolving weights overcomes the tension of the spring, the injector racks will be moved toward the no fuel position. Also, whenever the centrifugal force of the weights allows the spring to expand, the injector racks will move toward the full-fuel position.

Adjustment for the no-load speed on a single range governor is made by varying the tension of the spring by the use of shims. The addition of shims behind the spring will raise the engine speed; likewise, the removal of shims will lower the engine speed. On a dual range governor, the top speed is adjusted by the use of shims, the lower speed by use of an adjusting screw.

When governor difficulties are encountered which would necessitate governor service, refer to Section 2.7.1 for the proper procedure.

When engine tune-up is necessary, refer to Section 14.6.

HYDRAULIC GOVERNORS

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 betweeen the throttle control and the fuel injectors.

Engines, subjected to varying load conditions that require an automatic fuel compensation to maintain more nearly constant engine speed with a minimum speed droop, are equipped with a hydraulic governor.

In the hydraulic governor, the fuel is decreased by the action of the governor throttle control terminal lever retracting spring and increased by the opposing action of the power piston. A pilot valve controls the admission of oil flow to the power piston and the movement of the pilot valve in turn is controlled by the governor flyweights. The centrifugal force of these flyweights is opposed by the speeder spring compression which may be varied and yet accurately set and held at any speed between idle and maximum speed. The speed droop, which is the difference between no-load speed and full-load speed, is adjustable to within a vary small percentage at maximum speed.

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 appear, the unit should be checked as follows:

1. 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 as outlined in Section 15.2. If a cylinder is not firing properly, the injector must be removed, tested and, if necessary, reconditioned as outlined in Section 2.1 or 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 clamp being too tight or improperly positioned. To correct this condition, loosen the injector clamp bolt, reposition the clamp, and retighten the bolt to 20-25 lb-ft torque.

2. A binding injector may result from internal dirt, defective plunger and bushing or a bent injector rack. The injector must then be removed, reconditioned and tested as outlined in Section 2.1 or 2.1.1.

3. An injector rack may bind as the result of an improperly positioned control rack lever. Loosen the control rack adjusting screws. If this relieves the bind, relocate the lever on the control tube and position the rack as outlined in Section 14.7.1.

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 the 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 14.7.1

5. A bent 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 in the pin which connects the fuel rod to the injector control tube lever.

If neither load or engine irregularities are found to be the cause of the speed variations, the trouble may be in the governor or the governor drive.

1. If the speed changes noted are in rapid oscillation, the speed droop may be too high. The speed droop may be adjusted as outlined under *Adjust Speed Droop* in Section 14.7.1. This applies only in case the governor is overhauled or where the speed droop has been changed from the original factory setting.

2. Worn blower rotor bearings or rubbing of the rotors on the housing will cause the load on the blower drive coupling (between the gear train and blower) to vary erratically. This variation will be transmitted as a speed change to the governor which, in turn, will act to compensate for the change by moving the fuel rod. If this condition exists, inspect the blower.

3. If the speed variations are small in magnitude, the fault may lie in the governor drive. Excessive or insufficient clearance between the beveled drive gears may cause this condition.

If after making the preceding checks, the governor fails to control the engine properly, it should be removed and reconditioned.

SG HYDRAULIC GOVERNOR

The governors shown in Figs. 1 and 2 incorporate a speed droop stabilizer mechanism. Engine lubricating oil is admitted, under pressure, to an auxiliary oil pump in the governor. The auxiliary pump furnishes the necessary oil pressure to actuate the governor mechanism.

The governor is connected to the fuel injectors by a fuel rod that is attached to a lever on the injector control tube. The amount of fuel to the injectors is decreased by the governor throttle control terminal lever retracting spring and increased by the opposing action of a hydraulic power piston inside of a cylinder. Admission of oil to the cylinder is controlled by a pilot valve. The pilot valve, in turn, is controlled by the flyweights of the governor.

The two flyweights of the governor are mounted on a vertical shaft and driven, through a set of gears, by the camshaft or balance shaft gear (depending upon the engine model). The centrifugal force of the rotating flyweights is opposed by a speeder spring located on the vertical shaft between a spring fork at the top and the arms of the flyweights at the bottom. Compression of the speeder spring, which is controlled by the throttle, determines the speed at which the governor will control the engine.

In order that the governor operation may be stable

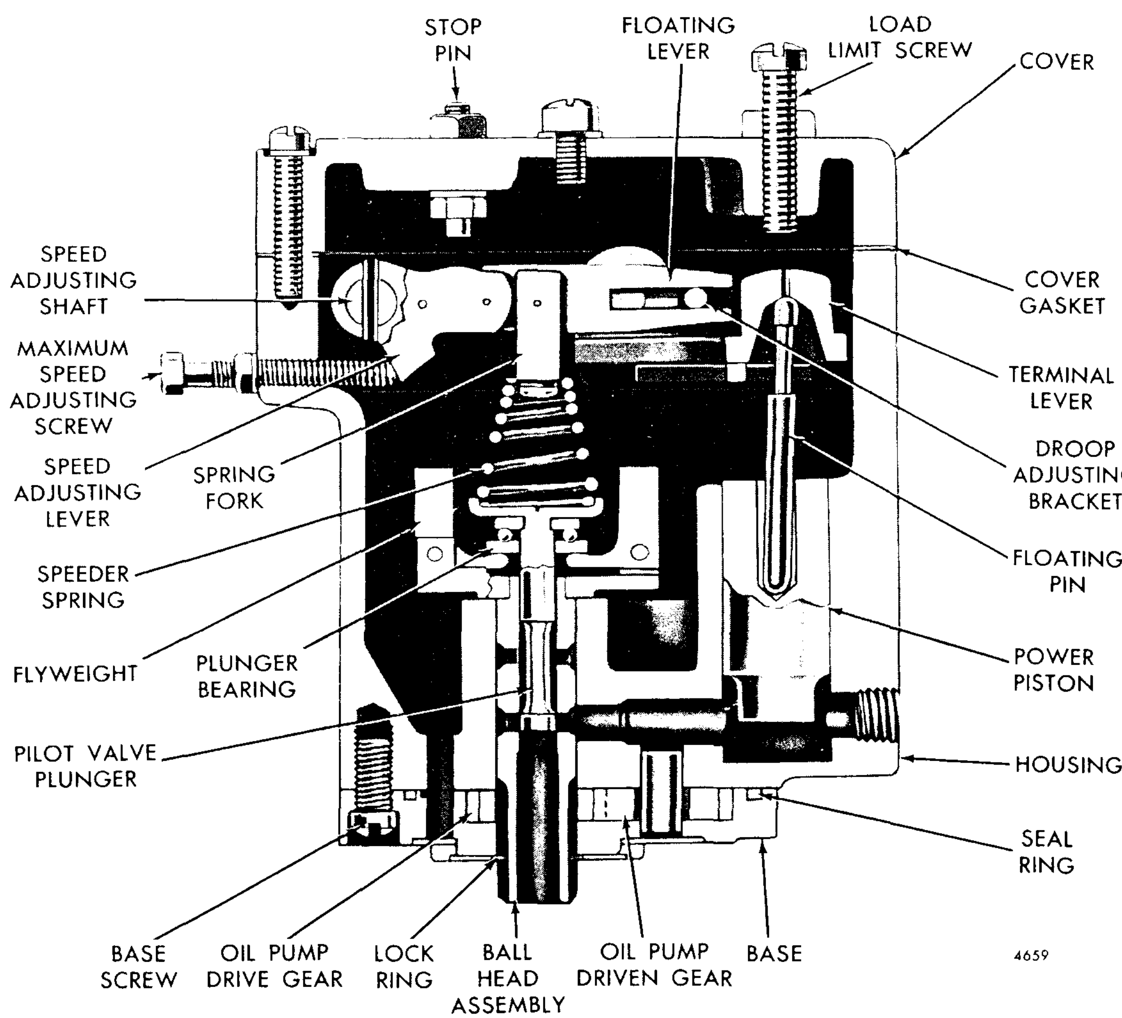


Fig. 1 - Hydraulic Governor Assembly (Current)

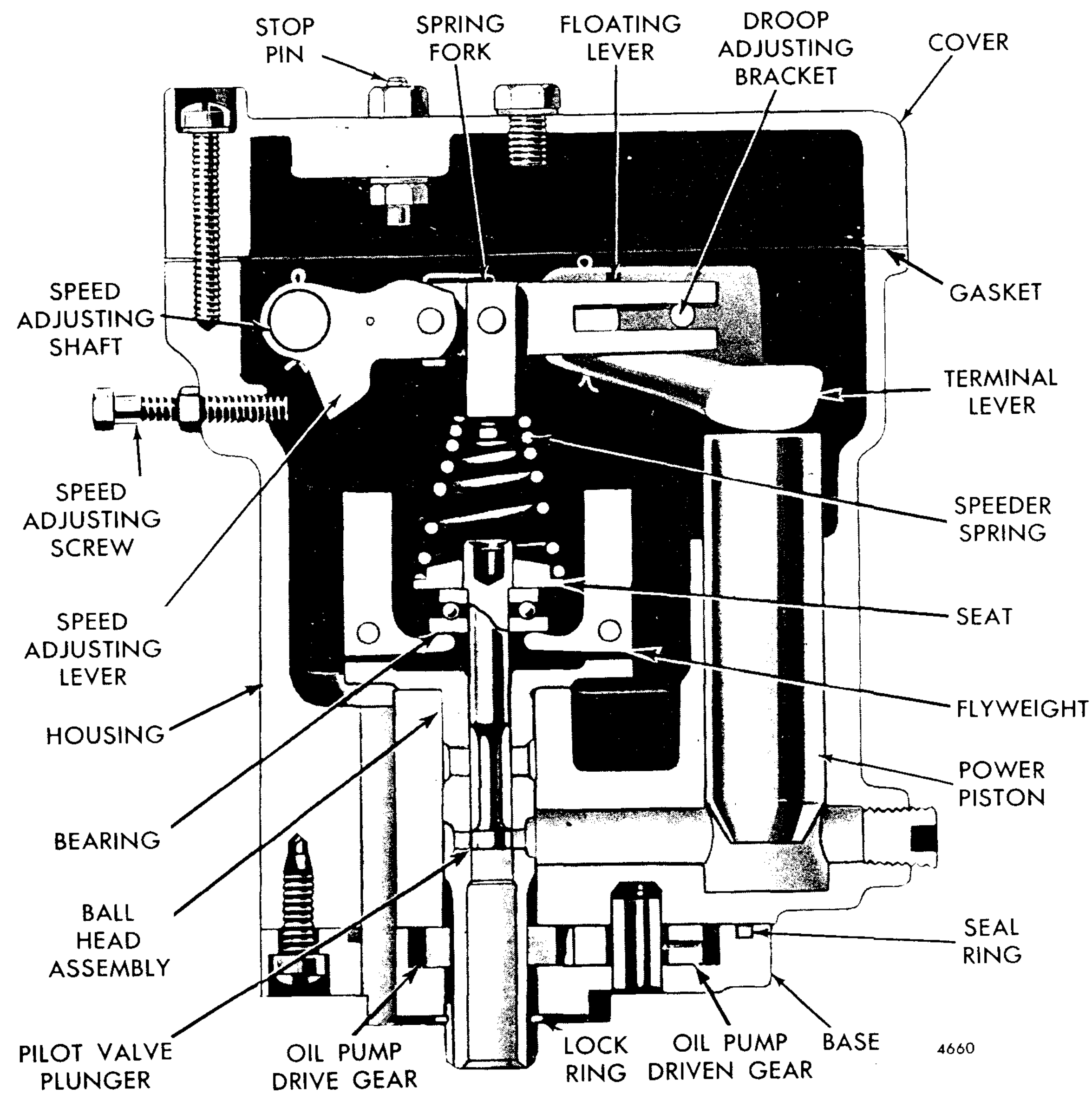


Fig. 2 - Hydraulic Governor Assembly (Former)

(that is, without hunting), an adjustable speed droop mechanism is used in the governing system. Speed droop adjustment is achieved through a slotted bracket attached to the terminal lever. Moving the droop adjusting bracket IN toward the engine increases governor droop, and OUT, away from the engine, decreases the governor droop.

When starting a cold engine, it may require several cranking periods for the lubricating oil pressure to become great enough to operate the governor and open the throttle so the engine can start. Since such a delay in starting is considered objectionable, the starting time can be reduced by moving the throttle control terminal lever to the full-fuel position to take control of the injector fuel racks away from the governor.

The engine can be stopped, regardless of the governor, by moving the throttle control terminal lever to the no-fuel position. Considerable force must be exerted to do this as the oil pressure against the power piston must be overcome.

In addition to its function of holding the engine speed constant under varying load conditions, the hydraulic governor acts as an automatic shutdown device in case of lubricating oil pressure failure. Should the engine fail to supply oil to the governor, the servo-piston will drop, letting the fuel rod return to the no-fuel position, and shut down the engine.

Effective with engine serial number 2D-13294, a new governor assembly (Fig. 1) replaced the former governor assembly (Fig. 2). The new governor incorporates the following revisions.

The current governor housing incorporates integral speed adjusting and terminal shaft bosses with bushings. The separate speed adjusting sleeve, terminal sleeve and spacer cap used in the former housing have been eliminated. Also the size of the tapped hole in the lower passage of the housing was increased from 5/8" - 18 to 11/16" - 16 to accomodate the new relief valve components.

The current servo-piston is shorter and the new terminal lever is actuated by a floating pin assembled between the piston and the lever. The lever cross pin actuates the fuel rod mechanism. The former lever was actuated by direct piston contact and the lever actuated the fuel rod mechanism by direct contact with the fuel rod collar.

The current adjusting shaft and lever are pinned and supported by the bushings in the housing. The former shaft was serrated at the speed adjusting lever end.

The current idler gear stud has drilled passages for supplying oil, under pressure, to the inner diameter of the current idler gear. Formerly the drilled oil passages were in the idler gear.

Operation

As the engine operates, oil from the lubricating system is admitted to the gear pump in the governor base. The governor gear pump raises the oil pressure to a value determined by the spring in the relief valve assembly opposing the relief valve plunger. The oil, now under pressure, is maintained in the annular space between the small diameter of the pilot valve plunger and the bore in the ballhead as shown in Fig. 3. For any given throttle setting, the speeder spring has a definite compression force which is opposed by the centrifugal force of the flyweights. When these two forces are in equilibrium, the land on the pilot valve plunger exactly covers the lower ports in the ballhead producing the constant speed condition as shown in Fig. 3.

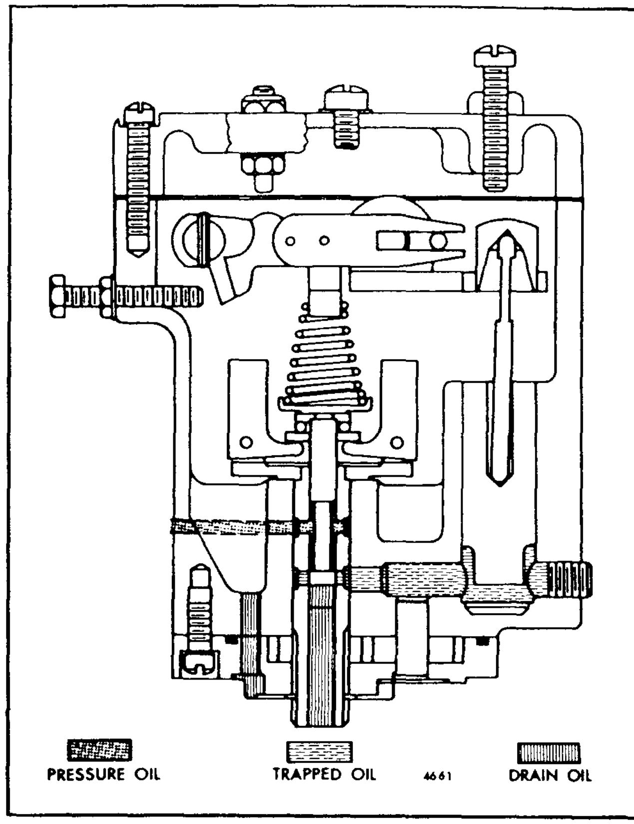


Fig. 3 - Stable Position of Governor Mechanism When Load on Engine is Constant

As a load increase is applied to the engine, the engine speed will drop and the governor flyweights will be forced inward, lowering the pilot valve plunger. Oil under pressure of the pump will now be admitted underneath the power piston which will rise. Upward movement of the piston is transmitted by the floating pin through the terminal lever and fuel rod to the injector control racks, causing the fuel setting of the engine to be increased as shown in Fig. 4.

As the power piston and terminal lever rise, the compression load on the speeder spring is reduced, allowing the flyweights to move out to their normal vertical position.

With the governor weights in a vertical position, the land on the pilot valve plunger will again cover the ports in the ballhead, trapping the regulating oil under the power piston. With the power piston held in its new position by the trapped regulating oil, the engine will carry the increased load at a slightly reduced speed.

Figure 5 illustrates the governor reaction as the load on the engine is decreased and the engine speed increases.

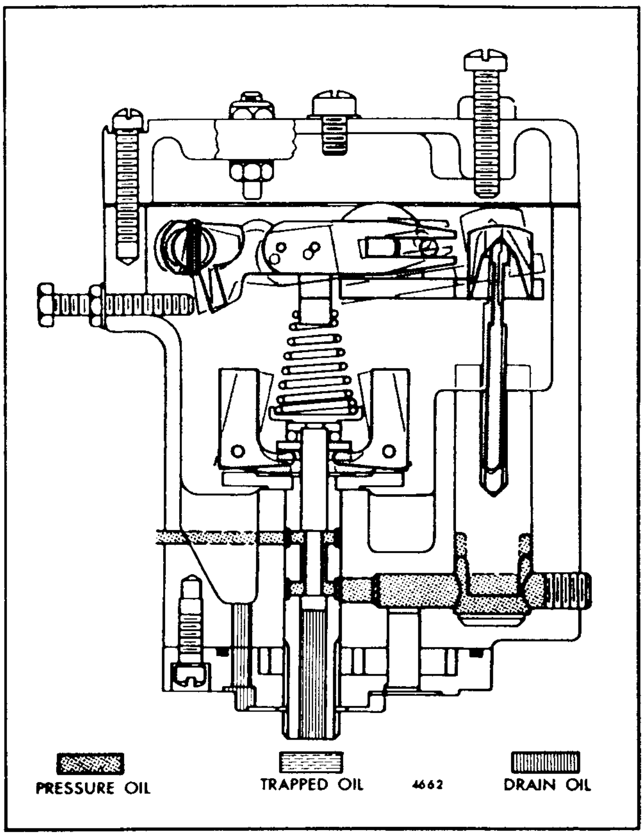


Fig. 4 - Position of Governor Mechanism as Load Increases and Engine Speed Tends to Decrease

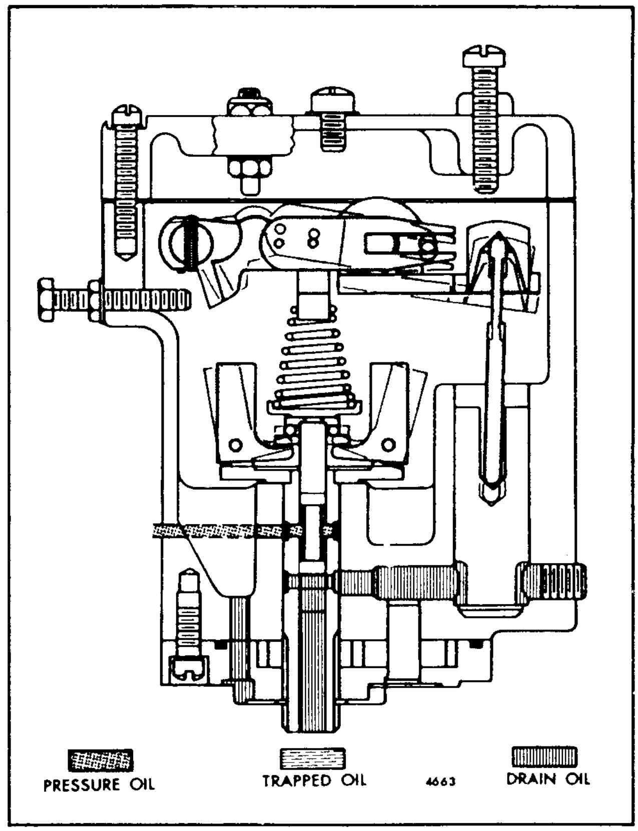


Fig. 5 - Position of Governor Mechanism as Load Decreases and Engine Speed Tends to Increase

Lubrication

The governor is lubricated by oil seeping into the governor housing past the power piston and the pilot valve plunger. Oil which collects on the floor of the governor drains into the gear drive beneath the governor. After reaching a certain level in the governor drive housing, the oil returns to the crankcase through a cored passage in the governor drive housing.

Remove Governor

Refer to Figs. 1, 2, 6 and 7 and remove the governor as follows:

1. Remove the throttle control terminal lever retracting spring from the terminal lever.

2. Disconnect the fuel rod from the throttle control terminal lever.

3. Remove the nut and lock washer securing the throttle control rod assembly to the throttle control lever.

4. Disconnect the oil inlet tube assembly from the governor oil inlet plug.

5. On a governor equipped with a synchronizing motor, tag and disconnect the wires from the motor.

6. Remove the four bolts and lock washers securing the governor assembly to the governor drive housing and remove the governor assembly and gasket.

Disassemble Governor (Current)

Before removing any parts from the governor, wash the unit thoroughly in clean fuel oil, dry it with compressed air and inspect it for worn or damaged parts that may be repaired or replaced without completely disassembling the governor.

Governor disassembly need be carried out only as far

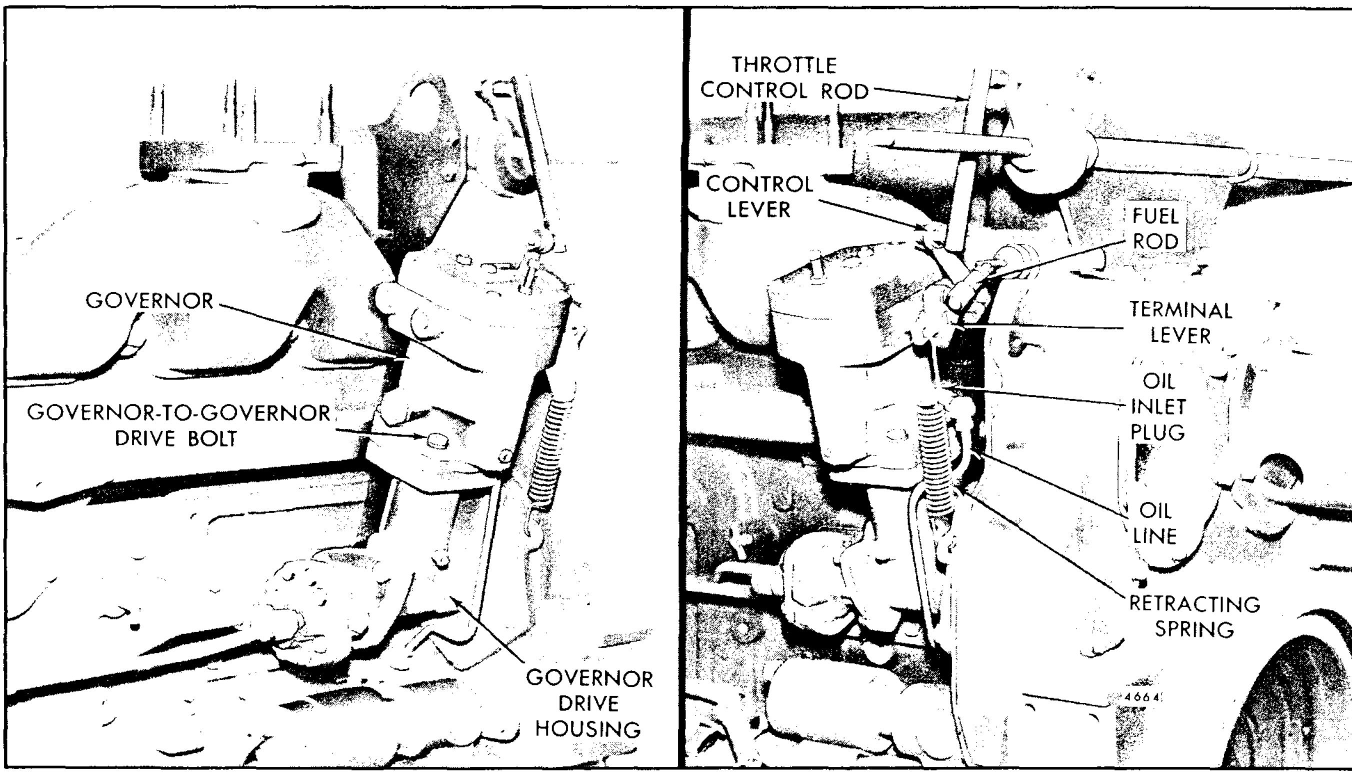


Fig. 6 - Hydraulic Governor Mounting

as necessary to correct the difficulties which interfere with proper governor operation.

Refer to Figs. 1, 7 and 11 for the location of the various parts and disassemble the governor as follows:

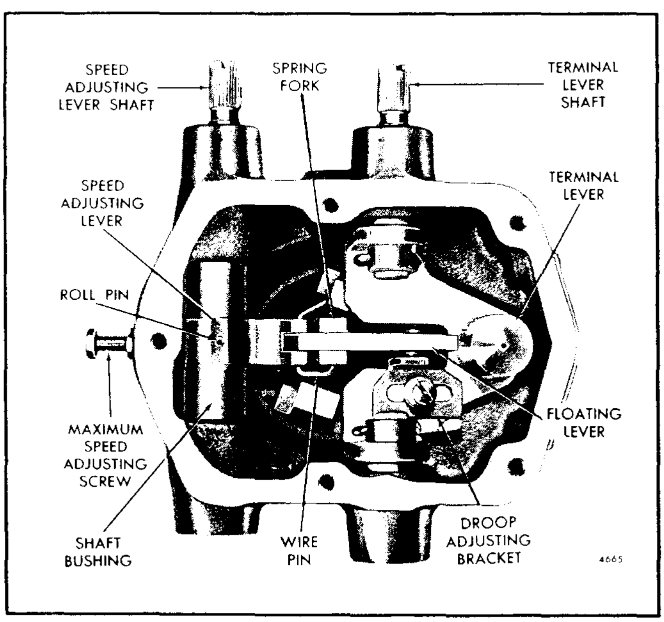


Fig. 7 - Top View of Governor With Cover Removed

1. Note and record the position of the throttle control lever on the speed adjusting shaft. Loosen the bolt securing the lever to the shaft, then slide the lever off the shaft.

2. Note and record the position of the throttle control terminal lever on the governor terminal lever shaft. Loosen the bolt securing the lever to the shaft, then slide it off the shaft.

3. If necessary, remove the oil inlet elbow from the governor housing oil inlet plug.

4. Clamp the governor housing and base assembly in a bench vise equipped with soft jaws (Fig. 8).

5. On a governor equipped with a synchronizing motor, remove the end of the speed adjusting lever retracting spring from the hole in the side of the speed adjusting lever, using a pair of small nose pliers.

6. Remove the three cover screws, then remove the cover and gasket from the housing.

7. Loosen the maximum speed adjusting screw lock nut and remove the adjusting screw from the governor housing.

CAUTION: If the maximum speed adjusting screw is not removed, the speed adjusting lever

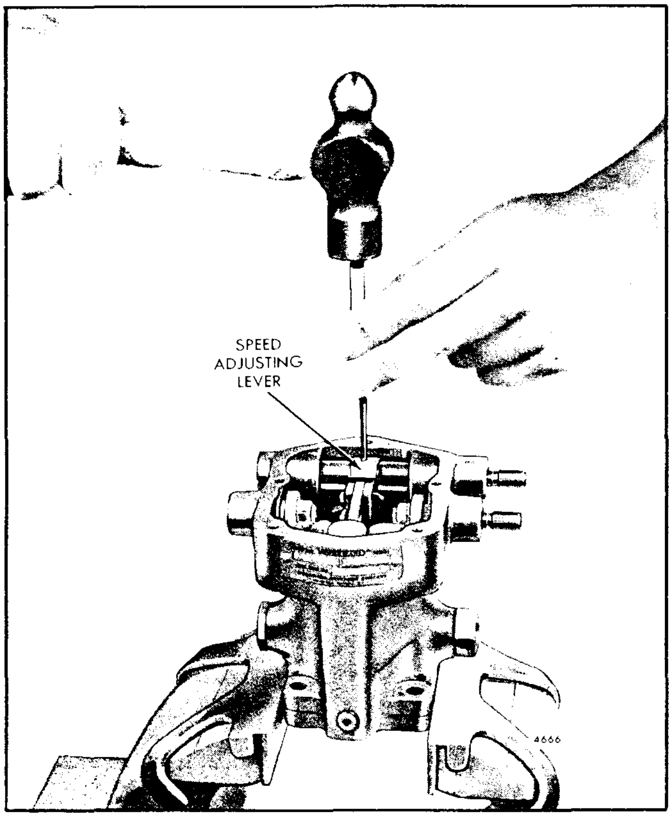


Fig. 8 - Removing Speed Adjusting Lever Roll Pin

spring pin will hit the screw when it is being removed from the adjusting lever.

8. Remove the speed adjusting lever roll (spring) pin from the speed adjusting lever and the lever shaft with a small punch and hammer as shown in Fig. 8.

9. Note and record the position of the groove in the outside diameter of the speed adjusting lever shaft to ensure the groove will be installed in the same position at the time of assembly. Then pull the shaft out of the speed adjusting lever and the governor housing.

10. Remove the speed droop adjusting bracket screw, lock washer and plain washer from the terminal lever; then remove the droop adjusting bracket from the speed adjusting floating lever and the terminal lever.

11. Lift the speed adjusting lever, floating lever, spring fork, speeder spring and pilot valve plunger as an assembly from the governor housing as shown in Fig. 9.

12. Remove the pilot valve plunger thrust bearing and the roll spring pin from the governor housing.

13. On a governor equipped with a synchronizing motor, slide the speed adjusting lever retracting spring

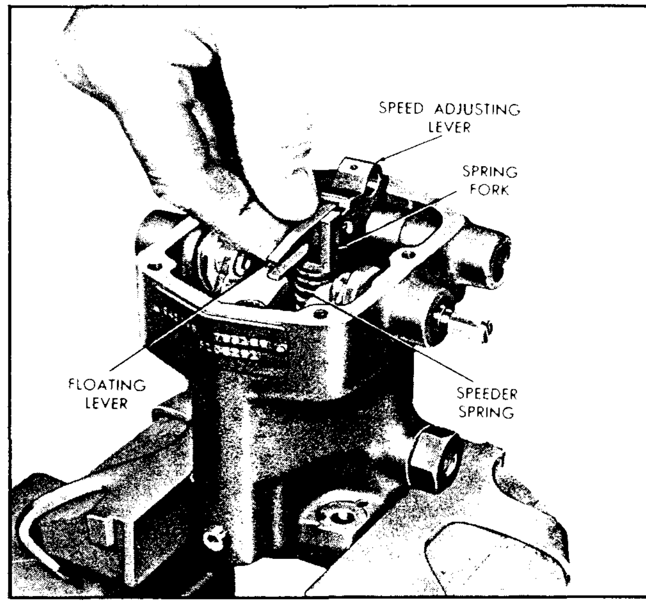


Fig. 9 - Removing Speed Adjusting Lever, Floating Lever, Spring Fork, Speeder Spring and Pilot Valve Plunger Assembly

off of the speed adjusting shaft bushing and remove it from the housing.

14. If necessary, the speed adjusting lever, floating lever, spring fork, speeder spring and pilot valve plunger and spring seat assembly may be disassembled as follows:

a. Straighten the bent end of the wire pin securing the speed adjusting lever and spring fork to the speed adjusting floating lever.

b. Pull the pin out of the speed adjusting lever,

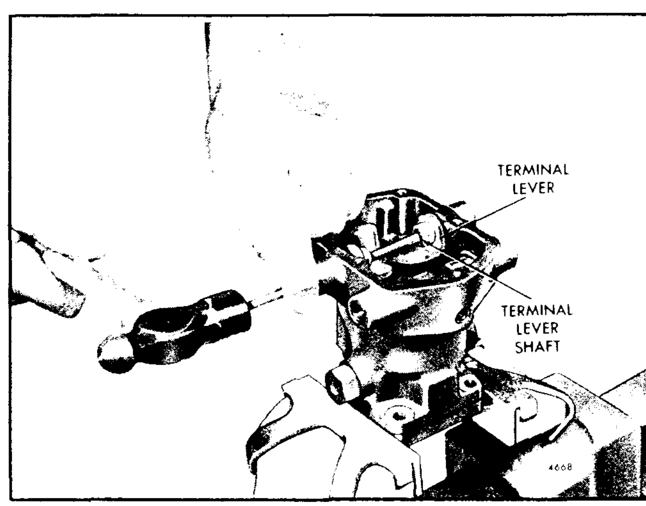


Fig. 10 - Removing Cup Plug from Governor Housing

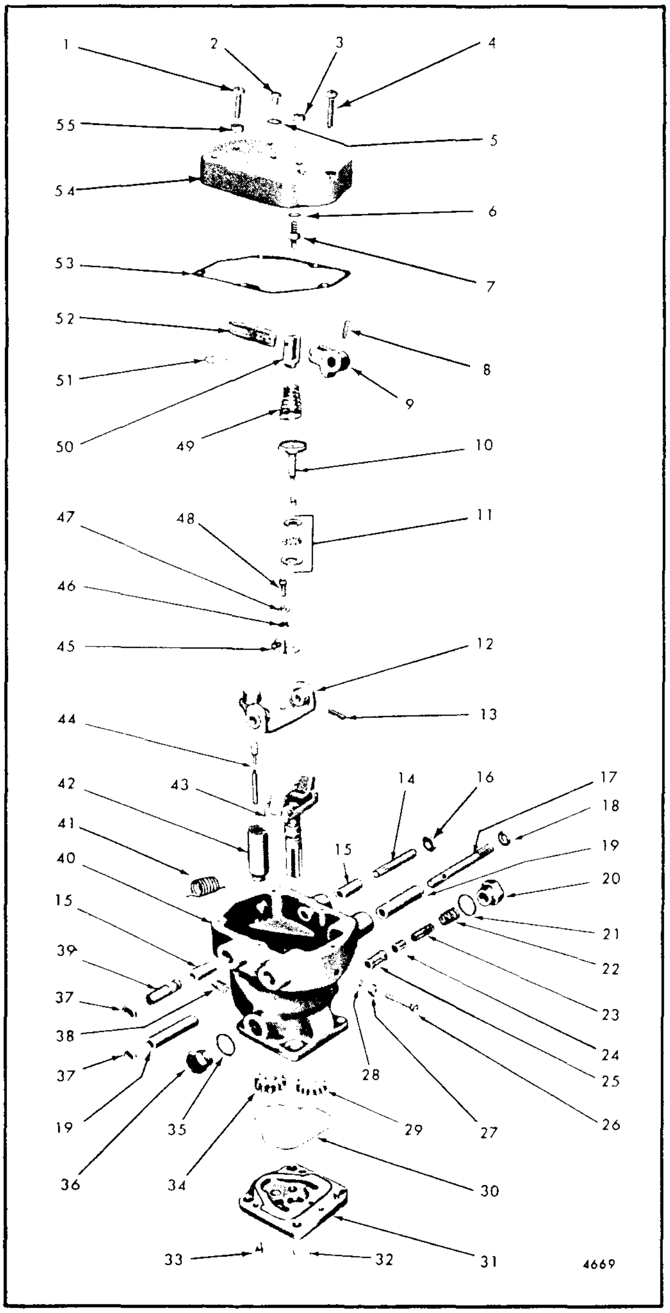


Fig. 11 - Hydraulic Governor Details and Relative Location of Parts (Current)

Fig. 11 - Hydraulic Governor Details and Relative Location of Parts (Current)

1. Screw--Load Limit
2. Screw--Cover Hole
3. Nut--Stop Pin
4. Screw--Cover
5. Copper Washer
6. Copper Washer
7. Pin--Speed Adjusting Lever Stop
8. Pin--Speed Adjusting Lever Roll
9. Lever--Speed Adjusting
10. Plunger--Pilot Valve
11. Bearing--Plunger
12. Lever--Terminal
13. Pin--Cotter
14. Shaft--Terminal Lever (Long)
15. Bushing--Terminal Lever Shaft
16. Seal--Terminal Lever Shaft Oil
17. Shaft--Speed Adjusting
18. Seal--Speed Adjusting Shaft Oil
19. Bushing--Speed Adjusting Shaft
20. Plug--Oil Inlet
21. Gasket--Plug
22. Spring--Sleeve Retaining
23. Spring--Relief Valve Plunger
24. Plunger--Relief Valve
25. Sleeve--Relief Valve Plunger
26. Screw--Maximum Speed Adjusting
27. Nut--Adjusting Screw
28. Copper Washer--Maximum Speed Adjusting Screw
29. Gear--Oil Pump Drive
30. Ring--Base to Housing Seal
31. Base--Governor
32. Lock Ring
33. Screw--Base to Housing
34. Gear--Oil Pump Driven
35. Gasket--Plug
36. Plug--Dummy Hole
37. Plug--Housing Cup
38. Plug--Housing
39. Shaft--Terminal Lever (Short)
40. Housing--Governor
41. Spring--Retracting (Syn. Motors Only)
42. Piston--Power
43. Ball Head Assy.
44. Pin--Terminal Lever to Piston
45. Bracket--Droop Adjusting
46. Lock Washer
47. Washer--Plain
48. Screw--Bracket
49. Spring--Speeder
50. Fork--Spring
51. Pin--Spring Fork Wire
52. Lever--Floating
53. Gasket--Cover
54. Cover--Governor
55. Nut--Load Limit Screw

floating lever and spring fork with a pair of pliers.

c. Insert a small screw driver between the spring and fork and pry the speeder spring from the spring fork.

d. Work a small screw driver around under the speeder spring and remove the spring from the pilot valve plunger and spring seat assembly.

15. Remove the two cotter pins securing the terminal lever to the terminal lever shafts.

16. Place a 1/4" brass rod, approximately 5" long, against the inner end of the terminal lever shaft, then drive the governor housing cup plug out of the boss at the side of the housing as shown in Fig. 10.

CAUTION: Use care when removing the cup plugs; do not damage the serrations inside the terminal lever with the rod.

17. Remove the remaining governor housing cup plug from the boss in the opposite side of the housing in the same manner as outlined in Step 16.

18. Push the terminal lever shafts out of the terminal lever and housing with the brass rod. Then lift the terminal lever out of the housing.

19. Remove the terminal lever-to-power piston pin from the piston.

20. Remove the governor housing from the bench vise. Turn the governor upside down and remove the power piston from the housing.

NOTE: It may be necessary to tap the face of the governor housing lightly against a wood block to jar the piston out of the housing.

21. Place the housing, bottom side up, on a bench.

22. Remove the lock ring from the groove in the shaft of the ball head with a pair of snap ring pliers, then remove the ball head and flyweight assembly from the housing.

23. Remove the three screws securing the governor base to the governor housing.

24. Tap the edge of the governor base lightly with a plastic hammer to loosen it, then remove the base and seal ring from the governor housing and dowel pins.

25. Remove the oil pump drive and driven gears from the governor base or housing.

26. Clamp the bottom (square portion) of the governor housing between the soft jaws of a bench vise.

27. Remove the oil inlet plug, gasket, relief valve plunger sleeve retaining spring and relief valve plunger spring from the governor housing.

28. Remove the dummy hole plug and gasket from the opposite side of the governor housing. Then insert a small brass rod through the dummy hole opening and push the relief valve plunger and the relief valve plunger sleeve out of the governor housing. Catch the plunger and sleeve by hand when removing them.

NOTE: The relief valve plunger incorporates a No. 8-32 thread to facilitate the removal of the plunger from the housing, if required, without removing and disassembling the governor.

29. If necessary, remove the speed adjusting lever shaft hole plug in the governor housing by inserting a 1/4" brass rod through the shaft opening and tap the cup plug out of the housing with a hammer.

30. If necessary, remove the speed adjusting shaft oil seal from the governor housing.

Disassemble Governor (Former)

Before removing any parts from the governor, wash it thoroughly in clean fuel oil, dry it with compressed air, and inspect it for worn or damaged parts that may be repaired or replaced without completely disassembling the governor.

Governor disassembly need be carried out only as far as necessary to correct the difficulties which interfere with proper governor operation.

Refer to Figs. 2 and 18 for the location of the various parts and disassemble the governor as follows:

1. Note and record the position of the throttle control lever on the speed adjusting shaft. Loosen the bolt securing the lever to the shaft, then slide the lever off the shaft.

2. Note and record the position of the throttle control terminal lever on the governor terminal lever shaft. Loosen the bolt securing the lever to the shaft, then slide it off the shaft.

3. Clamp the governor housing and base assembly in a bench vise equipped with soft jaws.

4. If necessary, remove the oil inlet elbow from the oil inlet plug.

5. Remove the three cover screws, then remove the cover and gasket from the housing.

6. Loosen the maximum speed adjusting screw lock nut and remove the adjusting screw and nut from the governor housing.

7. Remove the speed droop adjusting bracket bolt, lock washer and plain washer from the terminal lever; then, remove the droop adjusting bracket from the speed adjusting floating lever and terminal lever.

8. Remove the two cotter pins securing the terminal lever to the terminal lever shafts.

9. Drive on the lower edge of the terminal lever shaft sleeve cup plug with a small punch and hammer as shown in Fig. 10 to force the upper edge out of the sleeve. Then pull the plug out of the sleeve with a pair of pliers.

10. Place a small rod, slightly curved on one end, against the inner end of the terminal lever shaft and push the shaft out of the terminal lever and shaft sleeve.

11. Place a 1/4" rod, approximately 6" long, through the terminal shaft sleeve, terminal lever and against the end of the second terminal lever shaft. Then drive the cup plug out of the terminal lever shaft sleeve in the opposite side of the governor housing with a hammer.

12. Push the terminal lever shaft out of the terminal lever and sleeve. Then remove the rod and terminal lever from the housing.

13. Remove the speed adjusting shaft sleeve and gasket from the governor housing. Then remove the speed adjusting shaft cap and gasket from the opposite side of the housing.

14. Remove the speed adjusting shaft, floating lever, spring fork, speeder spring, speed adjusting lever, pilot valve plunger and plunger bearing from the governor housing.

15. If necessary, the speed adjusting shaft, speed adjusting lever, floating lever, spring fork, speeder spring and pilot valve plunger and spring seat assembly may be disassembled as follows:

a. Remove the cotter pin securing the speed adjusting lever to the speed adjusting shaft and pull the shaft out of the lever.

b. Straighten the bent end of the wire pin securing the speed adjusting lever and spring fork to the speed adjusting floating lever.

c. Pull the wire pin out of the speed adjusting lever and floating lever with a pair of pliers. Then, remove the two spring fork pins from the spring fork, floating lever and speed adjusting lever.

d. Insert a small screw driver between the spring and fork and pry the speeder spring from the spring fork.

e. Work a small screw driver around under the speeder spring and remove the spring from the pilot valve plunger and spring seat assembly.

16. Remove the relief valve assembly and gasket from the side of the governor housing. Then, remove the dummy hole plug and gasket from the opposite side of the housing.

17. Remove the governor housing from the bench vise. Turn the governor upside down and remove the power piston from the housing.

NOTE: It may be necessary to tap the face of the governor housing lightly on a wood block to jar the piston out of the housing.

18. Place the governor housing bottom side up on a bench.

19. Remove the lock ring from the groove in the shaft of the ball head with a pair of snap ring pliers; then remove the ball head and flyweight assembly from the housing.

20. Remove the three screws securing the governor base to the governor housing.

21. Tap the edge of the governor base lightly with a plastic hammer to loosen it; then, remove the base and seal ring from the governor housing and dowel pins.

22. Remove the oil pump drive and driven gears from the governor base or housing.

23. Inspect the terminal lever shaft sleeve bushings for wear or scoring and, if necessary, remove the sleeve and bushing assemblies from the governor housing as follows:

a. Clamp the bottom (square portion) of the governor housing between the soft jaws of a bench vise.

b. Insert a 5/16" bolt, approximately 5" long, through one of the terminal lever shaft sleeves, then thread a 5/16" nut, approximately 1/4" from the end, on the bolt inside of the housing.

c. Place the threaded end of the bolt inside the sleeve in the opposite side of the housing. Then drive the sleeve and bushing assembly out of the governor housing with a hammer.

d. Reverse the bolt in the governor housing and remove the remaining terminal lever shaft sleeve and bushing assembly.

24. If necessary, remove the pipe plug in the forward face of the governor housing.

Inspection

Wash all of the governor parts in clean fuel oil and dry them with compressed air.

Examine the pilot valve plunger and its bore in the ball head for scoring and burrs. If slightly scored, the area may be cleaned up with a fine india stone. Care must be used to prevent rounding off the edges of the plunger.

Examine the oil pump gears and the driven gear bushing for excessive wear and damage.

Examine the power piston and its cylinder (bore) in the governor housing for scoring and burrs. If slightly scored, the areas may be cleaned up with a fine india stone. Care must be used to prevent stoning flat areas and rounding off the edges of the piston.

Examine the ends of the power piston-to-terminal lever pin for wear and scoring. If slightly scored, clean the ends up with a fine india stone. Also check the pin seats in the terminal lever and power piston for wear and scoring.

Examine the ends of the terminal lever cross pin and the holes in the terminal lever for wear and scoring.

Examine the outside diameter of the ball head and its bore in the governor housing for scoring and burrs. If slightly scored, the areas may be cleaned up with a fine india stone. Care must be used to prevent flat areas and rounding off the edges of the ball head.

NOTE: The pilot valve plunger, power piston and ball head assembly must operate freely in their respective bores.

Examine the pilot valve thrust bearing for excessive wear and flat spots.

Inspect the finished radius (thrust bearing contact surfaces) of the flyweights for excessive wear or flat spots. The flyweights must operate freely on their support pins for satisfactory governor operation.

Inspect the terminal lever and speed adjusting lever shaft bushings in the governor housing. If scored or worn excessively, replace the bushings.

Examine the relief valve plunger and the inside diameter of the plunger sleeve for wear, scratches and sludge in the grooves and holes in the plunger and sleeve. The plunger in the former governors did not incorporate four relief holes and the sleeve and washer were separate pieces.

Inspect the bushings in the terminal lever and speed adjusting shaft sleeve in a former governor.

Check the speed adjusting lever retracting spring for fractured coils.

Replace all of the governor parts that are excessively worn or damaged.

Assemble Governor (Current)

Refer to Figs. 1 and 11 and assemble the governor as follows:

1. If removed, install new speed adjusting lever and terminal shaft bushings in the governor housing to the specified dimensions shown in Fig. 12.

2. Lubricate the two oil pump gears and place them in their respective positions in the governor base.

3. Place a new seal ring in the groove of the governor base, with the wide side of the seal down in the groove.

4. Set the governor housing on the base with the dowels in the base registering with the holes in the housing and the idler gear stud in the housing registering with the hole in the idler gear. Press the housing down against the base seal ring.

5. Lubricate the outside diameter of the ball head with engine oil; then insert the end of the ball head and flyweight assembly straight into and through the bore of the governor housing, drive gear and base.

CAUTION: It is important when installing the driven gear stud that it be installed with the arrow on the stud pointing towards the relief valve side of the governor. Also, that the shaft of the arrow is parallel to a line through the center of the governor and the relief valve.

6. Insert three screws through the governor base and thread them into the governor housing. Turn the ball head assembly while tightening the screws to make sure the ball head assembly revolves freely.

If a bind exists, loosen the screws, tap the sides of the base lightly with a plastic hammer and tighten the screws again. Revolve the ball head assembly again and check for bind. Repeat, if necessary, until all parts rotate freely.

NOTE: To install a current design governor base on a former design housing or a former design base on a current design housing, No. 3 taper dowel pins must be used. Refer to Fig. 13 for fabrication of tools necessary to properly align the base and the housing and proceed as follows:

a. Position the dummy gear over the idler gear stud.

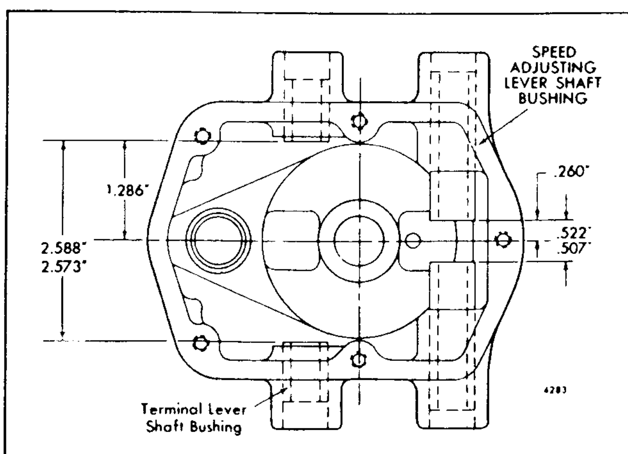


Fig. 12 - Location of Speed Adjusting Lever and Terminal Lever Shaft Bushings in Governor Housing

b. Position the base against the governor housing and align them with the tapered arbor.

c. Enlarge the dowel pin holes to .200"-.212" diameter and taper ream to allow for a No. 3 tapered pin. Always drill from the base to the housing and be sure the tapered pin is flush with the bottom of the governor mounting flange.

7. Install the ball head lock ring in the groove of the ball head shaft with a pair of snap ring pliers.

8. Refer to Fig. 14 and install the relief valve plunger, plunger sleeve, plunger retaining spring, sleeve retaining spring, oil inlet plug and dummy plug in the governor housing as follows:

a. Lubricate the outside diameter of the relief valve plunger and plunger sleeve with engine oil. Then insert the relief valve plunger inside of the plunger sleeve.

b. Determine the type of governor being assembled, right-hand or left-hand, then insert the relief valve plunger and sleeve assembly straight into the proper opening in the side of the governor housing, with the tapped hole in the relief valve plunger facing out, and push it in against the shoulder in the housing.

c. Place the relief valve plunger spring and the plunger sleeve retaining spring in the housing and against the plunger and sleeve.

d. Place a gasket on the oil inlet plug, then place the plug over the ends of the springs and thread it into the governor housing.

e. Place a gasket on the dummy hole plug and thread it into the opening in the opposite side of the governor housing.

f. Clamp the bottom (square portion) of the governor housing between the soft jaws of a bench vise. Then tighten the oil inlet plug and dummy hole plug securely.

9. Lubricate the power piston with engine oil, then insert the piston, small end down, straight into the piston bore in the governor housing and push it in until it bottoms.

10. Install the terminal lever, terminal lever shafts, cotter pins and cup plugs in the governor housing as follows:

a. Clamp the governor housing and base assembly in a bench vise equipped with soft jaws.

b. Lubricate one of the terminal lever shafts with

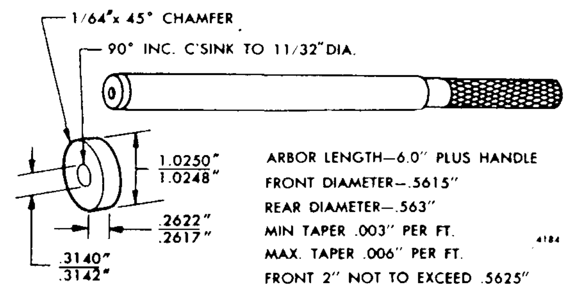


Fig. 13 - Fabrication of Governor Housing-to-Base Alignment Tool

engine oil. Place the terminal lever in between the ends of the two bushings inside of the governor housing; then insert the serrated end of the shaft into the bushing in the housing with the cotter pin holes in the shaft and terminal lever in alignment as shown in Fig. 15. Push the shaft into the lever until the two holes are in alignment.

c. Install a cotter pin through the terminal lever and shaft and bend the ends over against the side of the terminal lever.

d. Install the second terminal lever shaft in the housing and terminal lever at the opposite side of the governor housing in the same manner as outlined in Steps b and c.

e. Apply a thin coat of sealing compound to the outside diameter of a new governor housing cup plug. Start the plug, open end out, straight into one of the shaft openings, then press the plug in flush with the outside face of the housing boss.

f. Install the second new governor housing cup plug in the boss at the opposite side of the housing in the same manner as described in Step e.

11. Lubricate the terminal lever-to-power piston pin with engine oil. Raise the edge of the terminal lever and insert the pin in the hole in the power piston, then lower the terminal lever down on the pin.

12. If disassembled, the speed adjusting lever, floating lever, spring fork, speeder spring and the pilot valve plunger may be assembled as follows:

a. Place the non-slotted end of the speed adjusting

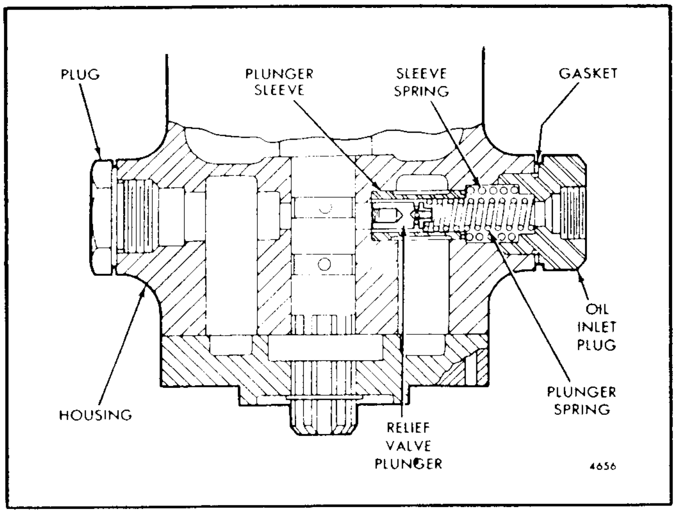


Fig. 14 - Location of Oil Relief Valve Plunger, Plunger Sleeve, Springs, Oil Inlet Plug and and Dummy Plug in Governor Housing (R.H. Governor Shown)

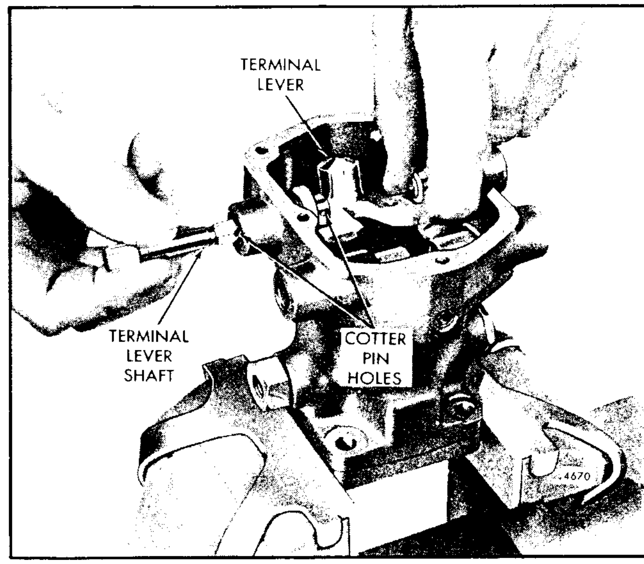


Fig. 15 - Installing Terminal Lever Shaft in Governor Housing and Terminal Lever

floating lever in the slot on the speed adjusting lever so the pin holes are in alignment.

b. Insert the long end of the speed adjusting lever-to-floating lever wire pin through the pin hole in the speed adjusting lever and floating lever.

c. Place the speed adjusting floating lever in the slot of the spring fork with the pin holes in alignment, then insert the short end of the wire pin through the hole in the spring fork and the floating lever.

d. Push the wire pin in against the speed adjusting lever and spring fork and bend the protruding end of the pin over toward the slotted end of the floating lever.

e. Press the lower end of the spring fork into the small end of the speeder spring; then insert the opposite end of the spring in the spring seat of the pilot valve plunger.

13. Remove the governor housing from the bench vise and place it on its side, oil inlet plug side up, on a work bench with the top of the housing facing out.

14. On a governor equipped with a synchronizing motor, place the speed adjusting lever retracting spring over the speed adjusting lever shaft bushing in the governor housing, with the hooked end of the spring over the slot between the two shaft bushings. See inset in Fig. 16.

15. Lubricate the pilot valve plunger thrust bearing with engine oil and place it over the end of the pilot valve plunger with the smallest, outside diameter, bearing race next to the spring seat.

16. Lubricate the pilot valve plunger with engine oil. Then hold the thrust bearing against the spring seat and insert the assembly in the governor housing with the speed adjusting lever facing the two bushings

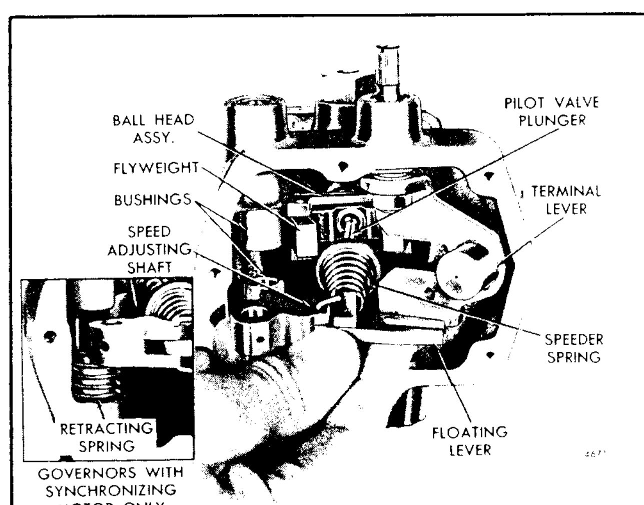


Fig. 16 - Installing Speed Adjusting Lever, Floating Lever, Speeder Spring and Pilot Valve Plunger Assembly

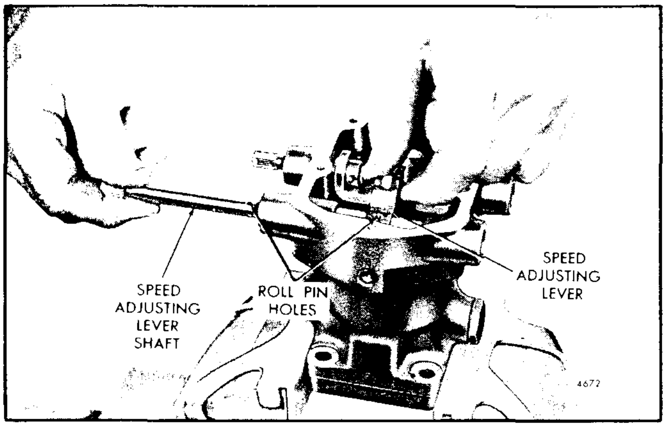


Fig. 17 - Installing Speed Adjusting Lever Shaft in Governor Housing and Adjusting Lever

inside the housing (Fig. 11). Start the pilot valve plunger straight into the bore of the ball head and push the assembly in until the speed adjusting lever is in position between the two bushings and the thrust bearing is resting on the lip of the flyweights.

17. Install the speed adjusting lever shaft, roll (spring) pin and cup plug in the governor housing as follows:

a. Clamp the governor housing and base assembly in a bench vise equipped with soft jaws.

b. Lubricate the speed adjusting lever shaft with engine oil. Rotate the shaft so the machined slot in the outside diameter of the shaft is in the same position it was in at the time of removal. Then insert the shaft in the shaft bushing in the housing, from the oil inlet plug side, with the roll pin hole in the shaft and lever in alignment (Fig. 17).

c. While holding the speed adjusting lever, push the shaft through the bushing, lever and into the second shaft bushing until the pin holes are in alignment.

CAUTION: On a governor equipped with a synchronizing motor, be sure the hooked end of the speed adjusting lever retracting spring is on top of the speed adjusting lever before installing the shaft (see inset in Fig. 16).

d. Start the speed adjusting lever roll (spring) pin straight into the pin hole in the lever, then tap the pin through the lever and shaft until it is flush with the top of the lever.

e. On a governor equipped with a synchronizing motor, rotate the speed adjusting lever retracting spring clockwise around the shaft bushing and insert the hooked end of the spring in the small hole in the side of the speed adjusting lever with a pair of small nose pliers.

f. If removed, apply a thin coat of sealing compound to the outside diameter of the speed adjusting lever shaft cup plug. Start the plug, open end out, straight into the boss in the opposite side of the governor housing, then press the plug in flush with the edge of the boss.

g. If removed, apply a thin coat of sealing compound to the outside diameter of the speed adjusting shaft oil seal. Place the oil seal, lip of seal facing in, over the end of the speed adjusting shaft and start it in the bore in the housing, then press the seal in flush with the edge of the boss.

18. Place the flat side of the speed droop adjusting bracket against the top (bolting) surface of the terminal lever, with the pin in the bracket in the slot of the speed adjusting floating lever. Secure the bracket to the terminal lever with a flat washer, lock washer, and screw.

19. If removed, thread the lock nut on the maximum speed adjusting screw. Place the copper washer on the adjusting screw, then thread the screw approximately half way in the governor housing.

20. If removed, place a copper washer over the threaded end of the speed adjusting lever stop pin. Insert the threaded end of the stop pin through the hole in the governor cover and secure it in place with a nut.

21. Affix a new governor cover gasket to the bottom face of the cover. Place the cover on the governor housing and secure it in place with the three screws with lock washers.

22. If removed, thread a lock nut on the load limit screw then thread it approximately half-way in the governor cover (Fig. 1).

23. Place the throttle control terminal lever on the governor terminal lever shaft in the same position it was in at the time of removal, then tighten the retaining bolt to 7-9 lb-ft torque.

24. Place the throttle control lever with the throttle control rod assembly attached, on the speed adjusting lever shaft in the same position it was in at the time of removal, then tighten the retaining bolt to 7-9 lb-ft torque.

25. If removed, install the oil inlet tube elbow in the oil inlet plug.

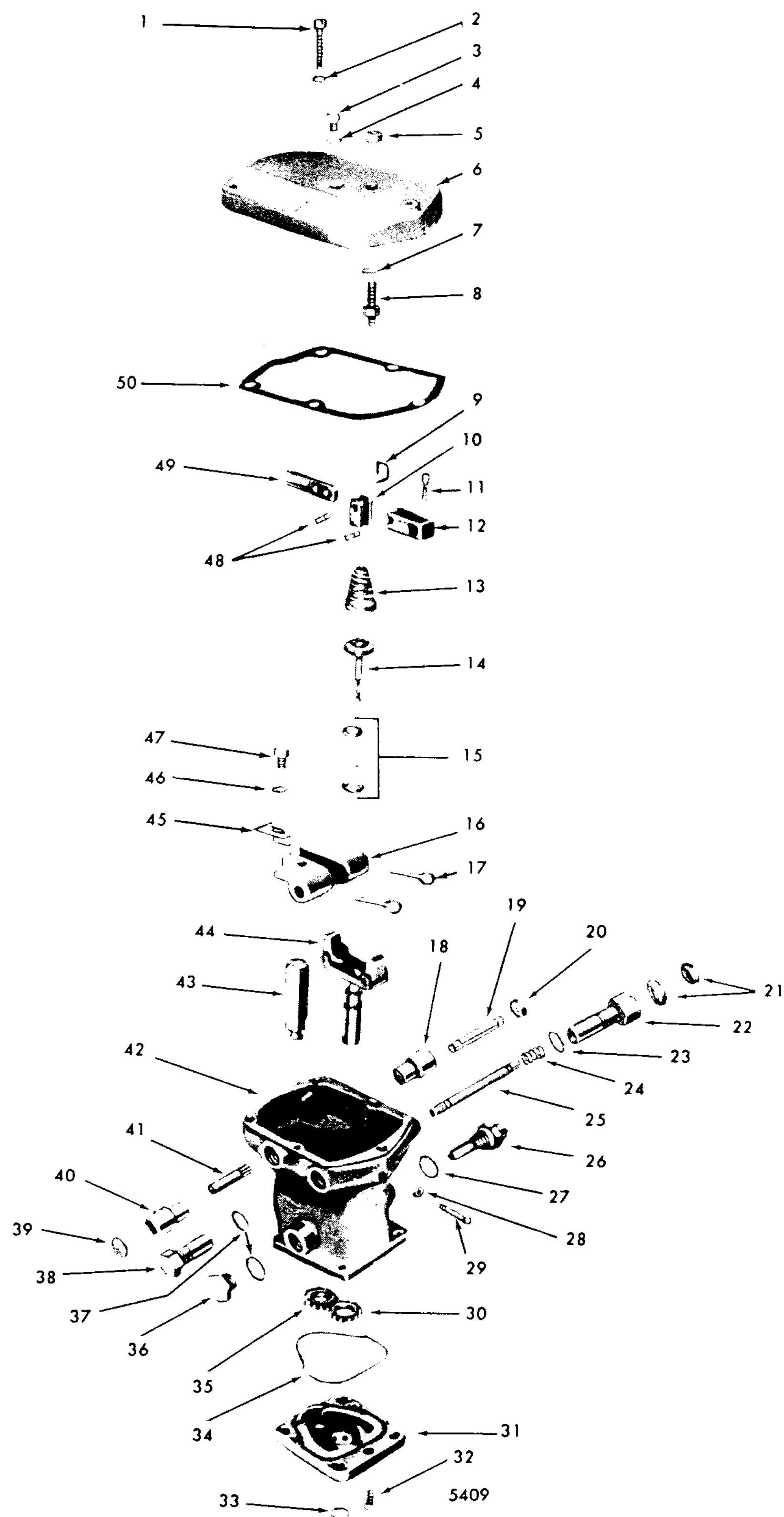


Fig. 18 - Hydraulic Governor Details and Relative Location of Parts (Former)

1. Screw--Cover
2. Lock Washer
3. Bolt
4. Washer--Copper
5. Nut--Stop Pin
6. Cover--Governor
7. Washer--Copper
8. Pin--Speed Adjusting Lever Stop
9. Pin--Spring Fork Wire
10. Fork--Spring
11. Pin--Cotter
12. Lever--Speed Adjusting
13. Spring--Speeder
14. Plunger--Pilot Valve
15. Bearing--Plunger
16. Lever--Terminal
17. Pin--Cotter
18. Sleeve--Shaft
19. Shaft--Terminal Lever
20. Plug--Sleeve
21. Seal--Speed Adjusting Shaft Oil
22. Sleeve--Speed Adjusting Shaft
23. Gasket--Sleeve
24. Spring--Speed Adjusting
25. Shaft--Speed Adjusting
26. Valve Assy.--Relief
27. Gasket--Relief Valve
28. Nut--Adjusting Screw
29. Screw--Maximum Speed Adjusting
30. Gear--Oil Pump Drive
31. Base--Governor
32. Screw--Fil. Head
33. Lock Ring
34. Ring--Housing to Base Seal
35. Gear--Oil Pump Driven
36. Plug--Dummy Hole
37. Gasket--Plug and Sleeve
38. Cap--Speed Adjusting Shaft
39. Plug--Sleeve
40. Sleeve--Shaft
41. Shaft--Terminal Lever
42. Housing--Governor
43. Piston--Power
44. Ball Head Assy.
45. Bracket--Droop Adjusting
46. Washer--Plain
47. Bolt--Bracket
48. Pin--Spring Fork
49. Lever--Floating
50. Gasket--Cover

Fig. 18 - Hydraulic Governor Details and Relative Location of Parts (Former)

Assemble Governor (Former)

Refer to Figs. 2 and 18 and assemble the governor as follows:

1. If removed, install the terminal lever shaft sleeve and bushing assemblies in the governor housing as follows:

a. Place a support plate, of the proper length, between the inside faces of the housing adjacent to each terminal lever shaft sleeve opening.

b. Support the governor housing on its side on the bed of an arbor press so it is level.

c. Start the small end of the terminal lever shaft sleeve straight in the opening in the housing, then press the sleeve in the housing until the shoulder on the sleeve contacts the housing.

d. Reverse the governor housing on the bed of the arbor press and install the remaining terminal lever shaft sleeve. Then remove the support plate.

2. If removed, install the pipe plug in the governor housing.

3. Lubricate the two oil pump gears with engine oil, and place them in their respective positions in the governor base.

4. Place a new seal ring in the groove in the governor base, with the wide side of the seal down in the groove.

5. Set the governor housing on the base with the dowels in the base registering with the holes in the housing and the idler gear stud in the housing registering with the hole in the idler gear. Press the housing down against the seal ring in the base.

CAUTION: It is important when installing the driven gear stud that it be installed with the arrow on the stud pointing towards the relief valve side of the governor. Also, that the shaft of the arrow is parallel to a line through the center of the governor and the relief valve.

6. Lubricate the outside diameter of the ball head and flyweight assembly with engine oil; then insert the end of the ball head straight into and through the bore of the governor housing, drive gear and base.

7. Insert the three screws through the governor base and thread them into the governor housing. Turn the ball head assembly while tightening the three screws to make sure the ball head assembly revolves freely.

If a bind exists, loosen the screws, tap the sides of the base lightly with a plastic hammer, and tighten the screws again. Revolve the ball head assembly again and check for bind. Repeat, if necessary, until all parts rotate freely.

NOTE: To install a current design governor base on a former design housing or a former design base on a current design housing, No. 3 tapered dowel pins must be used. Refer to Fig. 13 for fabrication of tools necessary to properly align the base and the housing and proceed as follows:

a. Position the dummy gear over the idler gear stud.

b. Position the base against the governor housing and align them with the tapered arbor.

c. Enlarge the dowel pin holes to .200"-.212" diameter and taper ream to allow for a No. 3 tapered pin. Always drill from the base to the housing and be sure the tapered pin is flush with the bottom of the governor mounting flange.

8. Install the ball head lock ring in the groove in the ball head shaft with a pair of snap ring pliers.

9. Determine the type of governor being assembled, right-hand or left-hand, then place a new gasket on the relief valve assembly and thread it into the proper opening in the side of the governor housing.

10. Place a new gasket on the dummy hole plug and thread it into the opening in the housing opposite the relief valve assembly.

11. Clamp the bottom (square portion) of the governor housing between the soft jaws of a bench vise. Then tighten the relief valve assembly and dummy hole plug securely.

12. Lubricate the power piston with engine oil; then insert the piston, small end down, straight into the piston bore in the governor housing and push it in until it bottoms.

13. If disassembled, refer to Figs. 2 and 18 and assemble the speed adjusting lever, floating lever, spring fork, speeder spring, pilot valve plunger and speed adjusting shaft as follows:

a. Place the non-slotted end of the speed adjusting floating lever in the slot of the speed adjusting lever so the pin holes are in alignment.

b. Insert the pin through the pin holes in the levers, with the small pin hole in the pin and floating lever in alignment, then insert the long end of the wire pin through the floating lever and pin.

c. Place the speed adjusting floating lever in the slot of the spring fork so the pin holes are in alignment.

d. Insert the second pin through the pin holes in the spring fork and floating lever, with the small pin hole in the pin and floating lever in alignment, then insert the short end of the wire pin through the floating lever and pin. Push the wire pin in against the floating lever and bend the long end of the wire pin over against the floating lever.

e. Insert the serrated end of the speed adjusting shaft into the speed adjusting lever with the cotter pin hole in the shaft and lever in alignment and the machined slot in the non-splined end of the shaft in the same position it was in at the time of removal. Align the pin holes in the shaft and lever and install the cotter pin. Bend the ends of the cotter pin over.

f. Press the lower end of the spring fork into the small end of the speeder spring; then insert the large end of the spring in the spring seat of the pilot valve plunger.

14. Lubricate the pilot valve plunger thrust bearing with engine oil and place it over the end of the pilot valve plunger with the smallest, outside diameter, bearing race next to the spring seat.

15. Hold the bearing against the bottom of the spring seat and start the end of the speed adjusting shaft through the proper opening, relief valve assembly side, in the governor housing. Then start the end of the pilot valve plunger straight in the opening in the ball head assembly and push it in until the bearing race rests on the flyweights.

CAUTION: Do not damage the plunger by applying undue pressure.

On a governor equipped with a synchronizing motor, place the speed adjusting lever retracting spring over the speed adjusting lever shaft and place the hooked end of the spring over the top of the speed adjusting lever before installing the assembly in the governor housing.

16. If removed, apply a thin coat of sealing compound to the outside diameter of the new speed adjusting shaft oil seals, then press the oil seals in the speed adjusting shaft sleeve with the lip of the inner seal facing down and the lip of the outer seal facing up.

17. Place a gasket on the speed adjusting shaft sleeve. Lubricate the speed adjusting shaft with engine oil, then start the small end of the sleeve over the end of the shaft and thread it into the governor housing. Tighten the sleeve securely.

18. Place a gasket on the speed adjusting shaft cap and thread the cap into the opposite side of the governor housing and over the end of the speed adjusting shaft. Tighten the cap securely.

19. On a governor equipped with a synchronizing motor, rotate the speed adjusting lever retracting spring clockwise around the shaft sleeve and insert the hooked end of the spring in the small hole in the side of the speed adjusting lever with a pair of small nose pliers.

20. Install the terminal lever, terminal lever shafts, cotter pins and cup plugs in the governor housing as follows:

a. Place the flat side of the droop adjusting bracket against the inside face of the terminal lever boss as shown in Fig. 2 and secure it to the terminal lever with a flat washer, lock washer and bolt.

b. Place the terminal lever between the ends of the terminal lever shaft sleeves in the governor housing with the convex bearing surface resting on the power piston and the droop adjusting bracket pin in the slot of the floating lever as shown in Fig. 2.

c. Lubricate one of the terminal lever shafts with engine oil. Insert the serrated end of the shaft into the bushing in the sleeve with the cotter pin holes in the shaft and terminal lever in alignment as shown in Fig. 15. Push the shaft into the lever until the two holes are in alignment.

d. Install a cotter pin through the terminal lever and shaft and bend the ends over against the side of the terminal lever.

e. Install the second terminal lever shaft in the sleeve and terminal lever at the opposite side of the governor housing in the same manner as outlined in Steps c and d.

f. Apply a thin coat of sealing compound to the outside diameter of a new terminal lever shaft sleeve cup plug. Start the plug, open end out, straight into one of the shaft sleeves; then press the plug in flush with the end of the sleeve.

g. Install the second new terminal lever shaft sleeve cup plug in the sleeve at the opposite side of the housing in the same manner as outlined in Step f.

21. If removed, thread the lock nut on the maximum speed adjusting screw. Place the copper washer on the adjusting screw, then thread the screw approximately half way in the governor housing (Fig. 2).

22. If removed, place a copper washer over the threaded end of the speed adjusting lever stop pin. Insert the threaded end of the stop pin through the hole in the governor cover and secure it in place with a nut.

23. Affix a new governor cover gasket to the bottom face of the cover. Place the cover on the governor housing and secure it in place with the three screws with lock washers.

24. Place the throttle control terminal lever on the governor terminal lever shaft in the same position it was in at the time of removal, then tighten the retaining bolt to 7-9 lb-ft torque.

25. Place the throttle control lever with the throttle control rod assembly attached, on the speed adjusting lever shaft in the same position it was in at the time of removal, then tighten the retaining bolt to 7-9 lb-ft torque.

26. If removed, install the oil inlet tube elbow in the oil inlet plug.

Install Governor

Refer to Fig. 6 and proceed as follows:

1. Affix a new gasket to the top of the governor drive housing.

2. Position the governor over the governor drive housing with the throttle control levers facing the rear of the engine. Turn the ball head assembly slightly to align splines of the ball head shaft with the splines in the driven shaft sleeve; then enter the shaft straight in the sleeve and rest the governor on the gasket.

3. Install the governor to drive housing bolts and lock washers. Tighten the bolts to 13-17 lb-ft torque.

4. Connect the oil inlet tube assembly to the oil inlet elbow.

5. Attach the throttle control rod assembly to the throttle control cross shaft lever.

6. Attach the fuel rod to the throttle control terminal lever.

7. Attach the throttle control terminal lever retracting spring to the terminal lever.

8. On a governor equipped with a synchronizing motor, connect the wires to the motor.

After the governor has been installed, the engine must be tuned-up as outlined under *Engine Tune-Up Procedures* in Section 14.

HYDRAULIC GOVERNOR DRIVE

The governor drive assembly (Fig. 1) consists of a horizontal drive shaft and bevel drive gear and a vertical driven sleeve and bevel driven gear mounted on ball bearings and contained in the governor drive housing.

A second ball bearing is mounted in the drive housing to support the drive gear end of the horizontal drive shaft and is retained in the housing by a snap ring.

The vertical driven gear, bearing and sleeve are retained in the governor drive housing by two conical set screws, copper washers and elastic stop nuts.

The horizontal drive shaft is driven by the governor drive gear which is keyed to and retained on the drive shaft by a self-locking nut and driven by either the camshaft gear or the balance shaft gear, depending upon the engine model.

The governor drive housing is attached to the forward face of the cylinder block end plate as shown in Fig. 2. The engine fuel pump is attached to the forward end of the drive housing and is driven by the governor drive shaft.

The governor is attached to the top of the governor drive housing and is driven through splines on the lower end of the ball head which register with splines in the upper end of the driven gear sleeve.

Lubrication

The governor drive beveled gears and bearings are lubricated by the surplus oil from the governor which

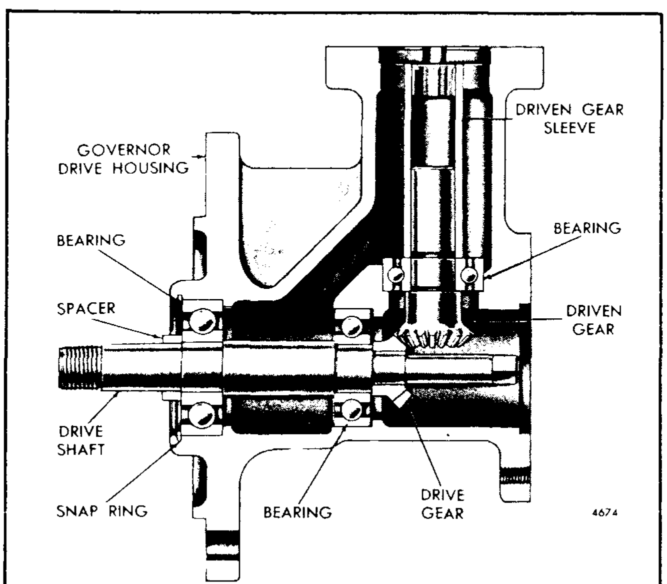


Fig. 1 - Hydraulic Governor Drive Assembly

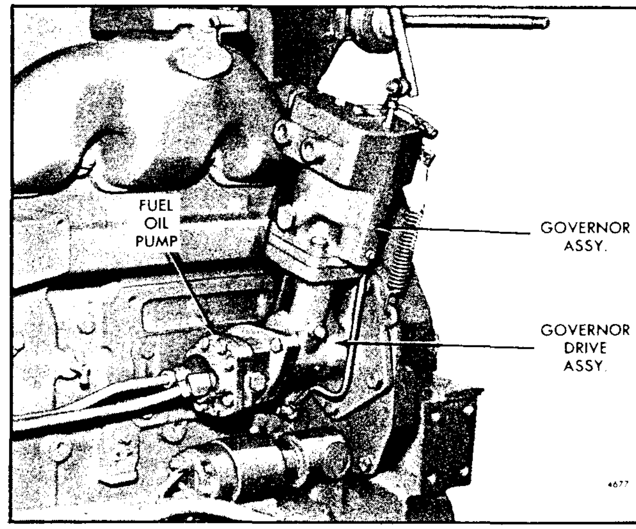


Fig. 2 - Hydraulic Governor Drive Mounting

spills over the moving parts inside of the drive housing. The surplus oil returns to the crankcase through a cored passage in the drive housing.

Remove Governor Drive

Refer to Fig. 2 and proceed as follows:

1. Remove the governor as outlined under *Remove Governor* in Section 2.8.1.

2. Disconnect and remove the fuel oil inlet and outlet tube assemblies from the fuel oil pump.

3. Remove the three bolt and seal assemblies securing the fuel oil pump to the governor drive housing, then remove the pump, drive coupling and gasket.

4. Disconnect and remove the governor oil inlet supply tube from the elbow in the cylinder block under the governor drive housing.

5. Remove the three 3/8" -24 (12 pt. hd.) bolts and copper washers and the two 3/8" -16 (hex hd.) bolts and plain washers securing the governor drive housing to the cylinder block end plate.

6. If necessary, tap the side of the drive housing with a plastic hammer to loosen it, then remove the drive assembly and gasket from the end plate.

Disassemble Governor Drive

Refer to Figs. 1 and 3 and proceed as follows:

1. Clamp the governor drive gear in a bench vise equipped with soft jaws; then, remove the nut securing the drive gear to the governor drive shaft.

2. Clamp the bolting flange of the governor drive housing in a bench vise equipped with soft jaws. Attach a suitable gear puller to the governor drive gear and pull the gear from the drive shaft.

3. Remove the key from the keyway in the drive shaft. Also, slide the spacer off the end of the shaft.

4. Loosen the two driven gear bearing retaining set screw lock nuts (Fig. 3), then back the set screws out of the housing enough to free the bearing.

5. Pull the bevel driven gear, bearing and sleeve assembly out of the drive housing with a pair of small nose pliers.

6. Remove the governor drive shaft and ball bearing retaining snap ring from the groove in the drive housing with a pair of snap ring pliers.

7. Pull the drive shaft, bearing and drive gear assembly from the drive housing. If necessary, support the drive housing on the bed of an arbor press and press the drive shaft, bearings and drive gear assembly out of the drive housing.

8. Inspect the drive shaft and driven gear ball bearings as outlined under *Inspection*. If necessary, remove the bearings from the drive shaft and driven gear as follows:

a. Place two plates between the bevel driven gear and the driven gear bearing; then, support the driven gear assembly and plates on the bed of an arbor press, with the driven gear over the opening in the bed of the press.

NOTE: The plates may be fabricated by drilling a 3/4" hole through the center of a 1/4" x 3" x 3" steel plate, then cutting the plate in half.

b. Place a steel rod in the opening in the end of the driven gear sleeve and against the gear shaft; then, press the driven gear from the sleeve and bearing. Catch the driven gear by hand when pressed from the sleeve and bearing.

c. Place the two plates around the drive shaft between the two bearings; then, support the drive shaft assembly and plates on the bed of an arbor press with the threaded end of the shaft facing up.

d. Place a short brass rod on the end of the drive shaft and press the shaft out of the rear bearing. Catch the drive shaft, forward bearing and drive gear by hand when pressed from the bearing.

e. Remove the drive gear and forward bearing from the drive shaft in the same manner as outlined in Steps c and d.

Inspection

Wash all of the governor drive parts in clean fuel oil and dry them with compressed air.

Examine the ball bearings for corrosion and pitting. Lubricate each bearing with engine oil; then, while holding the inner race from turning, revolve the outer race slowly by hand and check for rough spots.

Inspect the teeth of the drive and driven bevel gears for chipping, scoring or wear. Remove any slight score marks with a fine India stone.

Inspect the splines in the driven gear sleeve for wear. Also, the splines on the governor ball head for wear.

Examine the teeth of the governor drive gear for chipping, scoring or wear. Remove any slight score marks with a fine India stone.

Replace all of the governor drive parts that are excessively worn or damaged.

Assemble Governor Drive

Refer to Figs. 1 and 3 and proceed as follows:

1. Install the governor drive shaft bearings and drive gear on the drive shaft as follows:

a. Lubricate the inside diameter of the forward drive shaft bearing with engine oil and start the bearing, numbered end up, straight on the small non-threaded end of the drive shaft.

b. Place a suitable sleeve over the end of the drive shaft and against the inner race of the bearing. Then support the drive shaft, bearing and sleeve on the bed of an arbor press.

c. Place a short brass rod on the end of the drive shaft and press the shaft straight into the bearing until the shoulder on the shaft is tight against the bearing inner race.

d. Lubricate the inside diameter of the bevel drive gear with engine oil and start the gear straight on the small non-threaded end of the drive shaft.

e. Place a brass plate, with a 1/2" hole through its center, over the end of the drive shaft and against the gear teeth. Then support the drive shaft, bearing, drive gear and brass plate on the bed of an arbor press.

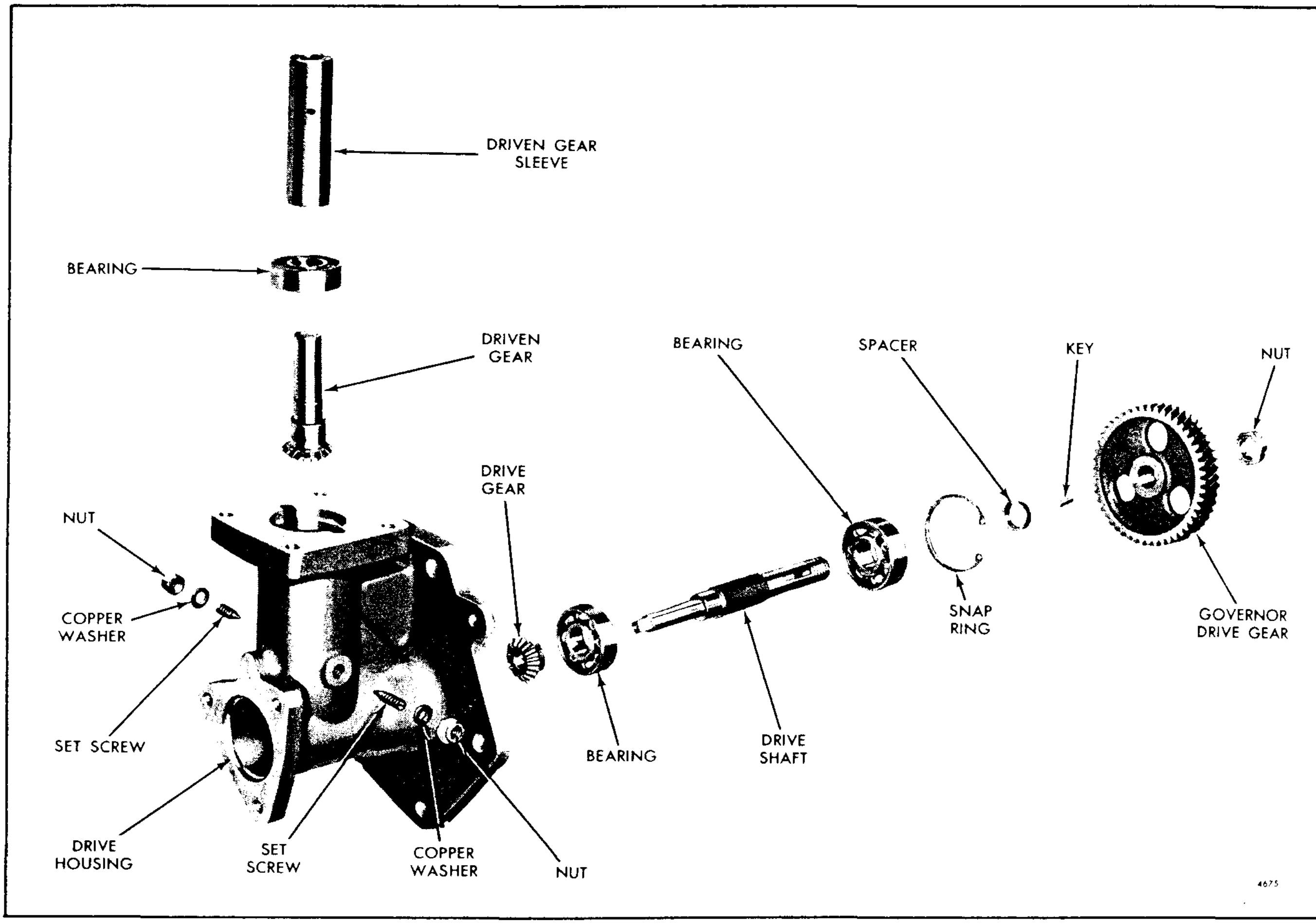


Fig. 3 - Hydraulic Governor Drive Details and Relative Location of Parts

f. Place a short brass rod on the end of the drive shaft and press the shaft straight into the drive gear until the shoulder on the shaft is tight against the drive gear.

g. Lubricate the inside diameter of the rear drive shaft bearing with engine oil and start the bearing, numbered end up, straight on the threaded end of the drive shaft.

h. Place a suitable sleeve over the end of the drive shaft and against the inner race of the bearing. Then support the drive shaft with bearings, drive gear and sleeve on the bed of an arbor press.

i. Place a short brass rod on the end of the drive shaft and press the shaft straight into the bearing until the shoulder on the shaft is tight against the bearing inner race.

2. Install the governor driven shaft bearing and sleeve on the driven gear as follows:

a. Lubricate the inside diameter of the driven gear bearing with engine oil and start the bearing, numbered end up, straight on the driven gear.

b. Place a suitable sleeve over the end of the driven gear and against the inner race of the bearing. Then support the driven gear and sleeve on the bed of an arbor press.

c. Place a short brass rod on the center of the driven gear and press the driven gear into the bearing until the shoulder on the gear is tight against the bearing inner race.

d. Lubricate the inside diameter of the driven gear sleeve with engine oil and start the non-splined end of the sleeve on the small end of the driven gear.

e. Support the driven gear with the bearing and sleeve on the bed of an arbor press with the teeth of the driven gear facing up.

f. Place a short brass rod on the center of the driven gear and press the driven gear into the sleeve until the end of the sleeve is tight against the bearing inner race.

3. Lubricate the two bearings on the drive shaft with engine oil. Insert the small end of the drive shaft into the drive shaft opening of the drive housing and start the large drive shaft bearing straight into the bearing bore of the housing. Then guide the inner bearing into its bore and push the drive shaft assembly in the housing until the bearing contacts the shoulder in the housing.

4. Install the governor drive shaft and ball bearing retaining snap ring in the groove in the housing with a pair of snap ring pliers.

5. Lubricate the driven gear bearing with engine oil. Insert the driven gear, bearing and sleeve assembly in the opening in the top of the drive housing and start the bearing straight into the bearing bore in the housing. Then push the driven gear assembly in the housing until the teeth of the drive and driven gears are in mesh and the bearing is seated on the shoulder in the housing.

6. Install the two driven gear bearing retaining set screws with copper washers and nuts in the holes in the side of the drive housing. Turn the screws in tight against the bearing and tighten the lock nuts.

7. Install the governor drive gear on the governor drive shaft as follows:

a. Place the governor drive shaft bearing spacer over the threaded end of the drive shaft and against the bearing inner race.

b. Install the key in the keyway in the drive shaft.

c. Lubricate the inside diameter of the governor drive gear with engine oil and start the gear on the drive shaft with the keyway in the gear in alignment with the key in the drive shaft.

d. Support the governor drive housing assembly with the governor drive gear on the bed of an arbor press, with a support under the small outside diameter end of drive shaft.

e. Place a suitable sleeve on top of the governor drive gear and under the ram of the press, then press the gear on the drive shaft and against the spacer.

f. Clamp the governor drive gear in a bench vise equipped with soft jaws.

g. Lubricate the threads of the governor drive gear retaining nut with engine oil. Thread the nut on the drive shaft and tighten the nut to 125-135 lb-ft torque.

Install Governor Drive

Refer to Fig. 2 and proceed as follows:

1. Affix a new gasket to the bolting flange of the governor drive housing.

2. Place the governor drive assembly in position against the cylinder block end plate with the teeth of the governor drive gear in mesh with the teeth of the camshaft or balance shaft gear, depending upon the engine model.

3. Install 3/8" -24 bolts and copper washers in the three bolt holes in the drive housing (one at the bottom and two next to the cylinder block). Then install a 3/8" -16 bolt and plain washer in each of the two remaining bolt holes in the drive housing. Tighten the 3/8" -16 bolts to 30-35 lb-ft torque and the 3/8" -24 bolts to 35-39 lb-ft torque.

4. Affix a new gasket to the bolting flange of the fuel pump assembly. Place the fuel pump drive coupling over the square end of the fuel pump drive shaft, then place the fuel pump in position against the front face of the drive housing with the drive coupling over the square end of the governor drive shaft. Install the three bolt and seal assemblies and tighten the bolts to 13-17 lb-ft torque.

5. Connect the fuel oil inlet and outlet tube assemblies to the fuel pump.

6. If removed, attach the governor oil inlet supply tube to the elbow in the cylinder block under the governor drive housing.

7. Install the governor on the drive housing as outlined under *Install Governor* in Section 2.8.1.

HYDRAULIC GOVERNOR SYNCHRONIZING MOTOR

Some hydraulic governors are equipped with a reversible electric synchronizing motor mounted on the governor cover (Fig. 1). This motor, used in place of a vernier control knob, permits close adjustment of the engine speed from a remote control point. This feature is especially valuable when synchronizing two generators from a central control panel.

The motor is connected to the source of electrical supply through a two-way switch as shown in the wiring diagram (Fig. 2).

The motor drive shaft and the governor speed adjusting lever are mechanically connected through a reduction gear on the motor and a friction drive.

Operation

The synchronizing motor is used to change the engine speed when the unit is running alone, or to adjust the load when the unit is operating in parallel with other units.

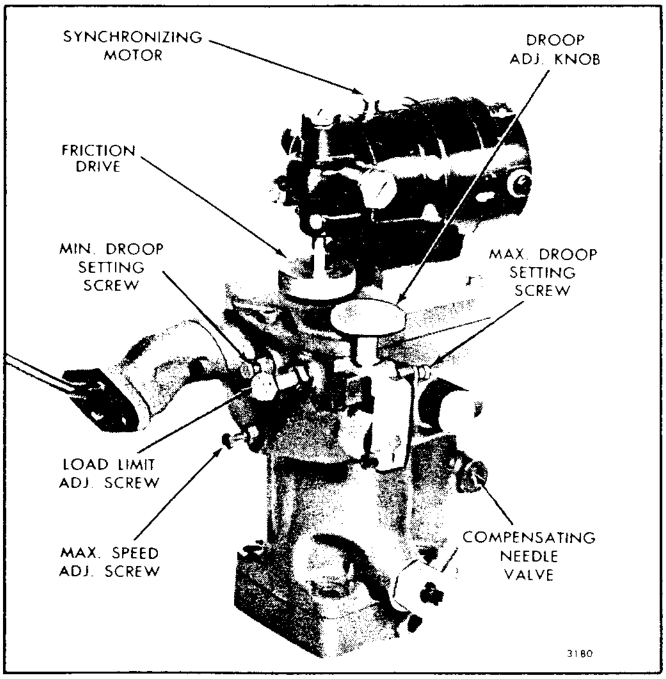


Fig. 1 - Synchronizing Motor Mounting

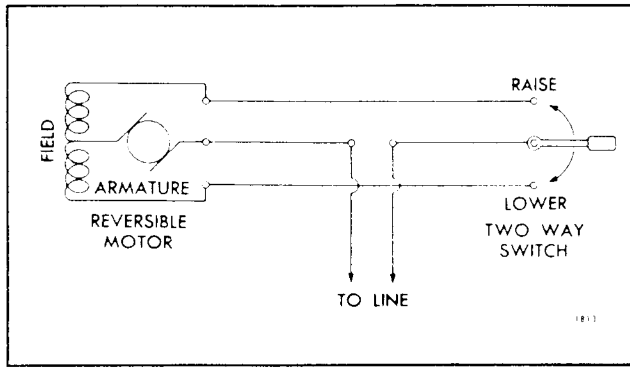


Fig. 2 - Synchronizing Motor Wiring Diagram

When the two-way control switch on the control panel is closed, the motor shaft turns the governor speed adjusting shaft by means of the reduction gear and friction drive. The direction of rotation (clockwise or counterclockwise) is dependent upon the position of the switch. When the desired engine speed is indicated on a tachometer or frequency meter on the control panel, the switch is returned to the OFF position by the operator.

If the switch is held in the LOWER speed position too long, the synchronizing motor will continue to lower the engine speed until it ultimately shuts the engine down. If the switch is held too long in the RAISE speed position, the motor will turn the governor speed adjusting shaft until it strikes the maximum speed adjusting screw, after which the friction drive will slip and the motor will continue to run at a slightly reduced speed without further effect.

Service

The synchronizing motor is constructed to render long satisfactory service. However, if the motor is damaged or fails to operate, replace the entire motor as an assembly.

The spring washer of the friction drive must be strong enough to permit the motor to carry the speed adjusting lever up against the maximum speed adjusting screw without slipping, yet it must be loose enough to slip after the lever contacts the screw. All of the components of the friction drive are available for service.

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 that it is operating properly. The following check 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 of 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 of 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 occurs, 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.

Fig. 1 - Refinishing Lapping Blocks

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 Fig. 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 the powder by rinsing the lapping blocks in trichloroethylene and scrubbing with a bristle brush.

When not in use, protect the lapping blocks against damage and dust by storing them in a close fitting wooden container.

INJECTOR TIMING

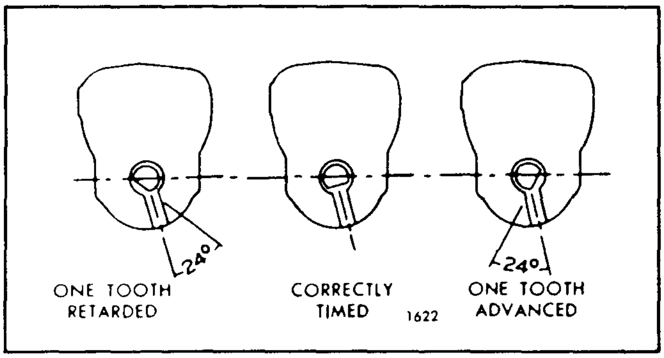


Fig. 2 - Injector Rack-to-Gear Timing

If it is suspected that a fuel injector is "out of time", the injector rack-to-gear timing may be checked without disassembling the injector.

A hole located in the injector body, on the side opposite the identification tag, may be used to visually determine whether or not the injector rack and gear are correctly timed. When the rack is all the way in (full-fuel position), the flat side of the plunger will be visible in the hole, indicating that the injector is "in time". If the flat side of the plunger does not come into full view (Fig. 2) and appears in the "advanced" or "retarded" position, the injector should 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 of 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 the fuel injector output for a particular injector after it has been rebuilt and tested on the comparator.

EFFECT 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, all of the injector assemblies should be removed and checked for burned spray tips or enlarged spray tip orifices.

Before replacing the injectors, check the engine for the cause of pre-ignition to avoid a 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 or dilution of the lubricating oil.

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 bluing solution can be prepared in the service shop by mixing the following materials:

6 lbs. of sodium hydroxide per gallon of water

3-1/2 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:

1. An alkaline solution bath (180 °-212 °F.) to preclean.

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. The bluing tank should be a double walled, 1-1/2 " insulated type of No. 10 gage steel.

The temperature of the sodium hydroxide, sodium nitrite and phosphoric acid solution for bluing steel parts should be 295 ° 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 aprons and protective glasses 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 be 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 make-up water can cause serious burns. *Always add water slowly and with extreme care.* When the parts to be 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.

INJECTOR COMPARATOR AND CALIBRATOR READINGS

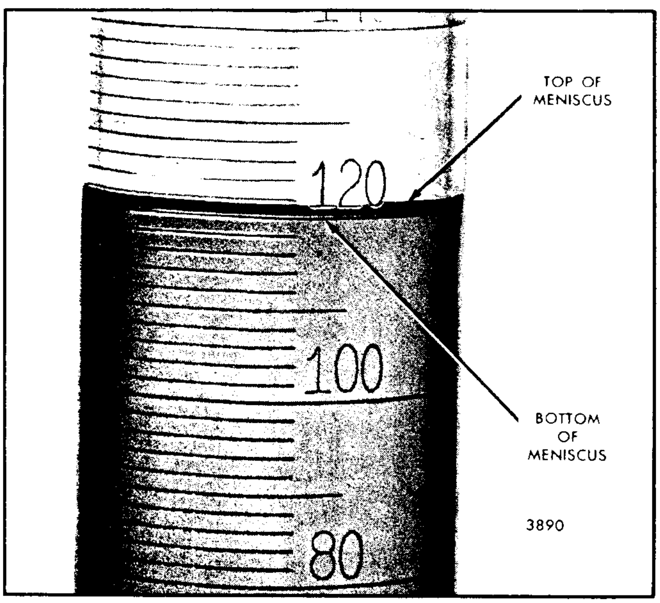


Fig. 3 - Checking Fuel Output

Several factors affect the injector comparator and calibrator output readings. The four major items are:

1. **Operator Errors:** 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 Fig. 3.

2. **Air In Lines:** This can be caused by starting a test before the air is purged from the injector and lines, or from an air leak on the vacuum side of the pump.

3. **Counter Improperly Set:** The counter is set at the factory to divert the injector output at 1,000 strokes, but must be reset for 1,200 strokes to check your 35 and 40 cu.mm injectors. It is possible that in returning to the 1,000 stroke setting, an error could be made.

This should 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 calibrator and the comparator and should always be used. If regular diesel fuel oil (or any other liquid) is used, variations are usually noted because of the affect 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 comparator or calibrator for a calibration check contaminates the test oil. Therefore, it is important that the comparator or calibrator have the test oil and test oil filter changed every six months, or sooner if necessary.

In addition, other malfunctions such as a slipping drive belt, low level of fuel oil, a clogged filter, a defective fuel pump or leaking line connections could cause bad readings. A frequent check should be made for any of these tell-tale conditions.

FUEL INJECTOR PLUNGERS

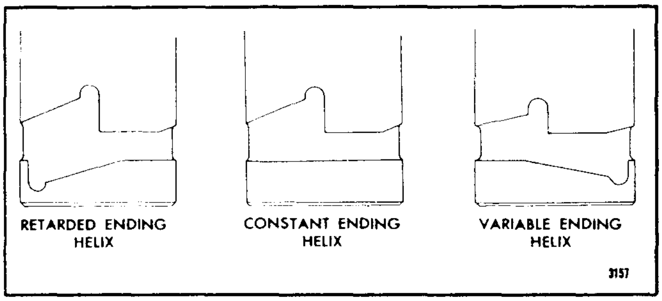


Fig. 4 - Types of Injector Plungers

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 Fig. 4. 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.

REPLACING INJECTOR FOLLOWER SPRING

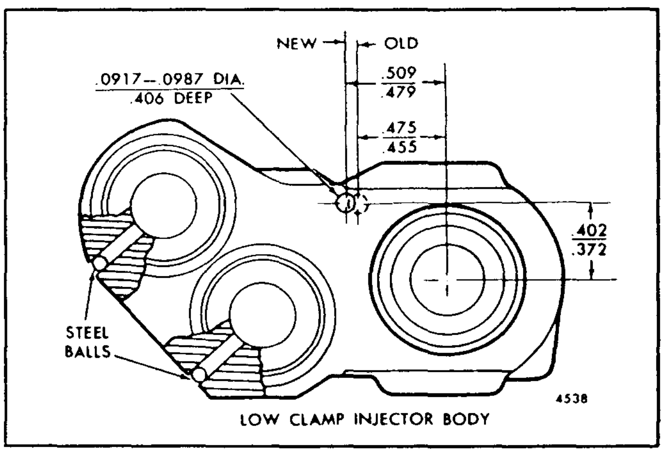


Fig. 5 - Relocating Timing Pin Hole in Injector Body

When replacing the injector follower spring (.120 " diameter wire) in a low clamp body injector built prior to June, 1965 with a new injector follower spring (.142 " diameter wire), it will be necessary to relocate the timing pin holes as illustrated in Fig. 5, or grind .022 " from the side of the injector timing gage shank, to permit continued use of the injector timing gage.

REFINISHING FACE OF INJECTOR FOLLOWER

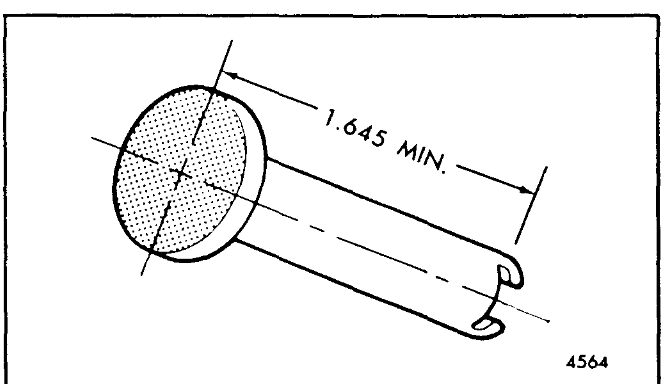


Fig. 6 - Injector Follower

When refinishing the face of an injector follower, it is extremely important that the distance between the injector face and the plunger slot is not less than the 1.645 " minimum shown in Fig. 6.

If the distance between the injector face and the plunger slot is less than 1.645 ", the height of the follower in relation to the injector body will be altered and proper injector timing cannot be realized.

NOTE: To ensure a sufficiently hardened surface for rocker arm contact, do not remove more than .010 " of metal from the injector follower head.

LOCATING AIR LEAKS IN FUEL LINES

Air drawn into the fuel system may result in uneven running of the engine, stalling when idling, or a loss of power. Poor engine operation is particularly noticeable at the lower engine speeds. An opening in the fuel suction lines may be too small for fuel to pass through but may allow appreciable quantities of air to enter.

Check for loose or faulty connections. Also check for improper fuel line connections such as a fuel pump suction line connected to the short fuel return tube in the fuel tank which would cause the pump to draw air.

Presence of an air leak may be detected by observation of the fuel filter contents after the filter is bled and the engine is operated for 15 to 20 minutes at a fairly high speed. No leak is indicated if the filter shell is full when loosened from its cover. If the filter shell is only partly full, an air leak is indicated.

FUEL LINES

Flexible fuel lines are used in certain applications to facilitate connection of lines leading to and from the fuel tank, and to minimize the effects of any vibration in the installation.

Be sure a restricted fitting of the proper size is used to connect the fuel return line to the fuel return manifold. Do not use restricted fittings anywhere else in the fuel system.

When installing fuel lines, it is recommended that connections be tightened only sufficiently to prevent leakage of fuel; thus flared ends of the fuel lines will not become twisted or fractured because of excessive tightening. After all fuel lines are installed, the engine should be run long enough to determine whether or not all connections are sufficiently tight. If any leaks occur, connections should be tightened only enough to stop the leak. Also check filter cover bolts for tightness.

TROUBLE SHOOTING CHARTS (Crown Valve Injectors)

Chart 1

LOW OR HIGH VALVE OPENING PRESSURE

LOW VALVE OPENING PRESSURE

Probable Cause

1. WORN OR ERODED VALVE SEAT
2. VALVE SEAT CHIPPED AT POINT OF CONTACT
3. CRACKED VALVE SEAT
4. WORN VALVE OR VALVE STOP
5. WORN OR BROKEN VALVE SPRING
6. DIRT OR FOREIGN MATERIAL IN INJECTOR
7. WORN VALVE STOP SEAT IN CAGE

HIGH VALVE OPENING PRESSURE

Probable Cause

8. CARBON OR FOREIGN MATERIAL IN SPRAY TIP
9. CARBON IN TIP ORIFICES

SUGGESTED REMEDY

1. A worn or eroded valve seat may be lapped, but not excessively, as this would reduce the thickness of the part causing a deviation from the valve stack-up dimension.

2. If the valve seat is chipped at the point of contact with the valve, lap the surface of the seat and the I.D. of the hole. Mount tool J 7174 in a drill motor and place the seat on the pilot of the tool, using a small amount of lapping compound on the lapping surface. Start the drill motor and apply enough pressure to bring the seat to the point of lap. Check the point of lap contact after a few seconds. If the edge of the hole appears sharp and clear, no further lapping is required. Excessive lapping at this point will increase the size of the hole and lower the injector valve opening pressure.

3. Replace the valve seat.

4. Replace the valve or valve stop.

5. Replace the spring. Check the valve cage and valve stop for wear; replace them if necessary.

6. Disassemble and clean the injector.

7. Replace the valve cage.

8. Carbon in the tip should be removed with tip reamer J 1243 which is especially designed and ground for this purpose.

9. Check the hole size of the spray tip orifices. Then, using tool J 4298-1 with the proper size wire, clean the orifices.

Chart 2

INSUFFICIENT INJECTOR HOLDING TIME

Probable Cause

1. POOR BUSHING TO BODY FIT
2. INJECTOR NUT NOT TIGHTENED TO SPECIFIED TORQUE
3. CRACKED VALVE PARTS
4. VALVE SEAT CHIPPED AT POINT OF CONTACT
5. WORN OR ERODED VALVE SEAT
6. WORN OR BROKEN VALVE SPRING
7. WORN VALVE
8. DEFECTIVE SEAL RING
9. BODY PLUG LEAKS
10. FILTER GASKET LEAKS
11. POOR SEALING SURFACES ON FUEL FITTINGS
12. DIRT OR FOREIGN MATERIAL IN INJECTOR

SUGGESTED REMEDY

1. Lap the injector body.

2. Tighten the nut to 55 to 65 lb-ft torque. Do not exceed the specified torque.

3. Replace the valve parts.

4. If the valve seat is chipped at the point of contact with the valve, lap the surface of the seat and the I.D. of the hole. Mount tool J 7174 in a drill motor and place the valve seat on the pilot of the tool, using a small amount of lapping compound on the lapping surface. Start the drill motor and apply enough pressure to bring the seat to the point of lap. Check the point of lap contact after a few seconds. If the edge of the hole appears sharp and clear, no further lapping is required. Excessive lapping at this point will increase the size of the hole and lower the injector valve opening pressure.

5. A worn or eroded valve seat may be lapped, but not excessively, as this would reduce the thickness of the part, causing a deviation from the valve stack-up dimension.

6. Replace the spring. Check the valve cage and valve stop for wear; replace them if necessary.

7. Replace the valve.

8. Replace the seal ring.

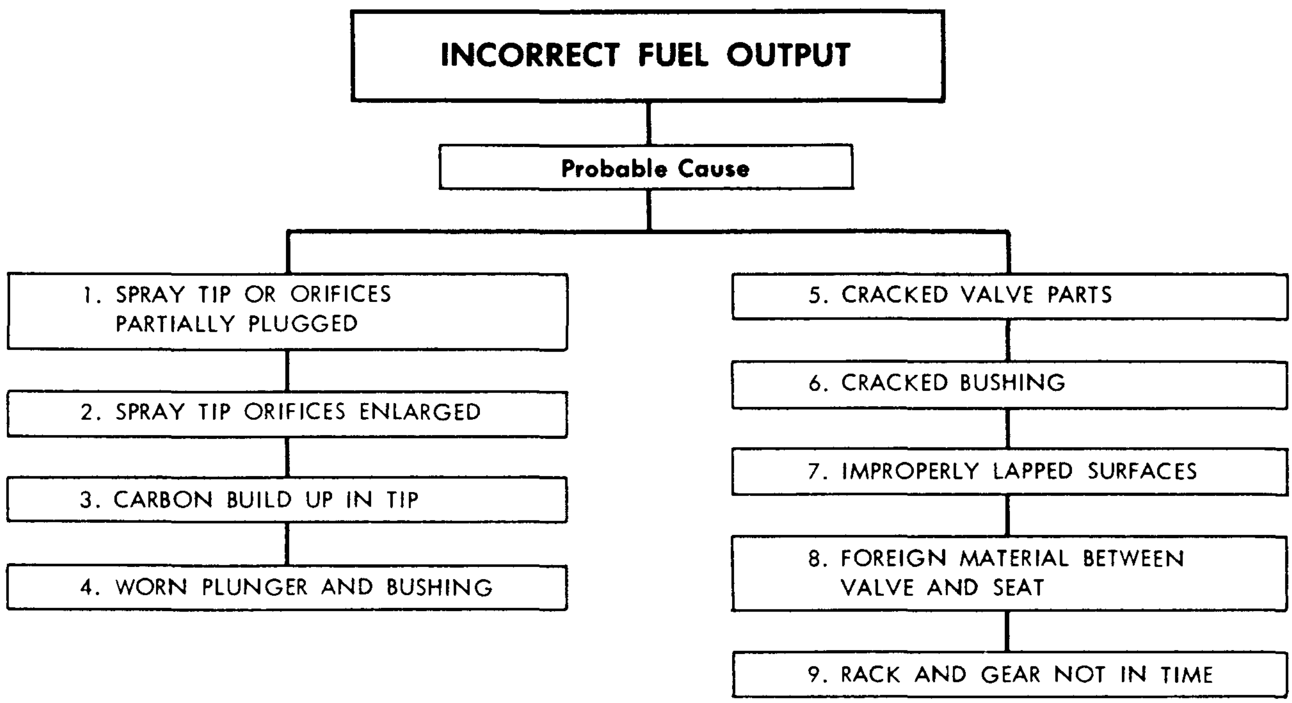
9. Install new body plugs.

10. Replace the filter gaskets and tighten the filter caps to 65 to 75 lb-ft torque.

11. Clean up the sealing surfaces or replace the filter caps, if necessary.

12. Disassemble the injector and clean all of the parts.

Chart 3



SUGGESTED REMEDY

1. Clean the orifices with tool J 4298-1, using the proper size wire.

2. Replace the spray tip.

   NOTE: The fuel output of an injector varies with the use of different spray tips of the same size due to manufacturing tolerances in drilling the tips. If the fuel output does not fall within the specified limits of the *Fuel Output Check Chart*, try changing the spray tip. However, use only a tip specified for the injector being tested.

3. Clean the injector tip with tool J 1243.

4. After the possibility of an incorrect or faulty tip has been eliminated and the injector output still does not fall within its specified limits, replace the plunger and bushing with a new assembly.

5. Replace the cracked parts.

6. Replace the plunger and bushing assembly.

7. Re-lap the sealing surfaces.

8. Disassemble the injector and clean the parts.

9. Assemble the gear with the drill spot mark on the tooth engaged between the two marked teeth of the rack.

TROUBLE SHOOTING CHARTS (Needle Valve Injectors)

Chart 4

LOW OR HIGH VALVE OPENING PRESSURE

LOW VALVE OPENING PRESSURE

Probable Cause

1. WORN OR ERODED NEEDLE VALVE OR VALVE SEAT IN TIP
2. WORN OR DAMAGED NEEDLE VALVE QUILL
3. WORN OR DAMAGED NEEDLE VALVE SPRING SEAT
4. WORN OR BROKEN VALVE SPRING
5. DIRT OR FOREIGN MATERIAL IN INJECTOR

HIGH VALVE OPENING PRESSURE

Probable Cause

6. CARBON OR FOREIGN MATERIAL IN SPRAY TIP
7. CARBON IN TIP ORIFICES

SUGGESTED REMEDY

1. Replace the needle valve and tip assembly.
2. Replace the needle valve and tip assembly.
3. Replace the spring seat.
4. Replace the valve spring.
5. Disassemble the injector and clean the parts.
6. Remove the carbon in the tip with tip reamer J 9464 which is especially designed and ground for this purpose.
7. Check the hole 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 GASKETS 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 75-85 lb-ft torque. Do not exceed the specified torque.

3,4,5 and 6. Replace the needle valve and spray tip assembly.

7. Replace the valve spring.

8. Replace the valve spring seat.

9. Replace the seal ring.

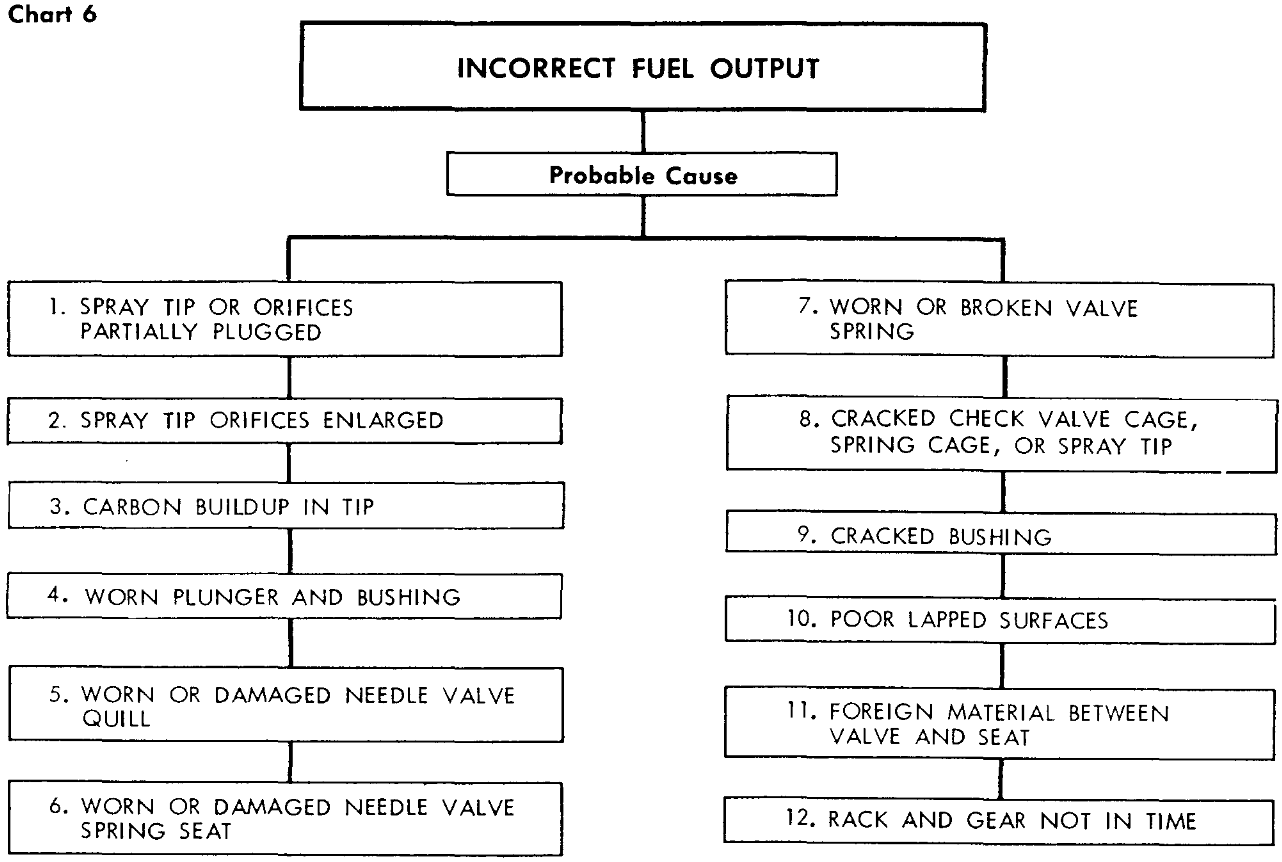
10. Install new body plugs.

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 the injector and clean the parts.

Chart 6



SUGGESTED REMEDY

1. Clean the spray tip as outlined under *Clean Injector Parts*.

2. Replace the spray tip assembly.

   NOTE: The fuel output of an injector varies with the use of different spray tips of the same size due to manufacturing tolerances in drilling the tips. If the fuel output does not fall within the specified limits of the *Fuel Output Check Chart*, try changing the spray tip. However, use only a tip specified for the injector being tested.

3. Clean the injector tip with tool J 1243.

4. After the possibility of an incorrect or faulty tip has been eliminated and the injector output still does not fall within its specific limits, replace the plunger and bushing with a new assembly.

5. Replace the needle valve.

6. Replace the spring seat.

7. Replace the valve spring.

8. Replace the cracked parts.

9. Replace the plunger and bushing assembly.

10. Re-lap the sealing surfaces.

11. Disassemble the injector and clean the parts.

12. Assemble the gear with the drill spot mark on the tooth engaged between the two marked teeth of the rack.

FUEL PUMP MAINTENANCE

The fuel pump is so constructed as to be inherently trouble free. By using clean water-free fuel and maintaining the fuel filters in good condition, the fuel pump will provide long satisfactory service and require very little maintenance.

However, if the fuel pump fails to function satisfactorily, first check the fuel level in the fuel tank, then make sure the fuel supply valve is open. Also check for external fuel leaks at the fuel line connections, filter gaskets and air heater lines. Make certain that all fuel lines are connected in their proper order.

Next, check for a broken pump drive shaft or drive coupling. Insert the end of a wire through one of the pump flange drain holes, then crank the engine momentarily and note whether the wire vibrates. Vibration will be felt if the pump shaft rotates.

All fuel pump failures result in no fuel or insufficient fuel being delivered to the fuel injectors and may be indicated by uneven running of the engine, excessive vibration, stalling at idling speeds or a loss of power.

The most common reason for failure of a fuel pump to function properly is a sticking relief valve. The relief valve, due to its close fit in the valve bore, may become stuck in a fully open or partially open position due to a small amount of grit or foreign material lodged between the relief valve and its bore or seat. This permits the fuel oil to circulate within the pump rather than being forced through the fuel system.

Therefore, if the fuel pump is not functioning properly, remove the relief valve plug, spring and pin and check the movement of the valve within the valve bore. If the valve sticks, recondition it by using fine emery cloth to remove any scuff marks. Otherwise, replace the valve. Clean the valve bore and the valve components. Then lubricate the valve and check it for free movement throughout the entire length of its travel. Reassemble the valve in the pump.

After the relief valve has been checked, start the engine and check the fuel flow at some point between the restricted fitting in the fuel return manifold at the cylinder head and the fuel tank.

CHECKING FUEL FLOW

1. Disconnect the fuel return tube from the fitting at the fuel tank or source of supply and hold the open end of the tube in a convenient receptacle.

2. Start and run the engine at 1200 rpm and measure the fuel flow return from the manifold. Refer to Section 13.2 for the specified quantity per minute.

3. Immerse the end of the fuel tube in the fuel in the container. Air bubbles rising to the surface of the fuel will indicate air being drawn into the fuel system on the suction side of the pump. If air is present, tighten all fuel line connections between the fuel tank and the fuel pump.

4. If the fuel flow is insufficient for satisfactory engine performance, then:

   a. Replace the element in the fuel strainer. Then start the engine and run it at 1200 rpm to check the fuel flow. If the flow is still unsatisfactory, perform Step "b" below.

   b. Replace the element in the fuel filter. If the flow is still unsatisfactory, do as instructed in Step "c".

   c. Substitute another fuel pump that is known to be in good condition and again check the fuel flow.

   When changing a fuel pump, clean all of the fuel lines with compressed air and be sure all fuel line connections are tight. Check the fuel lines for restrictions due to bends or other damage.

If the engine still does not perform satisfactorily, one or more fuel injectors may be at fault and may be checked as follows:

1. Run the engine at idle speed and cut out each injector in turn by holding the injector follower down with a screw driver. If a cylinder has been misfiring, there will be no noticeable difference in the sound and operation of the engine when that particular injector has been cut out. If the cylinder has been firing properly there will be a noticeable difference in the sound and operation of the engine when the injector is cut out.

2. Stop the engine and remove the fuel pipe between the fuel return manifold and the injector.

3. Hold a finger over the injector fuel outlet and crank the engine with the starter. A gush of fuel while turning the engine indicates an ample fuel supply; otherwise, the injector filters are clogged and the injector must be removed for service.

SPECIFICATIONS

STANDARD BOLT AND NUT TORQUE SPECIFICATIONS

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

EXCEPTIONS TO STANDARD BOLT AND NUT TORQUE SPECIFICATIONS

APPLICATION	THREAD SIZE	TORQUE (lb-ft)
Governor control housing to flywheel housing	5/16-18	10-12
Blower drive assembly to flywheel housing	3/8 -16	20-25
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
Governor drive gear retaining nut (in-line engine)	5/8 -18	125-135
Injector filter caps	5/8 -24	65-75
Injector nut (crown valve)	15/16-24	55-65
Injector nut (needle valve)	15/16-24	75-85

SERVICE TOOLS

TOOL NAME	TOOL NO.
INJECTOR TOOLS	
Injector body reamer	J 21089
Pin vise	J 22800-3
Injector bushing Inspectalite	J 21471
Injector calibrator	J 22410
Adaptor (standard body)	J 7041-61
Adaptor (offset body, high clamp)	J 7041-72
Adaptor (4-valve, low clamp)	J 7041-88
Adaptor (offset body, low clamp)	J 7041-130
Seat	J 22410-226
Injector comparator	J 7041
Adaptor	J 7041-61
Adaptor	J 7041-72
Adaptor	J 7041-88

SERVICE TOOLS

TOOL NAME	TOOL NO.
Adaptor	J 7041-130
Injector holding fixture	J 22396
Injector nut tip seat reamer (needle valve)	J 9418-1
Injector nut tip seat reamer (needle valve)	J 9418-5
Injector service tool set	J 1241-05
Spray tip cleaner	J 1243
Spray tip remover and bushing cleaner	J 1291-02
Injector spray tip hole cleaner	J 4298-1
Injector nut socket wrench	J 4983-01
Injector nut tip seat reamer	J 4986-01
Injector valve seat deburring tool	J 7174
Injector rack hole brush	J 8150
Injector body brush	J 8152
Injector wire honing stone	J 8170
Injector test oil (one gallon)	J 8130
Injector tester	J 9787
Test block	J 9787-49
Adaptor	J 8538-10
Injector tip carbon remover (needle valve)	J 9464-01
Special drill	J 9464-1
Injector tip concentricity gage	J 5119
Lapping block set	J 22090
Lapping compound	J 23038
Metyl Ethyl Keystone solvent (one gallon)	J 8257
Needle valve injector auxiliary tester	J 22640
Needle valve lift gage	J 9462-01
Polishing stick set	J 22964
Socket	J 8932-01
Spring tester	J 9666

INJECTOR TUBE TOOLS

Cylinder head holding plate set	J 3087-01
Injector tube service tool set	J 22525

GOVERNOR TOOLS

Control link lever bearing installer	J 8985
Governor cover bearing installer	J 21068
Governor cover bearing remover	J 21967
Governor operating shaft fork installer set (8V engine)	J 21995
Governor weight carrier installer	J 8984
Knurled nut	J 21995-1
Nut wrench	J 5895
Rod	J 21995-2
Spanner wrench	J 5345-5
Variable speed governor spring housing bearing installer set	J 9196
Installer body	J 9196-1
Installer body rod	J 9196-2

SECTION 3

AIR INTAKE SYSTEM

CONTENTS

AIR INTAKE SYSTEM

In the scavenging process employed in the Series 53 engines, a charge of air is forced into the cylinders by the blower and thoroughly sweeps out all of the burned 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, therefore, each cylinder is filled with fresh, clean air which provides for efficient combustion.

The air, entering the blower from the air cleaner, is picked up by the blower rotor lobes and carried to the discharge side of the blower as indicated by the arrows in Figs. 1 and 2. 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 cylinders. This motion persists throughout the compression stroke and facilitates scavenging and combustion.

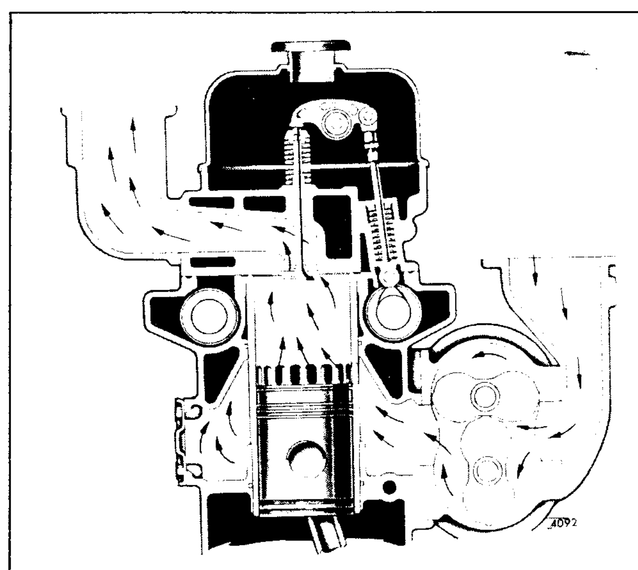


Fig. 1 - Air Flow Through Blower and Engine (In-Line Engine)

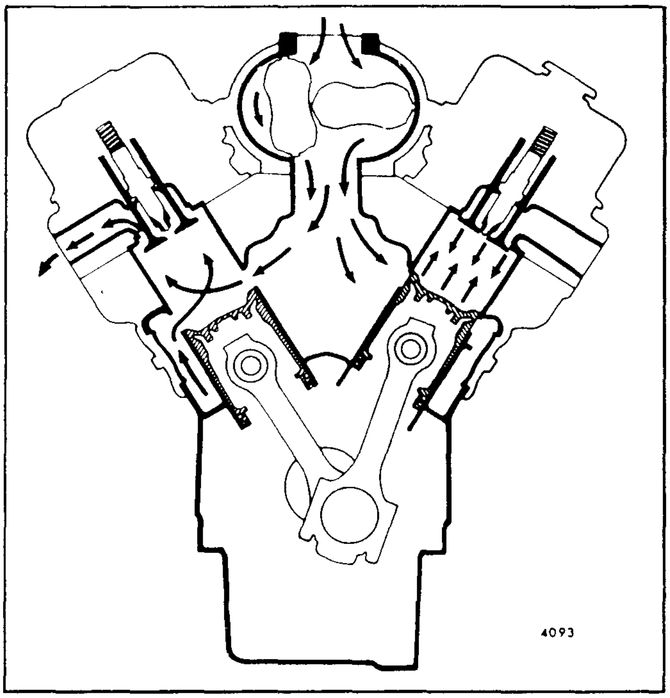


Fig. 2 - Air Flow Through Blower and Engine (V-Type Engine)

AIR CLEANER

The air cleaner is designed to remove foreign matter from the air, pass the required volume of air for proper combustion and scavenging, and maintain efficient operation for a reasonable period of time before requiring service.

The importance of keeping dust and grit-laden air out of the engine cannot be over-emphasized, since clean air is so essential to satisfactory engine operation and long engine life. Should dust in the air supply enter the engine, it would be carried directly into the cylinders and, due to its abrasive properties, cause premature wear of the moving parts. Dirt, which is allowed to build-up in the air cleaner passages, will eventually restrict the air supply to the engine and result in heavy carbon deposits on the valves and pistons due to incomplete combustion. The air cleaner sump must have a capacity large enough to retain the material separated from the air to permit operation for a reasonable length of time before cleaning is required.

Air Cleaner Maintenance

Although the air cleaner is highly efficient, this efficiency depends upon proper maintenance and periodic servicing.

Damaged gaskets, loose hose connections or leaks in the duct work, which permit dust-laden air to completely by-pass the cleaner and enter the engine directly, will lower the efficiency of the air cleaner. If the air cleaner is not serviced periodically, the engine will not receive a sufficient amount of clean air.

No set rule for servicing an air cleaner can be given since it depends upon the type of air cleaner, the condition of the air supply, and the type of application. An air cleaner operating in severe dust will require more frequent service than an air cleaner operating in comparatively clean air. The most satisfactory service period should be determined by frequently inspecting the air cleaner under normal operating conditions, then setting the service period to best suit the requirements of the particular engine application.

The following maintenance procedure will assure efficient air cleaner operation.

1. Keep the air cleaner tight on the air intake pipe to the engine.

2. Keep the air cleaner properly assembled so the joints are strictly oil and air tight.

3. Repair any damage to the air cleaner or related parts immediately.

4. Inspect and clean or replace the air cleaner element as operating conditions warrant. In certain dry type cleaners, it is possible to clean and reuse the element several times as long as the paper is not ruptured in the process. In an oil bath type cleaner, keep the oil at the level indicated on the air cleaner sump. Overfilling may result in oil being drawn through the element and into the engine, thus carrying dirt into the cylinders and also resulting in excessive engine speed.

5. After servicing the air cleaner, remove the air inlet housing and clean accumulated dirt deposits from the blower screen and the inlet housing. Keep all air intake passages and the air box clean.

6. Where rubber hose is employed, cement it in place. Use new hose and hose clamps, if necessary, to obtain an air tight connection.

7. Carefully inspect the entire air system periodically. Enough dust-laden air will pass through an almost invisible crack or opening to eventually cause damage to an engine.

OIL BATH TYPE AIR CLEANER

LIGHT-DUTY AIR CLEANER

The light-duty oil bath air cleaner (Fig. 1) consists of a metal wool cleaning element supported inside a housing beneath which is contained a bath of oil. The lower portion of the housing incorporates a chamber which serves as a silencer for the incoming air to the blower.

Air drawn into the cleaner by the blower passes over the top of the oil bath, where a major portion of the dirt is trapped, then up through the metal wool where the finer particles are removed, then down the central duct to the blower.

Service

Service the light-duty oil bath air cleaner as follows:

1. Loosen the wingbolt and remove the cleaner from the air inlet housing. The cleaner may then be separated into two sections; the upper section contains the metal wool element, the lower section is made up of the oil sump, removable baffle and center tube.

2. Soak the upper shell and element in fuel oil to loosen the dirt; then flush the element with clean fuel oil and allow it to drain thoroughly.

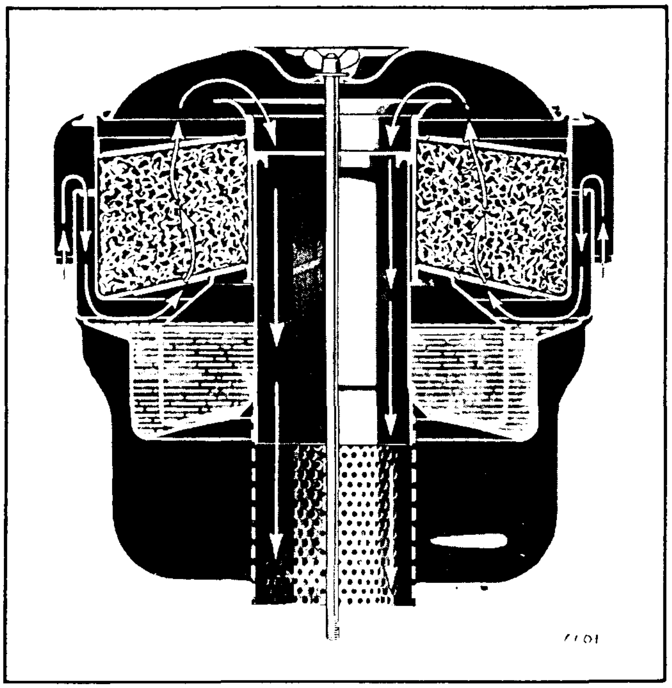


Fig. 1 - Light-Duty Oil Bath-Type Air Cleaner

3. Empty the sump, remove the baffle and clean both the sump and the baffle with fuel oil to remove all sediment.

4. Push a lint-free cloth through the center tube to remove dirt or oil from the walls.

5. Clean and check all gaskets and sealing surfaces to insure air tight seals.

6. Refill the sump to the oil level mark ONLY, with the same grade of oil used in the engine.

7. Before installing the air cleaner on the engine, check the air inlet housing for dirt. If the service period has been too long, or if dust-laden air has been leaking past the air cleaner to the air inlet housing seals, the inlet will be dirty. This will serve as a good check on the servicing of the air cleaner. When installing the cleaner (and its seal) on the inlet housing, be sure the cleaner seats properly, then tighten the wingbolt securely until the cleaner is rigidly mounted.

8. Install the baffle and reassemble the air cleaner.

HEAVY-DUTY AIR CLEANER

The heavy-duty oil bath air cleaner (Fig. 2) consists of a metal wool cleaning element supported inside a housing, beneath which a removable screen and an oil cup is located. Air, drawn into the air cleaner by the blower, enters the cleaner at the air inlet hood, passes down the central duct over the oil bath and up through the removable screen and metal wool cleaning element. The air leaves the cleaner through a tube at the side and enters the blower.

The major portion of dirt is washed from the air as it passes over the oil bath, and any remaining foreign matter is removed as the air passes up through the removable screen and the metal wool cleaning element.

Service

Service the heavy-duty air cleaner as follows:

1. Remove the oil sump from the cleaner by loosening the retaining band (or wing nuts). Empty the sump and wash it with fuel oil to remove all of the sediment.

2. Remove the detachable screen by loosening the wing nuts and rotating the screen one-quarter turn.

One of the most important steps in properly cleaning the tray type oil bath air cleaner is a step that is most overlooked. Unless the filter tray is thoroughly cleaned, satisfactory performance of any engine

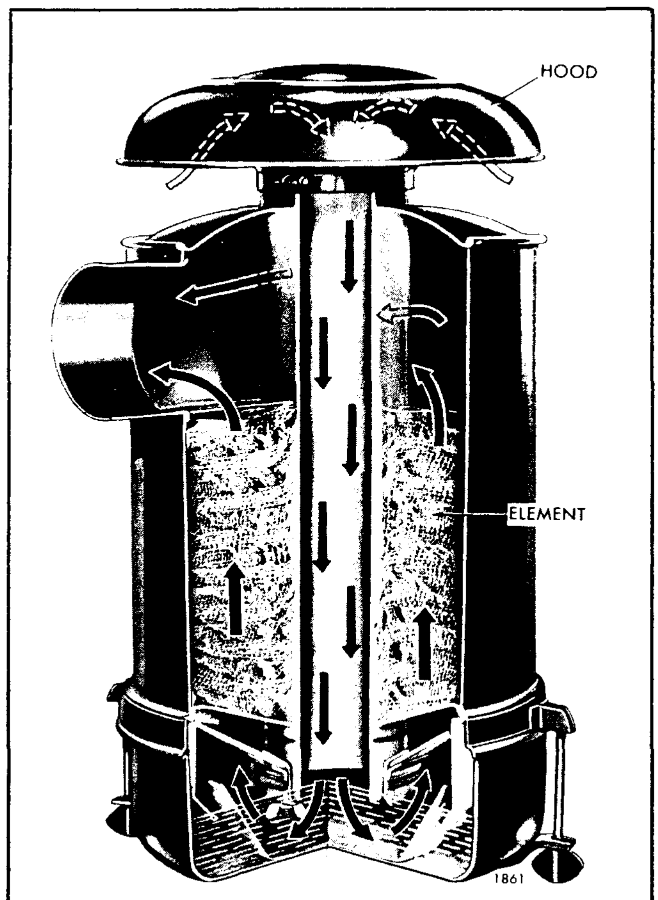
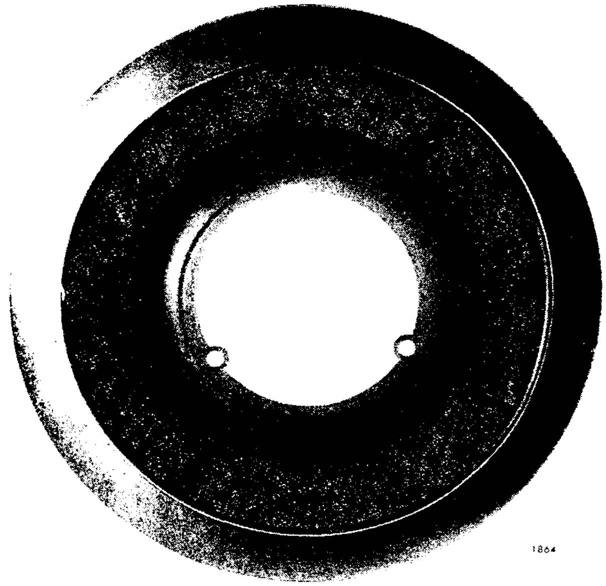


Fig. 2 - Heavy-Duty Oil Bath-Type Air Cleaner

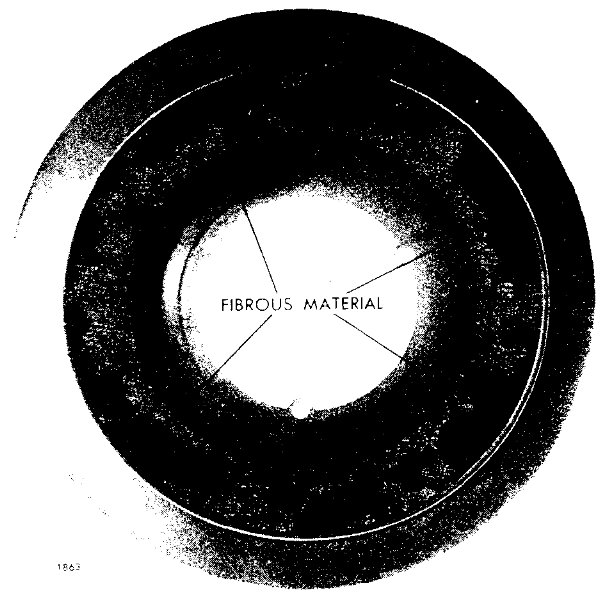
cannot be realized. The presence of fibrous material found in the air is often underestimated and is the main cause of the malfunctioning of heavy-duty air cleaners. This material comes from plants and trees during their budding season and later from airborne seed from the same sources. Figure 3 illustrates the severity of plugging in a tray that is 50% plugged. The solid black areas in the mesh are accumulations of this fibrous material. When a tray is plugged in this manner, washing in a solvent or similar washing solution will not clean the tray satisfactorily. It must also be blown out with high velocity compressed air or steam to remove the material that accumulates between the layers of screening. When a clean tray is held up to the light, an even pattern of light should be visible. It may be necessary, only as a last resort, to burn off the lint. Extreme care must be taken not to melt the galvanized coating in the tray screens. Some trays have equally spaced holes in the retaining baffle. Check to make sure that they are clean and open. A thoroughly cleaned tray is illustrated in Fig. 4. The dark spots in the mesh indicate the close overlapping of the mesh and emphasize the need for using compressed air or steam. It is suggested that users of heavy-duty air cleaners have a spare tray on hand to replace the tray that requires cleaning. Having an extra tray available makes for better service and the dirty tray can be cleaned thoroughly as recommended. Spare trays are well worth their investment.

3. Remove the hood and clean it by brushing or by blowing out with compressed air. Push a lint-free cloth



THOROUGHLY CLEANED

Fig. 3 - Air Cleaner Tray (50% Plugged)



50% PLUGGED

Fig. 4 - Air Cleaner Tray (Clean)

through the center tube to remove dirt or oil from the walls.

4. The fixed element should be serviced as operating conditions warrant. Remove the entire cleaner from the engine, soak the unit in fuel oil to loosen the dirt, then flush with clean fuel oil and allow to drain thoroughly.

5. Clean and check all gaskets and sealing surfaces to insure air tight seals.

6. Refill the oil cup to the oil level mark ONLY. Use oil of same grade as used in the engine crankcase.

7. Install the removable screen in the housing and reinstall the housing.

8. Install the oil cup and the hood.

9. Check all of the joints and tubes and make sure they are air tight.

All oil bath air cleaners should be serviced as operating conditions warrant. At no time should more than 1/2" of "sludge" be allowed to form in the oil cup or the area used for sludge deposit, nor should the oil cup be filled above the oil level mark.

DRY TYPE AIR CLEANER

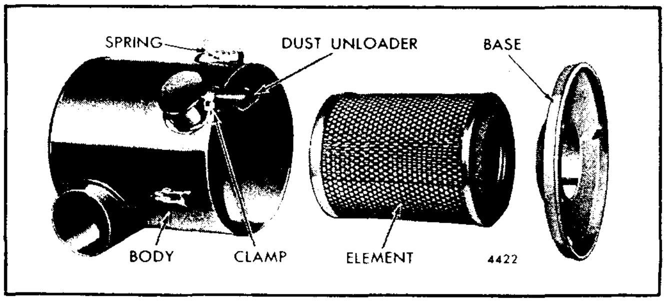


Fig. 5 - United Specialties Dry Type Air Cleaner

UNITED SPECIALTIES AIR CLEANER

The dry type United Specialties air cleaner shown in Fig. 5 consists of a body, dust unloader and element clamped to a base.

Air is drawn through the cleaner intake pipe and is automatically set into a circular motion. This positive spinning of the dirty air "throws out" the heavier particles of dust and dirt where they are collected in the dust port and then expelled through the dust unloader. The circular action continues even during low air intake at engine idle speed.

Service

Service the dry type United Specialties air cleaner as follows:

1. Loosen the clamp screw and check the dust unloader for obstruction or damage. Refer to Section 15.1 for maintenance.

2. Unlock the spring clamps that hold the cleaner body to the cleaner base which is bolted to the air inlet housing. Remove the body and then remove the element from the cleaner base.

3. Clean the paper pleated air cleaner element as follows:

a. For a temporary expedient in the field, tap the side or end of the element carefully against the palm of your hand.

CAUTION: Do not tap the element against a hard surface. This could damage the element.

b. Compressed air can be used when the major contaminant is dust. The compressed air (not to exceed 100 psi) should be blown through the element in a direction opposite to the normal air flow. Insert the nozzle inside of the element and gently tap and blow out the dust with air. When cleaning the dust from the outside of the element, hold the nozzle at least 6" from the element.

c. Wash the element if compressed air is not available, or when the contaminant is carbon, soot, oily vapor or dirt which cannot be removed with compressed air. Agitate the element in warm water containing a non-sudsing detergent.

CAUTION: Do not use water hotter than your hand can stand, solvents or oil, fuel oil or gasoline.

Preceding the washing, it helps to direct air (not exceeding 100 psi) through the element in a direction opposite to the normal air flow, to dislodge as much dust as possible. Reverse flush with a stream of water (not exceeding 40 psi) until the water runs clean to rinse all loosened foreign material from the element. Shake out excess water from the element and allow it to dry thoroughly.

CAUTION: Do not attempt to remove excess water by using compressed air.

4. Inspect the cleaned element with a light bulb after each cleaning for damage or rupture. The slightest break in the element will admit sufficient airborne dirt to cause rapid failure of piston rings. If necessary, replace the element.

5. Inspect the gasket on the end of the element. If the gasket is damaged or missing, replace the element.

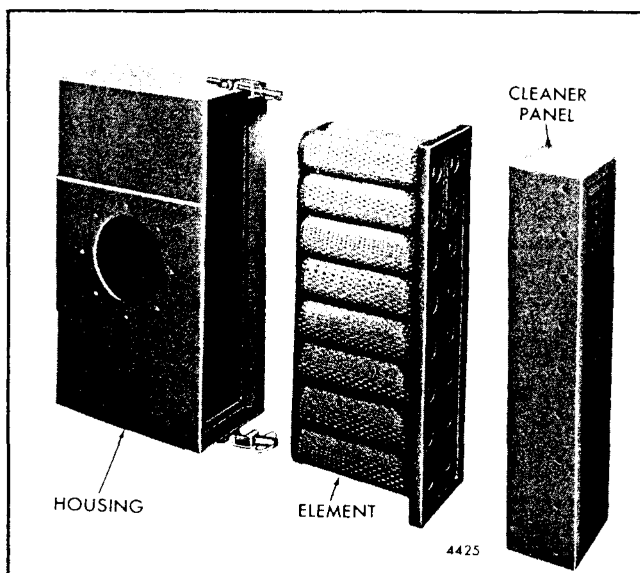


Fig. 6 - Farr Dry Type Air Cleaner

6. Install the element on the base with the gasket side of the element down against the base. Place the body over the element and the base and tighten the spring clamps by hand.

Replace the element after 10 washings or 1 year of service, whichever comes first, or any time damage is noted.

7. Install the dust unloader and tighten the clamp.

FARR AIR CLEANER

The Farr dry type air cleaner illustrated in Fig. 6 is designed to provide highly efficient air filtration under all operating conditions and is not affected by engine speed. The cleaner assembly consists of a cleaner panel with a replaceable impregnated paper filter element.

The cleaner panel and replaceable filter element are held together in a steel housing with fasteners.

Operation

The deflector vanes impart a swirling motion to the air entering the air cleaner and centrifuge the dust particles against the walls of the tubes. The dust particles are then carried to the dust bin at the bottom of the cleaner by approximately 10% bleed-off air and are finally discharged into the atmosphere.

The cleaner panel is fully effective at either high or low velocities.

The remainder of the air in the cleaner reverses direction and spirals back along the discharge tubes again centrifuging the air. The filtered air then reverses direction again and enters the replaceable filter element through the center portion of the discharge tubes. The air is filtered once more as it passes through the pleats of the impregnated paper element before leaving the outlet port of the cleaner housing.

Service

The cleaner panel tends to be self-cleaning. However, it should be inspected and any accumulated foreign material removed during the periodic replacement of the impregnated paper filter element. Overloading of the paper element will not cause dirt particles to by-pass the filter and enter the engine, but will result in starving the engine for air.

Replace the filter element as follows:

1. Loosen the wing nuts on the fasteners and swing the retaining bolts away from the cleaner panel.

2. Lift the cleaner panel away from the housing and inspect it. Clean out any accumulated foreign material.

3. Withdraw the paper filter element and discard it.

4. Install a new filter element.

5. Install the cleaner panel and secure it in place with the fasteners.

AIR SILENCER

In-Line and 6V Engines

The air silencer (Fig. 1) is attached to the intake side of the blower housing to reduce the sound level of the air entering the blower.

A perforated sheet metal partition divides the silencer into two sections. The engine side of the partition and the outer shell forms an air duct the entire length of the silencer. Air enters this duct from both ends and flows to the blower intake opening at the center. The area between the partition and the outer side of the silencer is filled with sound absorbent, flame-proof, felted cotton waste.

An air intake (blower) screen is used between the air silencer and the blower housing to prevent foreign objects from entering the blower.

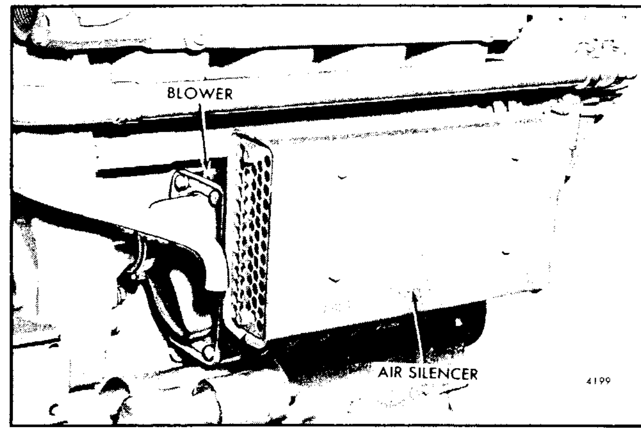


Fig. 1 - Air Silencer Mounted on In-Line Engine

Remove and Install Air Silencer

While no servicing is required on the air silencer, it may be necessary at times to remove it to clean or replace the blower screen or to perform other service operations.

1. Support the silencer and remove the attaching bolts and lock washers. Then remove the silencer and the blower screen. On the 6V engine, the air silencer adaptor must be removed to gain access to the blower screen.

2. Clean the blower screen with fuel oil and dry it with compressed air.

3. Place the blower screen on the 6V engine blower housing and install the air silencer adaptor.

4. Place the lock washers over the bolts and slide the bolts through the bolt holes in the silencer.

5. Place the blower screen (In-line engines) over the projecting bolts and position the silencer against the blower housing. Then tighten the bolts.

8V Engine

The air silencer (Fig. 2) is mounted on a support attached to the flywheel housing. The air outlet end is attached to the air inlet housing with a hose and clamps. An air filter element of polyurethane foam is used on the current air silencer inlet screen.

Remove Air Silencer

While no servicing is required on the air silencer, it may be necessary to remove it to perform other service operations.

1. Remove the air filter element, if used.

2. Loosen the clamps and slide the hose back on the air inlet housing.

3. Loosen the lower bolts which secure the mounting straps to the silencer support bracket. Then, while holding the silencer, remove the bolts and washers. Remove the silencer.

4. If necessary, remove the breather pipe clip from the silencer mounting strap. Then remove the bolts and washers and remove the mounting straps.

Install Air Silencer

1. If previously removed, attach the mounting straps to the top of the silencer support bracket with two 7/16" - 14 bolts, washers and nut (one bolt threads into the flywheel housing). Do not tighten the bolts at this time.

2. Position the air silencer under the mounting straps and install the 3/8" -16 bolts, lock washers, washers and nuts. Do not tighten the bolts at this time.

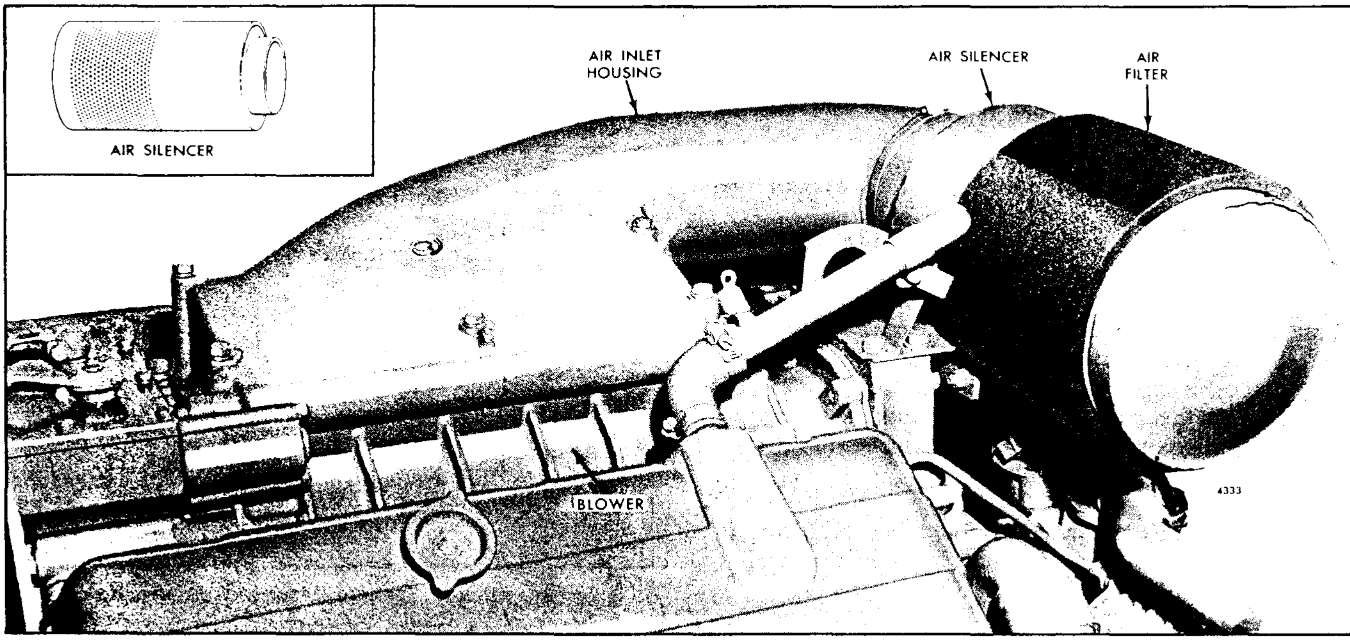


Fig. 2 - Air Silencer Mounted on 8V Engine

3. Align the silencer with the air inlet housing, slide the hose in place and tighten the clamps.

4. Tighten the mounting strap bolts at this time.

5. Install the breather pipe clip.

6. Slide the air filter element (if used) over the silencer air inlet screen.

AIR SHUT-DOWN HOUSING

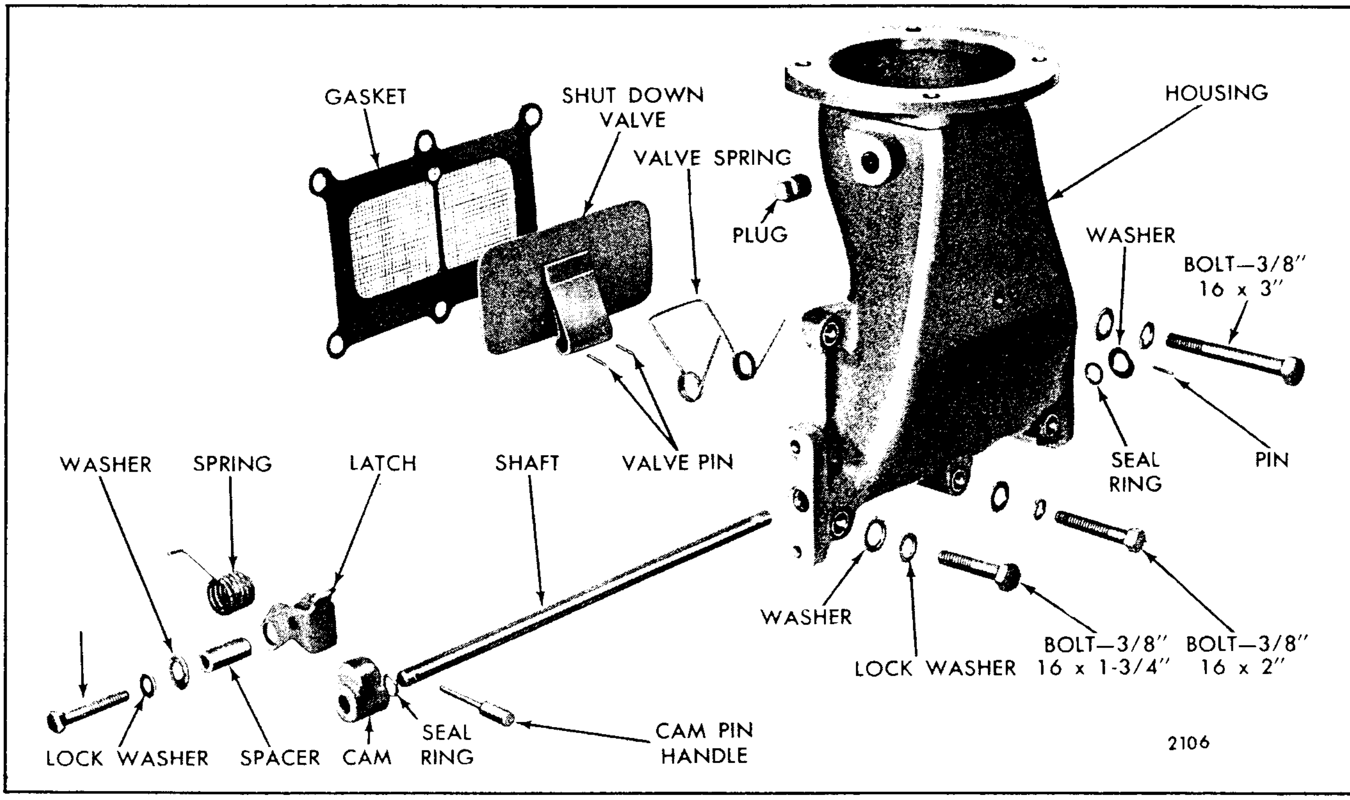


Fig. 1 - Typical In-Line Air Shut-Down Housing Details and Relative Location of Parts

The air shut-down housing on the in-line engine is mounted on the side of the blower, while the V-type engine has the air shut-down housing mounted on the top of the blower. The housing serves as a mounting for the air cleaner or the ducting for an air cleaner mounted away from the engine. The air shut-down housing contains an air shut-off valve that shuts off the air supply and stops the engine whenever abnormal operating conditions require an emergency shut-down.

Remove Air Shut-Down Housing

1. Disconnect and remove the air ducts between the air cleaner and the air shut-down housing.

2. Disconnect the control wire from the air shut-off cam pin handle.

3. Remove the bolts and washers that retain the housing to the blower and remove the housing from the blower. Remove the air shut-down housing gasket from the blower.

NOTE: Cover the blower opening to prevent dirt or foreign material from entering the blower.

Disassemble Air Shut-Down Housing

Refer to Fig. 1 and disassemble the air shut-down housing as follows:

1. Remove the pin from the end of the shut-down shaft. Then remove the washer from the shaft and the seal ring from the housing.

2. Remove the two pins that secure the shut-off valve to the shaft.

3. Remove the bolt, lock washer and plain washer which attach the latch to the housing. Then remove the latch, latch spring and spacer.

4. Note the position of the air shut-off valve spring and the valve (Fig. 2); then withdraw the shaft from the housing to release the valve and the spring. Remove the valve and spring and the seal ring from the housing.

5. Remove the cam pin handle and withdraw the cam from the shaft.

Inspection

Clean all of the parts thoroughly, including the blower screen, with fuel oil and dry them with compressed air. Inspect the parts for wear or damage. The face of the shut-down valve must be perfectly flat to assure a tight seal when it is in the shut-down position.

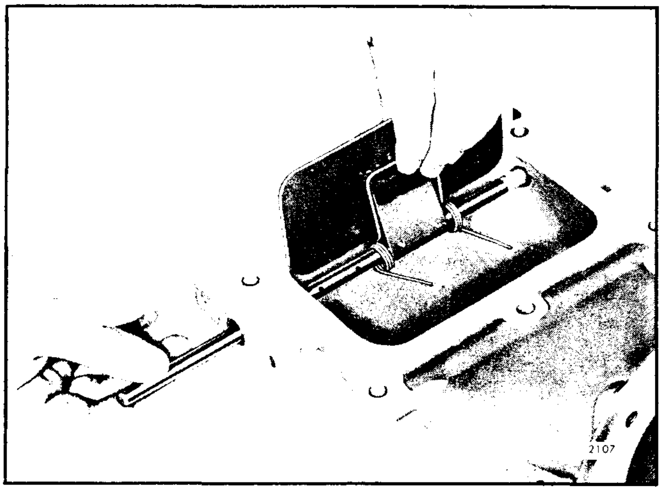


Fig. 2 - Installing Air Shut-Off Valve Spring and Valve

Assemble Air Shut-Down Assembly

The holes for the cam pin handle and the retaining pins must be drilled, using a 1/8" diameter drill, at the time a new service shaft or air shut-off valve(s) is assembled. The valve(s) must be in the same plane within .03" when in the stop position (flush with the housing face). Refer to Figs. 1 and 2 and proceed as follows:

1. Place the valve(s) and spring in position in the housing (Fig. 2) and slip the shaft in place. The shaft must extend .70" from the side of the housing where the shut-down latch is assembled.

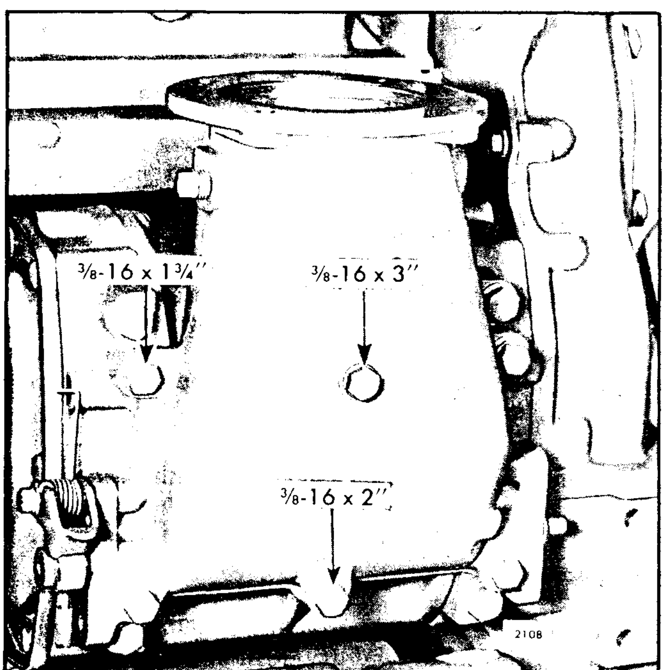


Fig. 3 - Location of Air Shut-Down Housing Mounting Bolts (In-Line Engines)

2. Install a new seal ring at each end of the shaft. Be sure the seals are seated in the counterbores of the housing.

3. Install the cam and cam pin handle on the shaft.

4. Install a washer and retaining pin at the other end of the shaft.

5. Assemble the spacer (bushing), spring and latch to the shut-down housing with the 1/4" -20 bolt, lock washer and plain washer.

a. Align the notch on the bushing with the notch on the latch and lock the bushing in this position.

b. Install the pins in the valve(s) to retain it to the shaft with the cam release latch set and the valve(s) in the run position.

c. Level the valve(s) in the shut-down position.

d. Adjust the bushing so the valve(s) contacts the housing when the cam release latch is set.

Install Air Shut-Down Housing (In-Line Engines)

1. Place the blower screen and gasket assembly in position with the screen side of the assembly toward the blower.

2. Refer to Figs. 1 and 3 and secure the air shut-down housing to the blower with bolts, washers and lock washers as follows:

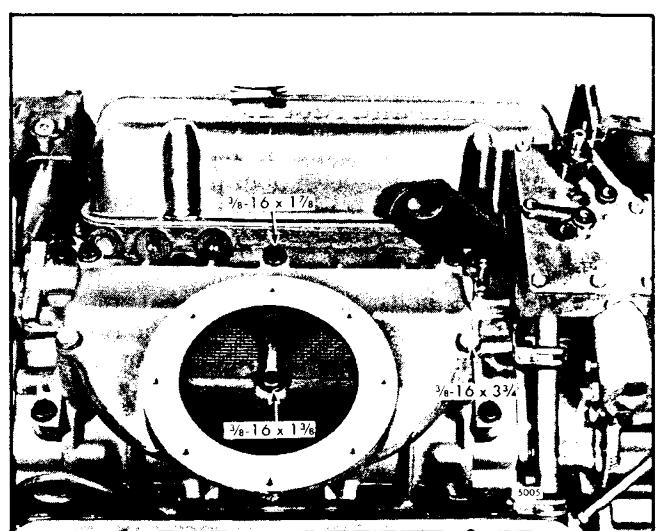


Fig. 4 - Location of Air Shut-Down Housing Mounting Bolts (6V Engines)

a. Install and finger tighten the six attaching bolts shown in Fig. 3.

b. Tighten the two center bolts to 16-20 lb-ft torque.

c. Then tighten the four corner bolts to 16-20 lb-ft torque.

CAUTION: A power wrench should not be used to tighten the above bolts.

3. Reset the air shut-down to the run position.

4. Start and run the engine at idle speed and no load. Trip the air shut-down. If the engine does not stop, check it for air leakage between the valve and the gasket. If necessary, reposition the valve.

Install Air Shut-Down Housing (6V Engines)

1. Place the blower screen and gasket assembly in position with the screen side of the assembly toward the blower.

2. Refer to Fig. 4 and mount the air inlet housing on the blower and secure it with bolts, washers and lock washers. Tighten the bolts to 16-20 lb-ft torque.

3. Reset the air shut-down to the run position.

4. Start and run the engine at idle speed and no load. Trip the air shut-down. If the engine does not stop, check it for air leakage between the valves and the gasket. If necessary, reposition the valves.

Install Air Shut-Down Housing and Adaptor (8V Engines)

1. Place the blower screen and gasket assembly in position with the screen side of the assembly toward the blower.

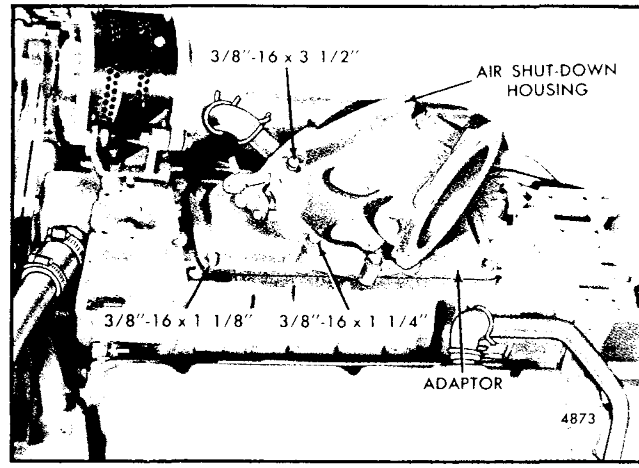


Fig. 5 - Location of Air Shut-Down Housing and Adaptor Mounting Bolts

2. Refer to Fig. 5 and install the air shut-down housing adaptor on the screen and gasket assembly. Install the six bolts and lock washers and tighten them to 16-20 lb-ft torque.

3. Affix a new gasket on the top of the air inlet housing adaptor, then place the air shut-down housing on top of the gasket. Install the six bolts and lock washers and tighten them to 16-20 lb-ft torque.

4. Reset the air shut-down to the run position.

5. Start and run the engine at idle speed and no load. Trip the air shut-down. If the engine does not stop, check it for air leakage between the valves and the gasket. If necessary, reposition the valves.

BLOWER

IN-LINE AND 6V ENGINES

The blower supplies the 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 side of the in-line engines (Fig. 1) or on top of the cylinder block between the cylinder banks on the 6V engine (Fig. 2). The revolving motion of the rotors provides a continuous and uniform displacement of air.

The blower rotors are pinned to the 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 space the rotor lobes with a close tolerance. Since the lobes of the two rotors do not touch at any time, no lubrication is required.

Lip type oil seals are used in both the front and rear end plates on current engines. The seals prevent air leakage past the blower rotor shaft bearing surfaces and also keep the oil, used for lubricating the blower rotor gears, from entering the rotor compartment. Former blowers used a ring type oil seal consisting of a fiber washer, "0" ring, retainer and seal spring in each end of the blower rotors.

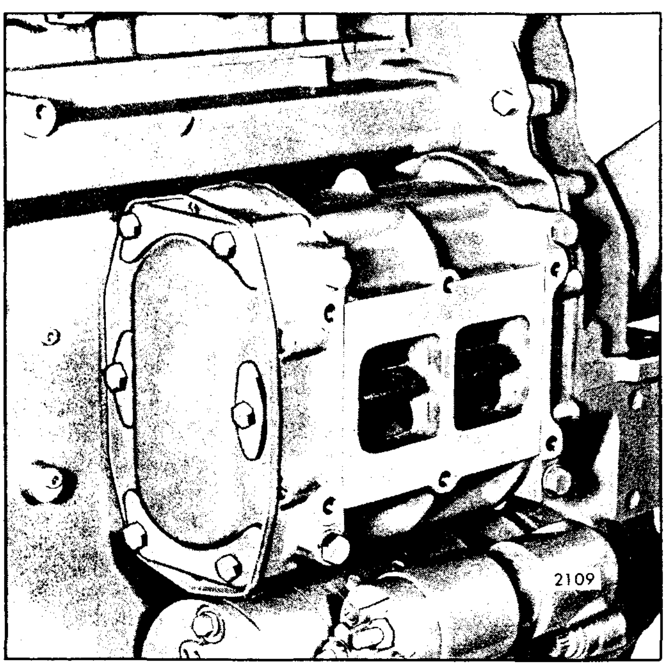


Fig. 1 - Blower Mounting (3-53 Engine)

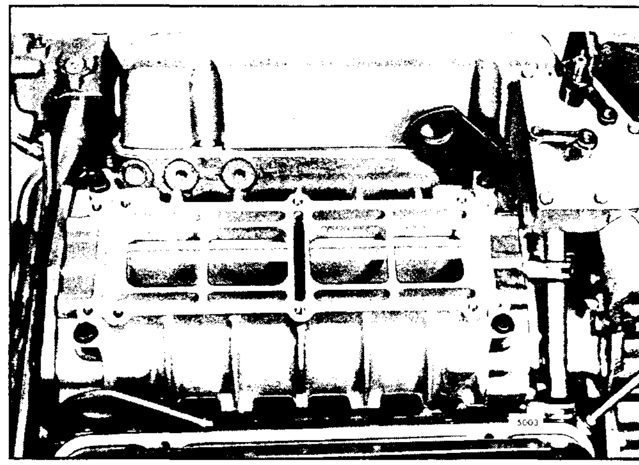


Fig. 2 - Blower Mounting (6V-53 Engine).

Inspect Blower (Attached to Engine)

The blower may be inspected without removing it from the engine. However, the air cleaner and the air inlet housing must be removed.

> **CAUTION:** When inspecting the blower with the engine running, keep your fingers and clothing away from the moving parts of the blower and run the engine at low speeds only.

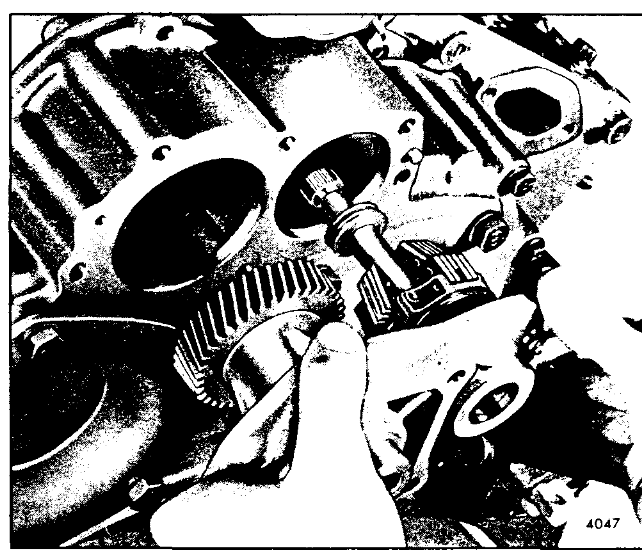


Fig. 3 - Removing/Installing Blower Drive Support (6V-53 Engine)

Dirt or chips drawn through the blower will make deep scratches in the rotors and housing. Burrs around such abrasions may cause interference between the rotors or between the rotors and the blower housing.

Leaky oil seals are usually indicated by the presence of oil on the blower rotors or inside surfaces of the blower housing. Run the engine at low speed and direct a light into the rotor compartment and toward the end plates and the oil seals. A thin film of oil radiating away from a seal indicates an oil leak.

A worn blower drive resulting in a loose, rattling sound within the blower may be detected by running the engine at approximately 500 rpm.

Loose rotor shafts or worn rotor shaft bearing surfaces will result in contact between the rotor lobes, the rotors and the end plates, or the rotors and the housing.

Excessive backlash between the blower rotor gears usually results in the rotor lobes rubbing throughout their entire length.

Remove Blower

Before removing the blower from the engine, remove the air shut-down housing as outlined in Section 3.3.

2 and 3-53 ENGINE BLOWER

1. Remove the six bolts, special washers and reinforcement plates which secure the blower to the engine end plate and the flywheel housing. *Note the location of the two shorter bolts.* Then remove the front end plate cover and gasket from the blower.

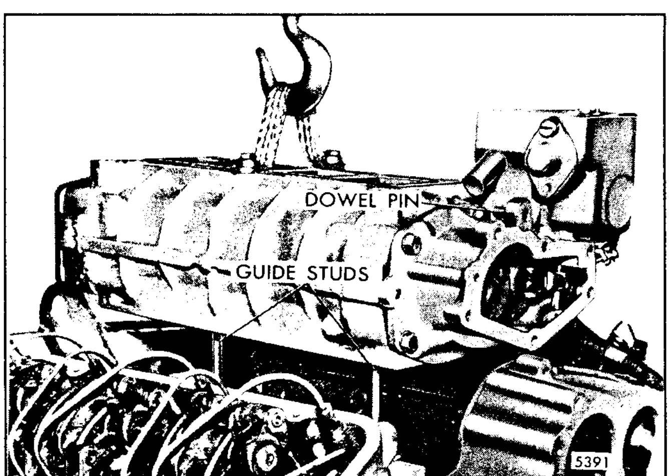


Fig. 4 - Removing/Installing Blower (6V-53 Engine)

2. Remove the four blower-to-block bolts and special washers and lift the blower away from the engine.

4-53 ENGINE BLOWER

1. Loosen the clamp retaining the cover-to-support seal.

2. Remove the four blower-to-block bolts and special washers and lift the blower away from the engine, being careful not to damage the serrations on the blower drive shaft.

6V-53 ENGINE BLOWER

1. Disconnect the linkage to the governor control levers.

2. Remove the screws and lock washers which attach the governor cover to the governor housing. Remove the cover and gasket.

3. Remove the two bolts and lock washers which hold

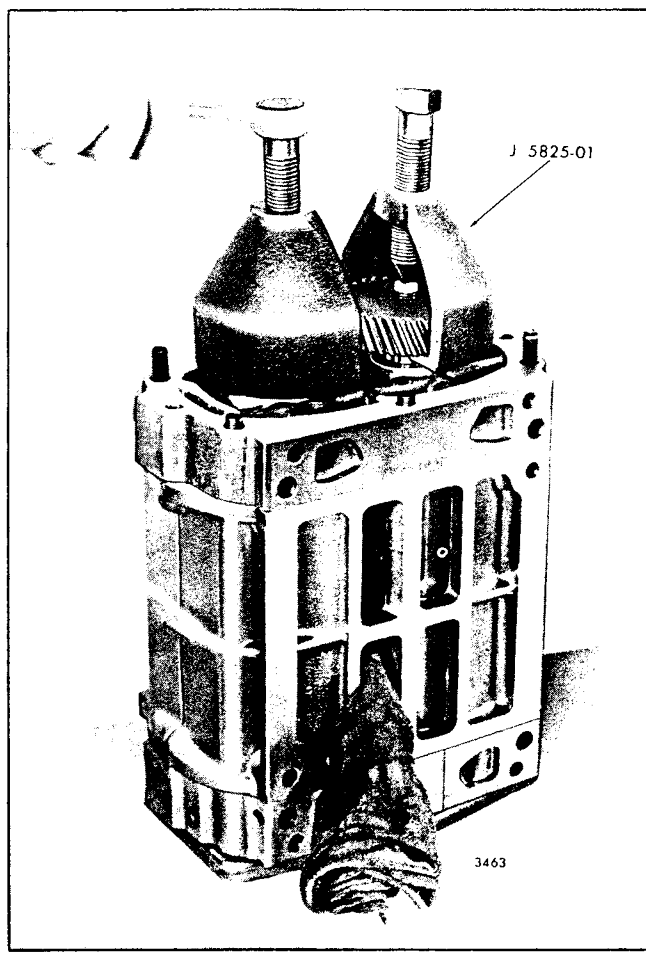


Fig. 5 - Removing Blower Rotor Gears

the spring housing to the governor housing. Remove the spring housing and gasket.

4. Remove the spring assembly from the governor.

5. Loosen the hose clamps and slide the hoses back on the fuel rod covers.

6. Clean and remove the valve rocker cover from each cylinder head.

7. Disconnect the lower fuel rod from each injector control tube lever and also from each upper fuel rod.

8. Remove the threaded pins connecting the fuel rods to the control link lever. Remove the upper fuel rods.

9. Remove the blower drive cover plate. Remove the snap ring and withdraw the blower drive shaft from the housing.

10. Remove the two bolts and copper washers securing the blower drive support assembly. Then withdraw the drive assembly until the splined end of the drive shaft is free from the drive plate (Fig. 3). Turn the drive assembly slightly so the serrated end of the governor weight shaft will pass around the governor operating fork. Remove the drive support from the engine.

11. The governor is doweled to the cylinder block rear end plate. Use a suitable tool to press or drive the dowel pin from the end plate.

12. Remove the four bolts and flat washers which attach the blower to the top face of the cylinder block. Lift the blower and governor assembly from the engine (Fig. 4).

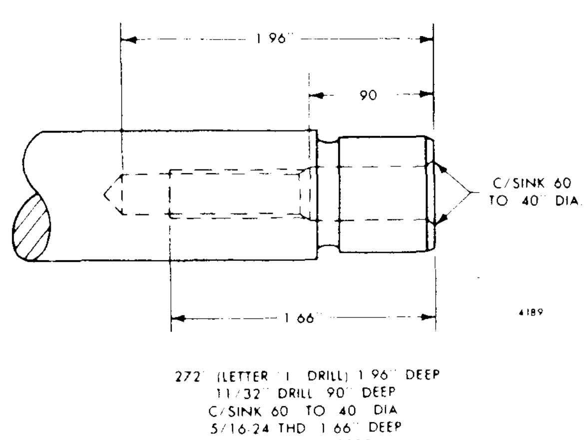


Fig. 6 - Dimensions for Reworking 6V Blower Rotor Shafts

13. Remove the six bolts and lock washers which attach the governor housing to the blower rear end plate. Remove the governor and gasket.

Disassemble Blower

2 and 3-53 ENGINE BLOWER

1. Wedge a clean cloth between the rotors to prevent their turning. Then remove the blower gear retaining bolts and washers.

2. For identification, mark the R.H. helix gear. Then remove the gears with pullers J 5825-01 as follows:

a. With the pullers in place under the gears (Fig. 5), place a brass bar, approximately 1" long and 5/8" diameter, between the point of each puller bolt and blower rotor shaft.

CAUTION: If the brass bar is larger than 5/8" diameter, the serrations in the blower drive gear may be damaged.

b. Alternately turn the bolt in each puller until the gears are off the shafts.

3. Remove the rotor shims and the gear spacers and place them with their respective gears to ensure correct re-assembly.

4. At the other end of the blower, remove the three thrust plate bolts, the thrust plate and three spacers from the front end plate. Remove the bolts and thrust washers (refer to Fig. 7).

5. Remove the two screws that retain the end plate to the blower housing. Tap the end plate off of the dowel pins and housing with a soft (plastic) hammer, being careful not to damage the mating surfaces of the end plate and the housing.

6. Remove the rotors from the blower housing.

7. Remove the retaining screws and remove the rear end plate as in Step 5.

8. Remove and discard the lip type oil seals from the end plates on current blowers. Remove the seal washer, "O" ring, retainer and retainer spring from each rotor shaft on former blowers.

4-53 and 6V-53 ENGINE BLOWERS

1. Refer to Fig. 8 and remove the six bolts, special washers and reinforcement plates which secure the front end plate cover and the front end plate to the blower housing. Then remove the end plate cover and gasket from the end plate.

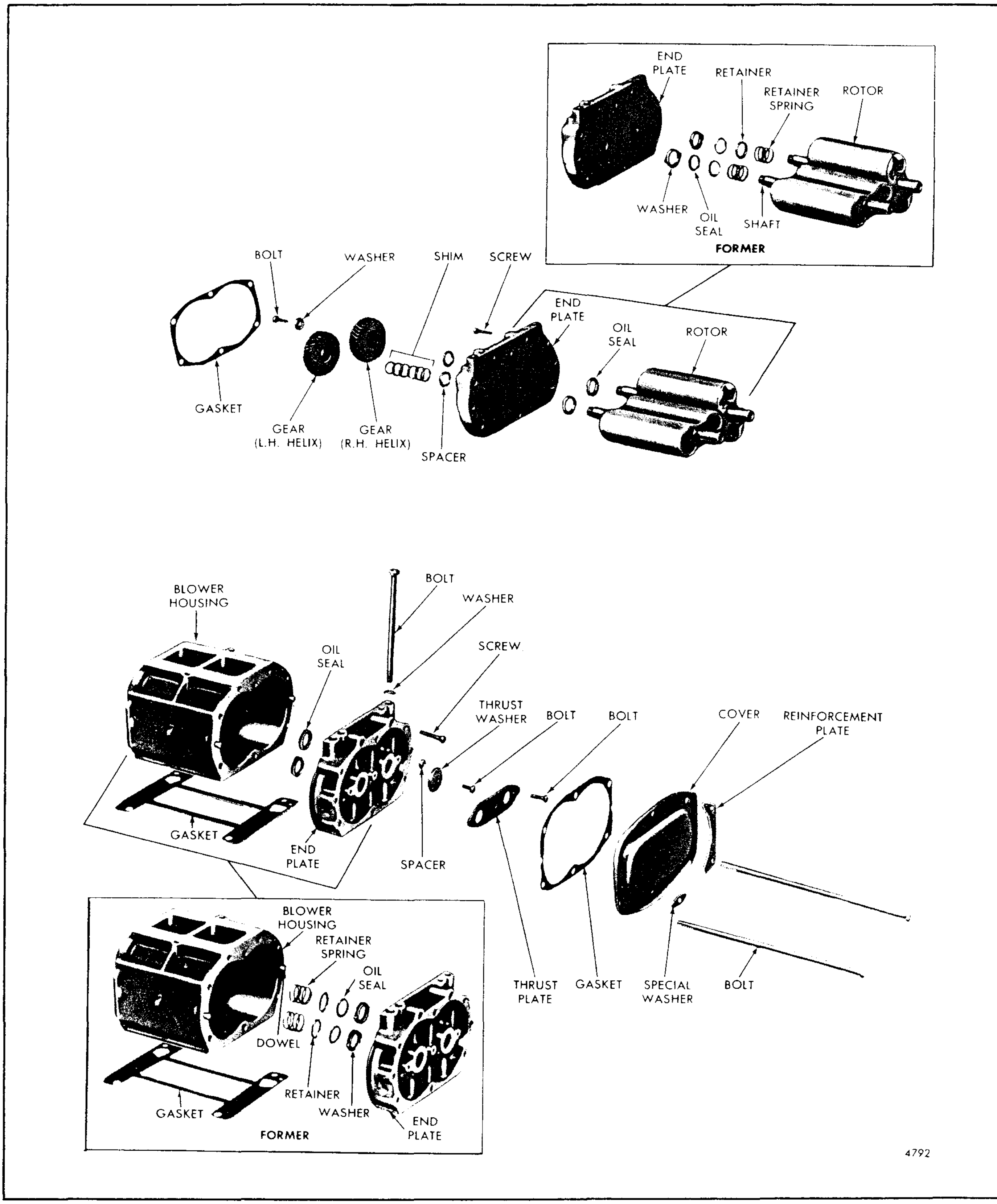


Fig. 7 - Typical Blower Details and Relative Location of Parts (3-53 Engine Blower)

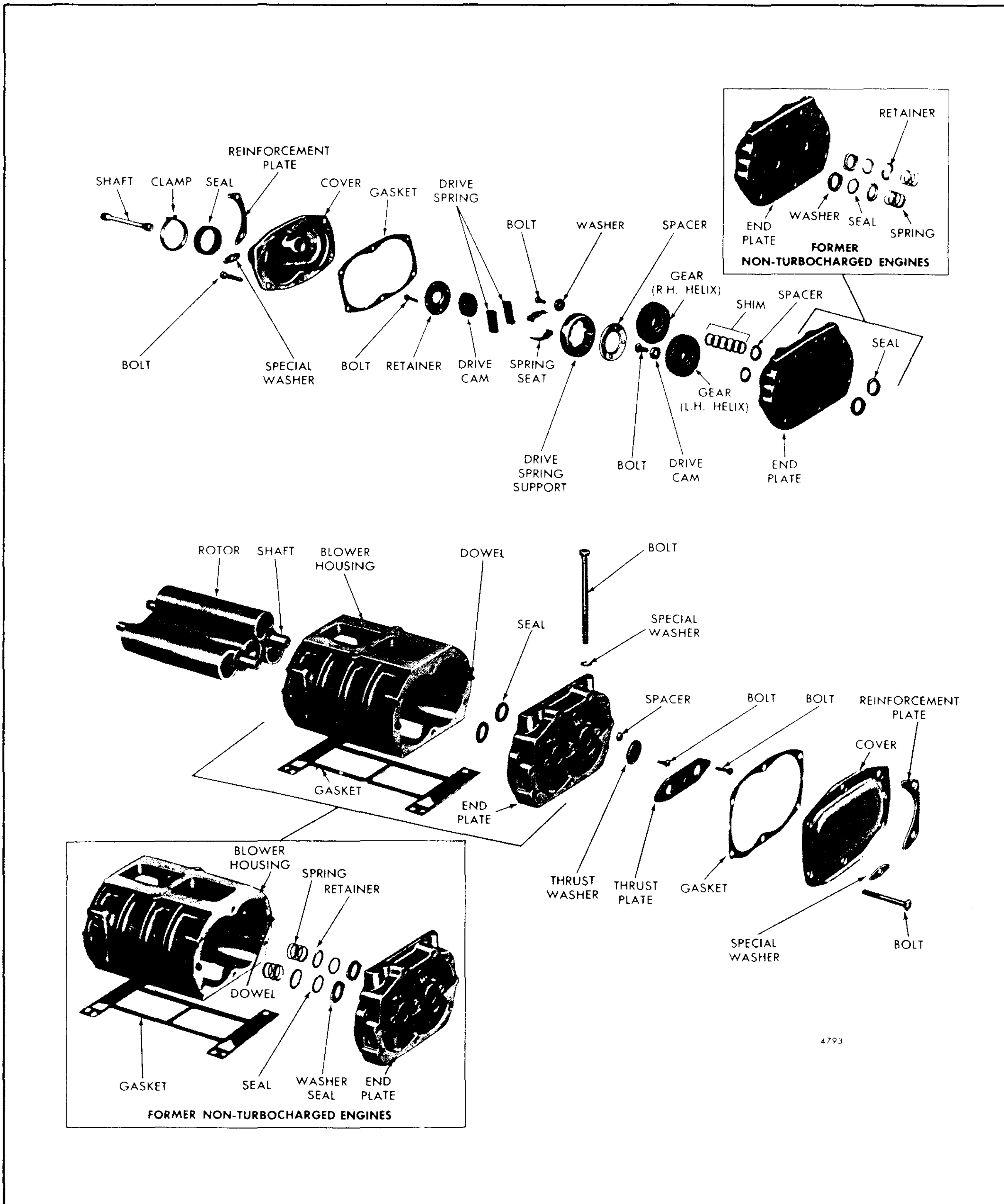


Fig. 8 - Typical Blower Details and Relative Location of Parts (4-53 Engine Blower)

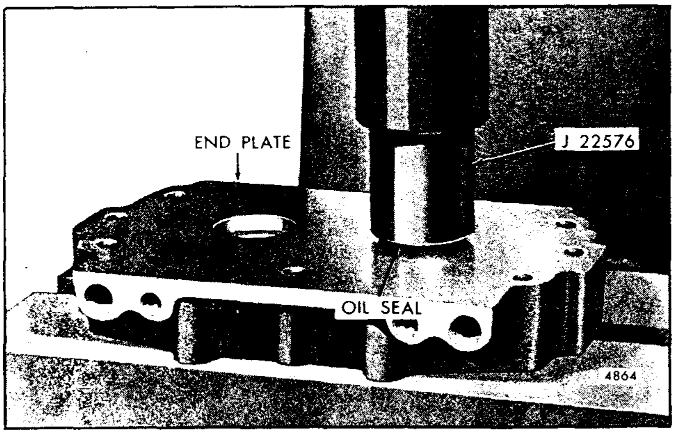


Fig. 9 - Installing Lip Type Oil Seal in End Plate

2. On a 4-53 engine blower, remove the six bolts, special washers and reinforcement plates which secure the rear end plate cover and the rear end plate to the blower housing. Then remove the end plate cover and gasket from the end plate.

NOTE: On the 6V engine, this step is accomplished by removing the governor.

3. Wedge a clean cloth between the rotors to prevent their turning and remove the four bolts that hold the blower drive cam retainer and blower drive spring support to the gear. Separate the retainer, support and spacer from the gear.

NOTE: On the 6V engine, the governor drive plate must also be removed from the opposite gear.

4. On a 4-53 engine blower, remove the retaining bolts and the washer and the blower drive cam pilot from the blower gears. On the 6V engine blower, a cam pilot is used on both gears.

5. For identification, mark the upper gear on the 4-53 blower or the left-hand gear on the 6V blower.

6. Use two pullers J 4794-01 to remove the two gears simultaneously.

7. Remove the rotor shims and the gear spacers and place them with their respective gears to ensure correct re-assembly.

8. At the other end of the blower, remove the three thrust plate bolts, the thrust plate and three spacers from the front end plate. Remove the bolts and thrust washers.

9. Tap the end plate off of the dowel pins and housing with a soft (plastic) hammer, being careful not to damage the mating surfaces of the end plate and the housing.

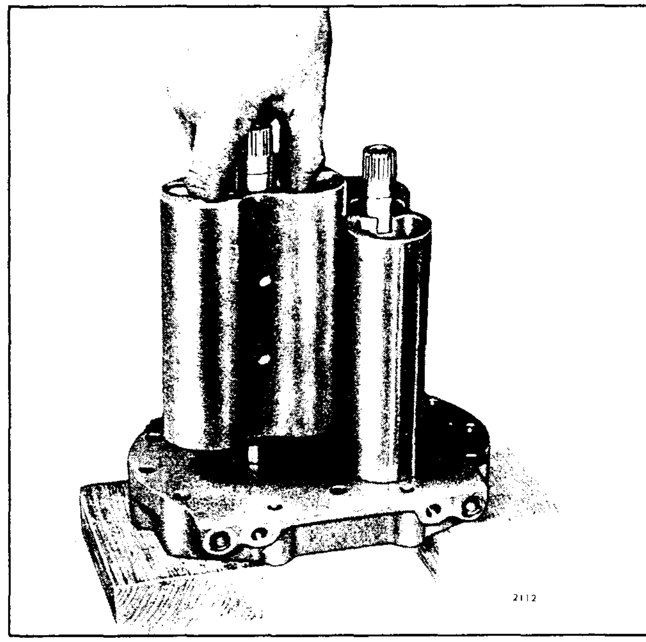


Fig. 10 - Installing Blower Rotors in Front End Plate

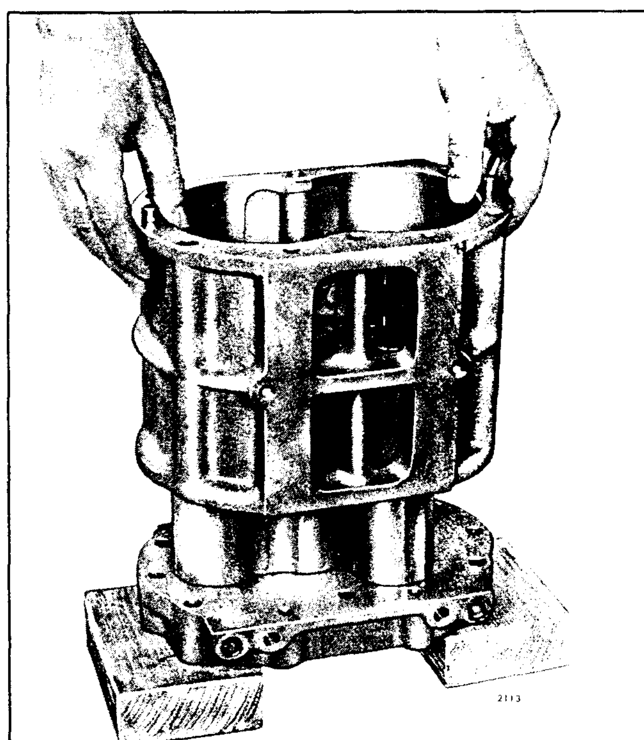


Fig. 11 - Installing Blower Housing Over Rotors

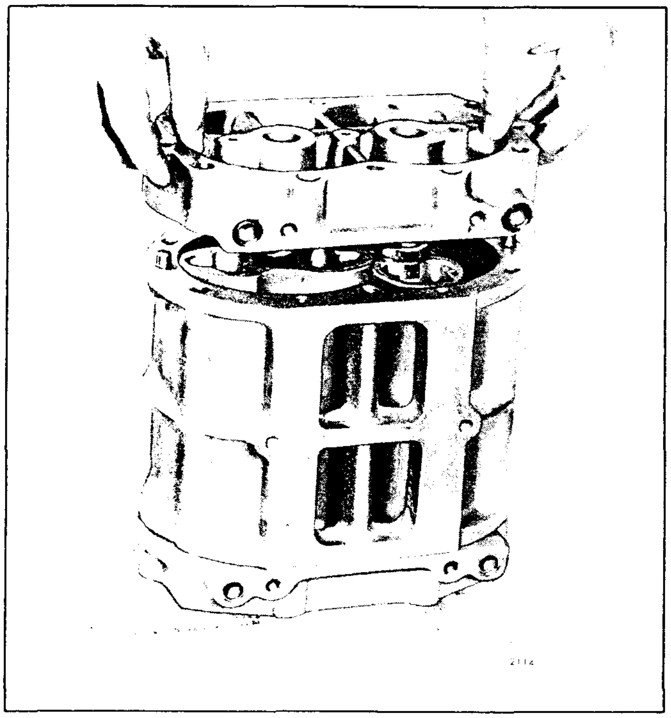


Fig. 12 - Installing Rear End Plate

10. Remove the rotors from the blower housing.

11. Remove the rear end plate as in Step 9.

12. Remove and discard the lip type oil seals from the end plates on current blowers. Remove the seal washer, "O" ring, retainer and retainer spring from each rotor shaft on former blowers.

13. If required, disassemble the blower drive spring support by driving the cam from the support with a brass drift, permitting the springs and spring seats to fall free.

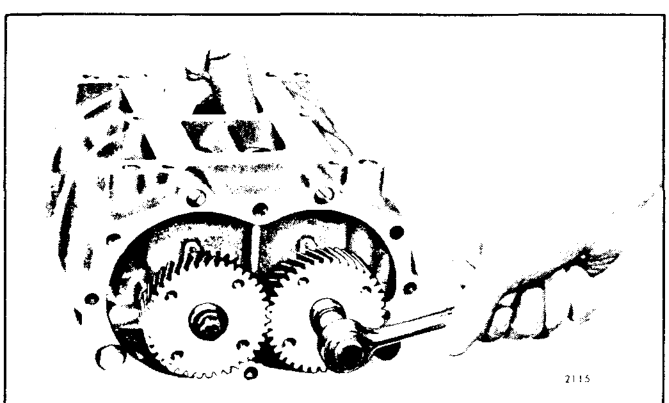


Fig. 13 - Installing Blower Rotor Gears

Inspection

Clean and dry all of the parts thoroughly.

The finished inside face of each end plate must be smooth and flat. Slight scoring may be cleaned up with a fine grit emery cloth. If the surface is badly scored, replace the end plate.

Inspect the surfaces of the rotors and the blower housing. Remove burrs or scratches with an oil stone.

Examine the rotor shaft, gear or drive coupling for burred or worn serrations.

Inspect the blower gears for excessive wear or damage.

Check the bearing and oil seal contact surfaces of the rotor shafts and end plates for scoring, wear or nicks.

If an oil seal sleeve is used on the rotor shaft, it can be replaced as follows:

a. Place sleeve remover J 23679-2 over the rotor shaft and behind the oil seal sleeve.

b. Back out the center screw of one gear puller J 21672-7 and attach the puller to the sleeve remover with three 1/4"-20 x 3" bolts and flat washers.

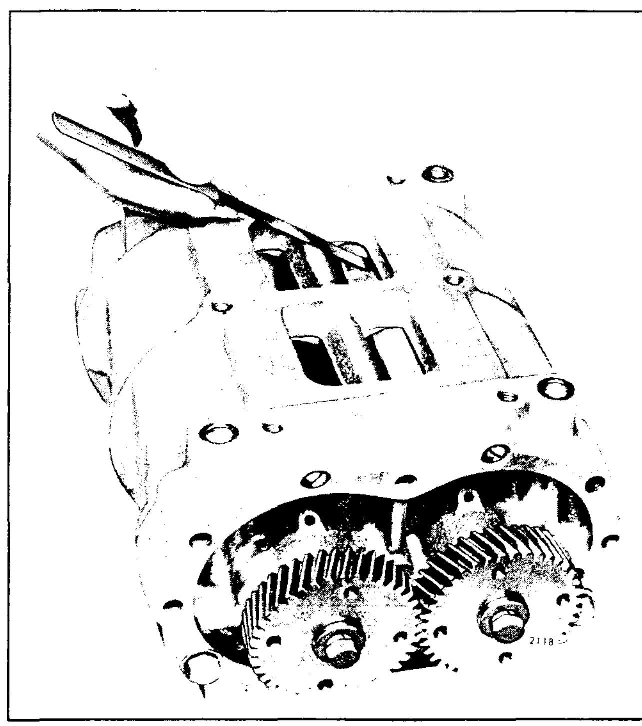


Fig. 14 - Measuring Rotor Lobe to Housing Clearance

c. Turn the puller screw clockwise and pull the sleeve off of the shaft.

d. Support the rotor, gear end up, on the bed of an arbor press.

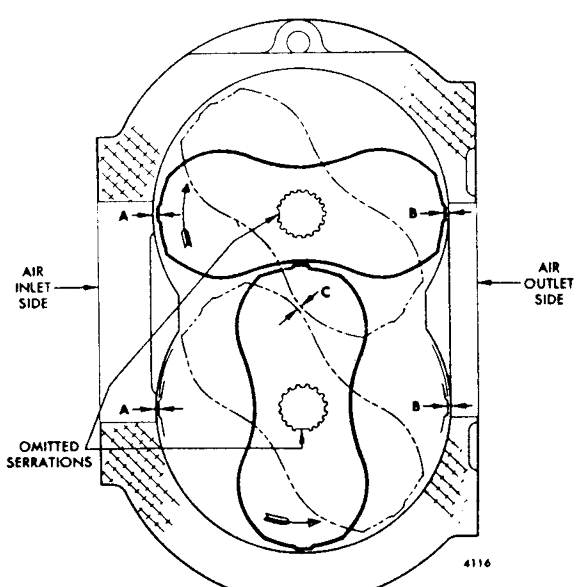
e. Start a new sleeve straight on the shaft.

f. Place sleeve installer J 23679-1 on top of the sleeve and press the sleeve on the shaft until the step in the installer contacts the shoulder on the shaft.

NOTE: The step in the sleeve installer properly positions the sleeve on the shaft.

The rotor assemblies for the 6V engine blower have been revised to permit the use of longer (1-3/4 ") gear retention bolts. The former bolts were 7/8 " long. If a former blower is removed for repair or overhaul, rework the rotor shafts as illustrated in Fig. 6.

To replace the former "0" ring oil seals by the current lip type oil seals, rework the end plates by following the instructions given in *Shop Notes* in Section 3.0.



	A	B	C
2-53	.0075"	.004"	.010"
3-53	.0075"	.004"	.010"
4-53	.0075"	.004"	.010"
6V-53	.010"	.004"	.010"

MINIMUM BLOWER ROTOR CLEARANCES

Fig. 15 - Minimum Blower Rotor Clearance

Assemble Blower

Refer to Figs. 7 and 8 and assemble the blower as follows:

1. Install new lip type oil seals in each end plate in *current blowers* as follows:

a. Place the end plate on the bed of an arbor press.

b. Lubricate the outer diameter of the seal and, using installer J 22576, press the seal (lip facing down) into the counterbored hole until the shoulder on the installer contacts the end plate (Fig. 9).

NOTE: A step on the seal installer will position the oil seal below the finished face of the end plate within the .002 " to .008 " specified.

2. Install the ring type oil seals on the rotor shafts of *former blowers* as follows:

a. Install a retainer spring on each shaft of each rotor. Then place an "0" ring retainer (dished side up) on each spring.

b. Lubricate the "O" rings with clean engine oil, then slide one ring on each shaft.

c. Lubricate and place a seal on each shaft. Note that the tangs on each seal are flush with one side of the seal; this side of the seal must face toward the rotor.

3. Place the front end plate on two wood blocks. Then install the rotors, gear end up, on the end plate (Fig. 10). On the former blowers, be sure that the ring type oil seals are properly positioned on the rotors.

4. Install the blower housing over the rotors (Fig. 11).

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 for the *2 and 3-53 blower* does not have tapped holes for the thrust washer plate bolts and no thrust washer lubricating oil holes. The rear end plate for the *6V-53 blower* does not have tapped holes for the thrust washer plates and is the only cover that has the horizontal oil passage drilled through into the pocket on the left side of the end plate for supplying oil to the blower drive gear support bearing.

5. Place the rear end plate over the rotor shafts (Fig. 12). On the former blowers, be sure that the ring type oil seals are properly positioned on the rotors. Then secure each end plate to the 3-53 blower housing with two end plate retaining screws and two cover

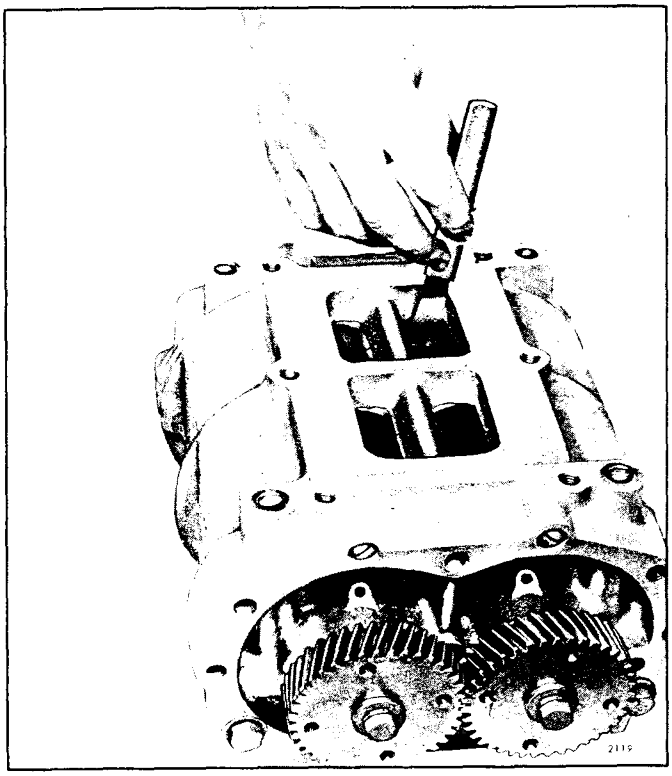


Fig. 16 - Measuring Rotor Lobe to End Plate Clearance

bolts and plain washers. Secure each end plate to the 4-53 or 6V blower with four end plate cover bolts and plain washers.

6. Attach the two thrust washers to the front end of the blower with the washer retaining bolts. If 5/16 ''-24 bolts are used, tighten them to 25-30 lb-ft torque; if 3/8 '' - 24 bolts are used, tighten them to 54-59 lb-ft torque.

7. Attach the three spacers and the thrust plate to the front end of the blower. Tighten the three bolts to 7-9 lb-ft torque. Then check the clearance between the thrust plate and the thrust washers. The specified clearance is .001 '' to .003 ''.

NOTE: The current thrust plate is .260 '' thick. The former plate was .180 '' thick.

8. 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 toward the bottom (Fig. 14). Install the shims and spacers in the counterbore in the rear face of the rotor gears. Then place the gears on the ends of the shafts with the missing serrations in alignment with the missing serrations on the shafts.

9. 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 marks do not match, re-position the gears.

10. Wedge a clean cloth between the blower rotors. Use the gear retaining bolts and plain washers to press the gears on the rotor shafts (Fig. 13). Turn the bolts uniformly until the gears are tight against the shoulders on the shafts.

11. Remove the gear retaining bolts and washers. Then proceed as follows:

2 and 3-53 Blower -- Place the gear washers on the gears and start the gear retaining bolts in the rotor shafts. Tighten the bolts to 25-30 lb-ft torque.

4-53 Blower -- Place the blower drive cam pilot in the counterbore of the upper gear and start the gear retaining bolt in the rotor shaft. Place the gear washer on the face of the lower gear and start the gear retaining bolt in the rotor shaft. Tighten the bolts to 25-30 lb-ft torque.

6V Blower -- Place a pilot in the counterbore of each gear and start the 12-point bolt in the right-hand rotor shaft and start the hex head bolt in the left-hand rotor shaft. Tighten the bolts to 25-30 lb-ft torque.

12. Check the backlash between the blower gears, using a suitable dial indicator. The specified backlash is .0005 '' to .0025 '' with new gears or a maximum of .0035 '' with used gears.

13. Time Blower Rotors

After the blower rotors and gears have been installed, the blower rotors must be timed. When properly positioned, the blower rotors run with a slight clearance between the rotor lobes and 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 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 a single feeler gage. Take measurements from both the inlet and outlet sides of the blower.

a. Measure the clearance between the rotor lobes and

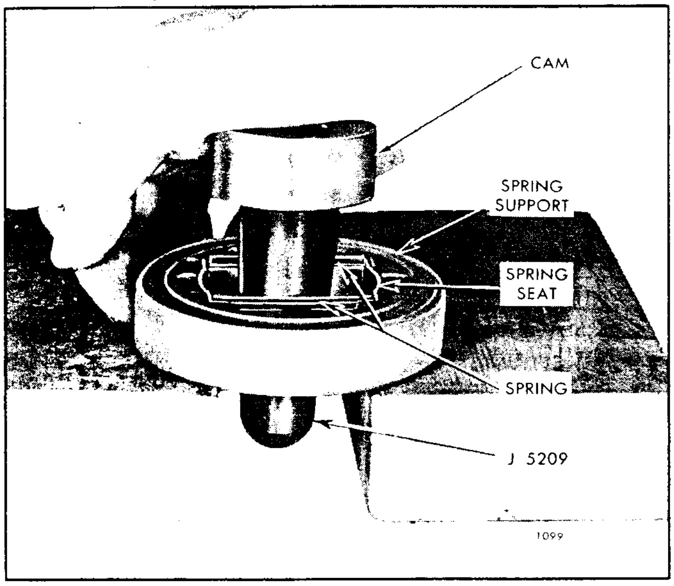


Fig. 17 - Inserting Cam in Blower Drive Support

the housing as shown in Fig. 14. 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 " (in-line engine blower) or .010 " (6V engine blower) exists at the *air inlet side* of the blower (Fig. 15).

b. Measure the clearance between the rotor lobes, across the length of the lobes, in a similar manner. By rotating the gears, position the lobes so that they are at their closest relative position (Fig. 15). The clearance between the lobes should be a minimum of .010 ".

c. Measure the clearance between the end of the rotor and the blower end plate as shown in Fig. 16. Refer to the chart for the required minimum clearances.

NOTE: Push and hold the rotor toward the end plate at which the clearance is being measured.

After timing the rotors, complete assembly of the blower.

14. Remove the bolts and washers used to temporarily secure the front end plate to the housing. Then install the front end plate to the blower with six bolts and special washers and two reinforcement plates and tighten the bolts to 20-25 lb-ft torque.

NOTE: The current front and rear end plate gaskets on the 4-53 engine blower are identical and may be used in either position. Formerly these gaskets were not interchangeable. The gasket used between the blower and the governor housing on the 6V engine is not interchangeable with the front end plate cover gasket.

BLOWER ROTOR END CLEARANCES (Minimum)		
Engine	Front End Plate	Rear End Plate
2-53	.006"	.006"
3-53	.006"	.008"
4-53	.006"	.009"
6V-53	.008"	.012"

15. Assemble the blower drive spring support as follows:

a. Place the drive spring support on two blocks of wood (Fig. 17).

b. Position the drive spring seats in the support.

c. Apply grease to the springs to hold the leaves together, then slide the two spring packs (15 leaves per pack) in place.

d. Place the blower drive cam over the end of tool J 5209, insert the tool between the spring packs and press the cam in place.

16. Install the drive spring support coupling on the rotor gear at the rear end of the blower.

IMPORTANT: Effective with engine serial number 4D-14120, the blower assembly for the 4-53 engine has been revised by the use of a new longer drive gear pilot and the addition of a drive coupling spacer (Fig. 18). Tighten the 5/16 "-24 drive gear pilot bolt to 25-30 lb-ft torque. Prior to the above change, a shorter drive coupling was used and no spacer was required.

NOTE: The coupling is placed on the upper rotor gear on the in-line engine blower and on the left-hand gear on the 6V engine blower. A spacer is placed between the gear and the coupling on the 6V engine blower.

17. Secure the cam retainer to the coupling with four 1/4 "-28 bolts and tighten them to 14-18 lb-ft torque.

18. On the 6V engine blower, install the governor drive plate on the right-hand rotor gear with four bolts and tighten them to 8-10 lb-ft torque.

19. Remove the bolts and washer used to temporarily secure the rear end plate to the 4-53 engine blower. Then install the rear end plate cover and gasket and secure the cover and end plate to the blower with six bolts and special washers and two reinforcement plates and tighten the bolts to 20-25 lb-ft torque.

> **NOTE:** This step is accomplished on the 6V engine blower by securing the governor to the end plate with six bolts.

Install Blower

Examine the inside of the blower for any foreign material. Also revolve the rotors by hand to be sure that they turn freely. Then install the blower on the engine as follows:

3-53 ENGINE BLOWER

1. Affix a new blower-to-block gasket on the side of the cylinder block. Use Scotch Grip Rubber Adhesive No. 4300, or equivalent, only on the block side of the gasket.

2. Position the blower front end plate and gasket on the end of the blower and install six bolts with two special washers on the center bolts and the reinforcement plates on the two top and two bottom bolts. Install a new engine end plate to blower gasket over the threaded ends of the bolts. Apply Scotch Grip Rubber Adhesive No. 4300, or equivalent, to the engine end plate side of the gasket.

> **NOTE:** The current front and rear end plate gaskets are identical and may be used in either position. Formerly these gaskets were not interchangeable due to a difference in thickness.

3. Place the blower on the cylinder block locating flanges and, while holding the blower in place, thread the six bolts finger tight in the rear engine end plate and flywheel housing. Then install the blower-to-block mounting bolts and washers and tighten them to 10-15 lb-ft torque.

4. Tighten the center blower-to-end plate bolts first and then the top and bottom bolts to 20-25 lb-ft torque. Then tighten the blower-to-block bolts to 55-60 lb-ft torque.

5. Check the backlash between the upper rotor gear and the camshaft or balance shaft gear. The backlash should be .003 " to .007 ".

6. Install the air shut-down housing (Section 3.3).

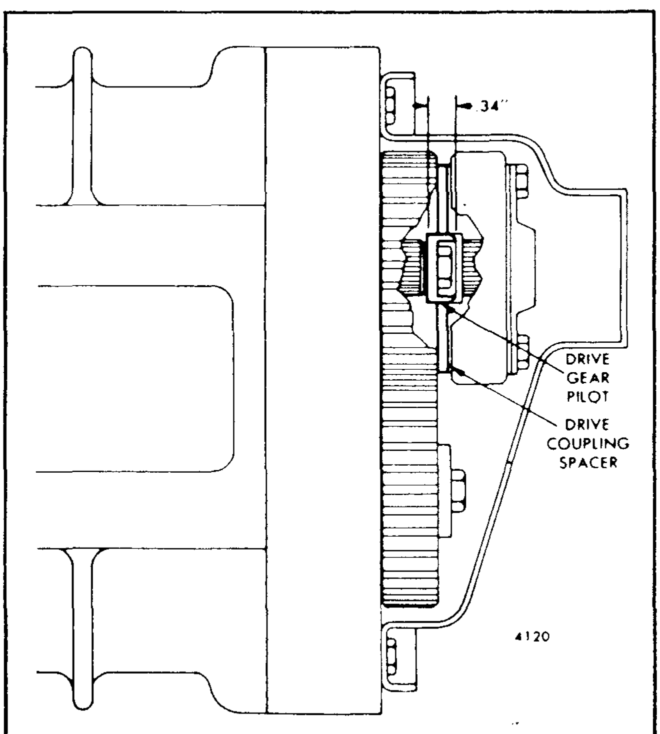


Fig. 18 - Current Pilot and Spacer Used on 4-53 Blower

4-53 ENGINE BLOWER

1. Affix a new blower-to-block gasket on the side of the cylinder block. Use Scotch Grip Rubber Adhesive No. 4300, or equivalent, only on the block side of the gasket.

2. Install the seal and clamp on the blower rear end plate cover.

3. Slide one end of the blower drive shaft into the drive cam.

4. Position the blower on the side of the cylinder block. Use care so that the blower gasket is not damaged or dislocated during installation of the blower.

5. Secure the blower to the cylinder block with bolts and washers. Tighten the bolts to 55-60 lb-ft torque.

6. Slide the seal and clamp back against the blower drive gear support and tighten the clamp to hold the seal in place.

7. Check the backlash between the blower drive gear and the camshaft gear. The backlash should be .003 " to .007 ".

8. Install the air shut-down housing (Section 3.3).

6V-53 ENGINE BLOWER

1. Install a new blower-to-block seal ring and two new blower-to-block gaskets. Affix the gaskets to the cylinder block and engine end plate with Scotch Grip Rubber Adhesive No. 4300, or equivalent.

2. Install the blower and governor assembly on the engine as follows:

a. To install the blower and governor on the engine without disturbing the gaskets and seal, use guide studs (Fig. 4). Install the guide studs in the end blower bolt holes in the cylinder block.

b. While lowering the blower and governor assembly over the guide studs, push the blower away from the governor housing gasket attached to the rear end plate.

c. Remove the guide studs and install the blower to block bolts and flat washers. Tighten the bolts finger tight only.

d. Press or drive the governor housing dowel pin into the rear end plate with a suitable tool.

3. Tighten the blower to block bolts to 10-15 lb-ft torque.

4. Install the blower drive support as follows:

a. Affix a new gasket to the blower drive support.

b. Position the light governor weights (high speed-limiting speed governor) in a horizontal position to provide clearance (Fig. 3). Turn the operating shaft fork away from the blower, if necessary, for additional clearance.

c. Move the blower drive assembly into the openings in the flywheel housing until the blower drive gear enters the housing. Then turn the drive assembly slightly so that the serrated end of the governor weight shaft may pass around behind the governor operating fork, permitting the fork to slip into place between the serrated end of the shaft and the riser bearing.

d. Push the drive support assembly up against the flywheel housing; the serrations in the governor weight shaft and in the governor drive plate on the blower timing gear must mesh. The blower drive gear must also mesh with the mating gear.

5. Secure the small end of the blower drive support to the flywheel housing with two 3/8"-16 bolts and copper washers. Tighten the bolts to 20-25 lb-ft torque.

6. Insert the blower drive shaft into the blower gear shaft. If necessary, turn the crankshaft so that the serrations on the blower drive shaft register with the serrations in the blower drive cam and the blower drive gear shaft.

7. Install the snap ring in the blower drive gear shaft to secure the blower drive shaft.

8. Attach a new gasket to the blower drive support cover. Then secure the cover to the support with four 3/8"-16 bolts and lock washers. Tighten the bolts to 20-25 lb-ft torque.

9. Tighten the blower-to-block bolts to 55-60 lb-ft torque.

10. Insert the upper fuel rods through the fuel rod covers and attach the rods to the governor control link lever.

11. Attach the lower fuel rods to the injector control tube levers and upper fuel rods.

12. Slide the fuel rod cover hoses in place and secure them with hose clamps.

13. Install the spring assembly in the governor.

14. Install the air shut-down housing (Section 3.3).

BLOWER (8V)

The blower, designed especially for efficient diesel operation, supplies the fresh air needed for combustion and scavenging. Its operation is similar to that of a gear-type oil pump. Two hollow three-lobe rotors revolve with very close clearances in a housing mounted between the two banks of cylinders and bolted to the top deck of the cylinder block. To provide continuous and uniform displacement of air, the rotor lobes are made with a helical (spiral) form (Fig. 1).

Two rotor gears, located on the drive end of the rotor shafts, space the rotor lobes with a close tolerance; therefore, as the lobes of the two rotors do not touch at any time, no lubrication is required.

Lip type oil seals located in the blower end plates prevent air leakage and also keep the oil, used for lubricating the rotor gears and rotor shaft bearings, from entering the rotor compartment.

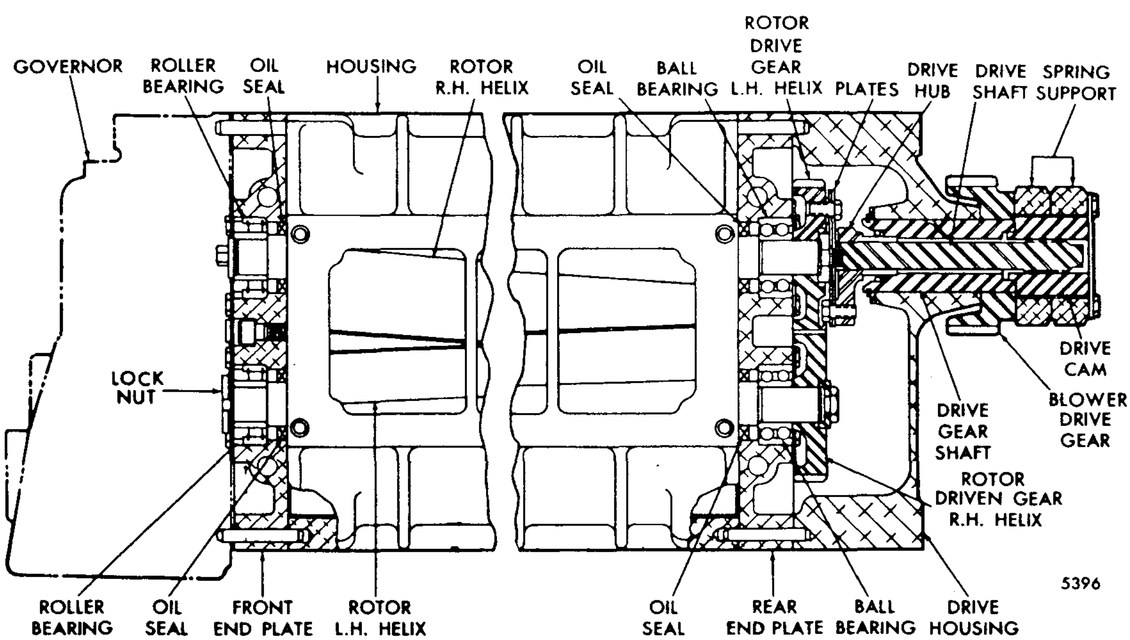
Effective with engine serial number 8D-4508, new blowers are used on the 8V engines. The current blowers differ from the former blowers in that the double-row ball bearings are now in the rear end plate (gear end) rather than the front end plate and the roller bearings are in the front end plate.

On the current blower, new rotors are used which have a counterbore for a cup plug in the balance holes to increase blower efficiency. Each rotor is supported in the end plates by a roller bearing in the front end plate and a two-row ball bearing at the gear end. The oil seal sleeves have been discontinued in the rear position of the non-turbocharged engine blower. The same oil seal is now used in both the front and rear end plates. The oil seal sleeves will continue to be used in both the front and rear end plates (four positions) in the turbocharged engine blower.

The right-hand helix rotor of an 8V blower is driven at approximately twice (2.205:1) engine speed by the blower drive shaft. The blower drive shaft is splined at one end to two flexible couplings attached to the blower drive gear and at the other end to a hub attached to the left-hand helix rotor drive gear. The mating right-hand helix rotor driven gear drives the left-hand helix rotor.

A flexible coupling, formed by an elliptical cam driven by four bundles of leaf springs which ride on four spring seats, is attached to the rear face of the blower drive gear and prevents the transfer of torque fluctuations to the blower.

The blower rotors are timed by the two rotor gears at the rear end of the rotor shafts. This timing must be correct, otherwise the required clearance, obtained by



• Fig. 1 - Current Blower and Drive Assembly the use of shims behind the rotor gears, between the rotor lobes will not be maintained.

Normal rotor gear wear causes a decrease of rotor-to-rotor clearance between the leading edge of the right-hand helix (drive) rotor and the trailing edge of the left-hand helix (driven) rotor. Clearance between the opposite sides of the rotor lobes is increased correspondingly.

While the rotor lobe clearance may be corrected by adjustment, rotor gear backlash cannot be corrected. When rotor gears have worn to the point where the backlash exceeds .004 ", replace the gears.

Lubrication

The blower bearings, rotor gears and governor drive mechanism are pressure lubricated by means of oil passages in the top deck of the cylinder block which lead from the main oil galleries to an oil passage in each blower end plate (Fig. 2). The oil flows upward to the horizontal oil passage in the end plate and leaves through a small orifice just below each bearing bore in the end plate. The oil is ejected from these orifices against the rotor gears at the rear end of the blower and the governor weights at the front end of the blower.

The bearings are splash lubricated by oil thrown by the rotor gears and governor weights. Oil which collects at the bottom of each end plate overflows into two drain passages which lead back to the crankcase via oil passages in the cylinder block.

The blower drive support bearing receives oil under pressure from the horizontal oil passage in the blower rear end plate (Fig. 2) which leads to the oil passage in the blower drive support housing.

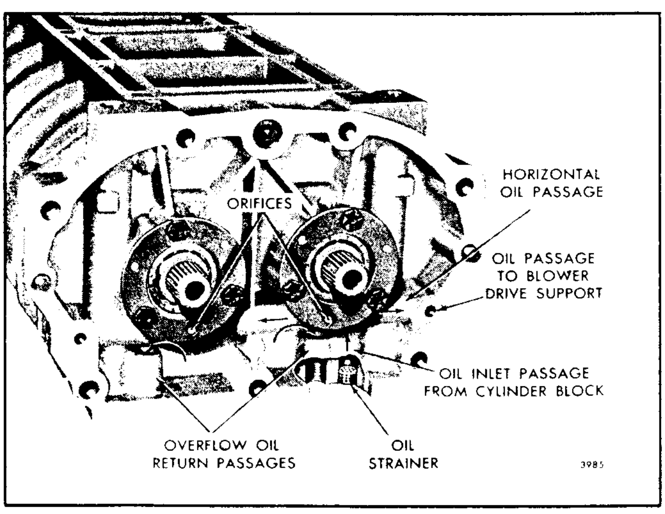


Fig. 2 - Blower Lubrication

Inspection

The blower may be inspected without being removed from the engine. However, the air silencer and adaptor, or the air inlet housing, air shut-down housing and adaptor must first be removed.

> **CAUTION:** When inspecting a blower on an engine with the engine running, keep fingers and clothing away from the 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 badly scored.

Leaky oil seals are usually manifest by the presence of oil on the blower rotors or the 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 seals is indicative of an oil leak.

A worn blower drive usually results in a rattling noise inside the blower and may be detected by grasping the right-hand helix rotor firmly and attempting to rotate it. Rotors may move from 3/8 " to 5/8 ", measured at the lobe crown, with a springing action. When released, the rotors should move back at least 1/4 ". If the rotors cannot be moved as directed above, or if the rotors move too freely, inspect the flexible blower drive coupling and replace it if necessary. The drive

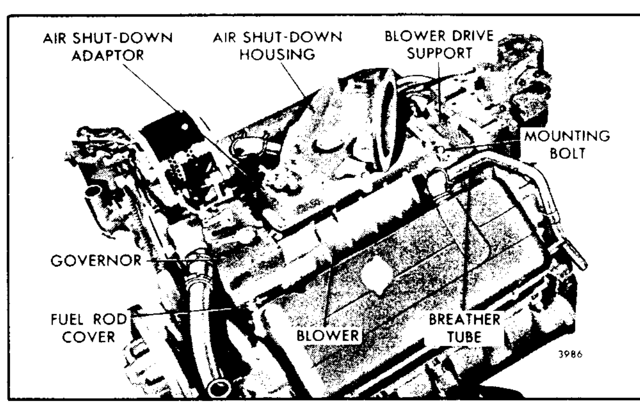


Fig. 3 - Typical Blower Mounting

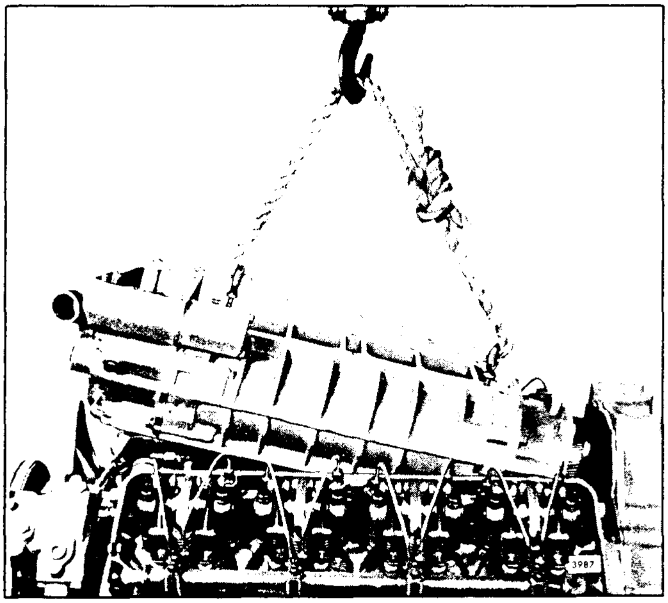


Fig. 4 - Removing Blower From Engine

coupling is attached to the left-hand helix rotor drive gear.

Loose rotor shafts or damaged bearings will cause rubbing and scoring between the crowns of the rotor lobes and the mating rotor roots, between the rotors and the end plates, or between the rotors and the housing. Generally, a combination of these conditions exists. A loose shaft usually causes rubbing between the rotors and the end plates. Worn or damaged bearings will cause rubbing between the mating rotor lobes at some point or perhaps allow the rotor assemblies to rub the blower housing. This condition will usually show up at the end where the bearings have failed.

Excessive backlash between the rotor gears usually results in rotor lobes rubbing throughout their entire length.

Inspect the blower inlet screen periodically for accumulation of dirt which, after prolonged operation, may affect the air flow. Servicing of the screen consists of thoroughly washing it in fuel oil and cleaning it with a stiff brush until the screen is free of all dirt deposits.

To correct any of the above conditions, remove the blower from the engine and either repair or replace it.

Remove Blower

The engine governor components are assembled in a combination governor housing and blower front end plate cover. The blower drive components are assembled in a combination blower drive housing and blower rear end plate cover. Therefore, when removing the blower assembly from the engine, the governor and blower drive support assemblies will also be removed at the same time. Refer to Fig. 1 and proceed as follows:

1. Disconnect the throttle control rods from the governor levers.

2. Remove the six bolts and lock washers securing the air shut-down housing to the air inlet adaptor. Remove the shut-down housing and gasket.

3. Remove the six bolts and lock washers securing the air inlet adaptor to the blower housing. Remove the air inlet adaptor and blower screen and gasket assembly.

4. Loosen the battery-charging generator adjusting strap bolt. Also loosen the nuts on the bolts securing the generator to its mounting bracket. Then remove the generator drive belts from the generator pulley.

5. While supporting the generator, remove the two nuts, lock washers and bolts securing the generator to the generator mounting bracket. Then lift the generator off the engine.

6. Remove the four bolts and lock washers securing the generator mounting bracket to the governor housing.

7. Loosen the governor housing breather tube hose clamp at the forward face of the governor and the breather tube clamp at the water pump attaching bolt. Remove the tube, hose and hose clamps from the governor and the engine.

8. Remove the four bolts and lock washers securing the water by-pass tube to the thermostat housing. Slide the

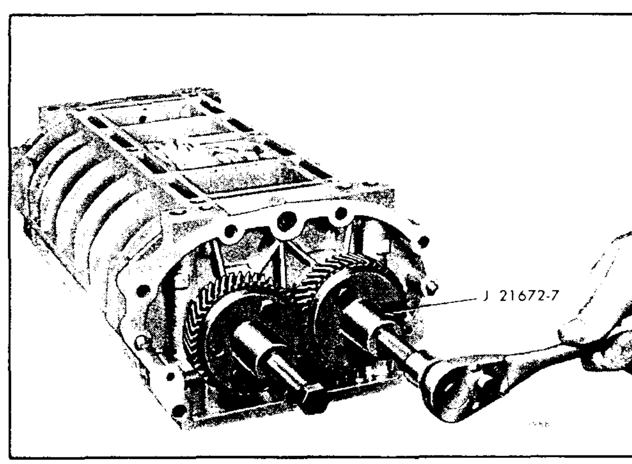


Fig. 5 - Removing Rotor Gears

tube back on one of the thermostat housings, then lift the opposite end of the tube up and remove it from the thermostat housing.

9. Disconnect and remove the fuel oil supply and return lines connecting the fuel manifolds and the cylinder heads.

10. Remove the valve rocker cover breather tube hose clamp on each rocker cover and the tube clamp attached to the rear face of the flywheel housing; then remove the breather tubes from the engine.

11. If an air compressor is attached to the rear face of the flywheel housing, it may be removed as follows:

a. Disconnect the air compressor water inlet and outlet tubes from the air compressor. Then disconnect the oil supply line from the air compressor.

b. While supporting the air compressor, remove the four bolts and lock washers securing the air compressor to the rear face of the flywheel housing. Then remove the air compressor and gasket. If necessary, remove the air compressor drive coupling.

12. Remove the five bolts and lock washers securing the blower drive hole cover to the flywheel housing. Remove the cover and gasket.

13. Remove the two bolts securing the blower drive shaft retainer to the blower drive coupling support, then remove the retainer.

14. Pull the blower drive shaft out of the blower drive hub and cam. If necessary, use a pair of small nose pliers.

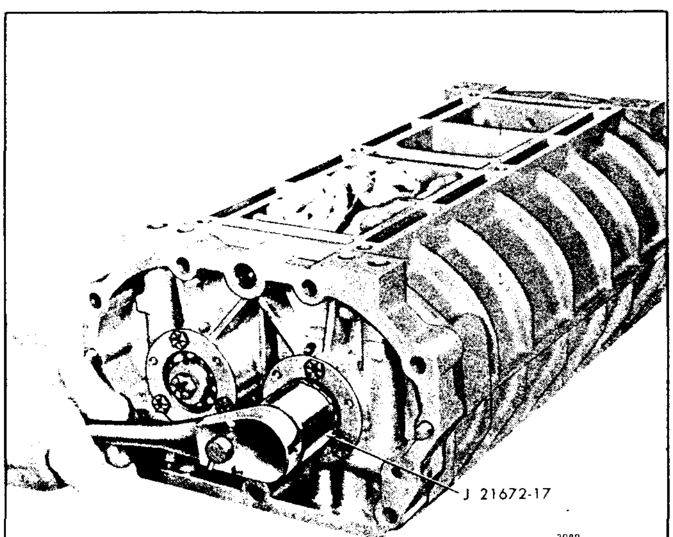


Fig. 6 - Removing Rotor Bearing Retaining Nut

15. Remove the two remaining bolts and flat washers securing the blower drive couplings to the blower drive gear, then remove the blower drive couplings.

16. Remove the five bolts, lock washers and one plain washer securing the blower drive support housing to the engine end plate.

17. Disconnect and remove the fuel oil supply line between the fuel oil pump and the fuel oil filter.

18. Clean and remove the valve rocker cover from each cylinder head.

19. Remove the eight screws and lock washers securing the governor cover to the governor housing.

20. Disconnect the fuel rods from the injector rack control tube levers and the governor and remove the fuel rods.

21. Loosen the hose clamps and slide the fuel rod cover hose down against each cylinder head.

22. Remove the two 7/16"-14 x 7/8" bolts, lock washers and plain washers securing the governor housing to the cylinder block.

23. Remove the two bolts and special washers from each blower end plate securing the blower assembly to the cylinder block.

24. Thread eyebolts in diagonally opposite air inlet adaptor-to-blower bolt holes. Attach a rope sling and a chain hoist to the eyebolts. Then lift the blower assembly, at an angle, from the cylinder block as shown in Fig. 4 and place it on a bench.

Remove Accessories from Blower

Remove the accessories from the blower as follows:

1. Remove the six bolts, lock washers, plain washers and one socket head bolt securing the blower drive support housing to the blower rear end plate.

2. Tap each end of the blower drive support housing with a plastic hammer to loosen it from the gasket and dowel pins. Then remove the drive support assembly and gasket.

3. Remove the three self-locking bolts (current blowers) or four self-locking bolts (former blowers) securing the blower drive hub to the left-hand helix rotor drive gear.

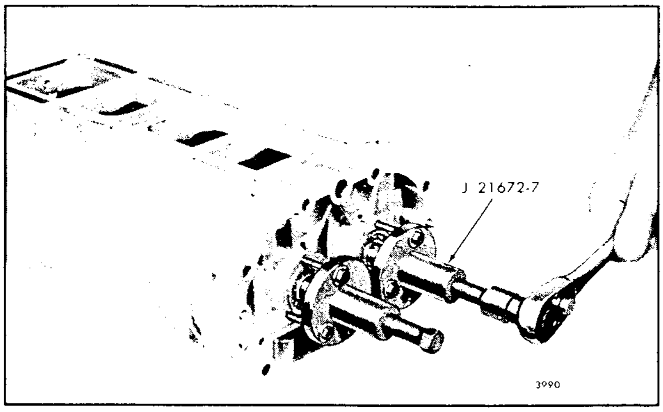


Fig. 7 - Removing Blower Rotors from Front End Plate Ball Bearings (Former Blower)

4. Remove the seven bolts and lock washers securing the breather body to the governor housing. Remove the breather body and gasket.

5. Remove the seven bolts and copper washers, two inside and five outside, securing the governor assembly to the blower front end plate.

6. Tap the governor housing with a plastic hammer to loosen it from the gasket and dowel pins. Then remove the governor assembly and gasket.

Disassemble Blower

Cover the air inlet and outlet openings and clean the exterior of the blower with fuel oil and dry it with compressed air.

Refer to Figs. 3 and 10 and disassemble the blower as follows:

1. Place a clean folded shop towel between the rotors and a towel between the rotor and housing to prevent the rotors from turning.

2. Remove the two bolts and pilots (43) securing the blower rotor gears to the blower rotor shafts.

3. Remove the blower rotor gears with pullers J 21672-7 (Fig. 5). Both rotor gears must be pulled at the same time as follows:

a. Back the center screws out of both pullers, then place the flange end of the pullers against the rotor gears. Align the large holes in the puller flanges with the 3/8 ''-24 tapped holes in the gears. Secure the pullers to the gears with four 3/8 ''-24 x 1 '' bolts.

b. With the shop towels between the blower rotors and housing to prevent them from turning, turn the puller screws uniformly clockwise and pull the gears from the rotor shafts as shown in Fig. 5.

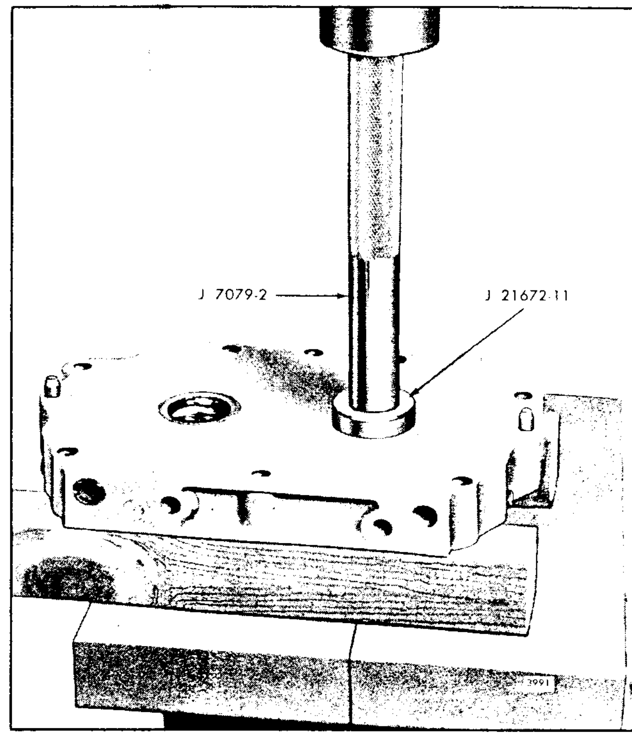


Fig. 8 - Removing Oil Seal and Roller Bearing from Rear End Plate (Former Blower)

4. Remove the shims from the rotor shafts and note the number and thickness of the shims on one or both of the rotor shafts.

5. Remove the bolts securing the rotor shaft bearing retainers (71) to the rear end plate, then remove the retainers.

6. Remove the bolt and special washer (80) securing the ball bearing (former blower) or roller bearing (current blower) on the right-hand helix rotor shaft at the front end of the blower.

7. Bend the tang of the bearing retainer nut lock washer (81) up out of the notch in the bearing lock nut (82). Then remove the bearing lock nut with spanner wrench J 21672-17 as shown in Fig. 6.

8. Remove the bolts securing the rotor shaft bearing retainers to the front end plate, then remove the retainers.

9. Remove the socket head bolt (50) securing the blower rear end plate to the blower housing. Tap each end of the rear end plate with a plastic hammer to

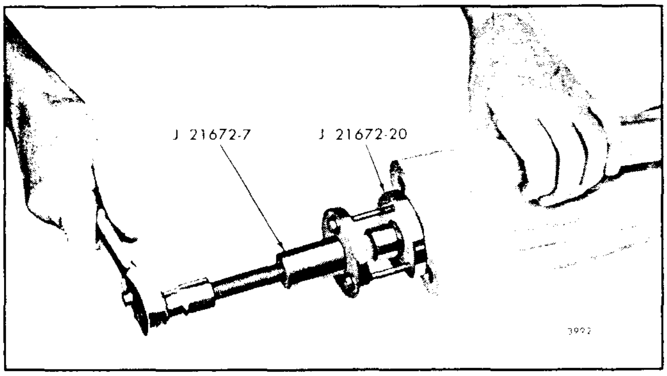


Fig. 9 - Removing Oil Seal Sleeve and Roller Bearing Inner Race from Rotor Shaft

loosen it from the blower housing, then remove the end plate and bearings from the rotor shafts.

10. Remove the blower rotors from the ball bearings (former blowers) and from the roller bearings (current blowers) in the front end plate and the blower housing as follows:

a. Back the center screw out of both pullers J 21672-7, then attach the pullers to the blower front end plate with six 1/4 ″-20 x 1-1/2 ″ or longer bolts as shown in Fig. 7.

b. Remove the shop towels from between the blower rotors and the housing.

c. Turn the puller screws uniformly clockwise and push the rotor shafts out of the ball bearings (former blower) or roller bearings (current blower) in the end plate. Then slide the rotors out of the blower housing.

d. Remove the pullers from the blower front end plate.

11. Remove the socket head bolt securing the blower front end plate to the blower housing. Tap each end of the front end plate with a plastic hammer to loosen it and remove it from the blower housing.

12. Inspect the rotor shaft oil seals. If the seals are scored or hard, remove the bearings and oil seals from the blower end plates as follows:

a. Support the blower end plate, inner face up, on two wood blocks on the bed of an arbor press as shown in Fig. 8.

b. Place the oil seal remover J 21672-11 with handle J 7079-2 on top of the oil seal and under the ram of the press, then press the oil seal and bearing out of the end plate as shown in Fig. 8. Discard the oil seal.

c. Remove the remaining oil seals and bearings from the end plates in the same manner as outlined in items "a" and "b" above.

CAUTION: When the roller bearings are removed from the rear end plate, each bearing must be tagged to be sure it will be installed in the same bearing bore in the end plate that it was removed from.

NOTE: Oil seal sleeves have been discontinued in the rear position of the current non-turbocharged engine blower. The oil seal sleeves will continue to be used in both the front and rear end plates (four positions) in the turbocharged engine blower.

13. If the roller bearings or the oil seal sleeves are to be replaced, the roller bearing inner races and oil seal sleeves may be removed from the rotor shafts as follows:

The roller bearing inner race may be removed separately or the oil seal sleeve and inner race may be removed together.

a. Place the roller bearing inner race and oil seal sleeve remover J 21672-20 over the rotor shaft behind the oil seal sleeve as shown in Fig. 9.

b. Back out the center screw of one gear puller J 21672-7, then attach the puller to the oil seal sleeve remover with three 1/4 ″-20 x 3 ″ bolts and flat washers as shown in Fig. 9.

c. Turn the puller screw clockwise and pull the roller bearing inner race and oil seal sleeve off of the rotor shaft.

d. Remove the roller bearing inner race and oil seal sleeve from the remaining rotor shaft.

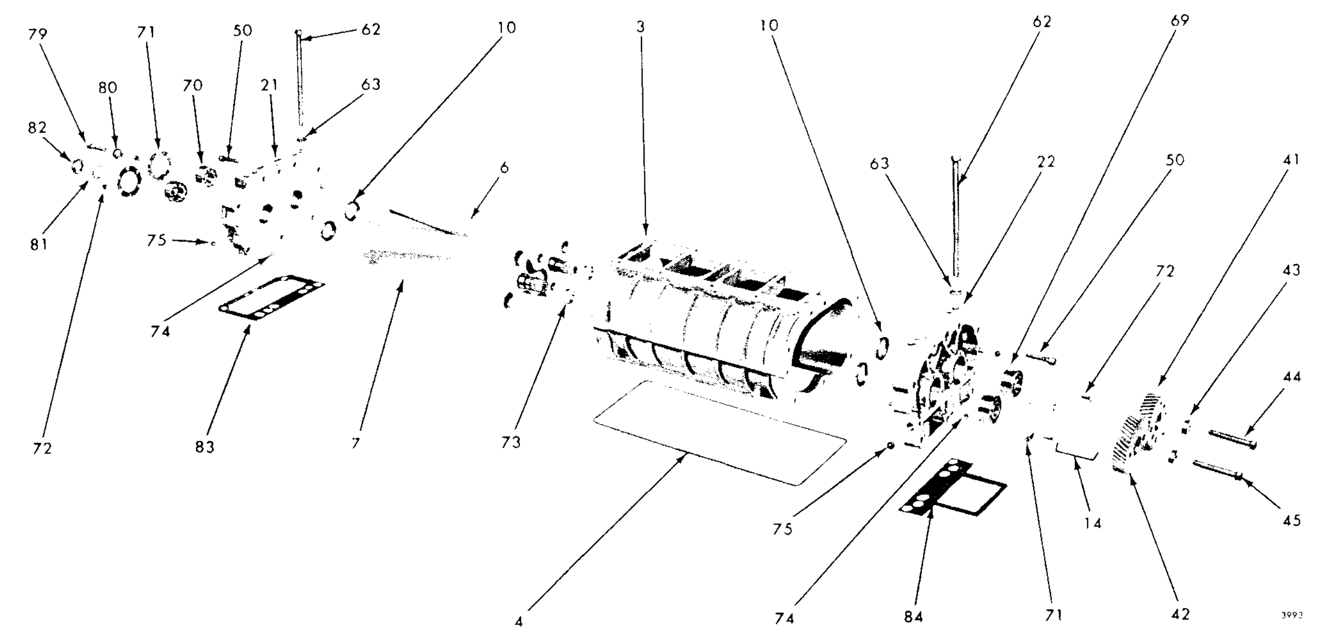
CAUTION: Be sure and tag or place each roller bearing inner race with its mating roller bearing. Do not intermix the inner races and roller bearings.

Inspection

Wash all of the blower parts in clean fuel oil and dry them with compressed air.

Examine the bearings for any indications of corrosion or pitting. Lubricate each bearing with light engine oil. Then while holding the bearing inner race from turning, revolve the outer race slowly by hand and check for rough spots.

The double-row ball bearings are pre-loaded and have



3. Housing--Blower
4. Gasket
6. Rotor Assy.--R.H. Helix
7. Rotor Assy.--L.H. Helix
10. Oil Seal--Rotor Shaft
14. Shims
21. Plate--Front End
22. Plate--Rear End
41. Gear--Rotor Drive L.H. Helix
42. Gear--Rotor Driven R.H. Helix
43. Pilot--Rotor Gear
44. Bolt--Drive Gear
45. Bolt--Driven Gear
50. Bolt--Socket Head
62. Bolt--Blower-to-Block
63. Washer--Special
69. Bearing--Rotor Rear (Roller)
70. Bearing--Rotor Front (Ball)
71. Retainer--Bearing
72. Bolt--Bearing Retainer
73. Sleeve--Oil Seal
74. Strainer--End Plate Oil Passage
75. Plug--Pipe
79. Bolt
80. Washer
81. Lock Washer
82. Nut
83. Gasket
84. Gasket

Fig. 10 - Blower Details and Relative Location of Parts (8V-53) (Former Blower)

no end play. A new double-row bearing will seem to have considerable resistance to motion when revolved by hand.

Examine the rotor shafts and the oil seal sleeves (used on former blowers and turbocharged engine blowers) for wear.

Inspect the blower rotor lobes, especially the sealing ribs, for burrs and scoring. If the rotors are slightly scored or burred, they may be cleaned up with emery cloth.

Examine the rotor shaft serrations for wear, burrs or peening. Also inspect the bearing contact surfaces of the shafts for wear and scoring.

Inspect the inside surface of the blower housing for burrs and scoring. If the inside surface of the housing is slightly scored or burred, it may be cleaned up with emery cloth.

Check the finished ends of the blower housing for flatness and burrs. The end plates must set flat against the blower housing.

The finished inside face of each end plate must be smooth and flat. If the finished face is slightly scored or burred, it may be cleaned up with emery cloth.

Examine the serrations in the blower rotor gears for wear and peening; also check the teeth for wear, chipping or damage. If the gears are worn to the point where the backlash between the gear teeth exceeds .004 " or damaged sufficiently to require replacement, both gears must be replaced as a set.

> **NOTE:** The left-hand helix rotor drive gear in the current blower has three bolt holes. The gear in the former blower has four bolt holes. This is due to the bolting arrangement (three bolt holes current drive hub, four bolt holes former drive hub) of the drive hub.

Check the blower drive shaft serrations for wear or peening. Replace the shaft if it is bent.

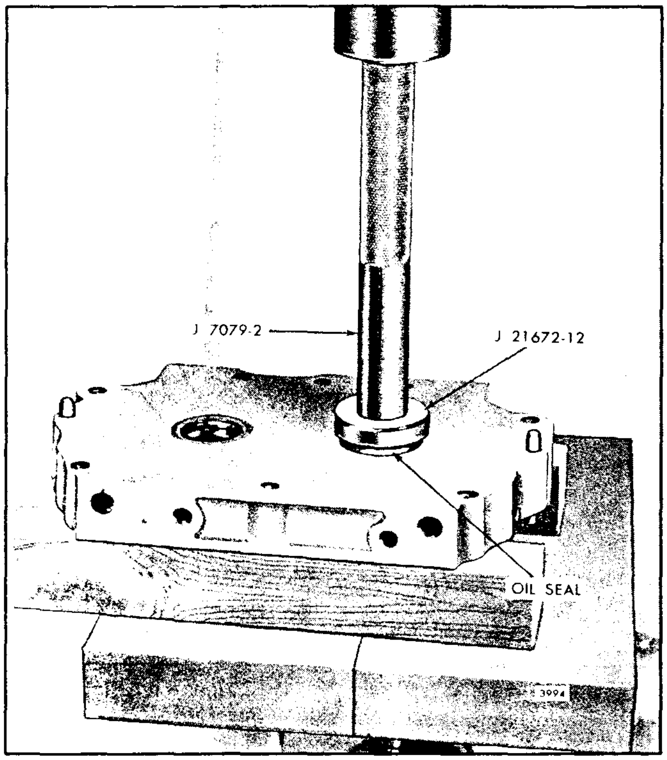


Fig. 11 - Installing Oil Seal in Rear End Plate (Former Blower)

Inspect the blower drive coupling springs (pack) and the cam for wear.

Replace all worn or excessively damaged blower parts.

Clean the oil strainer in the vertical oil passage at the bottom of each blower end plate and blow out all oil passages with compressed air.

Assemble Blower

The lobes on the *driving* blower rotor form a right-hand helix and the teeth on its gear form a left-hand helix while the lobes on the *driven* blower rotor form a left-hand helix and the teeth of its gear form a right-hand helix. Hence, a rotor with right-hand helix lobes must be used with a gear having left-hand helix teeth and vice versa.

> **NOTE:** New rotors with a different helix angle have been incorporated in the 8V engine blowers. The former and new rotors must not be mixed in a blower assembly. The proper clearances cannot be obtained in a mix of the former and new rotors.

With this precaution in mind, proceed with the blower

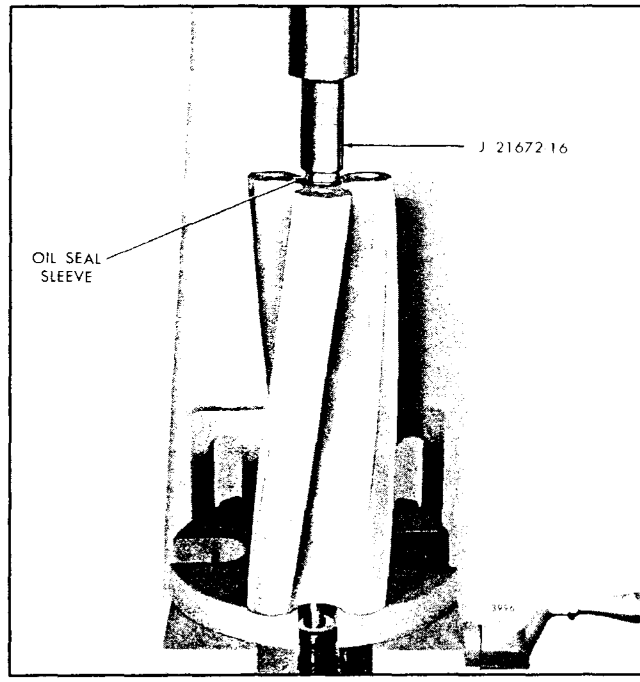


Fig. 12 - Installing Oil Seal Sleeve on Rotor Shaft (Former Blower)

assembly, referring to Figs. 10 through 20 as directed in the text:

1. If removed, press a new oil strainer into the vertical oil passage at the bottom of each end plate from flush to .015 " below the bottom surface (Fig. 2). Also, if removed, install a pipe plug in the horizontal oil passage at each end of both end plates.

2. Install new oil seals in the blower end plates as follows:

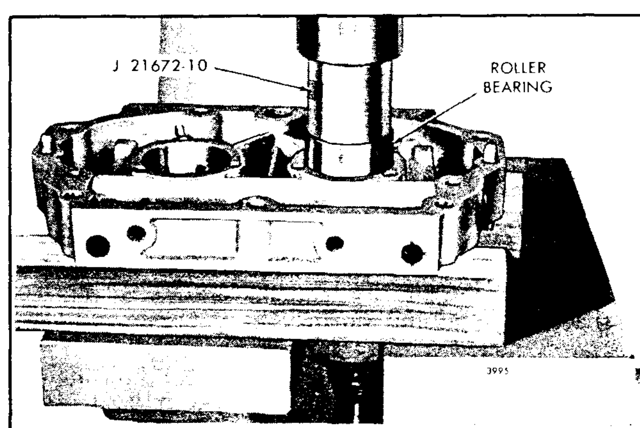


Fig. 13 - Installing Roller Bearing in Rear End Plate (Former Blower)

a. Support the blower rear end plate, finished surface facing up, on wood blocks on the bed of an arbor press.

CAUTION: The rotor shaft oil seals used in the former blower end plates have two different inside diameters. Install the oil seal with the largest inside diameter in the former blower rear end plate. On current blowers, the oil seal sleeves have been discontinued in the rear position, therefore the same oil seal is now used in both the front and rear end plates.

NOTE: The rear end plate may be identified by the bolt guide sleeve pressed into the right-hand bolt hole in the bottom of the end plate.

b. Start the large inside diameter oil seal straight into the bore in the rear end plate with the lip of the seal facing down (toward the bearing bore).

c. Place the oil seal installer J 21672-12 with handle J 7079-2 on top of the oil seal as shown in Fig. 11. Then press the oil seal straight into the end plate until the shoulder on the installer contacts the end plate.

d. Install the second oil seal in the rear end plate and the oil seals in the front end plate in the same manner.

NOTE: The oil seals must be flush to .010" below the finished surface of the end plate.

3. If removed, install the rear end plate oil seal sleeve and the roller bearing inner race on the gear end of each blower rotor shaft as follows:

a. Support the blower rotor, gear end up, on the bed of an arbor press as shown in Fig. 12.

b. Start the oil seal sleeve straight on the sleeve surface of the shaft.

c. Place the oil seal sleeve installer J 21672-16 on top of the oil seal sleeve. Then press the sleeve on the shaft until the step in the installer contacts the shoulder on the shaft.

NOTE: The step in the installer properly positions the oil seal sleeve on the rotor shaft.

d. Install the remaining oil seal sleeve on the shaft of the second blower rotor.

e. Press a roller bearing inner race on the gear end of each blower rotor shaft with installer J 21672-16.

CAUTION: When installing a roller bearing

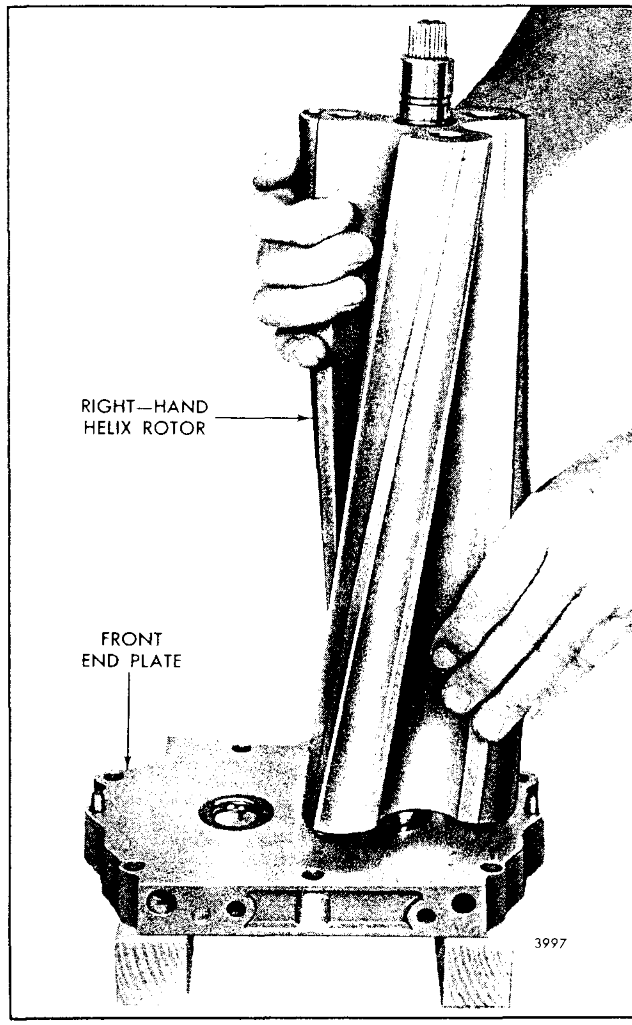


Fig. 14 - Installing Blower Rotor in Front End Plate

inner race, note the tags previously placed on the bearings and races at the time of removal and install the bearing inner races, numbered end up, on the rotor shafts in their original positions. Do not intermix the races and bearings.

4. Install the roller bearings in the rear end plate as follows:

a. Support the rear end plate (inner face down) on two wood blocks on the bed of an arbor press as shown in Fig. 13.

NOTE: The rear end plate may be identified by the bolt guide sleeve pressed into the right-hand bolt hole in the bottom of the end plate.

b. Lubricate the outside diameter of a roller bearing with engine oil. Note the tag previously placed on

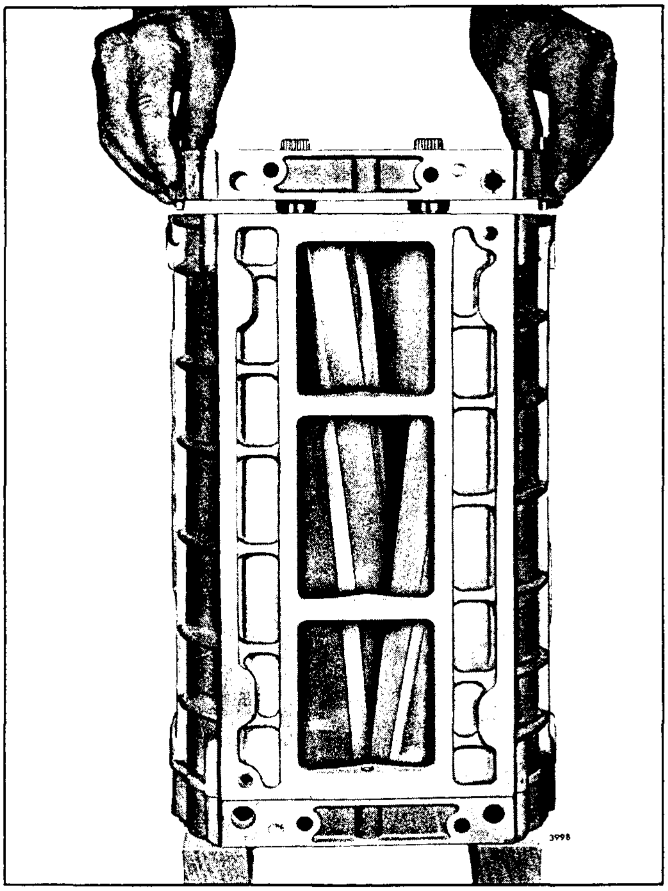


Fig. 15 - Installing Rear End Plate on Blower Rotors and Mounting

the bearing at the time of removal, then start the bearing, numbered end up, straight into the bearing bore in the end plate.

CAUTION: Be sure the bearing installed in the end plate will mate with its inner race on the rotor shaft.

c. Place the bearing installer J 21672-12 on top of the roller bearing, then press the bearing straight into and against the shoulder in the end plate.

d. Install the remaining roller bearing in the rear end plate in the same manner.

5. Install the blower rotors in the front end plate.

The rotors must be assembled in the blower housing with the omitted serrations in the rotor shafts aligned as shown in Fig. 20.

The front end plate should be attached to the front end of the blower housing first. The rear end plate is attached to the blower housing after the rotors are in place. The front end plate does not incorporate the bolt guide sleeve in the counterbored bolt hole in the bottom of the end plate. Install the blower rotors in the front end plate as follows:

a. Check the dowel pins. The dowel pins must project .380 " from the flat inner face of the front end plate to assure proper alignment of the end plate with the housing.

b. Hold the right-hand helix rotor in a vertical position, gear end up, with the omitted serration in the splines of the shaft facing to the right as shown in Fig. 20. Then start the end of the shaft straight into the oil seal in the right-hand shaft opening in the end plate as shown in Fig. 14 and lower it until the lobes of the rotor contact the end plate.

c. Position the left-hand helix rotor so the lobes of the rotors are in mesh and the omitted serration in the splines of the rotor shaft is facing in the same direction as the omitted serration in the right-hand helix rotor shaft. Then start the end of the shaft straight into the oil seal in the left-hand shaft opening in the end plate and lower it until the lobes contact the end plate.

6. Position the blower housing over the rotors, rear end of housing up, with the bottom of the housing facing toward the bottom of the end plate (Fig. 15). Lower the housing over the rotors and start it straight on the dowel pins in the front end plate, then push it down tight against the end plate. If necessary, tap the housing lightly with a plastic hammer.

NOTE: The blower housing is marked **REAR** near the top on the outside face of the housing and must be at the gear end of the rotors when assembled to the front end plate.

7. Install the blower rear end plate on the rotor shafts and housing as follows:

a. Check the dowel pins. The dowel pins must project .380 " from the flat inner face of the rear end plate to assure proper alignment of the end plate with the housing.

b. Lubricate the inside diameter of the roller bearings with engine oil.

c. Position the rear end plate over the top of the rotor shafts with the inner face of the end plate facing the rotors and the **TOP** side of the end plate facing the top side of the blower housing.

d. Lower the end plate straight over the rotor shafts until the dowel pins in the end plate contact the blower housing (Fig. 15), then carefully work the dowel pins into the dowel pin holes in the housing

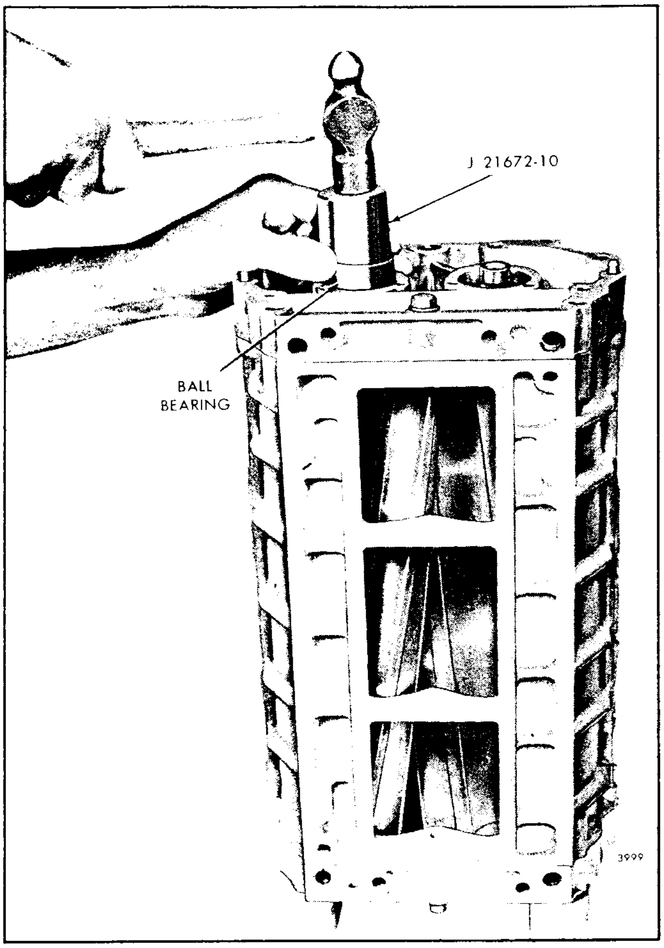


Fig. 16 - Installing Ball Bearings on Rotor Shafts and in Front End Plate (Former Blower)

and push the end plate tight against the housing. If necessary, tap the end plate lightly with a plastic hammer.

e. Install the 3/8"-16 socket head bolt in the counterbored bolt hole at the top of the end plate. Then install a 3/8"-16 hex head bolt with a flat washer in the center bolt hole at the bottom of the end plate.

f. Place the bearing retainers on top of the bearings and the end plate, then install the retainer bolts. Tighten the bolts to 7-9 lb-ft torque.

8. Reverse the blower housing, rotors and end plates on the wood blocks.

9. Install a 3/8"-16 socket head bolt in the counterbored bolt hole at the top of the end plate. Then install a 3/8"-16 hex head bolt with a flat washer in the center bolt hole at the bottom of the end plate.

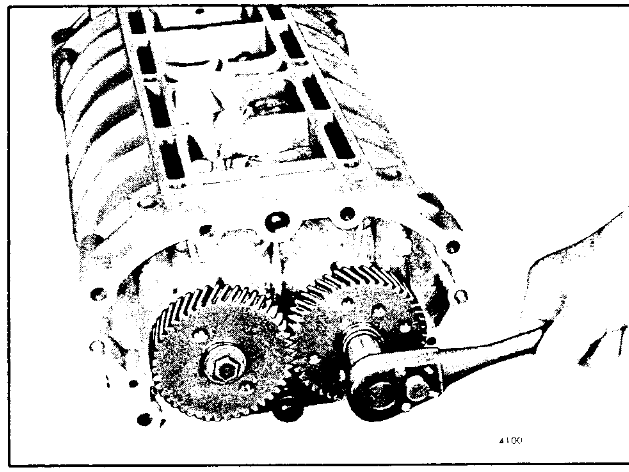


Fig. 17 - Installing Blower Rotor Gears

10. Install the ball bearings on the blower rotor shafts and in the front end plate as follows:

a. Lubricate one of the ball bearings with light engine oil. Start the bearing, numbered end up, straight on one of the rotor shafts.

b. Place installer J 21672-10 on top of the bearing and tap the bearing straight on the shaft and into the front end plate as shown in Fig. 16.

c. Install the second ball bearing on the remaining rotor shaft in the same manner.

d. Place the bearing retainers on top of the bearings and the end plate, then install the retainer bolts. Tighten the bolts to 7-9 lb-ft torque.

11. Place the blower assembly on a bench and make a preliminary check of the rotor-to-end plate and rotor-to-housing clearances at this time with a feeler gage as shown in Fig. 21. Refer to Fig. 19 for minimum blower clearances.

12. Install the blower rotor gears on the rotor shafts as follows:

a. Place the blower assembly on the bench, with the top of the housing up and the rear end (serrated end of rotor shafts) of the blower facing the outside of the bench.

b. Rotate the rotors to bring the omitted serrations on the shafts in alignment and facing to the right (Fig. 20).

c. Install the same number and thickness of shims on the rotor shafts that were removed at the time of disassembly.

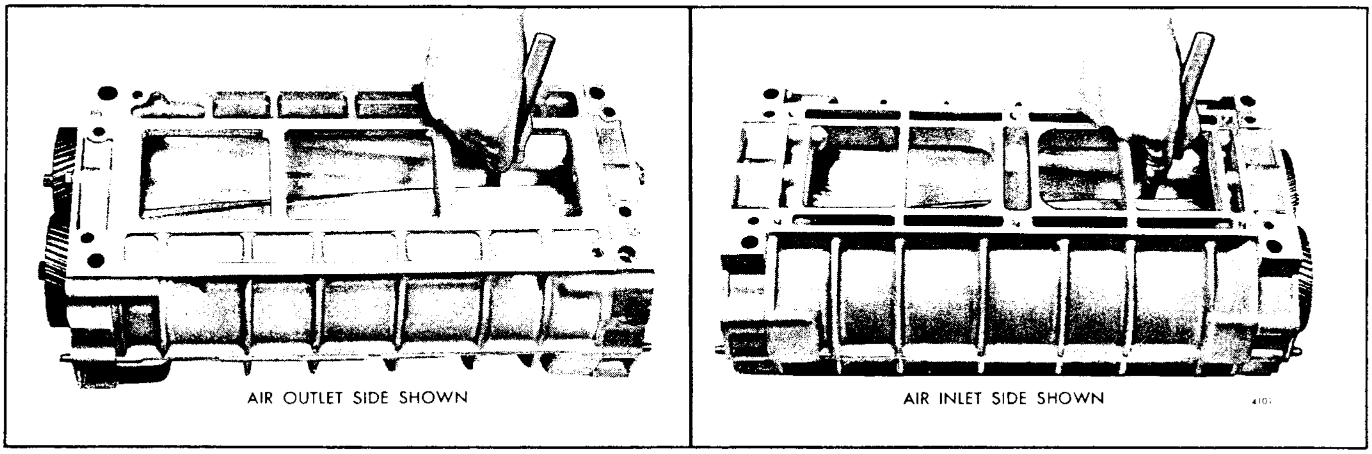
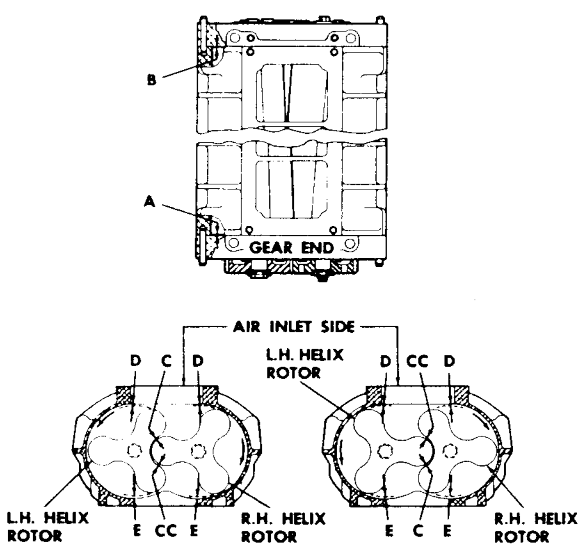


Fig. 18 - Measuring Clearance Between Blower Rotor Lobes

d. Lubricate the serrations of the rotor shafts with light engine oil.

e. Place the teeth of the rotor gears in mesh so that the omitted serrations inside the gears are in alignment and facing the same direction as the serrations on the shafts.



	A	B	C	CC	D	E
MIN.	.007"	.017"	.018"	.008"	.017"	.005"
• MIN.	.014"	.007"	.018"	.008"	.017"	.005"

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NOTE: Time rotors to dimensions on above chart for clearance between trailing side of R.H. Helix Rotor and leading side of L.H. Helix Rotor (cc) from both inlet and outlet side of blower.

***Use these clearances for blowers with ball bearings at the front and the roller bearings at the (rear) gear end.**

• Fig. 19 - Chart of Minimum Blower Clearances

NOTE: A center punch mark placed in the end of each rotor shaft at the omitted serrations will assist in aligning the gears on the shafts.

f. Start the left-hand helix gear on the right-hand helix rotor and the right-hand helix gear on the left- hand helix rotor, with the omitted serrations in the rotor gears in line with the omitted serrations on the rotor shafts.

g. Place the rotor gear pilots (43) on two 3/8 "-24 x 2-3/4 " bolts, then thread a bolt into the end of each rotor shaft. Place a clean shop towel between the rotors and one between the rotor and the housing (Fig. 17) to prevent the gears from turning. Then draw the gears approximately half-way on the rotor shafts.

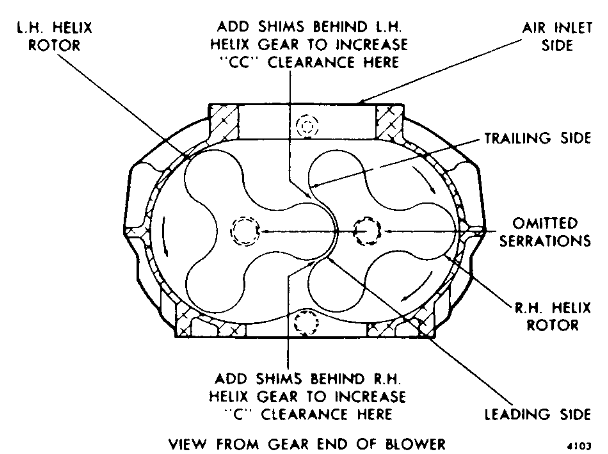


Fig. 20 - Diagram Showing Proper Location of Shims for Correct Rotor Lobe Clearances

h. Remove the two bolts and pilots that were used to draw the rotor gears half-way on the rotor shafts.

i. Lubricate the threads of the rotor gear retaining bolts with engine oil.

j. Place a pilot on each rotor gear retaining bolt with the counterbored side facing away from the bolt head.

k. Thread the hex head bolt in the left-hand helix rotor shaft and the twelve point head bolt in the right- hand helix rotor shaft and draw the rotor gears into position tight against the shims and the bearing inner races as shown in Fig. 17. Tighten the bolts to 50-55 lb-ft torque.

l. Check the back lash between the rotor gears. The backlash should be .0005 " to .0025 " with new gears. Replace the gears if the backlash exceeds .0035 ".

13. Install the 3/8 "-24 x 2 " bolt with special flat washers in the right-hand helix rotor shaft at the front end of the blower. Tighten the bolt to 50-55 lb-ft torque.

14. Place the bearing retainer nut lock washer over the end of the left-hand rotor shaft with the tang in the inner diameter of the washer in the notch in the shaft. Then thread the bearing lock nut on the shaft. Tighten the lock nut to 50-60 lb-ft torque with spanner wrench J 21672-17.

15. Bend the tang of the lock washer over the notch of the bearing retainer nut.

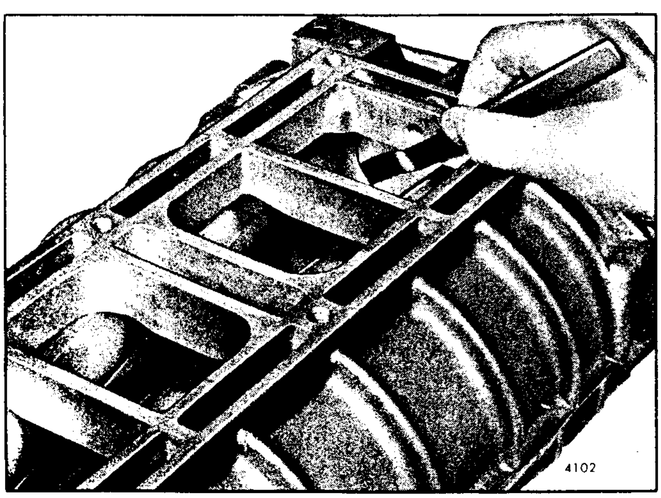


Fig. 21 - Measuring End Clearance Between Blower Rotors and End Plate

Timing Blower Rotors

After the blower rotors and rotor gears are installed, the blower rotors must be timed.

1. The blower rotors, when properly positioned in the housing, run with a slight clearance between the lobes. This clearance may be varied by moving one of the helical gears in or out on the shaft relative to the other gear.

2. If the left-hand helix gear is moved out, the right-hand helix rotor will turn clockwise when viewed from the gear end. If the right-hand helix gear is moved out, the left-hand helix rotor will turn counterclockwise when viewed from the gear end. This positioning of the gear, to obtain the proper clearance between the rotor lobes, is known as blower timing.

3. Moving the gears *out* or *in* on the rotor shafts is accomplished by adding or removing shims between the gears and the bearings.

4. The clearance between the rotor lobes may be checked with 1/2 " wide feeler gages in the manner shown in Fig. 18. When measuring clearances of more than .005 ", laminated feeler gages that are made up of .002 ", .003 " or .005 " feeler stock are more practical and suitable than a single feeler gage. Clearances should be measured from both the inlet and outlet sides of the blower.

5. A specially designed feeler gage set J 1698-02 for the blower clearance operation is available. Time the rotors as follows:

a. Time the rotors to pass an .008 " feeler gage at the closest point between the *trailing* edge of the right-hand helix rotor and the *leading* edge of the left-hand helix rotor ("CC" clearance) measured from both the inlet and outlet sides as shown in Figs. 18 and 21.

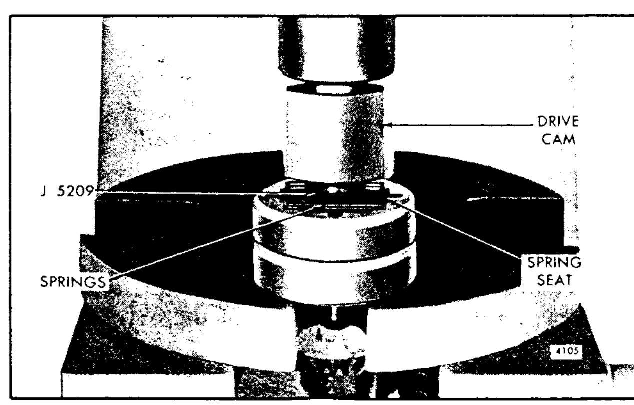


Fig. 22 - Inserting Blower Drive Cam in Springs

b. Then check the clearance between the *leading* edge of the right-hand helix rotor and the *trailing* edge of the left-hand helix rotor ("C" clearance) for the minimum clearance of .018 ". Rotor-to-rotor measurements should be taken 1 " from each end and at the center of the blower.

6. After determining the amount one rotor must be revolved to obtain the proper clearance, add shims back of the proper gear as shown in Fig. 20 to produce the desired result. When more or less shims are required, both gears must be removed from the rotors. Placing a .003 " shim in back of a rotor gear will revolve the rotor .001 ".

7. Install the required thickness of shims back of the proper gear and next to the bearing inner race and reinstall both gears. Recheck the clearances between the rotor lobes.

8. Determine the minimum clearances at points "A" and "B" shown in Fig. 19. Insert the feeler gages, as shown in Fig. 21, between the end plates and the ends of the rotors. This operation must be performed at the ends of each lobe, making 12 measurements in all. Refer to Fig. 19 for the minimum clearances.

9. Check the clearance between each rotor lobe and the blower housing at both the inlet and outlet side -- 12 measurements in all. Refer to Fig. 19 for the minimum clearances.

Attach Accessories to Blower

On the former blowers, the drive hub is attached to the left-hand helix gear with four bolts. On the current blowers, a new drive hub is used with three bolt holes and utilizing two steel plates. The plates are bolted between the left-hand helix rotor drive gear and the drive hub to provide a flexible drive connection. On former blowers, the right-hand helix rotor gear is separately interchangeable, but the current drive hub and attaching parts must be included to replace the left-hand helix rotor gear.

1. On the former blower, attach the blower drive hub to the left-hand helix rotor gear with four bolts. On the current blower, bolt two steel plates between the left-hand helix rotor drive gear and the drive hub. Tighten the bolts to 15-19 lb-ft torque.

2. If removed, install the blower drive hub oil seal in the groove in the outside diameter of the drive hub.

3. Attach the blower drive support assembly to the blower assembly as follows:

a. Affix a new gasket to the blower rear end plate. Then place the blower drive support assembly over the two dowel pins in the rear end plate and against the gasket.

b. Attach the blower drive support assembly to the rear end plate with six bolts, lock washers, plain washers and one socket head bolt. Tighten the bolts to 20-24 lb-ft torque.

4. Attach the governor assembly to the blower assembly as follows:

a. Affix a new gasket to the blower front end plate.

b. Position the governor assembly in front of the blower, then start the weight shaft straight into the end of the rotor shaft. If necessary, rotate the weight shaft or rotor shaft to align the splines. Now push the governor assembly on the dowel pins in the end plate and against the gasket.

c. Attach the governor to the front end plate with seven bolts and copper washers (two bolts inside and five outside). Tighten the bolts to 20-24 lb-ft torque.

Install Blower

1. Affix a new governor housing gasket (83), Fig. 10, to the cylinder block.

2. Affix a new blower drive support housing gasket (84) to the cylinder block. Also affix a new gasket to the cylinder block rear end plate.

> **NOTE:** Use Scotch Grip Rubber adhesive No. 4300, or equivalent, on the governor housing and blower drive support housing gaskets to prevent them from slipping when the blower assembly is lowered into position.

3. Place the blower housing-to-cylinder block seal ring in the groove in the top of the cylinder block.

4. If removed, place a fuel rod cover tube hose and clamp on each fuel rod cover tube at the side of each cylinder head.

5. Thread eyebolts in two diagonally opposite tapped holes in the top of the blower housing. Then attach a rope sling and a chain hoist to the eyebolts as shown in Fig. 4.

6. Lift the blower assembly at a slight angle and position it over the top of the cylinder block. Then lower the assembly on the cylinder block and mesh the blower drive gear with the camshaft gear.

7. Install two 7/16 "-14 x 7-1/2 " bolts and special

washers in each blower end plate. Tighten the bolts to 60-65 lb-ft torque.

8. Install the two 7/16 "-14 x 7/8 " governor housing-to-cylinder block bolts and copper washers. Tighten the bolts to 46-50 lb-ft torque.

9. Install the five blower drive support housing-to-engine end plate bolts, lock washers and one plain washer. Tighten the bolts to 20-24 lb-ft torque.

10. If disassembled, install the springs and blower drive cam in the two blower drive coupling supports as follows:

a. Place the drive spring supports on a bench. Then place the drive spring seats inside the support.

b. Lubricate the springs with engine oil. Then place the spring packs, consisting of 15 leaves per pack, in between the spring seats as shown in Fig. 22.

c. Place the second drive spring support on top of the first drive spring support, then install the spring seats and spring packs in the second support as outlined in Steps "a" and "b" above.

d. Place the two drive spring supports, with springs, over a small opening in the bed of an arbor press so the spring seats and the ends of the spring packs will rest on the bed of the arbor press.

e. Place the blower drive cam, the protruding end of the cam down, over the end of the installer J 5209. Insert the tapered end of the installer in between the spring packs and under the ram of the press, then press the cam into place between the spring packs as shown in Fig. 22. Catch the installer by hand after it passes through the spring packs.

11. Attach the blower drive coupling supports to the blower drive gear as follows:

a. Insert the blower drive coupling supports through the opening in the rear face of the flywheel housing, with the protruding end of the drive cam facing the drive shaft (Fig. 1).

b. Align the bolt holes in the supports with the holes in the blower drive gear, then thread two bolts with flat washers in two diametrically opposite holes, finger tight only. Install the two remaining bolts finger tight only.

c. Insert the blower drive shaft, flat end first, through the blower drive cam and into the blower drive hub. Then tighten the two bolts with the flat washers to 8 - 10 lb-ft torque.

d. Check the blower drive shaft for alignment and freeness by sliding the shaft in and out of the splines in the drive hub and cam. If the drive shaft binds, loosen the two bolts with flat washers and move the blower drive support coupling slightly and retighten the bolts.

e. Remove the two bolts without the flat washers. Place the blower drive shaft retainer against the end of the blower drive support, then install the two bolts and tighten them to 8-10 lb-ft torque.

12. Affix a new gasket to the blower drive gear hole cover, then place the cover in position against the flywheel housing and install the five bolts and lock washers. Tighten the 5/16 "-18 bolts to 13-17 lb-ft torque and the 3/8 "-16 bolt to 20-24 lb-ft torque.

13. Slide the fuel rod cover tube hoses up on the cover tubes in the governor housing and tighten the hose clamps.

14. Install the governor fuel rods and connect them to the governor and injector rack control levers.

15. Place the governor cover on the governor housing and secure it in place with eight screws and lock washers.

16. Connect the fuel oil supply line to the fuel oil pump and the fuel oil filter.

17. Connect the fuel oil supply and return lines to the fuel manifold fittings in the cylinder heads.

18. Place the water by-pass tube with seal rings and flanges in between the two thermostat housings and secure it in place with four bolts and lock washers. Tighten the bolts to 7-9 lb-ft torque.

19. Connect the blower housing breather tube and hose to the breather housing with a hose clamp, then attach the tube clamp at the lower end of the tube to one of the water pump attaching bolts.

20. Attach the air compressor (if used) to the engine flywheel housing as follows:

a. Affix a new gasket to the bolting flange of the air compressor.

b. Install the air compressor drive coupling in the drive plate attached to the rear face of the camshaft gear.

c. Place the air compressor in position at the rear of the flywheel housing and guide the teeth on the drive coupling into the teeth in the drive plate on the air compressor, then push the air compressor against the flywheel housing. If necessary, rotate the crankshaft to align the teeth of the drive coupling and the drive plate.

d. Install the four bolts and lock washers and tighten them to 71-75 lb-ft torque.

e. Connect the water inlet and outlet tubes to the air compressor. Then connect the oil supply line to the air compressor and the cylinder block.

21. If removed, attach the battery-charging generator mounting bracket to the top of the governor housing with four bolts and lock washers. Tighten the bolts to 30-35 lb-ft torque.

22. Attach the battery-charging generator to the mounting bracket. Install the generator drive belts, then tighten the generator mounting bolts and adjust the drive belt tension.

23. Use new gaskets and install a valve rocker cover on each cylinder head.

24. Attach a valve rocker cover breather tube to each rocker cover with a hose clamp, then secure the breather tube clamp at the lower end of each tube to the flywheel housing.

25. Place the blower screen and gasket assembly in position on top of the blower, with the screen side of the assembly toward the blower. Then place the air inlet adaptor on the blower screen. Install the six bolts and lock washers and tighten them to 16-20 lb-ft torque.

26. Affix a new gasket to the top of the air inlet adaptor, then place the air shut-down housing on top of the gasket. Install the six bolts and lock washers and tighten them to 16-20 lb-ft torque.

27. Connect the throttle control rods to the governor levers.

28. Attach any other accessories that were removed from the engine.

29. Adjust the governor and injector rack control levers as outlined in Section 14. Check for and repair any coolant or oil leaks detected when performing the tune-up.

TURBOCHARGER (Airesearch)

The TE0675 turbocharger (Figs. 1 and 2) is designed to increase engine efficiency and power output. Power to drive the turbocharger is extracted from the waste energy in the engine exhaust gas.

The turbocharger consists of a turbine wheel and shaft, a compressor wheel, a center housing which serves to support the rotating assembly, bearings, seals, a turbine housing and a compressor housing.

The turbine wheel is located in the turbine housing and is mounted on one end of the turbine shaft. The compressor wheel is located in the compressor housing and is mounted on the opposite end of the turbine wheel shaft to form an integral rotating assembly.

The rotating assembly consists of the turbine wheel and shaft assembly, thrust ring, thrust spacer, compressor wheel and wheel retaining nut. The rotating assembly is supported on two pressure lubricated bearings which are retained in the center housing by retaining rings. Internal oil passages are drilled in the center housing to provide lubrication to the turbine wheel shaft bearings and thrust bearing, thrust ring and thrust spacer.

The oil is sealed off from the compressor and the turbine by seal arrangements at both ends of the center housing. Oil drains from the center housing by gravity.

The turbine housing is a heat resistant alloy casting which encloses the turbine wheel and provides a flanged engine exhaust gas inlet and an axially-located turbocharger exhaust gas outlet. The turbine housing is bolted to the turbine end of the center housing, thus providing a compact and vibration free assembly.

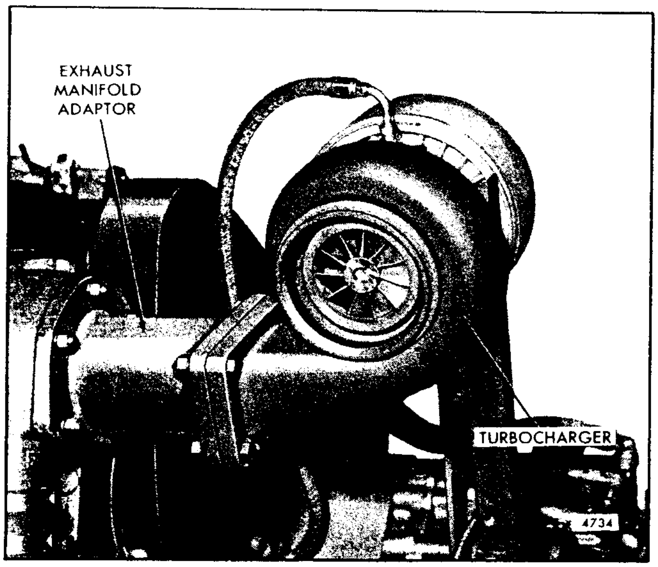


Fig. 1 - Turbocharger Mounting

The compressor housing which encloses the compressor wheel provides an ambient air inlet and a compressed air discharge outlet. The compressor housing is bolted to the compressor end of the center housing.

Operation

The turbocharger is mounted on the exhaust outlet flange of the engine exhaust manifold. After the engine is started, the exhaust gases flowing from the engine and through the turbine housing cause the turbine wheel and shaft to rotate (Fig. 3). The gases are discharged into the atmosphere after passing through the turbine housing.

The compressor wheel, which is mounted on the opposite end of the turbine wheel shaft, rotates with the turbine wheel. The compressor wheel draws the ambient air into the compressor housing, compresses the air and delivers it to the engine blower.

During operation, the turbocharger responds to the engine load demands by reacting to the flow of the engine exhaust gases. As the power output of the engine increases, the flow of exhaust gases increases and the speed and output of the rotating assembly increases proportionately, delivering more air to the engine blower.

Certain engines are equipped with an intercooler to

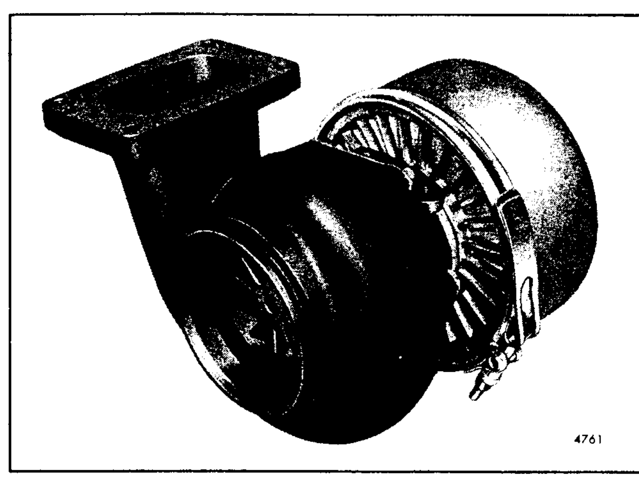


Fig. 2 - Turbocharger Assembly

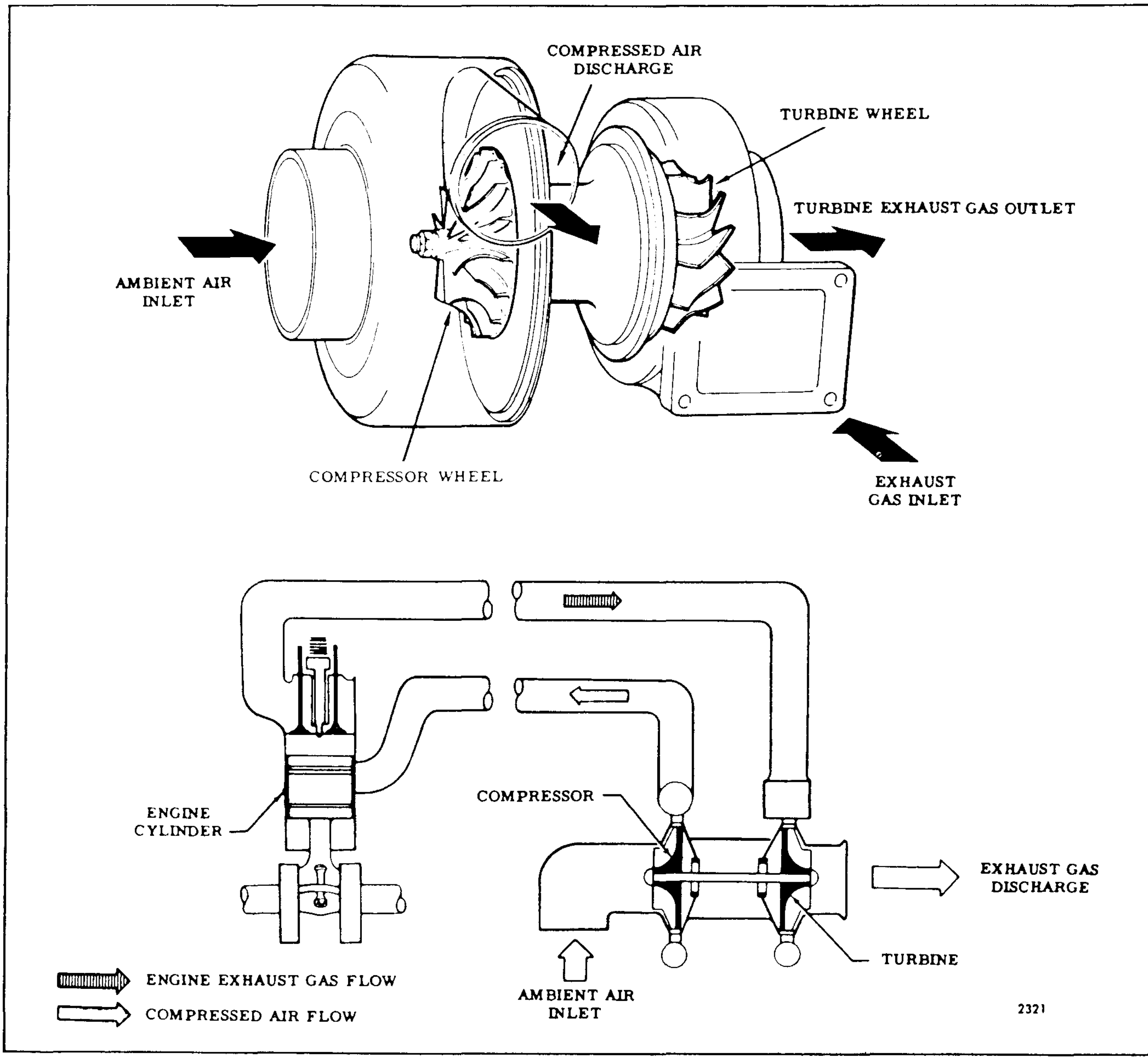


Fig. 3 - Schematic Flow Diagram

reduce the temperature of the discharge air from the turbocharger before it enters the engine blower (Section 3.5.2).

Lubrication

Lubricating oil for the turbocharger is supplied under pressure through an external oil line extending from the engine cylinder block to the top of the center housing. From the oil inlet in the center housing, the oil flows through the drilled oil passages in the housing to the shaft bearings, thrust ring, thrust bearing and thrust plate. The oil returns by gravity to the engine oil pan through an external oil line extending from the bottom of the turbocharger center housing to the side of the cylinder block.

Minimum oil flow to the turbocharger with the engine at idle is achieved at 10 psi with an oil temperature of 200 °F.

Before the initial engine start, when a new or overhauled turbocharger is installed, the turbocharger must be pre-lubricated as outlined under *Install Turbocharger.*

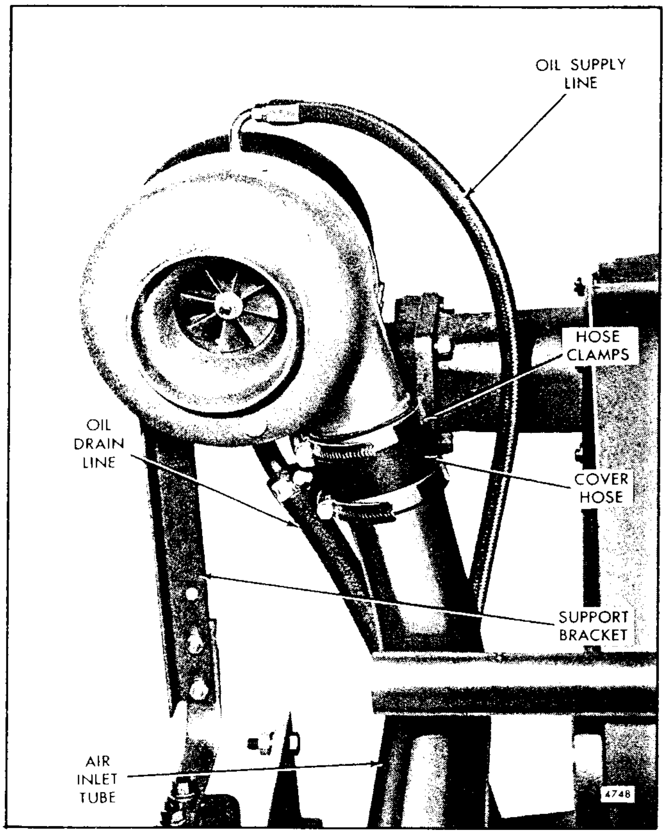


Fig. 4 - Turbocharger Support Bracket, Oil Lines and Air Inlet Tube

Periodic Inspection

A periodic inspection of the turbocharger should be made along with periodic engine inspection.

1. Inspect the oil inlet and oil return lines to make certain all of the connections are tight and the lines are not dented, restricting the flow of oil to and from the center housing.

> **CAUTION:** Be sure the oil lines are filled with oil. Refer to *Install Turbocharger*.

2. Inspect all of the air ducting and connections for leaks. Make the inspection both with the engine running and shut down. Check for leaks at the manifold connection, the turbine inlet and the exhaust manifold gasket.

> **CAUTION:** Do not operate the turbocharger if leaks are found in the ducting or if the air cleaner is not filtering efficiently. Dust leaking into the air ducting can damage the turbocharger and the engine.

3. Remove the air inlet duct and compressor housing and check for dirt or dust build-up. Remove all such foreign matter and determine and correct the cause. Refer to *Troubleshooting Turbocharger* in Section 3.0. Uneven deposits left on the compressor wheel can affect the balance and cause premature bearing failure.

> **NOTE:** It is not necessary to disassemble the turbocharger center housing and rotating assembly to remove dirt and dust build-up.

4. With the compressor housing removed, push the compressor wheel toward the turbine end and turn the rotating assembly by hand. Check for binding or rubbing. Listen carefully for unusual noises. If binding or rubbing is evident, remove the turbocharger for disassembly and inspection.

Remove Turbocharger

1. Refer to Fig. 4 and remove the turbocharger support bracket.

2. Disconnect the oil supply line and the oil drain line from the turbocharger.

3. Cover the end of each oil inlet and oil outlet line and the air inlet and exhaust outlet openings on the engine to prevent the entrance of foreign material.

4. Loosen the two hose clamps securing the cover hose to the turbocharger and the air inlet tube and slide the cover hose down over the inlet tube.

5. Remove the four bolts, nuts and lock washers securing the turbocharger to the exhaust manifold adaptor and remove the turbocharger and gasket. Refer to Fig. 1.

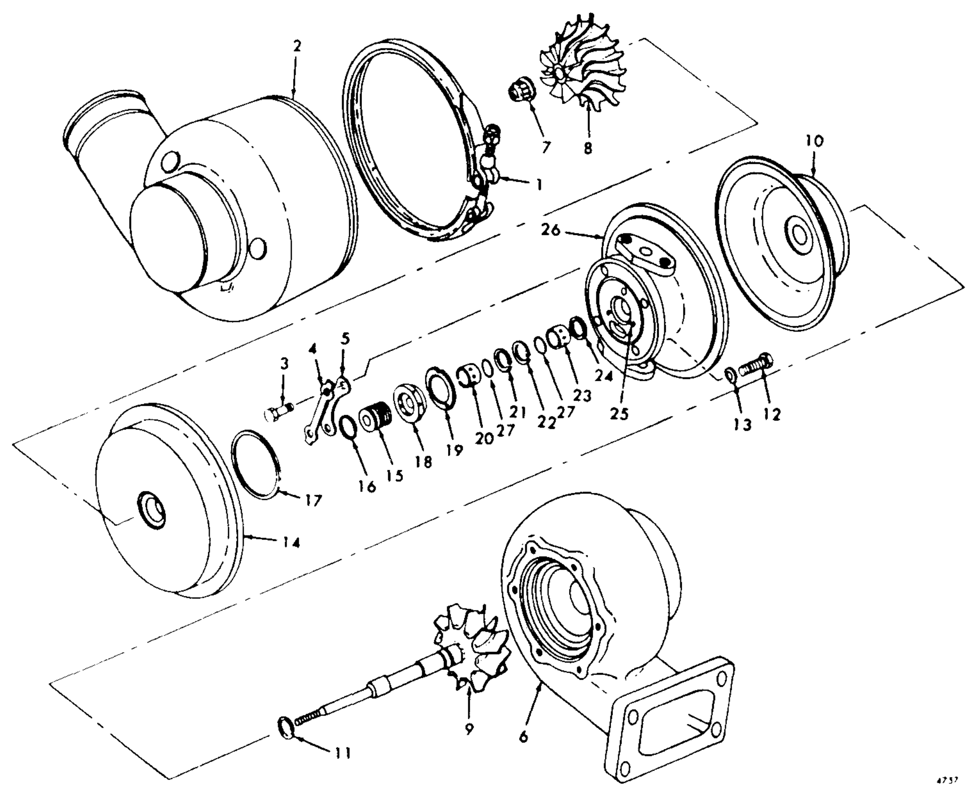
Disassemble Turbocharger

Clean the exterior of the turbocharger with a non-caustic cleaning solvent before disassembly, then proceed as follows:

> **CAUTION:** Exercise care when removing the center and turbine housings to prevent damage to the compressor or turbine wheel.

1. Loosen the "V" band coupling (1) securing the compressor housing (2) to the backplate assembly (14) and remove the compressor housings and "V" band.

2. Remove the eight bolts (3) securing the four lockplates (4) and turbine housing clamps (5) to the center housing (26) and turbine housing (6). Remove the turbine housing from the center housing.



1. Coupling--"V" Band
2. Housing--Compressor
3. Bolt
4. Lockplate
5. Clamp--Turbine Housing
6. Housing--Turbine
7. Nut--Self-Locking
8. Wheel--Compressor
9. Shaft--Turbine Wheel Assembly
10. Shroud--Turbine Wheel
11. Ring--Piston
12. Screw
13. Lockplate
14. Backplate Assembly
15. Spacer--Thrust
16. Ring--Piston
17. Ring--Seal
18. Collar--Thrust
19. Bearing--Inboard Thrust
20. Bearing
21. Ring--Retaining
22. Ring--Retaining
23. Bearing
24. Ring--Retaining
25. Pin--Groove
26. Housing--Center
27. Spacer

Fig. 5 - Turbocharger Details and Relative Location of Parts

NOTE: Tap the housing with a soft headed hammer if force is needed for removal.

3. Position the turbine wheel (9) of the center housing assembly in a suitable holding fixture (Fig. 6).

4. Remove the wheel nut (7) from the shaft.

CAUTION: To prevent the possibility of bending the turbine wheel shaft, remove the compressor wheel nut from the shaft with a double universal socket and tee handle.

5. Place the center housing and rotating assembly in a oven, furnace or hot oil bath that has been preheated to 350 °F.-375 °F. for no longer than 10 minutes.

6. Remove the compressor wheel (8) from the wheel shaft assembly (9).

7. Withdraw the wheel shaft assembly (9) and wheel shroud (10) from the center housing.

8. Remove the piston seal (11) from the wheel shaft assembly (9).

9. Remove the screws (12) and lock tabs (13) securing the backplate assembly (14) to the center housing (26) and remove the backplate assembly.

10. Remove the seal ring (17) from the groove in the center housing.

11. Remove the thrust spacer (15) and piston ring (16) from the backplate assembly.

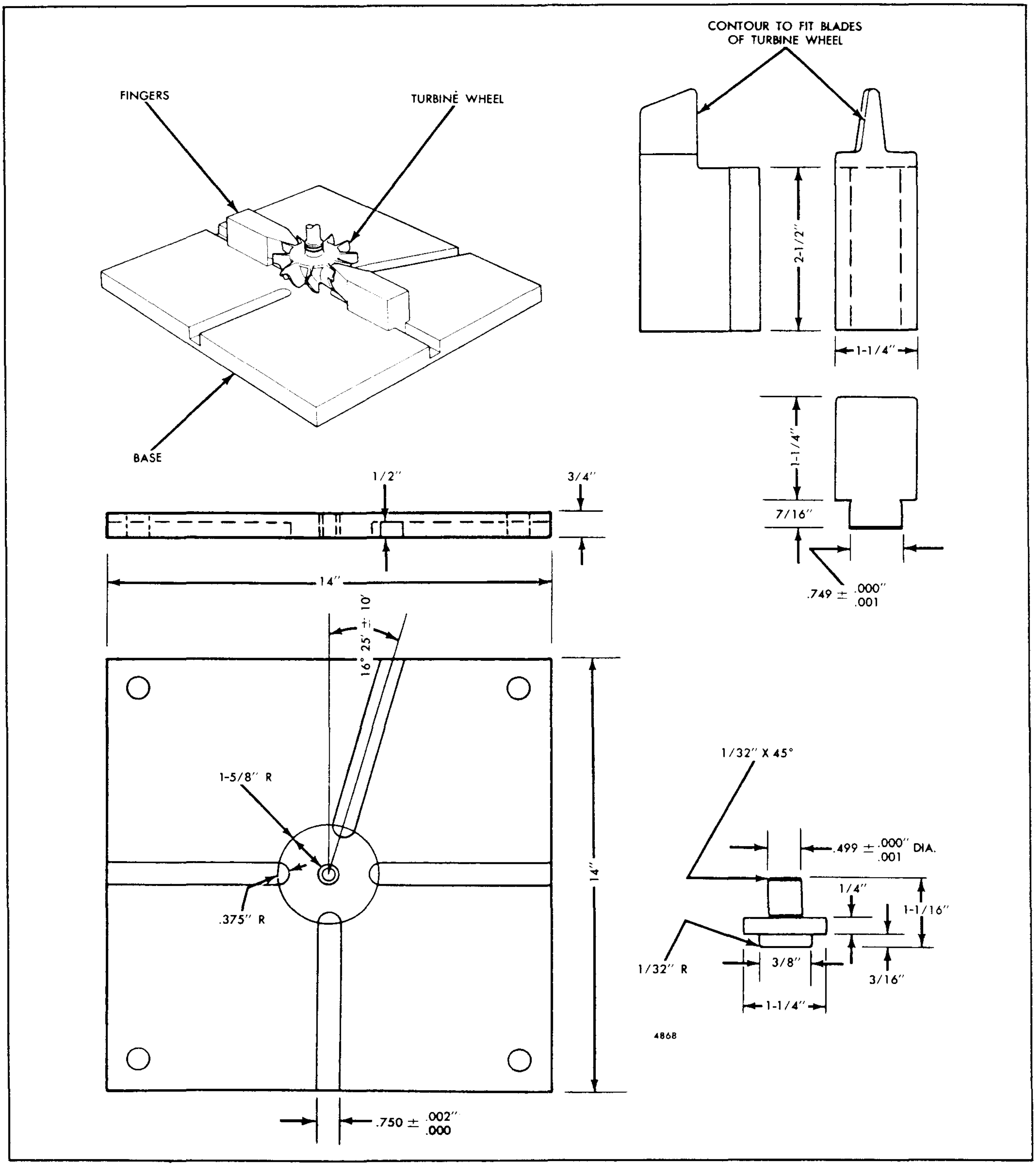


Fig. 6 - Turbocharger Holding Fixture

12. Remove the thrust collar (18), inboard thrust bearing (19), bearing (20), spacer (27) if used, and retaining ring (21) from the center housing.

13. Remove the retaining ring (22), spacer (27) if used, bearing (23) and retaining ring (24) from the center housing.

Cleaning

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

Soak all of the parts in a non-caustic cleaning solvent for about 25 minutes. After soaking, use a stiff bristle brush and remove all dirt particles. Dry all of the parts thoroughly.

Inspection

Inspect all of the parts for signs of damage, corrosion or deterioration. Check for nicked, crossed or stripped threads.

Visually check the turbine wheel for signs of rubbing. Also check the turbine wheel vanes for worn or feathered edges.

Inspect the shaft for signs of scoring, scratches or seizures with the bearings.

Check the compressor wheel for signs of rubbing or damage from foreign material. Check to see that the wheel bore is not galled. The wheel must be free of dirt and other foreign material.

Inspect the seal parts for signs of rubbing or scoring of the running faces.

Inspect the housing for contact with the rotating parts. The oil and air passages must be clean and free of obstructions.

Minor surface damage may be burnished or polished. Use a silicone carbide abrasive cloth for aluminum parts or a crocus abrasive cloth for steel parts.

Replace the bearings and thrust washer if they show signs of nicks, scores, shellac deposits or foreign material imbedment. It is recommended that when one bearing needs replacement that both rotor shaft bearings be replaced at the same time. The current bearing and spacer are serviced only as a kit.

Assemble Turbocharger

Check each part prior to installation to ensure cleanliness. As the parts are assembled, cover the openings to prevent entry of dirt or other foreign material.

Refer to Fig. 5 for parts orientation and proceed as follows:

1. Lubricate the bearings (20 and 23) with clean engine oil.

2. Install a new retaining ring (24), bearing (23), spacer (27) and new retaining ring (22) in the turbine housing end of the center housing (26).

3. Install a new retaining ring (21), spacer (27) and bearing (20) in the center housing.

4. Install a new piston ring (16) on the thrust spacer (15) and gently insert the spacer into the backplate assembly (14).

> **CAUTION:** Do not force the piston ring into place.

5. Position the inboard thrust bearing (19) against the center housing with the hole and cut-outs in the bearing in alignment with the pins (25) in the center housing.

6. Install the thrust collar (18) snugly against the thrust bearing (19). Lubricate the thrust collar and bearing with clean engine oil.

7. Install a new seal ring (17) in the groove in the backplate assembly (14).

8. Align the oil feed holes in the center housing (26) and the backplate assembly and install the backplate, using four bolts (12) and new lockplates (13). Tighten the bolts to 75-90 **lb-in** torque and bend the lockplate tangs up against the side of the bolt heads.

9. Install a new piston ring (11) on the wheel shaft assembly (9).

10. Position the wheel shroud (10) against the center housing (26) and insert the wheel shaft assembly (9) through the wheel shroud and into the center housing.

> **CAUTION:** Be careful not to scuff or scratch the bearings when installing the shaft. Do not use force to compress the piston ring into place. A gentle rocking and pushing action will allow the piston ring to seat and the shaft to bottom. A thin tool may be used as an aid in compressing the piston ring if difficulty is encountered.

11. Heat the compressor wheel in an oven or hot oil bath to 325-375 °F. for no more than 10 minutes.

12. Position the turbine wheel (9) of the center housing assembly in the holding fixture (Fig. 6).

13. Position the compressor wheel over the shaft and install the wheel retaining nut. Tighten the nut to 120 **lb-in** torque. After the compressor wheel has cooled to room temperature, remove the retaining nut.

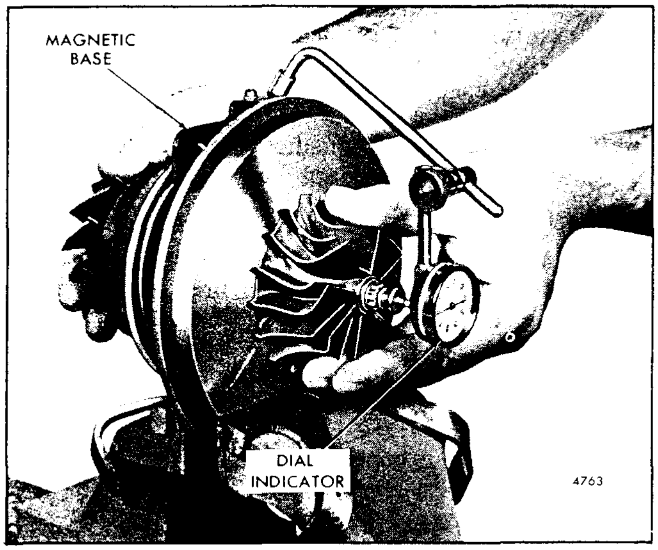


Fig. 7 - Checking Bearing Axial End Play

14. Check the face of the retaining nut and the wheel face to make sure they are smooth and clean. Lightly oil the shaft threads and washer face and reinstall the nut. Tighten the nut to 18-20 **lb-in** torque. Continue to tighten until the shaft increases in length .008 ″-.009 ″.

CAUTION: Tighten the retaining nut in such a manner so as not to impose a bending load on the shaft.

15. Check bearing axial end play:

a. Clamp the center housing assembly in a bench vise equipped with soft jaws as shown in Fig. 7.

b. Fasten the dial indicator and magnetic base (J 7872) to the center housing so that the indicator tip rests on the end of the rotating shaft on the compressor side.

c. Move the shaft axially back and forth by hand. The total indicator reading should be between .004 ″ and .007 ″. If the dial indicator readings do not fall within the specified limits, repair or replace the rotating assembly.

16. Position the turbine housing (6) against the center housing (26) and secure it in place with four clamps (5), four lockplates (4) and eight bolts (3). Tighten the bolts to 160-190 **lb-in** torque. Bend the lockplate tabs up against the flat on the bolt heads.

17. Position the compressor housing (2) against the center housing (26) and secure it in place with the "V" band coupling (1). Tighten the nut on the coupling to 30-45 **lb-in** torque.

18. After assembly, push the rotating assembly as far as possible from the turbine end. Then rotate the assembly and check for bind. Push the rotating assembly in the opposite direction and repeat the check.

19. Check shaft radial movement:

a. Position the magnetic base J 7872-2 with the swivel adaptor J 7872-3 on the flat surface of the turbine housing inlet flange as shown in Fig. 8.

b. Fasten the extension rod J 22758 to the dial indicator J 8001-3 and attach the dial indicator to the swivel adaptor.

c. Insert the extension rod into the oil drain tube mounting pad opening so that it is against the wheel shaft and is perpendicular to the shaft.

CAUTION: Make sure the extension rod does not make contact with the sides of the center housing, otherwise it will be impossible to obtain an accurate reading.

d. Grasp each end of the rotating assembly and, applying equal pressure at each end, move the rotating shaft first toward and then away from the dial indicator, creating a transverse movement in the shaft. The dial indicator displacement should be more than .003 ″ and less than .007 ″. If the displacement does not fall within the specified limits, disassemble and repair or replace the rotating assembly.

20. If it is to be stored, lubricate the turbocharger internally and install protective covers on all openings.

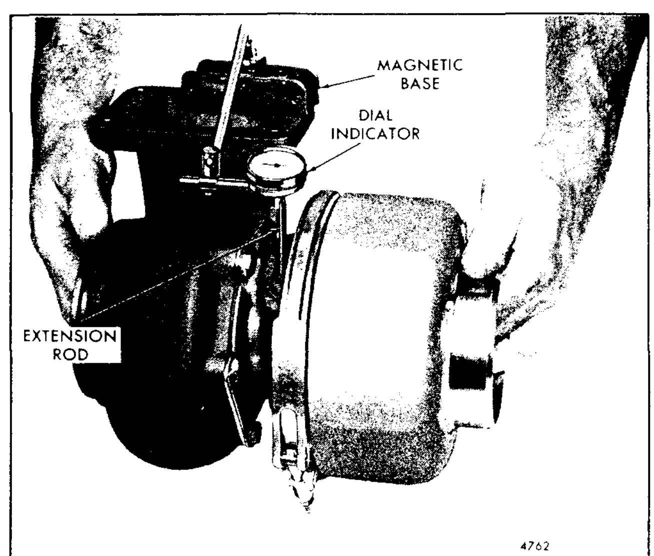


Fig. 8 - Checking Shaft Radial Movement

Install Turbocharger

If a turbocharger is to be installed on a new or overhauled engine, operate the engine for approximately one hour *before* the turbocharger is installed. This must be done to ensure that no foreign material is carried from the engine into the turbocharger lubrication system.

1. Position the turbocharger, using a new gasket, against the exhaust manifold adaptor and secure it in place with four bolts, lock washers and nuts (Fig. 1).

2. Slide the cover hose (Fig. 4) over the end of the turbocharger air outlet opening and tighten the two hose clamps.

3. Install the turbocharger support bracket.

4. Install the oil drain line from the opening in the bottom side of the center housing (Fig. 4) to the cylinder block.

5. Attach the oil inlet line at the cylinder block.

6. Before starting the engine, make sure that there is lubricating oil in the turbocharger.

a. Clean the area around the oil inlet opening, then pour about four ounces of engine oil in the oil inlet opening of the center housing. Turn the rotating assembly by hand to coat the bearings, thrust ring and thrust bearing with oil.

b. Fill the oil supply line with lubricating oil.

c. Use a socket wrench on the wheel nut to keep the compressor wheel from turning and start the engine.

d. As soon as oil appears at the end of the oil supply line, connect the oil supply line to the center housing (Fig. 4).

NOTE: The oil pressure should be at a minimum of 10 psig.

e. After the line is connected, release the compressor wheel.

7. Check all ducts and gaskets for leaks.

8. Operate the engine at rated output and listen for sounds of metallic contact from the turbocharger. If any such noise is apparent, shut down immediately and correct the cause.

NOTE: After the turbocharger has been operating long enough to permit the unit and the oil to warm up, the rotating assembly should coast freely to a stop after the engine is stopped. If the rotating assembly jerks to a sudden stop, the cause should be immediately determined and eliminated.

TURBOCHARGER INTERCOOLER

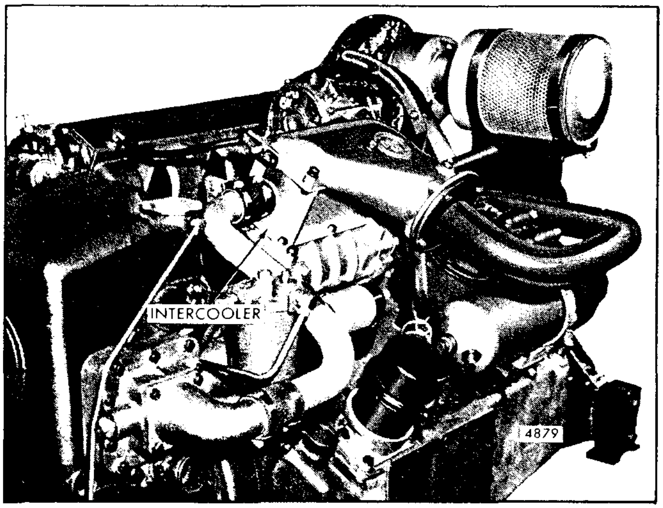


Fig. 1 - Turbocharger Intercooler Mounting

The turbocharger intercooler is mounted on the air inlet side of the engine blower and is used to reduce the temperature of the compressed air from the turbocharger before the air enters the engine blower. This permits a more dense charge of air to be delivered to the engine. The cooling is accomplished by the raw water from the heat exchanger passing through the cells of the intercooler core. The compressed air enters the intercooler via the air inlet housing and circulates past the cooler core of the intercooler.

Remove Intercooler

1. Drain the raw water system.

2. Loosen the two hose clamps on the hose connecting the raw water inlet tube to the inlet end of the intercooler (Fig. 1).

3. Remove the four 5/16 ″-18 x 1 ″ bolts and lock washers that retain the air inlet tube flange to the air inlet housing.

4. Disconnect the connection between the outlet end of the intercooler and the raw water discharge line.

5. Disconnect the manual shutdown, if used.

6. Remove the six bolts, nuts, washers and lock washers that retain the air inlet housing to the intercooler and remove the air inlet housing and the screen and gasket assembly.

> **NOTE:** The bolts are not all the same length and their location should be noted during removal to facilitate installation.

7. Remove the six bolts and lock washers that retain the intercooler to the blower and remove the intercooler. Note the location of the two shorter bolts.

8. Remove the gasket from the side of the blower.

Clean Intercooler

Check all of the intercooler tubes to be sure they are free of obstructions.

If the tubes contain dirt or any other foreign material, they can be cleaned with a small brush or by use of a suitable solvent cleaning solution. Flush the core thoroughly with water to remove the solvent.

Install Intercooler

1. Affix a new gasket to the side of the blower.

2. Mount the intercooler assembly on the blower with the six bolts and lock washers and tighten the bolts to 16-20 lb-ft torque.

3. Affix a new air inlet screen and gasket assembly on the intercooler.

4. Mount the air inlet housing on the intercooler with the six bolts, nuts, washers and lock washers and tighten the nuts to 35-39 lb-ft torque.

5. Affix a new gasket on the air inlet housing flange and secure the air inlet tube flange to the air inlet housing with the four 5/16 ″-18 x 1 ″ bolts and lock washers. Tighten the bolts to 13-17 lb-ft torque.

6. Connect the raw water inlet tube to the inlet end of the intercooler with the hose and clamps. Tighten the clamps securely.

7. Connect the raw water discharge line to the outlet end of the cooler.

8. Connect the manual shutdown, if used.

9. Fill the raw water system. Then start the engine and check for air or water leaks.

SHOP NOTES - TROUBLE SHOOTING - SPECIFICATIONS - SERVICE TOOLS

SHOP NOTES

REWORKING BLOWER END PLATES FOR IN-LINE AND 6V ENGINES

On non-turbocharged engines built prior to serial numbers 2D-20911, 3D-34008, 4D-36457 and 6D-24899, when oil is detected on the blower rotors or inside surface of the housing, the blower end plate can be reworked to accommodate a new lip type oil seal or a steel insert.

NOTE: Slight phonographic grooves can actually improve sealing. Unless wear is considerable and oil leakage is evident, the end plate need not be reworked.

Rework Blower End Plate

Use tool kit J 9533 to rework the end plate.

NOTE: On some prior serviced blowers, the end plates may have been reworked to accommodate a steel insert. In such cases, proceed as follows but omit Step 10.

1. Adjust the tool holder J 9533-2 and cutting tool J 9533-3 for the proper counterbore depth as follows:

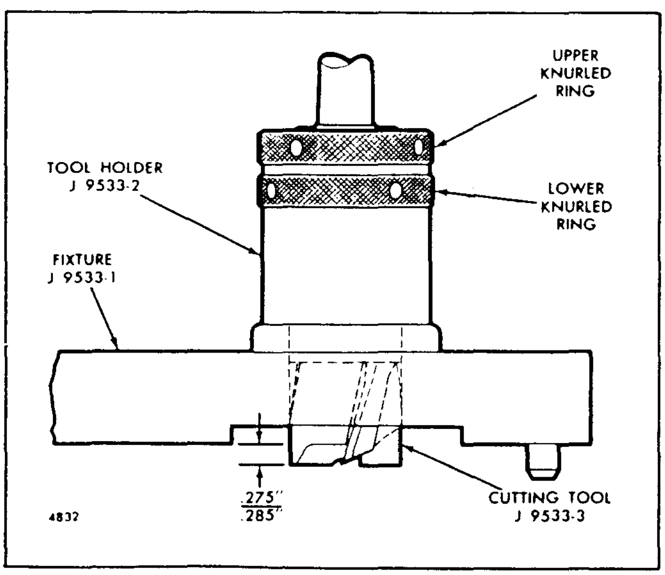


Fig. 1 - Adjustment of Tool Holder

a. Insert the rough cutting tool J 9533-3 in the tool holder as shown in Fig. 1.

b. Position the holder and the cutting tool in the fixture J 9533-1.

c. Loosen the "upper knurled ring" on the tool holder.

d. Rotate the "lower knurled ring" to raise or lower the cutting tool. Turn the "lower knurled ring" until there is a distance of .275 " - .285 " between the end of the cutting tool and the bottom of the fixture.

e. Tighten the "upper knurled ring".

2. Place fixture J 9533-1 on the blower end plate.

3. Clamp the fixture and the end plate loosely to the bed of a drill press.

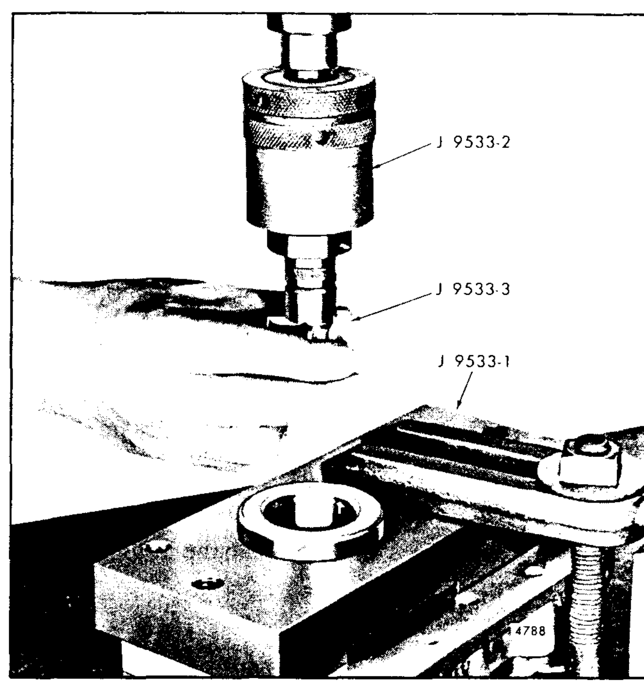


Fig. 2 - Install Cutting Tool in Holder

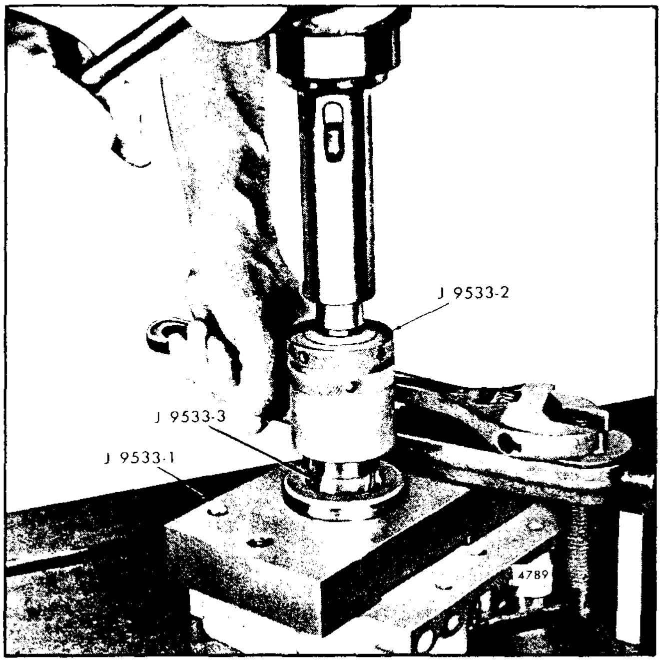


Fig. 3 - Positioning Cutting Tool in Fixture Guide

4. Install tool holder J 9533-2 in the drill press and insert the rough cutting tool J 9533-3 in the holder (Fig. 2).

5. Position the cutting tool in the fixture guide as shown in Fig. 3. Operate the drill press at 75-100 rpm so as to center the cutting tool in the rotor shaft hole. Tighten the clamp.

6. Lubricate the cutting tool and the area of the end plate that is being reworked with a lubricant (oleum or fuel oil).

7. Operate the drill press at 300-350 rpm and slowly counterbore the hole until the collar of the tool holder is approximately 1/16 " from the fixture guide. Then reduce the speed of the drill press to 75-100 rpm and continue counterboring until the collar contacts the top of the guide.

> **NOTE:** Raise the cutting tool periodically during the drilling operation and apply additional lubricant.

8. Stop the drill press and remove the rough cutting tool.

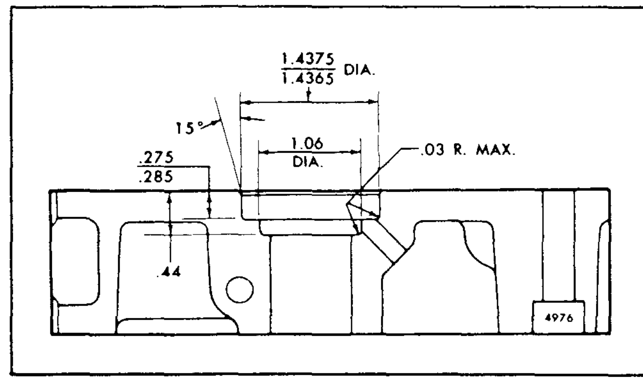


Fig. 4 - End Plate Oil Drain Back Counterbore

9. Insert the finish cutting tool J 9533-4 in the holder. Lubricate the cutting tool and the end plate. Operate the drill press at 75-100 rpm and finish-cut the counterbore. Feed the cutting tool into the work slowly.

10. Remove the finish cutting tool and install an end mill to machine the additional 1.06 " diameter counterbore. The total depth of the combined counterbores is .44 " (Fig. 4). The additional counterbore provides proper oil drain back from the oil seal area.

11. Remove the fixture from the end plate. Wipe the cuttings from the end plate and fixture and dry the plate and fixture with compressed air. Remove any burrs from the edge of the oil hole.

12. Thoroughly clean the cutting tool and the end mill flutes and repeat the procedures for the adjacent rotor shaft hole.

13. Place the blower end plate on the bed of an arbor press. Use installer J 22576 to press the seal (lip facing down) into the counterbored hole until the shoulder on the installer contacts the end plate.

> **NOTE:** A step under the shoulder of the installer will position the oil seal below the finished face of the end plate within the .002 " to .008 " specified.

Steel Inserts

To install steel inserts in the blower end plates, follow Steps 1 through 9 and 11 and 12. Press the inserts flush to .003 " above the blower end plate surface.

REWORKING BLOWER FRONT END PLATES - 6V ENGINES

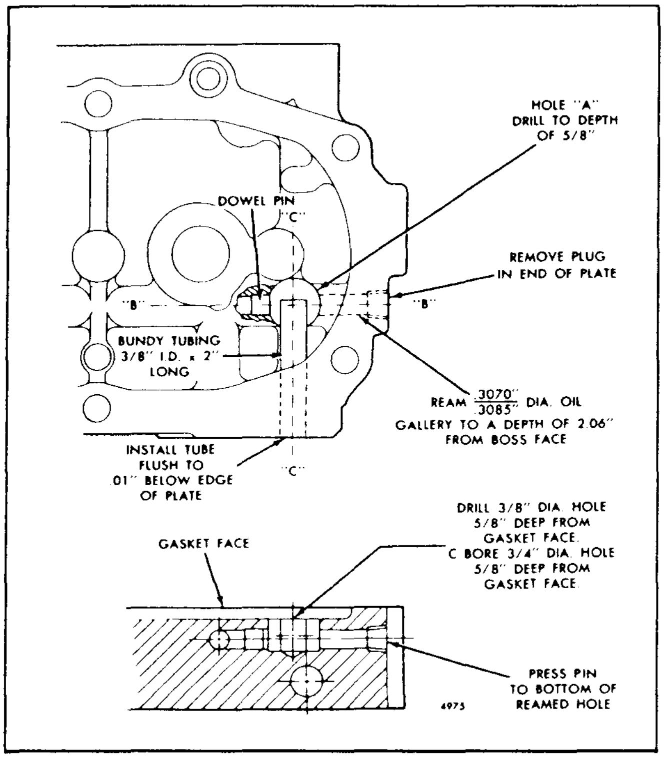


Fig. 5 - Dimensions for Reworking Front End Plate (6V Engine)

When rebuilding a 6V blower assembly in the field, the front end plate can be reworked to provide improved lubrication, when desirable, in the area of the thrust washers. The rework procedure is as follows:

1. Remove the pipe plug from the horizontal oil gallery (B-B) of the end plate. Place a reamer in the chuck of the drill press and ream a .3070 " - .3085 " diameter hole 2.06 " deep from the boss face (Fig. 5). Remove the metal cuttings from the hole.

2. Install the copper-plated dowel pin to the full depth of the reamed portion of the horizontal oil gallery.

3. Locate and mark the center of hole "A" as shown in Fig. 5. The center of hole "A" is where the center line (B-B) of the horizontal oil gallery intersects with the center line (C-C) of the drain hole. Clamp the end plate on the bed of the press and center drill at the location marked. Then drill a 3/8 " diameter hole 5/8 " deep from the gasket face of the end plate. Lubricate the drill and the area of the end plate that is being reworked with oleum or fuel oil.

4. Place either an end mill or a 3/4 " counterbore reamer (remove the pilot from the reamer) in the chuck of the drill press and counterbore a 3/4 " diameter hole 5/8 " deep from the gasket face of the end plate.

5. Wash the end plate in clean fuel oil to remove the metal cuttings and dry it with compressed air.

6. Cut a piece of 3/8 " I.D. Bundy tubing 2.00 " long. Coat the tubing with Gasola or an equivalent type sealant. Press the tubing into the oil drain hole in the end plate flush to .010 " below the edge of the plate. It is important that the area around the tube be oil tight.

7. Reinstall the pipe plug in hole (B-B).

8. When assembling the blower, apply a liberal amount of Lubriplate, or equivalent, on the surfaces of the thrust washers. This will provide lubrication of the thrust washers during initial start-up of the engine.

TROUBLE SHOOTING

TURBOCHARGER

CONDITION	PROBABLE CAUSE	SUGGESTED REMEDY
NOISY OPERATION OR VIBRATION	WHEEL SHAFT BEARINGS ARE NOT BEING LUBRICATED	Supply required oil pressure. Clean or replace oil line. If trouble persists, overhaul turbocharger.
	IMPROPER CLEARANCE BETWEEN TURBINE WHEEL AND HOUSING	Remove, disassemble, and inspect turbocharger.
	LEAK IN ENGINE AIR INTAKE OR EXHAUST MANIFOLD	Tighten all loose connections or replace exhaust manifold gaskets as necessary.
ENGINE WILL NOT DELIVER RATED POWER	CLOGGED AIR INTAKE SYSTEM	Check air cleaner and clean air intake ducts.
	FOREIGN MATERIAL LODGED IN COMPRESSOR OR TURBINE WHEELS	Remove, disassemble and clean turbocharger.
	EXCESSIVE DIRT BUILD-UP IN COMPRESSOR	Thoroughly clean compressor assembly. Clean air cleaner and check for leaks.
	LEAK IN ENGINE AIR INTAKE OR EXHAUST MANIFOLD	Tighten all loose connections or replace exhaust manifold gaskets as necessary.
	ROTATING ASSEMBLY BEARING SEIZURE	Remove and overhaul turbocharger.

SPECIFICATIONS

TABLE OF SPECIFICATIONS, NEW CLEARANCES AND WEAR LIMITS

These limits also apply to oversize and undersize parts.

ENGINE PART (Standard Size, New)	MINIMUM	MAXIMUM	LIMITS
Blower			
Backlash--rotor gears (all)	.0005 "	.0025 "	.0035 "
Backlash between upper rotor and camshaft or balance shaft gear (2,3-53)	.0030 "	.0070 "	
Backlash between blower drive gear and camshaft gear	.0030 "	.0070 "	
Oil seal (below end plate surface) (8V)	flush	.0100 "	
Oil strainer (below end plate surface) (8V)	flush	.0150 "	
Pin--dowel (projection beyond inside face of front or rear end plate) (8V)	.3800 "		
Clearances:			
Thrust plate and thrust washer (in-line, 6V)	.0010 "	.0030 "	
Rotor to air outlet side of housing:			
In-line and 6V	.0040 "		
8V	.0050 "		
Rotor to air inlet side of housing:			
In-line	.0075 "		
6V	.0100 "		
8V	.0170 "		
Rotor to front end plate:			
In-line	.0060 "		
6V	.0080 "		
+ 8V (former)	.0070 "		
†8V (current)	.0170 "		
Rotor to rear (gear) end plate:			
2-53	.0060 "		
3-53	.0080 "		
4-53	.0090 "		
6V	.0120 "		
+ 8V (former)	.0140 "		
†8V (current)	.0070 "		
Trailing edge of R.H. helix rotor to leading edge of L.H. helix rotor (8V)	.0080 "		
Leading edge of R.H. helix rotor to trailing edge of L.H. helix rotor (8V)	.0180 "		
Turbocharger (TE0675)			
Rotating shaft axial end play	.0040 "	.0070 "	
Rotating shaft radial movement	.0030 "	.0070 "	
Turbine wheel rotor shaft journal bearing:			
Inside diameter	.6268 "	.6272 "	
Outside diameter	.9780 "	.9785 "	
Turbine wheel shaft journal diameter	.6251 "	.6254 "	
Bearing bore diameter in center housing	.9827 "	.9832 "	

+ This clearance applies to former blowers with the ball bearings in the front end plate and roller bearings in the rear end plate.

†This clearance applies to current blowers with the roller bearings in the front end plate and ball bearings in the rear end plate.

STANDARD BOLT AND NUT TORQUE SPECIFICATIONS

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

EXCEPTIONS TO STANDARD BOLT AND NUT TORQUE SPECIFICATIONS

APPLICATION	THREAD SIZE	TORQUE (lb-ft)
Blower drive coupling to rotor gear bolt (in-line and 6V)	1/4 ″-28	14-18
Blower drive gear pilot bolt (in-line and 6V)	5/16 ″-24	25-30
Blower timing gear-to-rotor shaft bolts (in-line and 6V)	5/16 ″-24	25-30
Blower thrust washer retaining bolt (in-line and 6V)	5/16 ″-24	25-30
Front end plate cover bolts (4-53 and 6V-53)	3/8 ″ -16	20-25
Air inlet adaptor-to-blower bolts	3/8 ″ -16	16-20
Air inlet housing-to-adaptor or blower housing bolts	3/8 ″ -16	16-20
Governor-to-blower front end plate bolts	3/8 ″ -16	20-24
Blower drive support-to-blower rear end plate bolts	3/8 ″ -16	20-24
Flywheel housing-to-blower drive support bolts	3/8 ″ -16	20-24
Blower drive gear cover bolt	3/8 ″ -16	20-24
Blower-to-engine rear end plate and flywheel housing bolts (2-53 and 3-53)	3/8 ″ -16	20-25
	3/8 ″ -24	20-25
Blower thrust washer retaining bolt (in-line and 6V)	3/8 ″ -24	54-59
Blower timing gear-to-rotor shaft bolts (8V)	3/8 ″ -24	50-55
Rotor shaft ball bearing retaining bolt (8V)	3/8 ″ -24	50-55
Blower end plate-to-block bolts	7/16 ″-14	55-60
Rotor shaft ball bearing retaining nut (8V)	.781 ″-32	60-65

SERVICE TOOLS

TOOL NAME	TOOL NO.
BLOWER	
Blower clearance feeler gage set	J 1698-02
Universal puller (4-53 and 6V-53)	J 4794-01
Blower drive cam installer	J 5209
Gear puller (2 and 3-53)	J 5825-01
Handle	J 7079-2
Blower end plate counterbore set:	J 9533
Fixture	J 9533-1
Cutting tool - holder	J 9533-2
Cutting tool - roughing	J 9533-3
Cutting tool - finishing	J 9533-4
Blower service tool set:	J 21672
Gear pullers	J 21672-7
Rotor shaft ball bearing installer	J 21672-10
Oil seal and bearing remover	J 21672-11
Oil seal and roller bearing installer	J 21672-12
Oil seal sleeve and roller bearing inner race installer	J 21672-16
Spanner wrench	J 21672-17
Oil seal sleeve and roller bearing inner race remover	J 21672-20
Oil seal installer	J 22576
Oil seal sleeve installer (in-line and 6V)	J 23679-1
Oil seal sleeve remover (in-line and 6V)	J 23679-2
TURBOCHARGER	
Magnetic base indicator set	J 7872
Magnetic clamp	J 7872-2
Swivel adaptor	J 7872-3
Dial indicator	J 8001-3