Detroit Diesel Engines

Series 53 Service Manual

271.13

Detroit Diesel Allison

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.

6SE201 (Rev. 6/85)

Service Manual

Detroit Diesel Engines

SERIES 53

Detroit Diesel Allison

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Detroit, Michigan 48239-4001

NOTE:
Additional copies of this service manual may be purchased from Detroit Diesel Allison Distributors. See your yellow pages—under Engines, Diesel.

Printed in U.S.A.

FOREWORD

This manual contains instructions on the overhaul, maintenance and operation of the basic Series 53 Detroit Diesel Engines.

Full benefit of the long life and dependability built into these engines can be realized through proper operation and maintenance. Of equal importance is the use of proper procedures during engine overhaul.

Personnel responsible for engine operation and maintenance should study the sections of the manual pertaining to their particular duties. Similarly, before beginning a repair or overhaul job, the serviceman should read the manual carefully to familiarize himself with the parts or sub-assemblies of the engine with which he will be concerned.

The information, specifications and illustrations in this publication are based on the information in effect at the time of approval for printing. This publication is revised and reprinted periodically. It is recommended that users contact an authorized *Detroit Diesel Service Outlet* for information on the latest revisions. The right is reserved to make changes at any time without obligation.

TABLE OF CONTENTS

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 subsections which contain complete maintenance and operating instructions for a specific subassembly on the engine. For example, Section 1, which covers the basic engine, contains subsection 1.1 pertaining to the cylinder block, subsection 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 subsection. The illustrations are also numbered consecutively, beginning with a new Figure 1 at the start of each subsection.

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 subassembly 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 subsection 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 Allison service parts are available from authorized Detroit Diesel Allison distributors and service dealers throughout the world. A complete list of all distributors and dealers is available in the World Wide Parts and Service Directory, 6SE280. This publication can be ordered from any authorized distributor.

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".

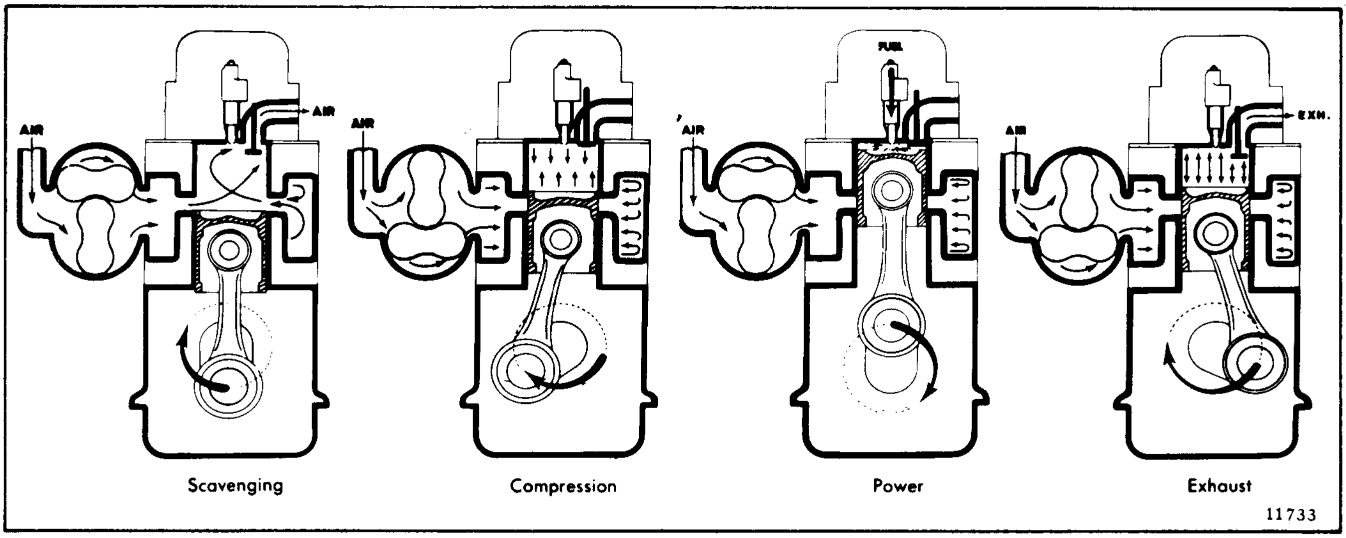


Fig. 1 - The Two Stroke Cycle

GENERAL DESCRIPTION

The two-cycle diesel engines covered in this manual have the same bore and stroke and many of the major working parts 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, and 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 a hydraulic, an air or an electrical starter. The electric starting motor is engerized by a storage battery. A battery-charging alternator or a 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
5047-5340	TURBOCHARGER

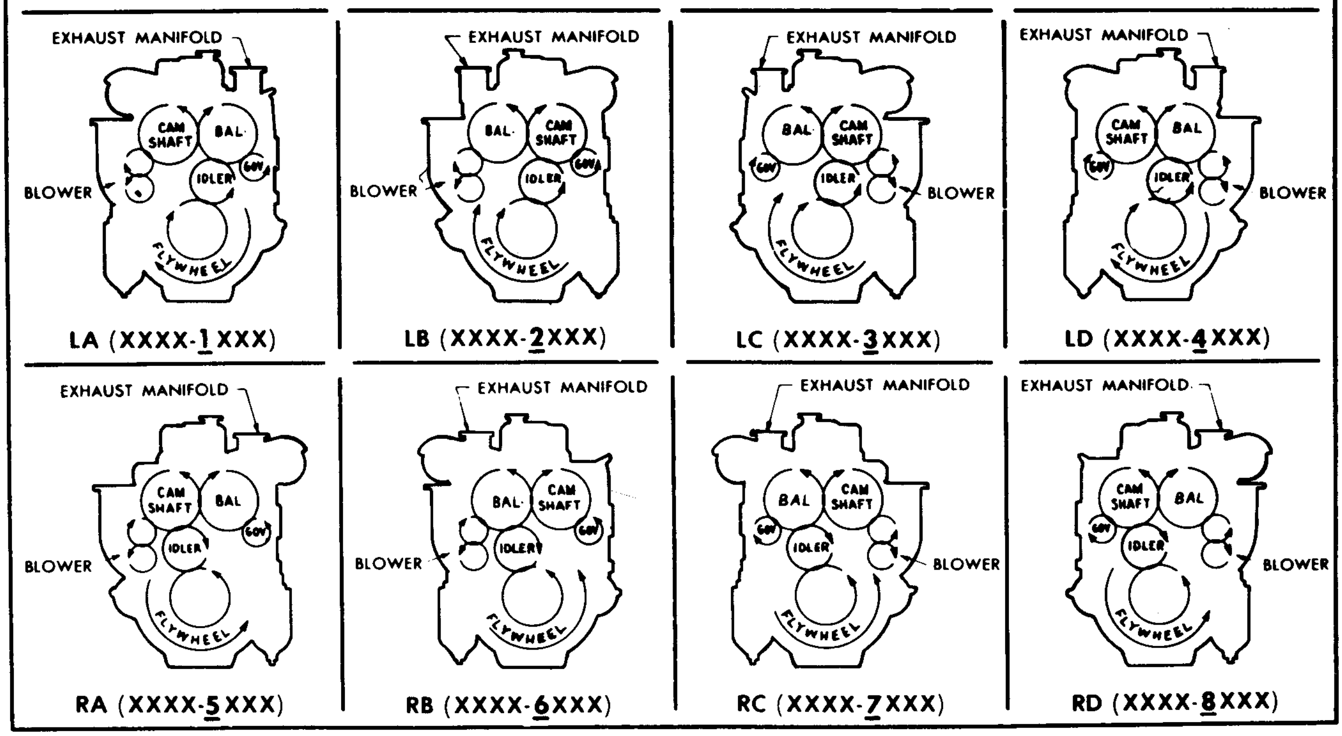
STARTER—BLOWER ARRANGEMENT

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

12223

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

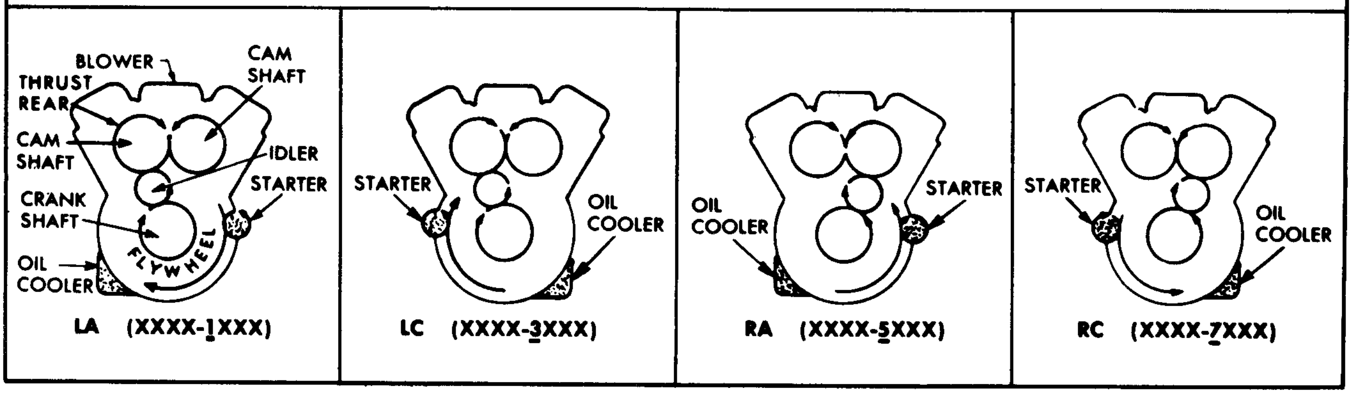
5062-3000 "N" ENGINE
5063-5200 4 VALVE HEAD
5067-5340 TURBOCHARGER

* **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.



ALL ABOVE VIEWS FROM REAR FLYWHEEL END OF ENGINE

11783

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

GENERAL SPECIFICATIONS

	2-53	3-53	4-53	6V-53	8V-53
Type	2 cycle	2 cycle	2 cycle	2 cycle	2 cycle
Number of cylinders	2	3	4	6	8
Bore (inches)	3.875	3.875	3.875	3.875	3.875
Bore (mm)	98	98	98	98	98
Stroke (inches)	4.5	4.5	4.5	4.5	4.5
Stroke (mm)	114	114	114	114	114
Compression ratio (nominal)--(std. engine)	17:1	17:1	17:1	17:1	-
Compression ratio (nominal)--("T"engine)	-	18.7:1	18.7:1	18.7:1	-
Compression ratio (nominal)--("N"engine)	-	21:1	21:1	21:1	21:1
Total displacement--cubic inches	106	159	212	318	424
Total displacement--litres	1.74	2.61	3.48	5.22	6.96
Number of main bearings	3	4	5	4	5

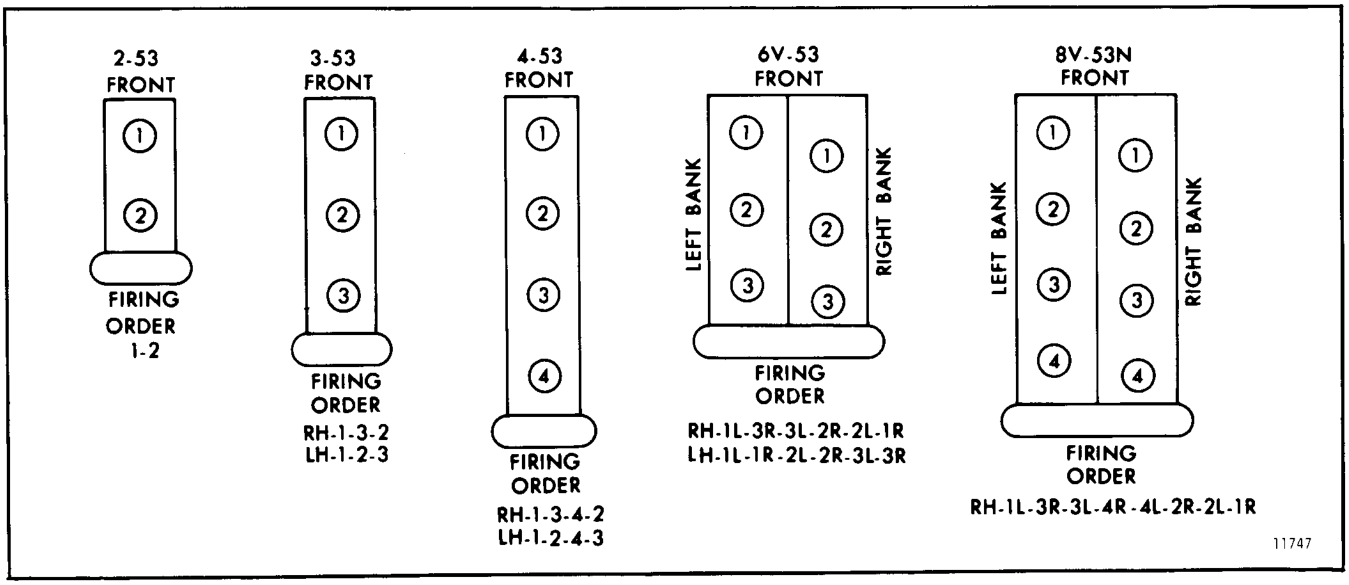


Fig. 4 - Cylinder Designation and Firing Order

ENGINE MODEL, SERIAL NUMBER AND OPTION PLATE

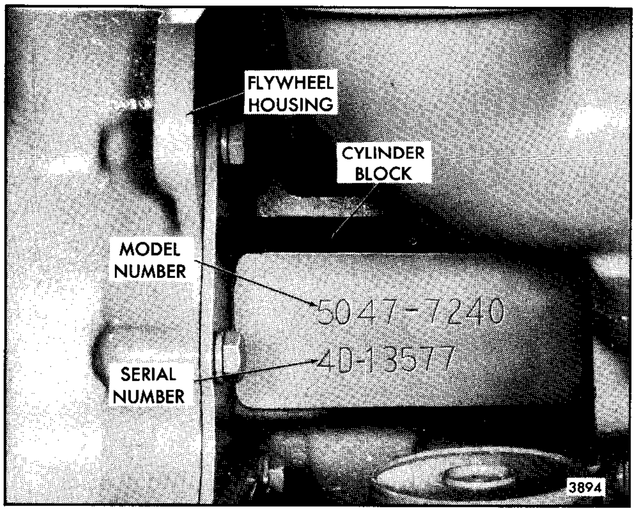


Fig. 5 - Typical Model and Serial Numbers as Stamped on Cylinder Block (In-Line Engine)

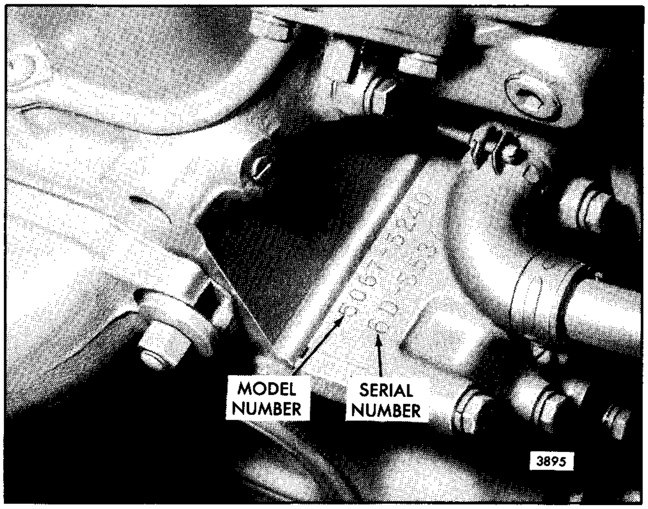


Fig. 6 - Typical Model and Serial Numbers as Stamped on Cylinder Block (6 and 8V Engines)

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).

An option plate, attached to the valve rocker cover, carries the engine serial number and model number and, in addition, lists any optional equipment used on the engine (Fig. 7). Engines built in Brazil have a serial number prefix of 3DB (three cylinder), 4DB (four cylinder) or 6DB (six cylinder).

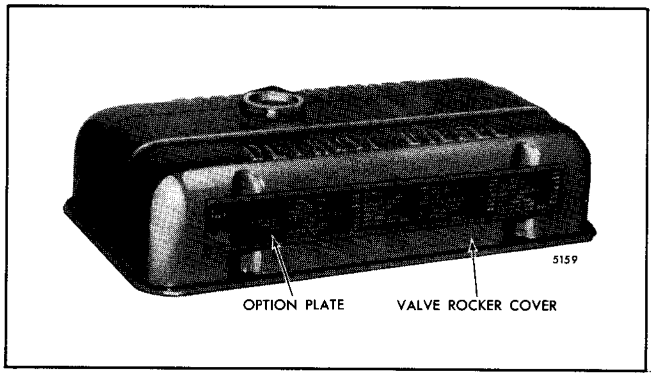


Fig. 7 - Option Plate

On-highway vehicle engines also carry an exhaust emission certification label, separate from the option plate and it is mounted permanently in the option plate retainer. The current label includes information relating to an engine family for the maximum fuel injector size and maximum speed. *Due to Federal regulations, the exhaust emission plate should not be removed from the rocker cover.* Refer to Section 14 for further information regarding emmision regulations.

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 an engine 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 subassemblies and other related parts mounted on the cylinder block will be treated as separate items in the various sections of the manual.

DISASSEMBLY

Before any major disassembly, the engine must be drained of lubricating oil, water and fuel. 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 vehicle and transmission, should be mounted on an engine overhaul stand; then the various subassemblies 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 subassemblies from the engine (but after removal of the electrical equipment), the exterior of the engine should be thoroughly cleaned. Then, after each subassembly is removed and disassembled, the individual parts should be cleaned. Thorough cleaning of each part is absolutely necessary before 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 subassemblies.

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 180-200°F (82-90°C).

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 subassemblies, 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.

To ensure a clean engine at time of rebuild, it is important that any plug, fitting or fastener (including studs) that intersects with a through hole and comes in contact with oil, fuel or coolant must have a sealer applied to the threads.

A number of universal sealers are commercially available. It is recommended that Loctite J 26558-92 *pipe sealer with teflon,* or equivalent, be used.

> **NOTE:** Certain plugs, fittings and fasteners available from the Parts Depot already have a sealer applied to the threads. This pre-coating will not be affected when the pipe sealer with teflon is also applied.

The sealer information above must not be confused with International Compound No. 2, which is a lubricant applied before tightening certain bolts. Use International Compound No. 2 only where specifically stated in the manual.

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:

1. 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.

2. 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 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.

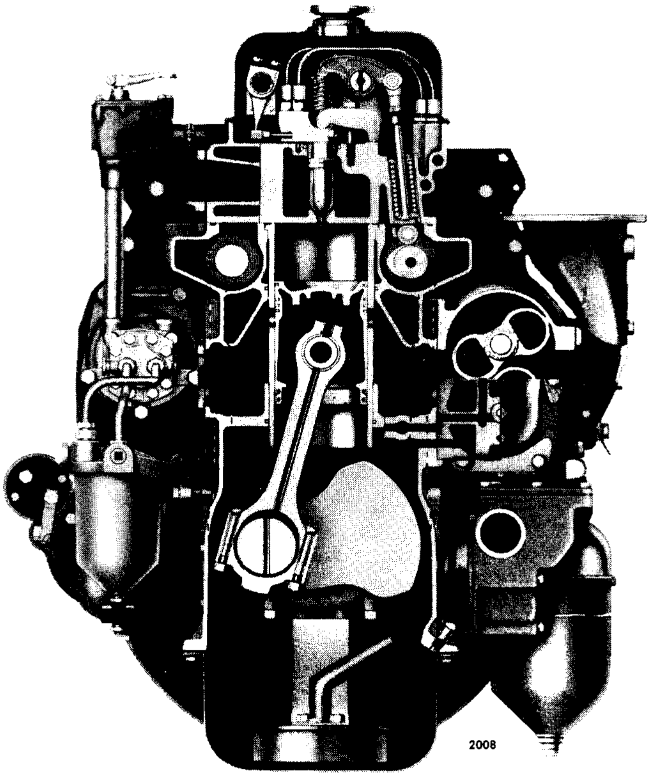
5. Avoid the use of carbon tetrachloride as a cleaning agent because of the harmful vapors that it releases. Use perchlorethylene or trichlorethylene. However, while less toxic than other chlorinated solvents, use these cleaning agents with caution. Be sure the work area is adequately ventilated and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

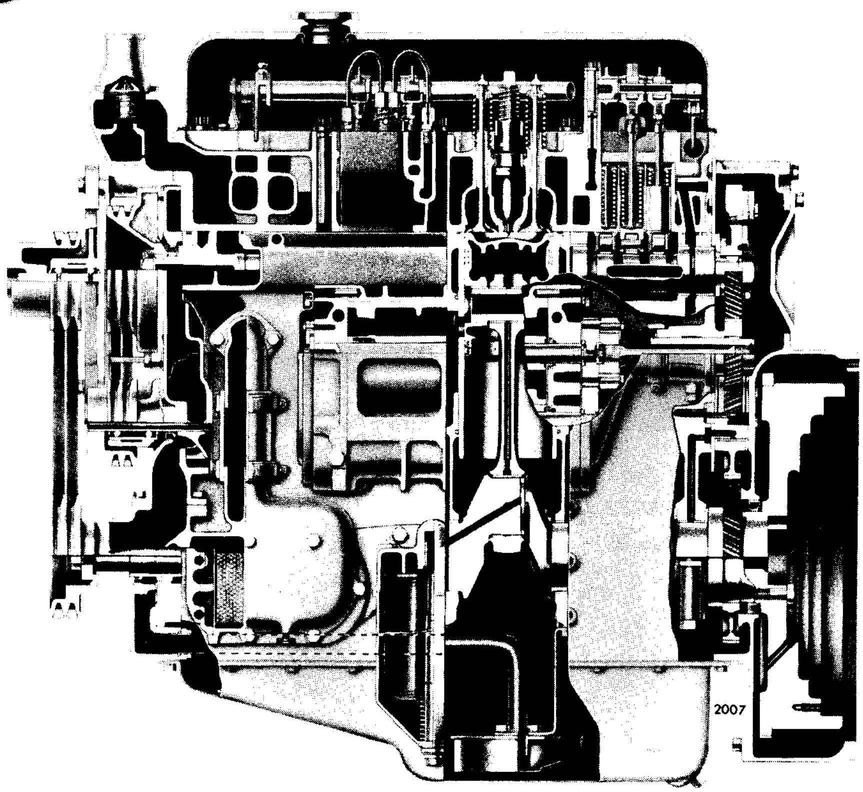
Exercise caution against burns when using oxalic acid to clean the cooling passages of the engine.

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

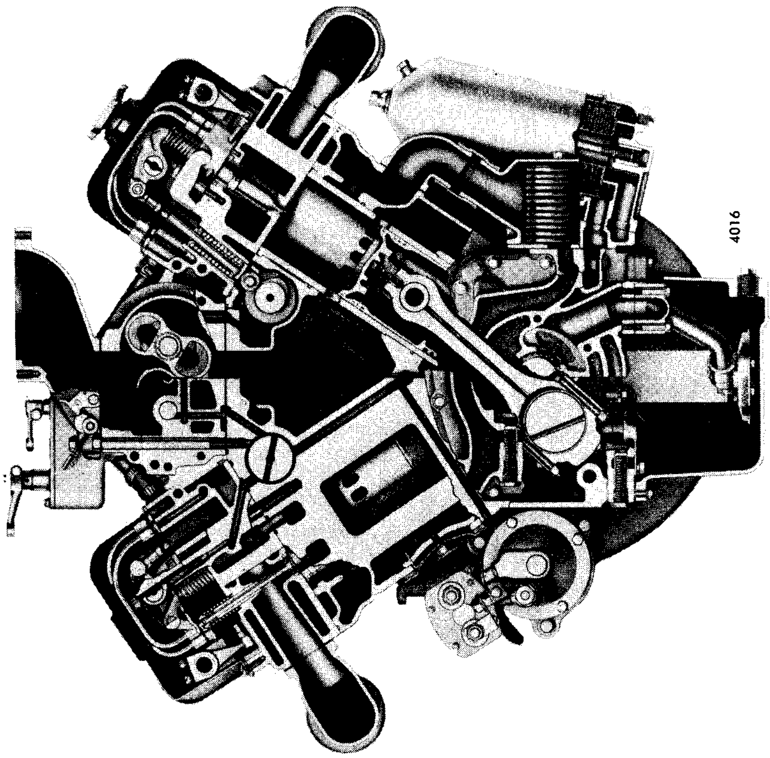
7. Avoid excessive injection of ether into the engine during start attempts. Follow the instructions on the container or by the manufacturer of the starting aid.

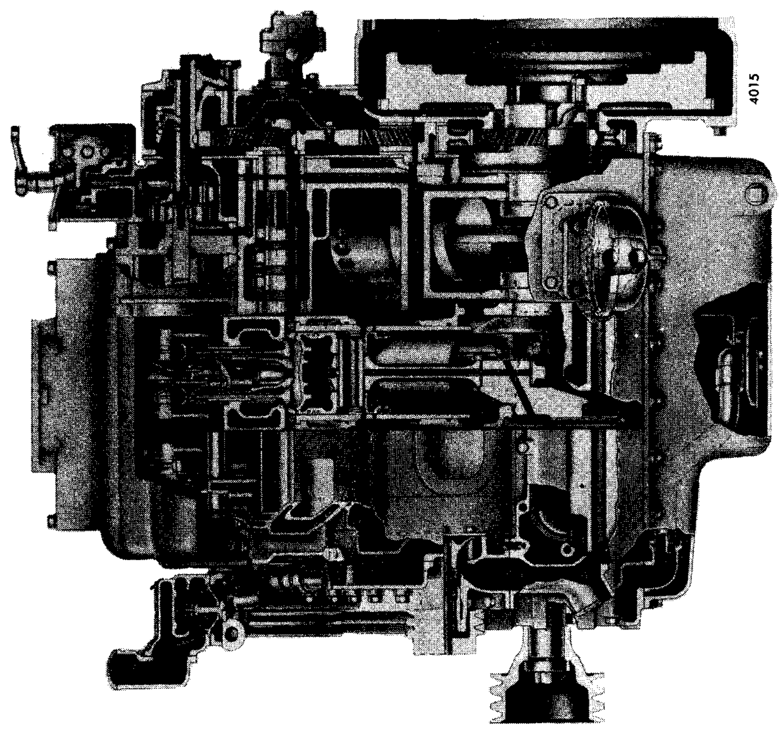
8. When working on an engine that is running, accidental contact with the hot exhaust manifold can cause severe burns. Remain alert to the location of the rotating fan, pulleys and belts. Avoid making contact across the two terminals of a battery which can result in severe arcing.



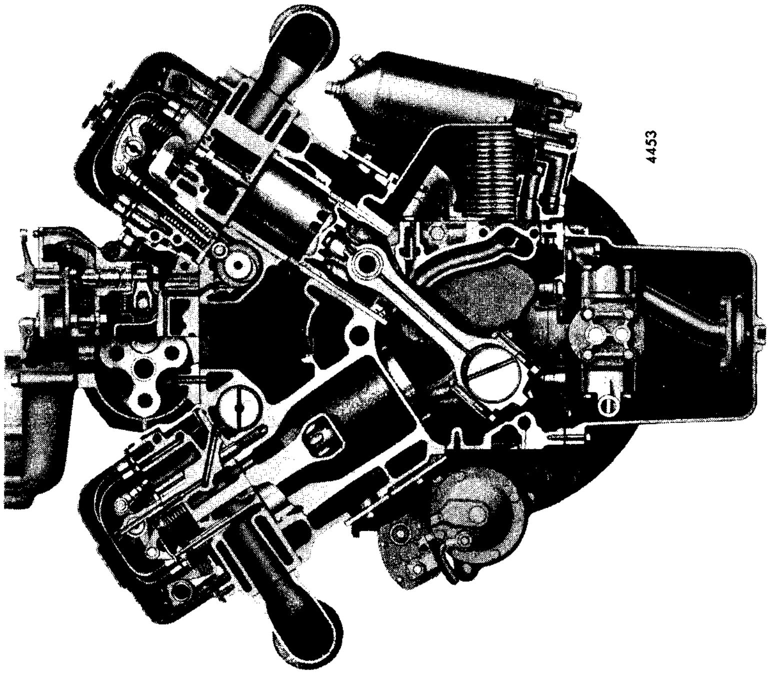


Cross Sections of a Typical In-Line Engine





Cross Sections of a 6V-53 Engine



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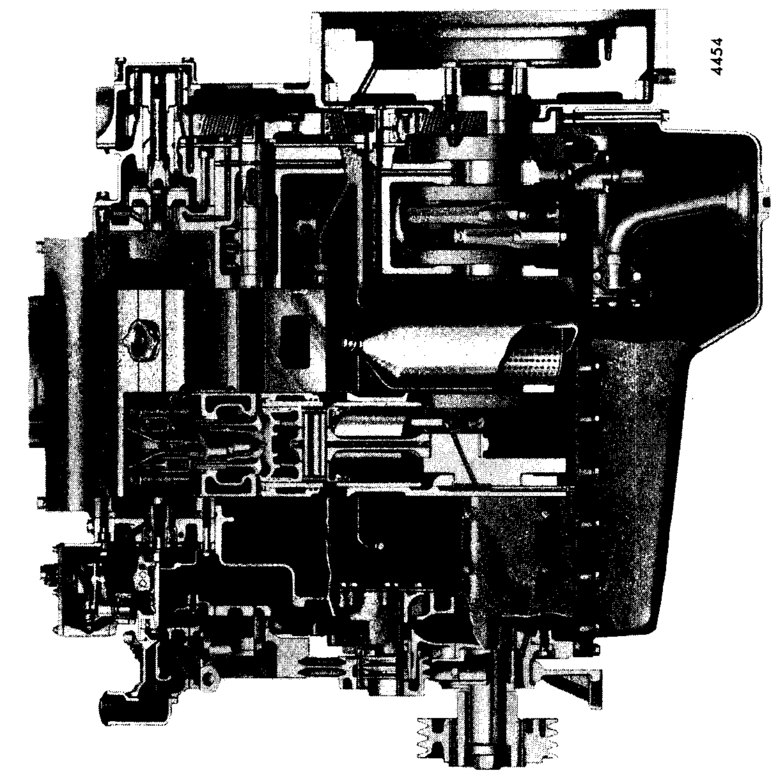

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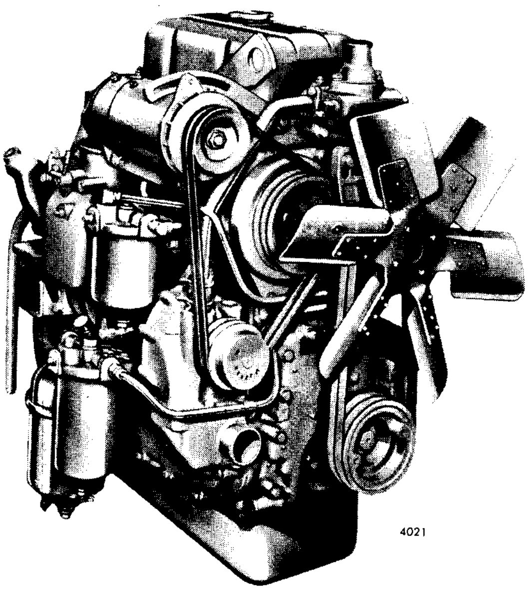
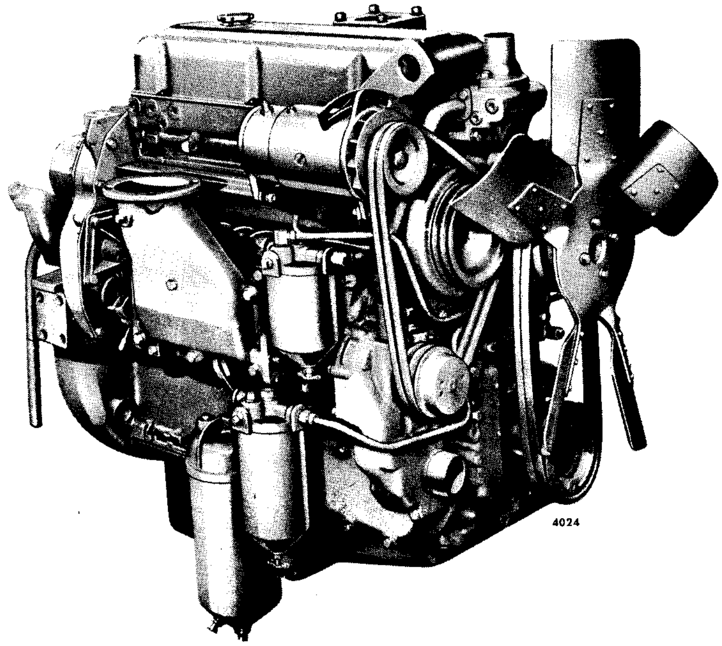
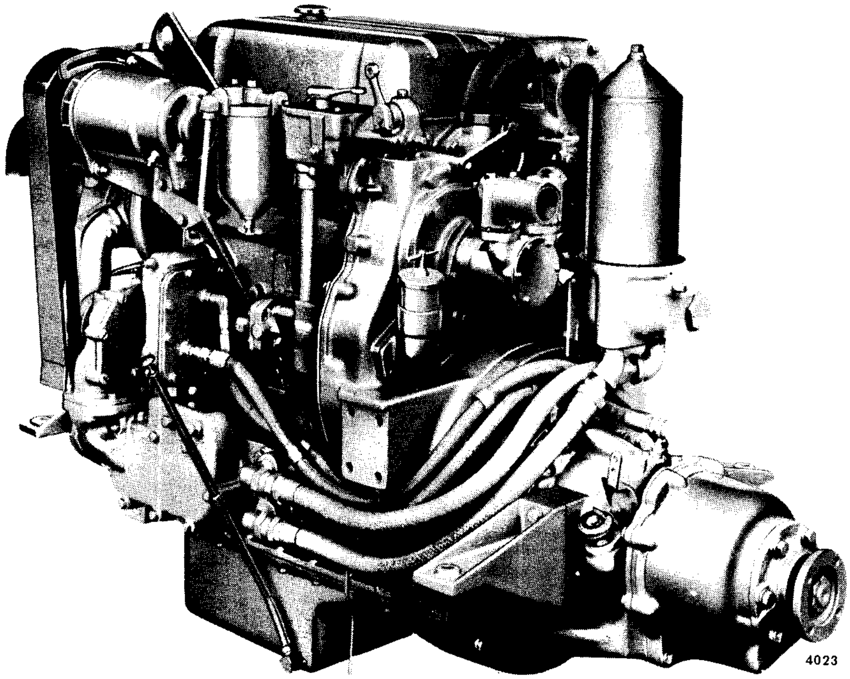
Cross Sections of an 8V-53 Engine



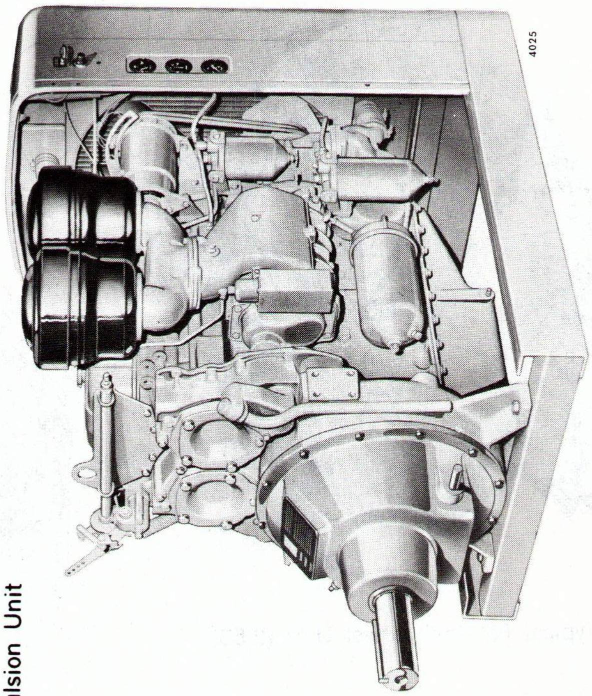
Typical Fan-to-Flywheel Unit (2-53)



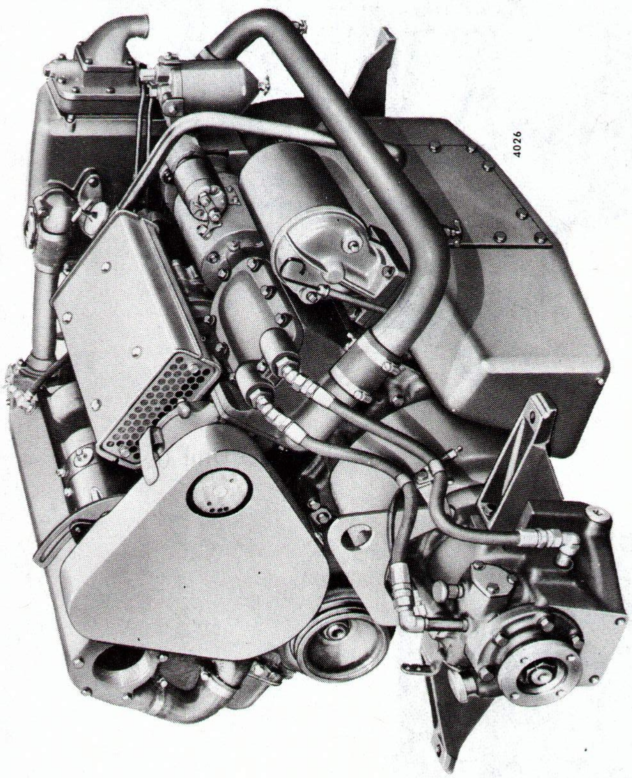
Typical Fan-to-Flywheel Unit (4-53)



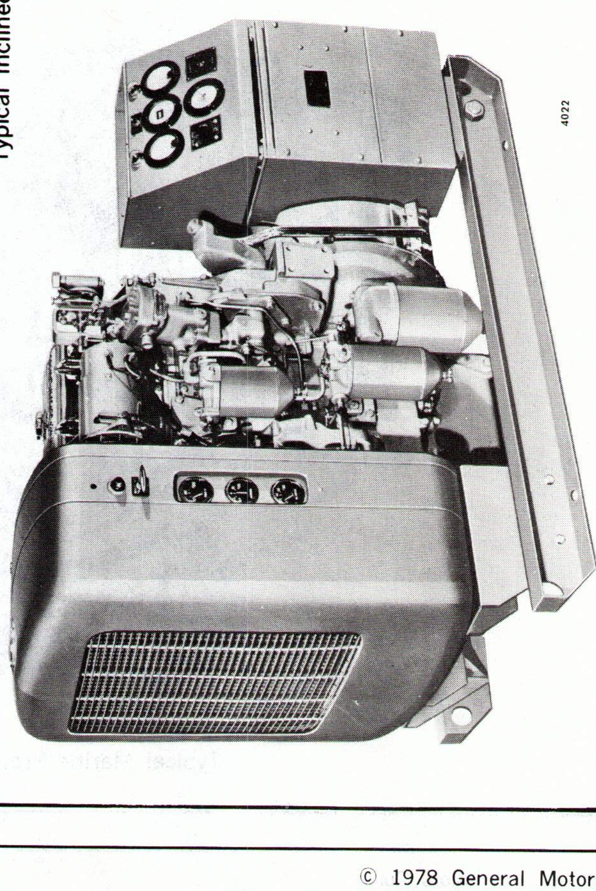
Typical Marine Propulsion Unit (3-53)



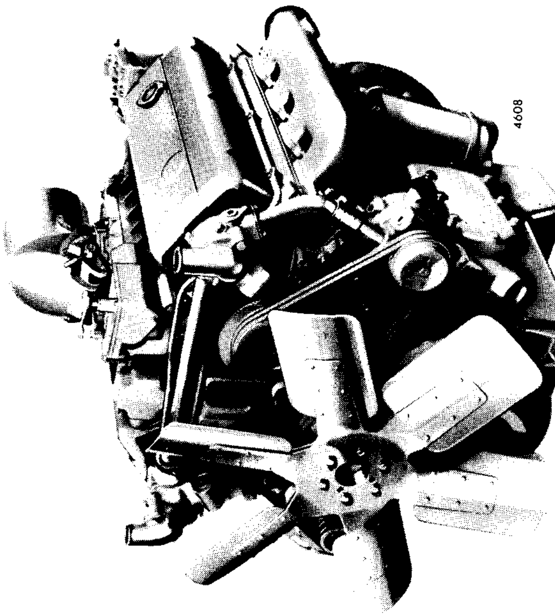
Typical Industrial Power Take-Off Unit



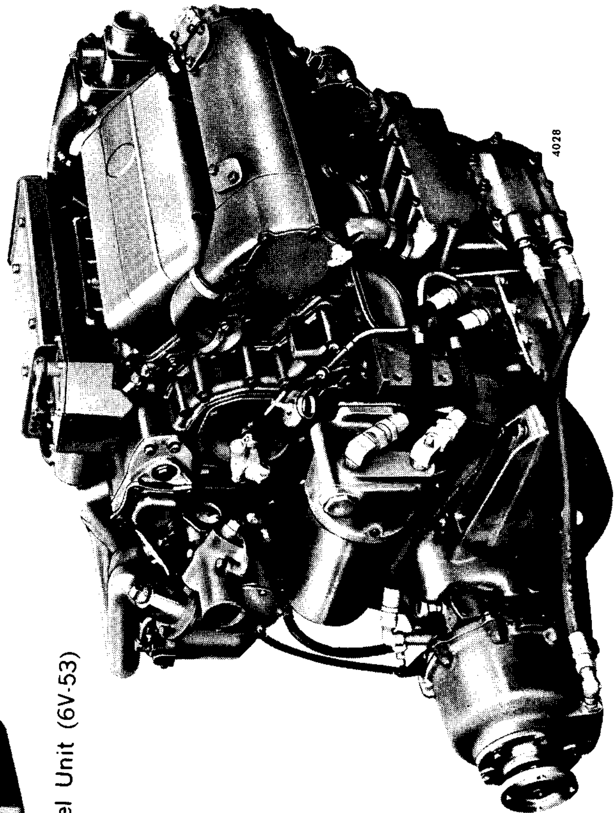
Typical Inclined Marine Propulsion Unit



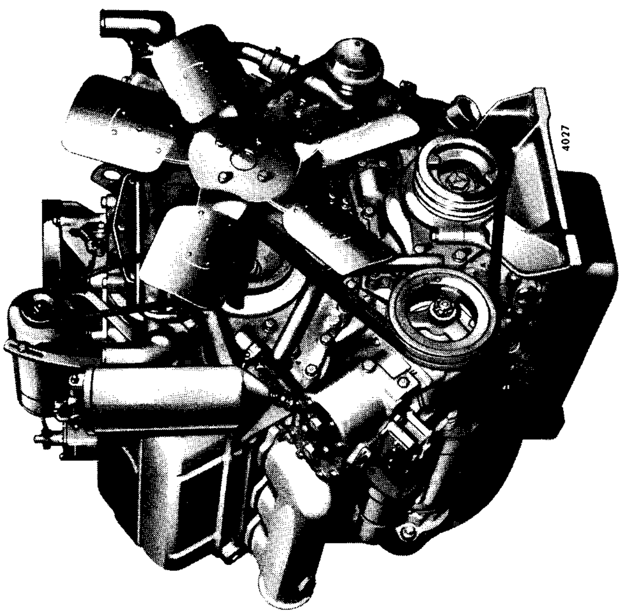
Typical Power Generator Unit



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 serves as the main structural part of the engine (Figs. 1 and 2). 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-53 cast iron cylinder blocks, a water jacket surrounds the upper half of each cylinder liner. On the 6V-53 aluminum and the 8V-53 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 two seal rings compressed between the liner and grooves 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.

Due to the higher air box pressure required for the 6V-53 turbocharged engines, thicker gage steel air box covers, polyacrylic rubber and cork gaskets and ductile iron clamps are used.

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.

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.

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

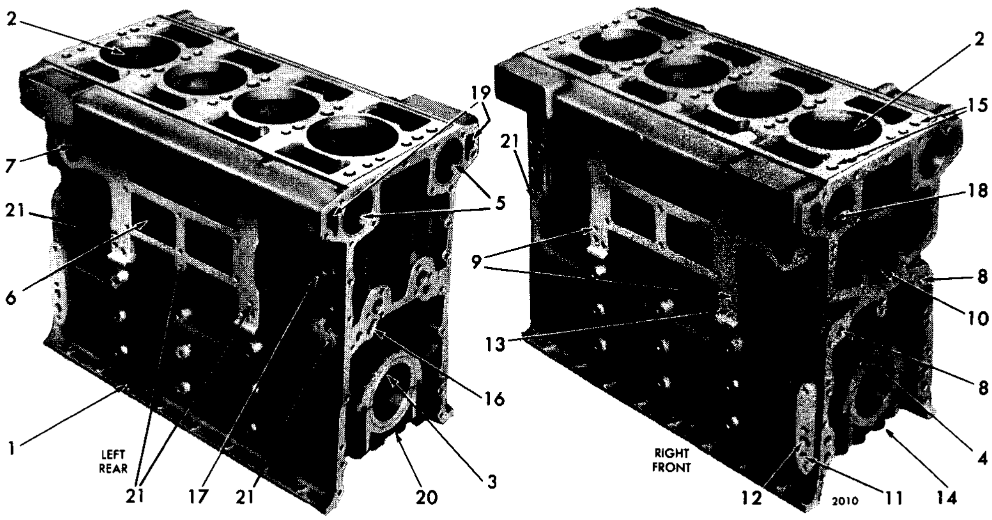
The 8V-53 cylinder block has been revised, effective with engine serial number 8D-2304, to provide improved scavenging and crankcase breathing by the addition of oil drains at the front corners of the cylinder block. The current 8V-53 service cylinder block now incorporates an oil drain at each corner 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.

Cylinder blocks manufactured in Brazil have larger oil passages for greater oil flow, reinforced main struts for added support, the rear of the cylinder block is closed in and oil grooves in the upper main bearing bore.

> **NOTE:** A Brazilian manufactured block can be used to service a naturally aspirated (N) engine or a turbocharged engine. However, a U.S. manufactured cylinder block *must not* be used to service a turbocharged engine.

On current 2 cylinder "C" and "D" engine cylinder blocks, the side opposite the blower is cast solid. The air



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. OilPassage 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 (4-53 Cylinder Block Shown)

box inspection is accomplished by removing the blower. Service blocks will continue to be cast open on both sides since the above does not apply to the "A" engines.

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

The hydraulically operated overhaul stand (Fig. 10) 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.

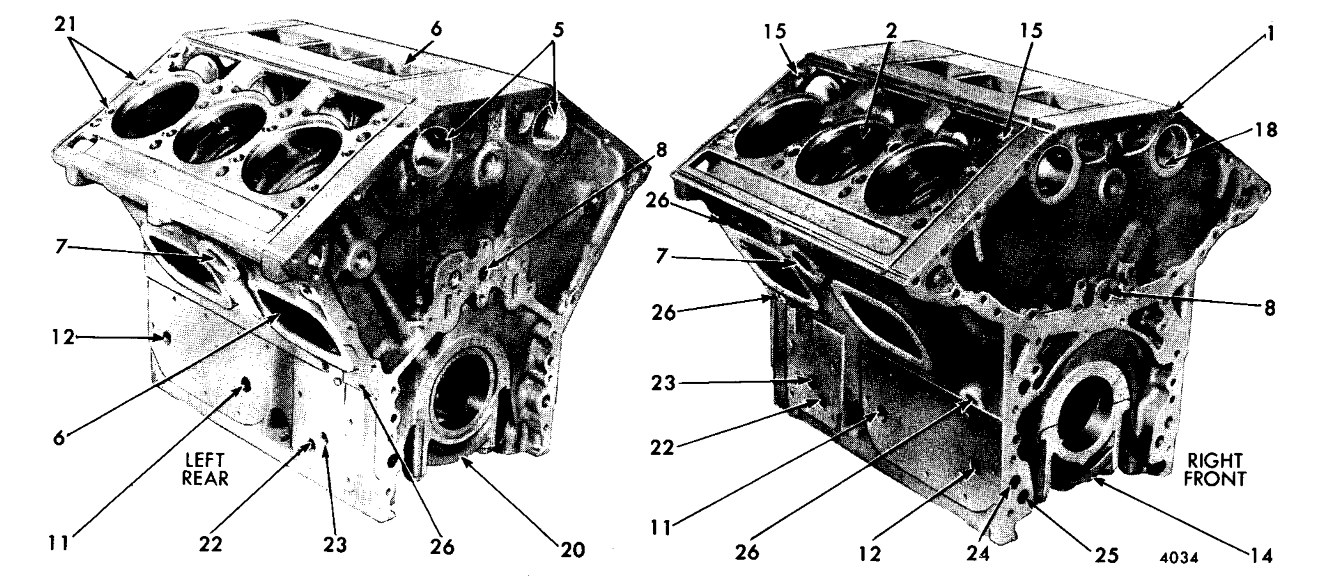
7. Disconnect the exhaust piping and remove the exhaust manifold(s).

8. Disconnect the throttle controls.

9. Disconnect and remove the starting motor, battery-charging generator or alternator 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.



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-53 Cast Iron Cylinder Block Shown)

12. Remove the air box drain tubes and fittings.

13. Remove the air box covers.

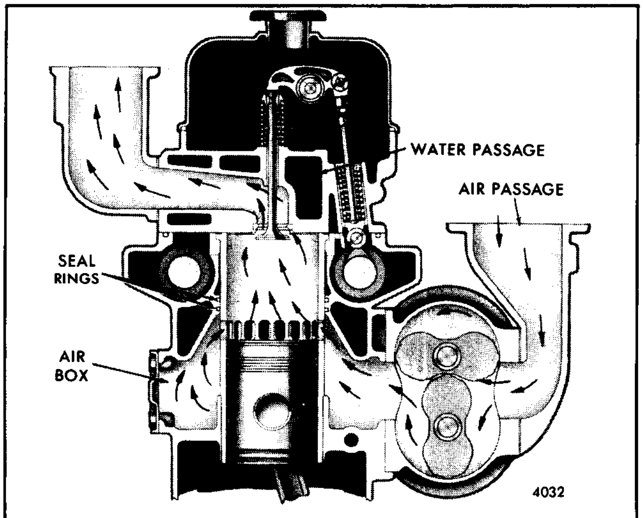


Fig. 3 - Air and Water Passages in In-line Cylinder Block

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

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

16. Remove the engine mounting bolts.

17. Use a spreader bar with a suitable sling and adequate chain hoist to lift the engine from its base (Fig. 9). To prevent bending of the engine lifter brackets the lifting device should be adjusted so the lifting hooks are vertical. To ensure proper weight distribution all engine lifter brackets should be used to lift the engine.

NOTE: Do not lift an engine by the webs in the air inlet opening of the cylinder block.

18. Place the side of the cylinder block against the adaptor plate on the overhaul stand (Fig. 10). Use adaptor plate J 7622-01 (In-line engine), J 8683 (6V-53 engine) or J 21966 (8V-53 engine) with overhaul stand J 29109.

19. Align the bolt holes in the adaptor plate with the holes in the cylinder block. Then, install the 3/8"-16

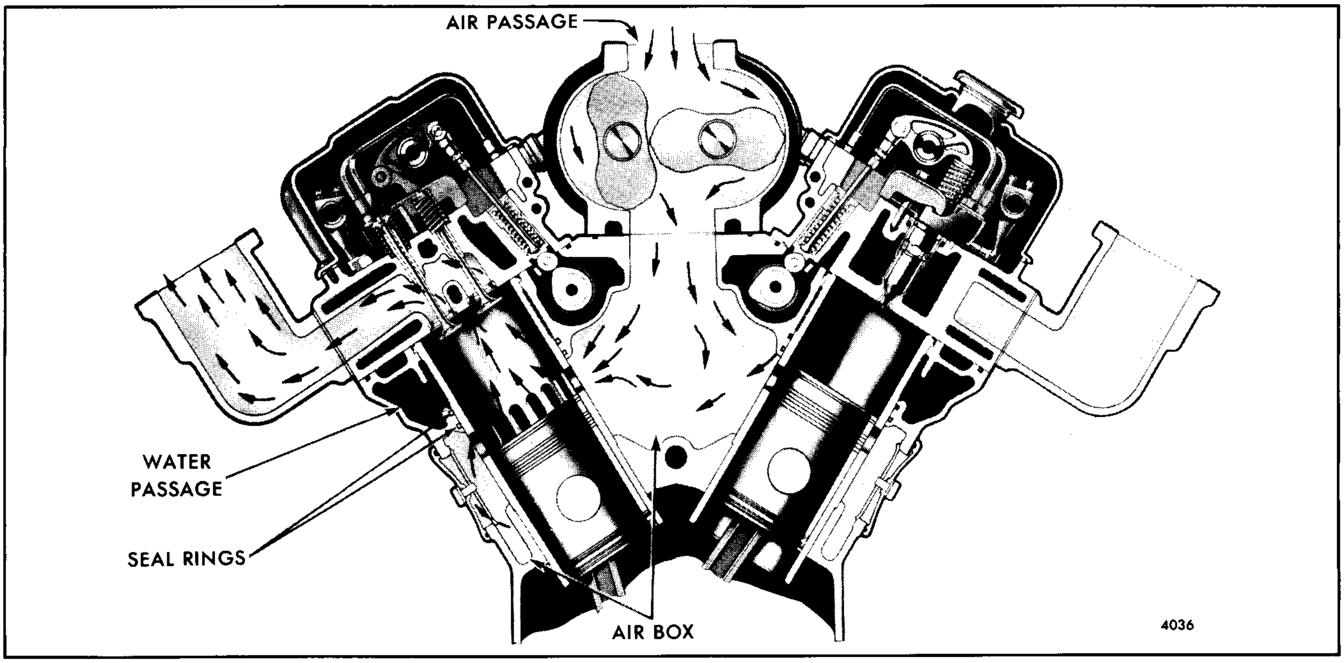


Fig. 4 - Air and Water Passages in 6V-53 Cast Iron Cylinder Block

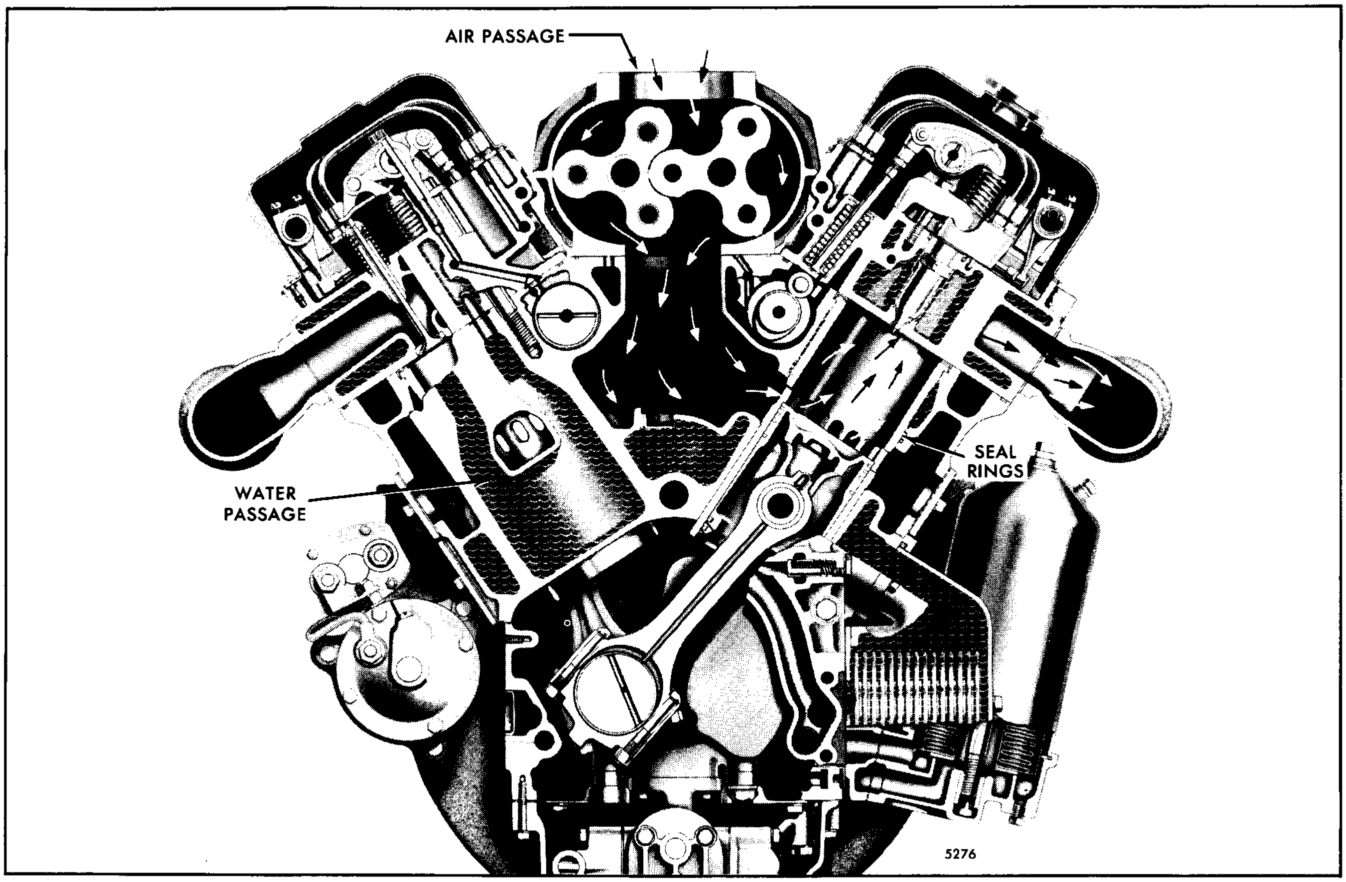


Fig. 5 - Air and Water Passages in 8V-53 Cylinder Block

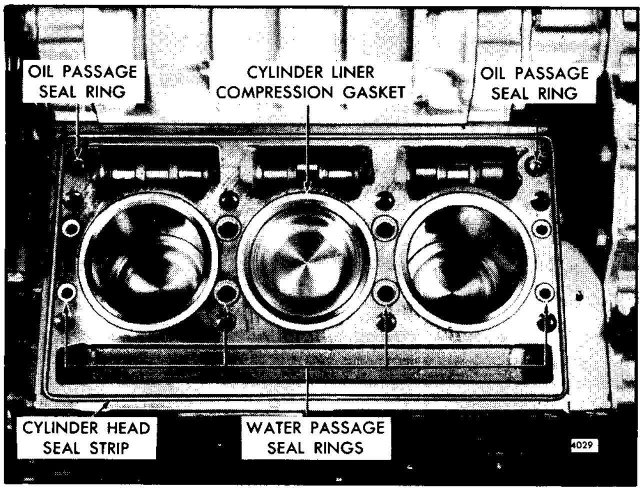


Fig. 6 - Cylinder Head Gaskets and Seals in Place on Cylinder Block

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 subassemblies and parts from the cylinder block.

The procedure for removing each subassembly from the cylinder block, together with disassembly, inspection, repair and reassembly of each, will be found in the various sections of this manual.

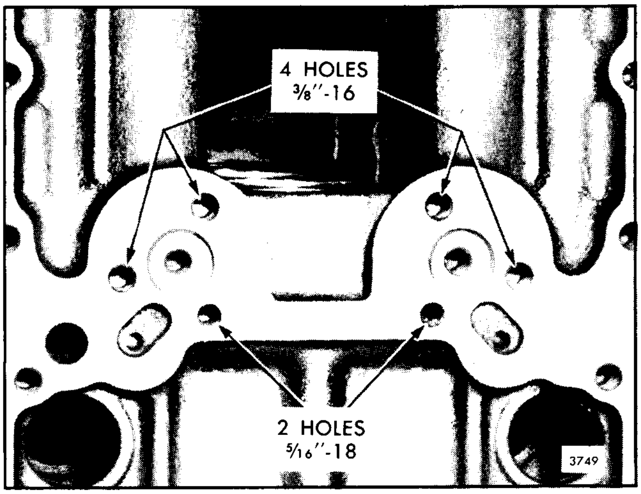


Fig. 7 - Location of the Four 3/8-16 Bolt Holes in Rear of Cylinder Block

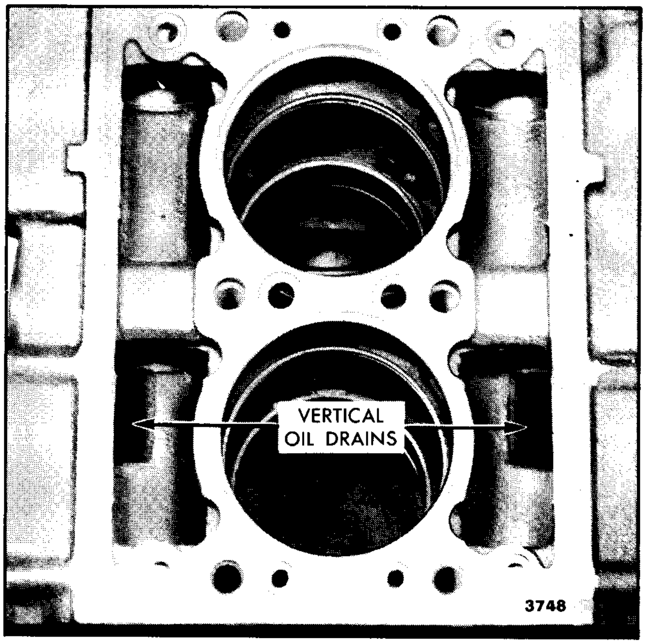


Fig. 8 - Vertical Oil Passages in Top of Cylinder Block

After stripping, the cylinder block must be thoroughly cleaned and inspected.

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. 11). The plate(s) will adequately seal the top surface of the block when used with cylinder

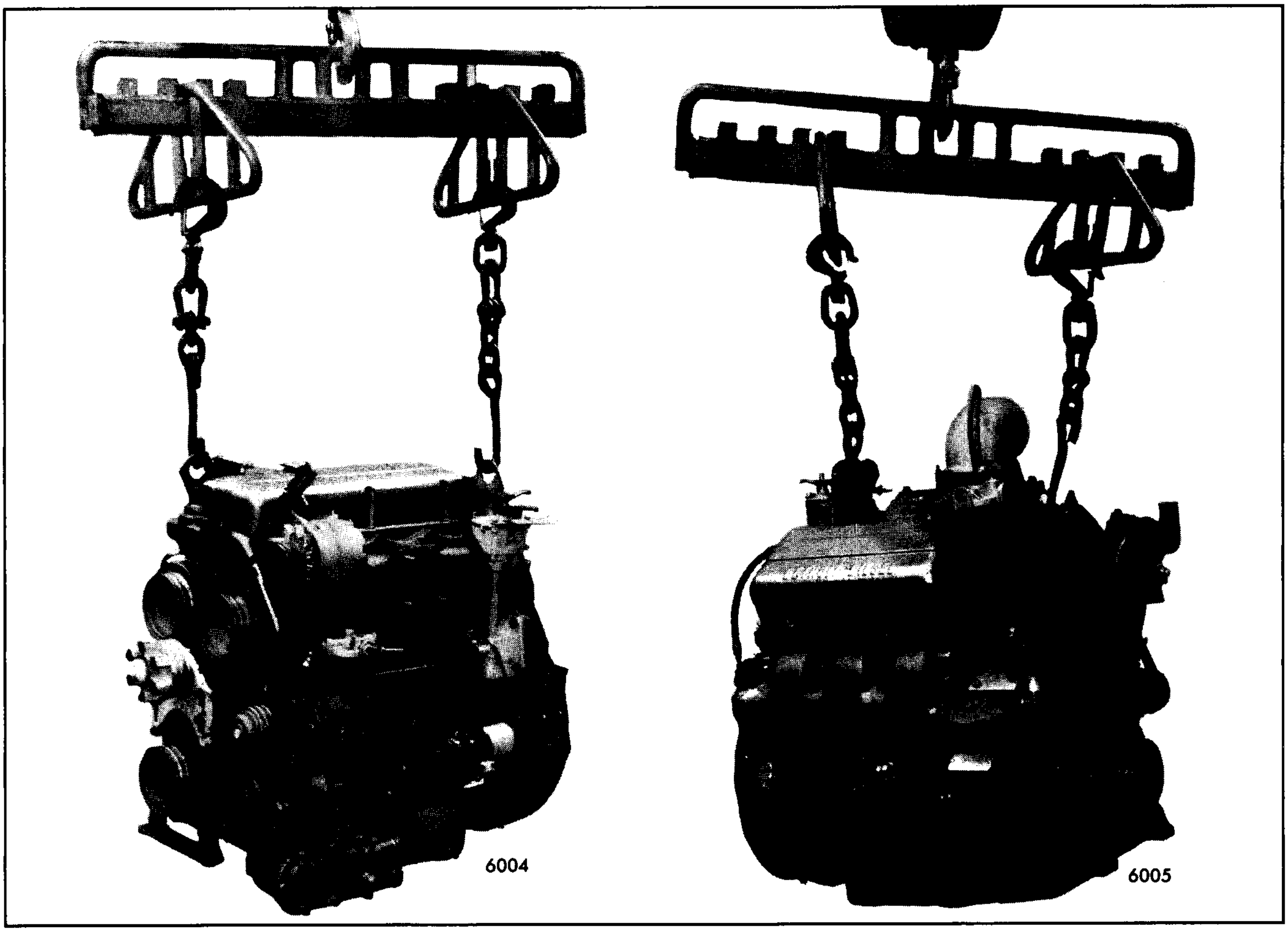


Fig. 9 - Lifting Engine with Spreader and Sling

liner compression gaskets and water hole 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.

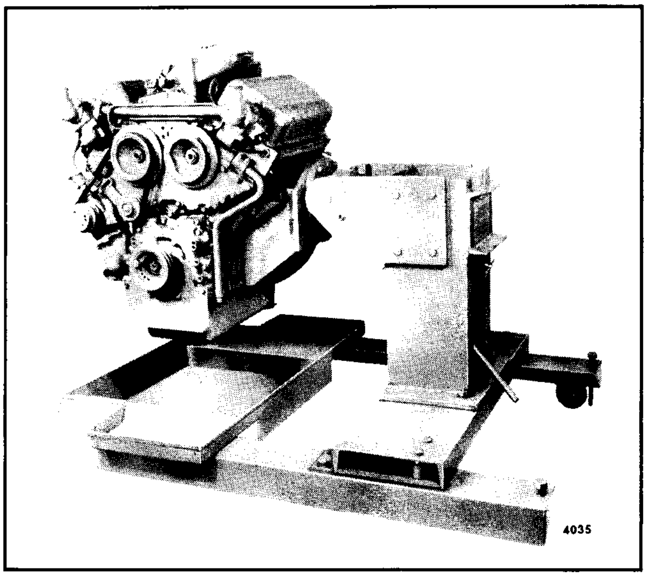


Fig. 10 - Engine Mounted on Overhaul Stand

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).

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

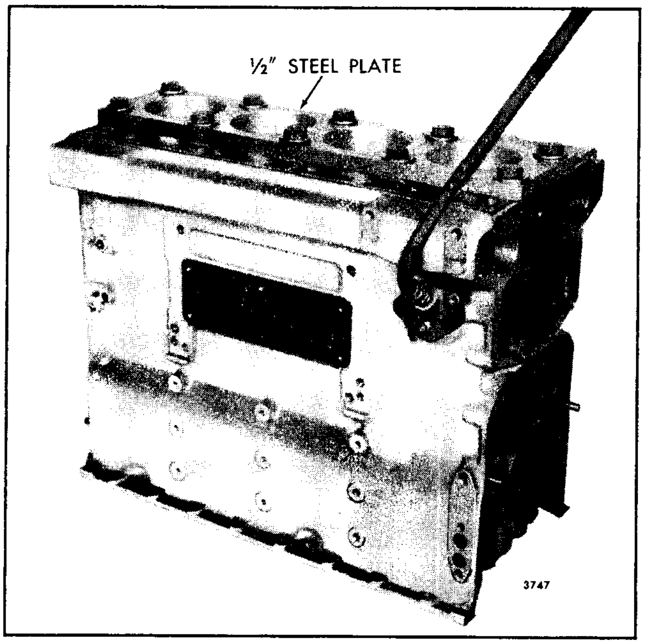


Fig. 11 - Cylinder Block Prepared for Pressure Test

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.

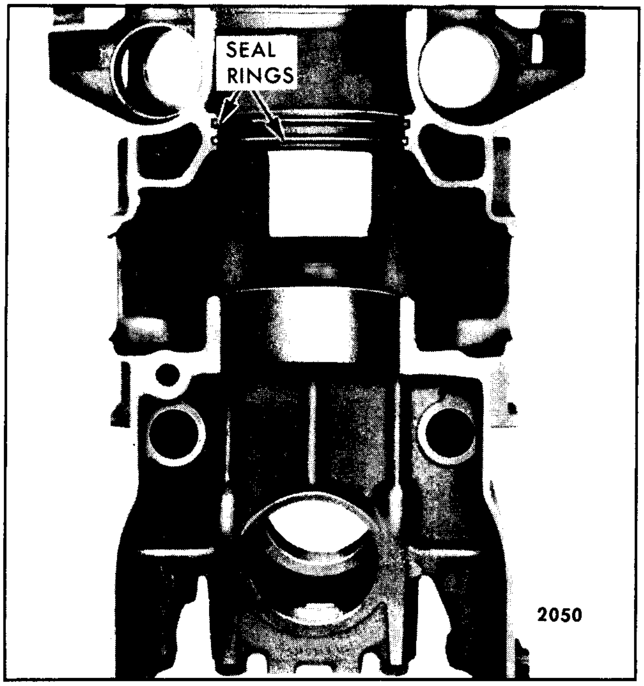


Fig. 12 - Location of Block Bore Seal Ring Groove

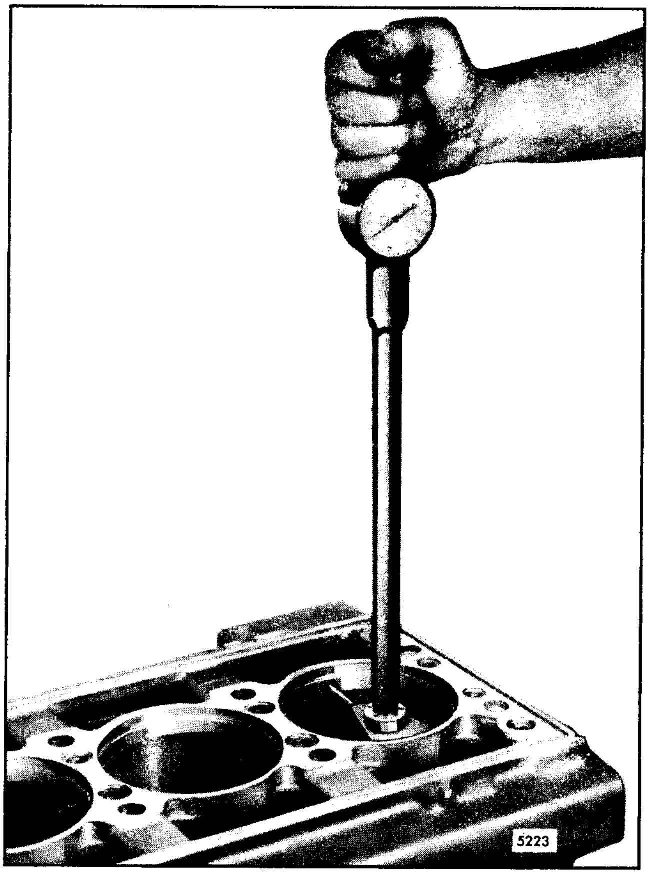


Fig. 13 - Checking Cylinder Block Bore with Tool J 5347-B

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 (82-93° C).

7. Attach an air line to the water hole cover plate and apply 40 psi (276 kPa) air pressure to the water jackets and observe the water in the tank for bubbles which will 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

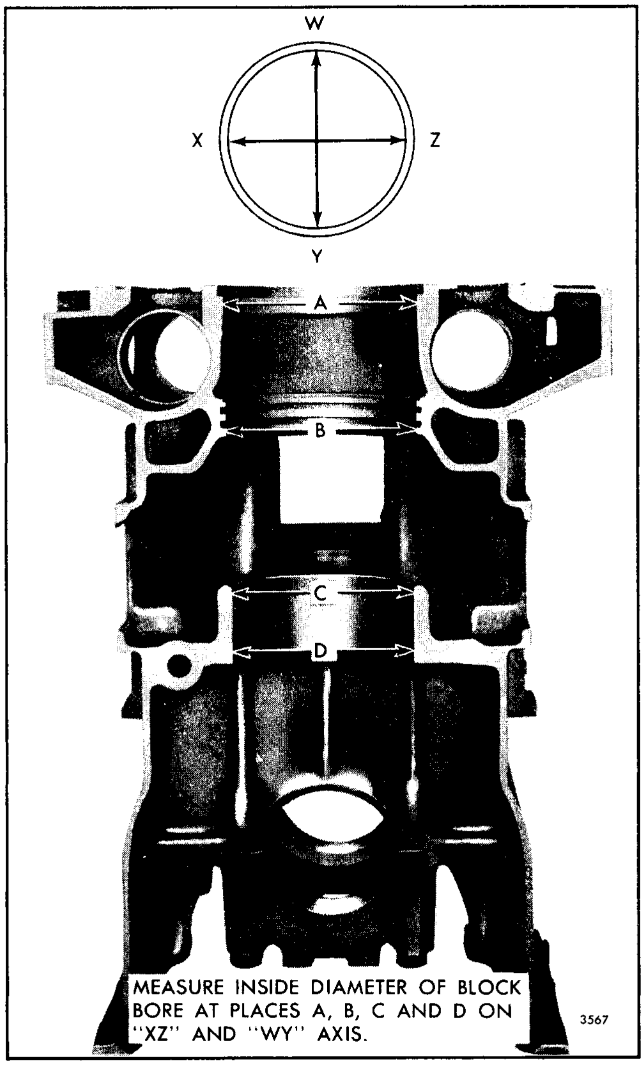


Fig. 14 - Block Bore Measurement Diagram

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 ethylene glycol base 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 40 psi (276 kPa) 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. 12) are thoroughly clean. Then inspect the grooves and lands for evidence of pitting and erosion. If the grooves are eroded to the extent that sealing is affected, then the block must be replaced.

b. To determine if an oversize O.D. cylinder liner is required, measure the entire bore of each cylinder with cylinder bore gage J 5347-B (Fig. 13) which has a dial indicator calibrated in .0001" increments. Use dial bore gage setting tool J 23059-01 to preset the cylinder bore gage to zero. Measure each block bore at the positions indicated in Fig. 14, 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".

Portable boring bars are commercially available to bore cylinder blocks oversized. Instructions on their correct

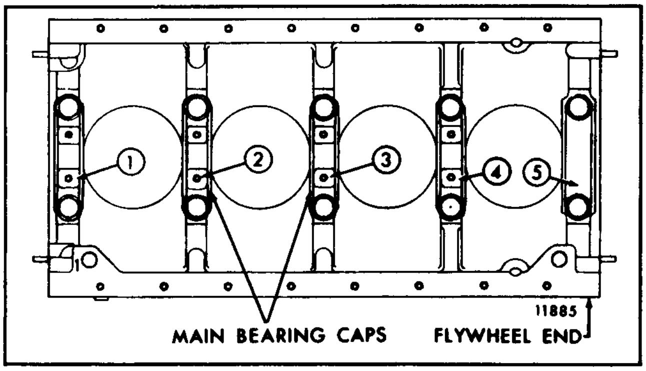


Fig. 15 - Typical Cylinder Block Markings

use are provided by the manufacturers. When boring the block, measure the block after each cut at the locations shown on Fig. 14 and observe the dimensional limits in Table 1.

OVERSIZE SERVICE CYLINDER LINERS

LINER OVERSIZE	"A" DIAMETER	"B" DIAMETER	"C" & "D" DIAMETERS
.010"	4.5295 / 4.5315	4.4965 / 4.4980	4.3665 / 4.3675
.020"	4.5395 / 4.5415	4.5065 / 4.5080	4.3765 / 4.3775

TABLE 1

Install the oversize liner in the proper bore of the cylinder block, and measure as outlined in Section 1.6.3.

> **NOTE:** A new liner-to-block seal ring (identified by two non-permanent yellow stripes) has also been released for use with the .020" oversized liner. The standard seal ring has no paint identification and is used only with the standard and .010" oversize O.D. liners.

When oversize liner is installed, stamp the amount of oversize on top of the cylinder bore adjacent to the liner counterbore.

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-53 engine) or .007" (4-53 or 8V-53 engine) logitudinally.

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. 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. 15). 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.

> **NOTE:** 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.

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 (see Section 1.0) 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 when 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. Refer to the *Cylinder Block Plugging Charts-Section 1.0 Shop Notes* - and install the necessary plugs and dowels.

NOTE: Use tool J 34650 to install the new sealant-coated 1/8"-27 pipe plugs.

6. 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 on the rear main bearing cap must extend .107" to .117" from the surface of the bearing cap.

NOTE: A stepped dowel pin is available to replace loose pins in the rear main bearing cap. Before installing the stepped pins, rebore the dowel holes in the bearing cap with a No. 11 (.1910") or No. 12 (.1890") drill. After pressing the pins into the bearing cap, remove all burrs from the base of the dowel pins to ensure proper seating of the thrust washers.

7. 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.

NOTE: Before rebuilding a used cylinder block, check for cracking in the area between the center water transfer holes and the cylinder head-to-block bolt holes (both cam and exhaust sides). If cracking is found, replace the cylinder block.

8. 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, thoroughly 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. 15) 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 non-hardening sealant 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 subassemblies 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 subassemblies 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 12-15 lb-ft (16-20 Nm) torque. On 6V-53 engines using ¼" thick air box cover clamps, tighten the bolts to 8-10 lb-ft (11-14 Nm) 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 PLATE

A flat steel plate, bolted to the rear end of the cylinder block, provides a support for the flywheel housing. A gasket is used between the block and the end plate.

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 cylinder block. Clean the end plate as outlined under *Clean Cylinder Block* in Section 1.1.

Inspect both surfaces of the end plate for nicks, dents, scratches or score marks and check it for warpage. Check the plug nuts in the end plate for cracks or 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.

Install 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 (the surface 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 (if used). 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.

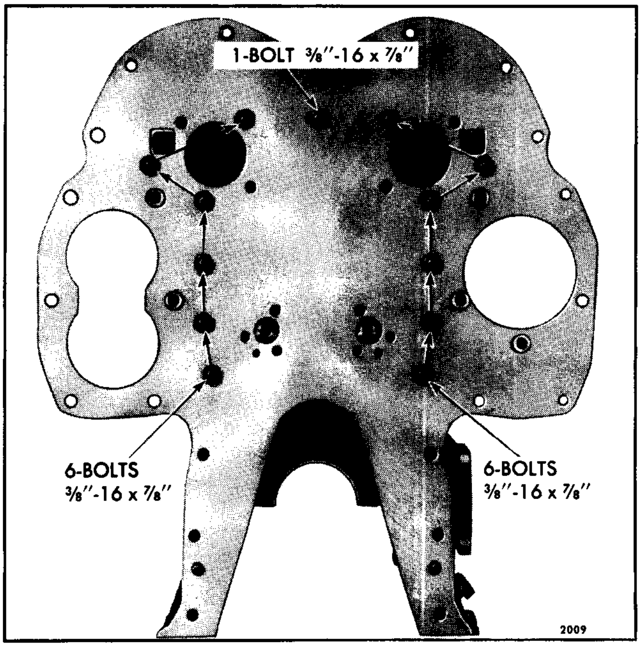


Fig. 1 - Cylinder Block Rear End Plate Mounting (3-53 Engine)

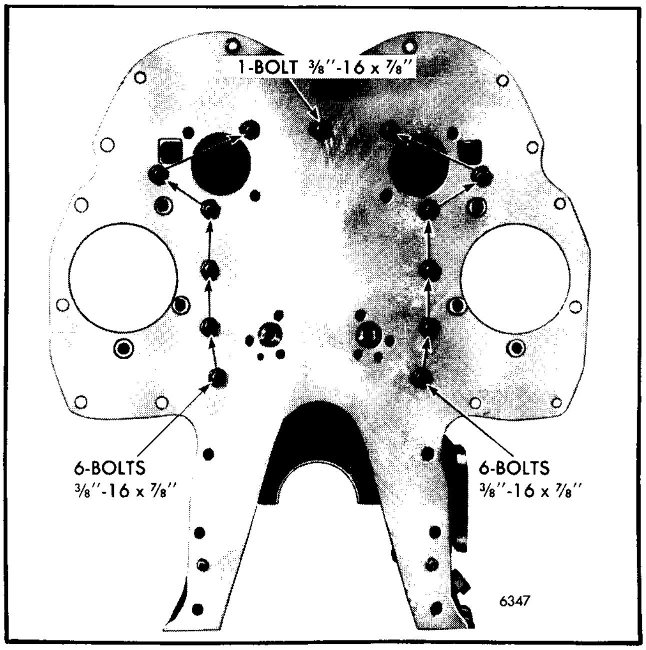


Fig. 2 - Cylinder Block Rear End Plate Mounting (4-53 Engine)

3. On In-line engines, refer to Fig. 1 or 2 and install the 3/8"-16 x 7/8" bolts with lock washers. Tighten the bolts to 30-35 lb-ft (41-47 Nm) 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. 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 the gear lash within specifications.

5. On a V-type engine, refer to Fig. 3 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 (41-47 Nm) torque and the 1/2"-13 bolts to 71-75 lb-ft (96-102 Nm) torque.

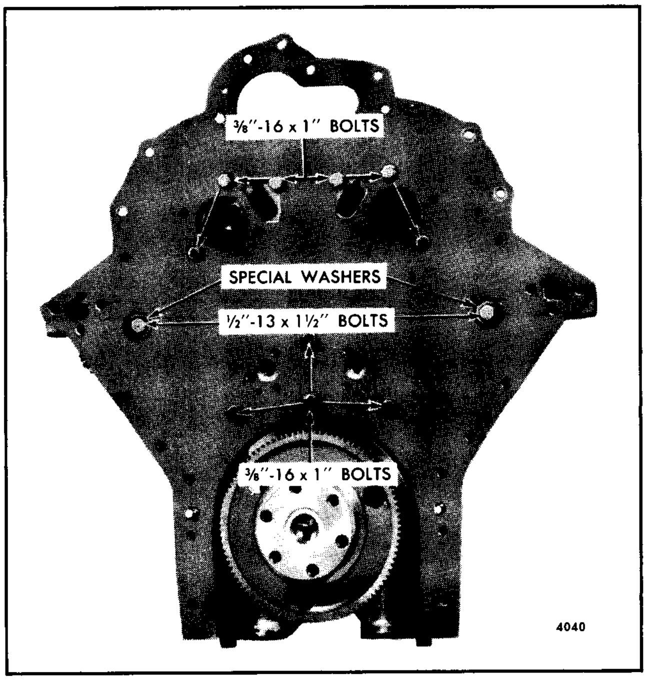


Fig. 3 - Cylinder Block Rear End Plate Mounting (V-Type Engine)

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, condenses and settles 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.

The air box drains must be kept open at all times, otherwise water and oil that may accumulate will be drawn into the cylinders.

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

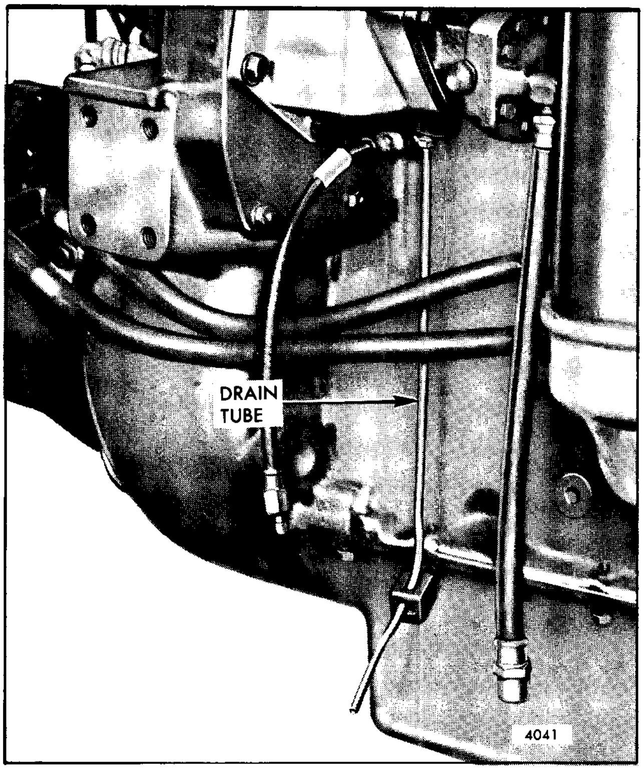


Fig. 1 - Air Box Drain Tube Mounting (In-Line Engines)

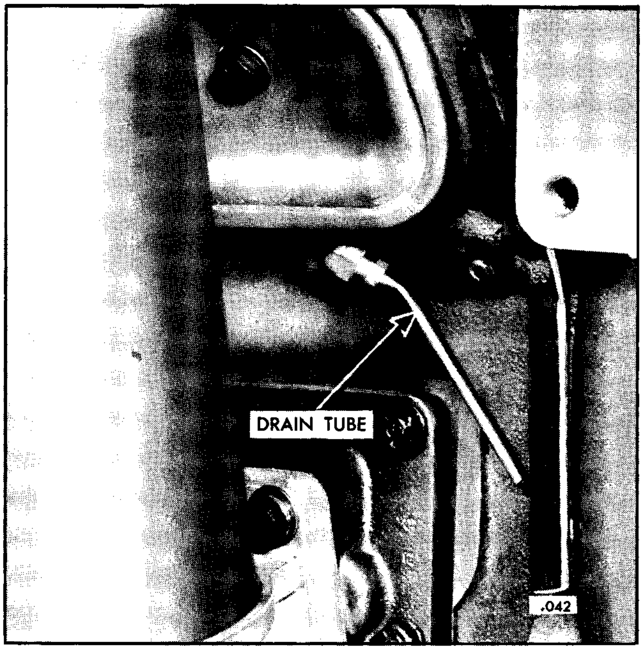


Fig. 2 - Air Box Drain Tube Mounting (6V Engine)

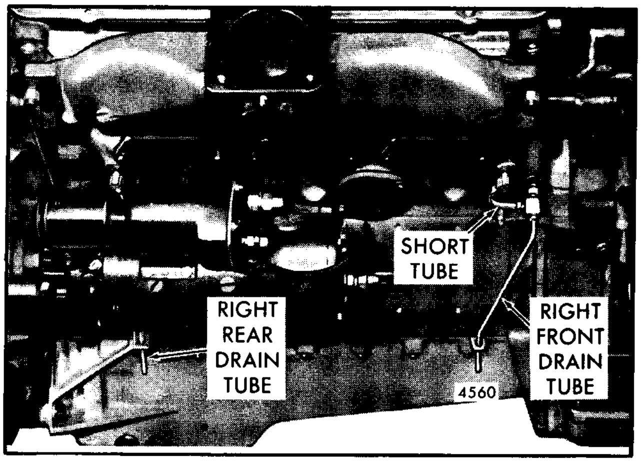


Fig. 3 - Air Box Drain Tube Mounting (8V Engine)

Inspection

A periodic check for air flow from the air box drain tubes should be made (refer to Section 15.1).

CYLINDER HEAD

The cylinder head is a one-piece casting securely held to the top of the cylinder block by special bolts (Fig. 1).

The exhaust valves, fuel injectors and the valve and injector operating mechanism are located in the cylinder head.

Depending upon the engine application, either two or four exhaust valves are provided for each cylinder.

Exhaust valve seat inserts, pressed into the cylinder head, permit accurate seating of valves under varying conditions of temperature and materially prolong the life of the cylinder head.

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 sealed upper end and flared lower end of the injector tube prevent water and compression leaks.

The exhaust passages from the exhaust valves of each cylinder lead through a single port to the exhaust manifold. The exhaust passages and the injector tubes are surrounded by engine coolant.

In addition, cooling of the above areas is further ensured by the use of water nozzles pressed into the water inlet ports in the four-valve cylinder head. The nozzles direct the comparatively cool engine coolant at high velocity toward the sections of the cylinder head which are subjected to the greatest heat. The coolant flow pattern in the two-valve cylinder head is such that nozzles are not required.

The fuel inlet and outlet manifolds are cast as an integral part of the cylinder head. Tapped holes are provided for connection of the fuel lines at various points along each manifold.

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 cylinder head and cylinder block are sealed with synthetic rubber seal rings which fit into the counterbored holes in the block. A synthetic rubber seal fits into a milled groove near the perimeter of the block. When the cylinder head is drawn down, a positive leakproof metal-to-metal contact is leakproof metal-to-metal contact is assured between the head and the block.

Cylinder Head Maintenance

Normal engine operating temperature should be maintained (see Section 13.2). The cooling system should be inspected daily and kept full at all times. The cylinder head fire deck will overheat and crack in a short time if the coolant does not cover the fire deck surface. When necessary, add water *slowly* to a hot engine to avoid rapid cooling which can result in distortion and cracking of the cylinder head (and cylinder block).

Abnormal operating conditions or neglect of certain maintenance items may cause cracks to develop in the cylinder head. If this type of failure occurs, a careful inspection should be made to find the cause and avoid a recurrence of the failure.

Unsuitable water in the cooling system may result in lime and scale formation and 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, use a reliable noncorrosive scale remover 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 *Coolant Specifications*.

Loose or improperly seated injector tubes may result in compression leaks into the cooling system, and also result in loss of engine coolant. The tubes must be tight to be properly seated. Refer to Section 2.1.4.

Overtightened injector clamp bolts may also cause head cracks. Always, use a torque wrench to tighten the bolts to the specified torque.

Other conditions which may eventually result in cylinder head cracks are:

1. Excess fuel in the cylinders caused by leaking injectors.

2. Slipping fan belts can cause overheating by reducing air flow through the radiator.

3. Accumulation of dirt on the radiator core which will reduce the flow of air and slow the transfer of heat from the coolant to the air.

4. Inoperative radiator cap which will result in loss of coolant.

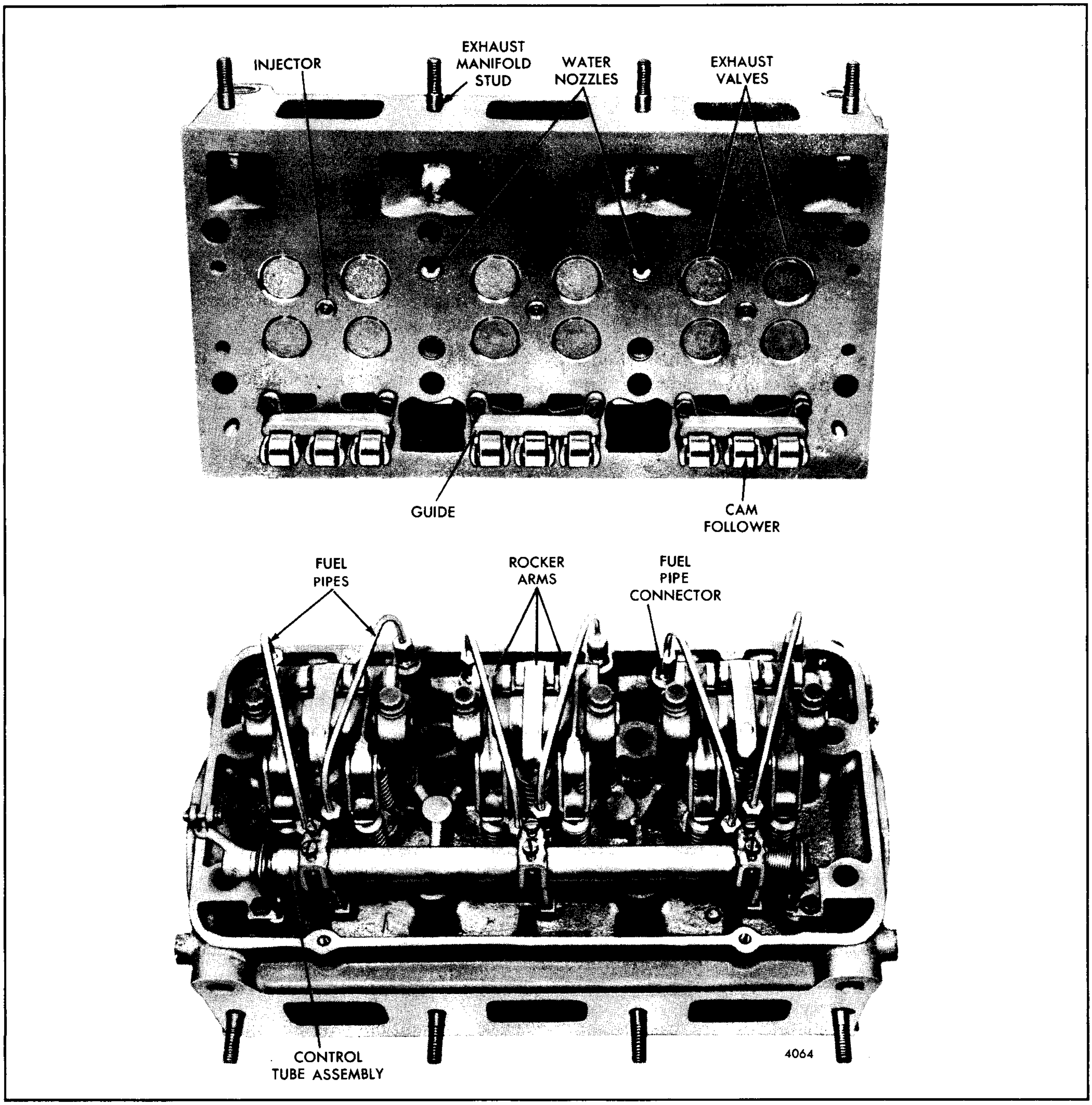


Fig. 1 - Typical Four-Valve Cylinder Head

Remove Cylinder Head

Certain service operations on the engine require removal of the cylinder head:

1. Remove and install pistons.

2. Remove and install cylinder liners.

3. Remove and install exhaust valves.

4. Remove and install exhaust valve guides.

5. Recondition exhaust valves and valve seat inserts.

6. Replace fuel injector tubes.

7. Install new cylinder head gaskets and seals.

8. Remove and install camshaft.

Due to the various optional and accessory equipment used, only the general steps for removal of the cylinder head are covered. If the engine is equipped with accessories that affect cylinder head removal, note the position of each before disconnecting or removing them to ensure correct reinstallation. Then, remove the cylinder head as follows:

1. Drain the cooling system.

2. Disconnect the exhaust piping at the exhaust manifold.

3. Remove the air cleaners 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 and the governor 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.

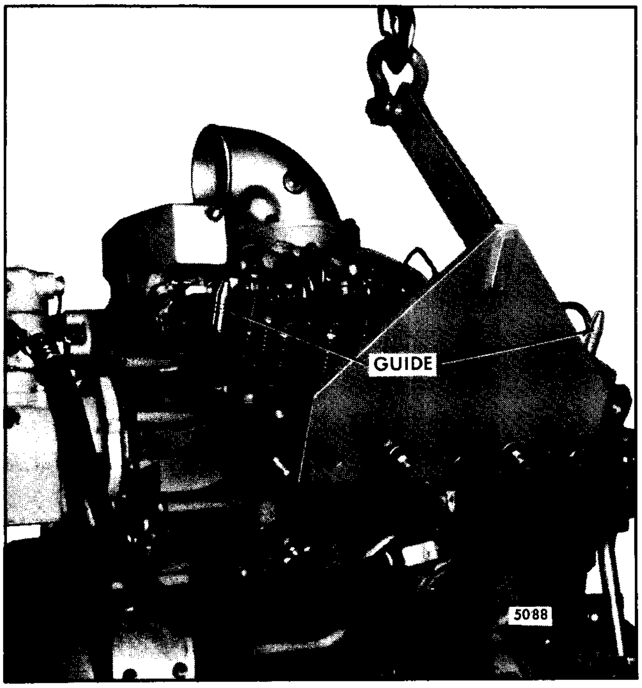


Fig. 2 - Lifting or Installing Cylinder Head with Tool J 22062-01

10. If the cylinder head is to be disassembled for reconditioning of the exhaust valves and valve seat inserts or for a complete overhaul, remove the fuel pipes and injectors at this time. Refer to Section 2.1 or 2.1.1 for removal of the injectors.

11. Check the torque on the cylinder head bolts before removing the head. Then, remove the bolts and lift the cylinder head from the cylinder block using tool J 22062-01 (Fig. 2). Checking the torque before removing the head bolts and examining the condition of the compression gaskets and seals after the head is removed may reveal the causes of any cylinder head problems.

> **NOTE:** When placing the cylinder head assembly on a bench, protect the cam followers and injector spray tips, if the injectors were not removed, by resting the valve side of the head on 2″ thick wood blocks.

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

13. After the cylinder head has been removed, drain the lubricating oil from the engine. Draining the oil at this time will remove any coolant that may have worked its way to the oil pan when the head was removed.

Disassemble Cylinder Head

If complete disassembly of the cylinder head is necessary, refer to Sections 1.2.1 and 1.2.2 for removal of the exhaust valve and injector operating mechanism.

Clean Cylinder Head

After the cylinder head has been disassembled and all of the plugs (except cup plugs) have been removed, thoroughly steam clean the head. If the water passages are heavily coated with scale, remove the injector tubes and water nozzles. Then, clean the cylinder head in the same manner as outlined for cleaning the cylinder block (Section 1.1).

Clean all of cylinder components with fuel oil and dry them with compressed air.

Inspect Cylinder Head

1. Before a cylinder head can be reused, it must be inspected for cracks. Any one or a combination of the following methods can be used for checking a cylinder head for cracks:

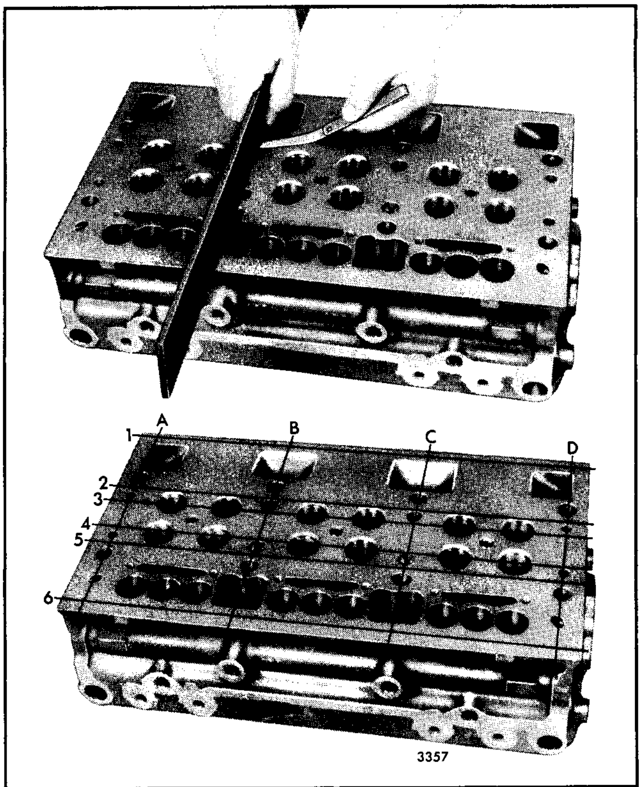


Fig. 3 - Checking Bottom Face of Cylinder Head for Warpage

NOTE: If any method reveals cracks, the cylinder head should be considered unacceptable for reuse.

Magnetic Particle Method: The cylinder head is magnetized and then covered with a fine magnetic powder or solution. Flaws, such as cracks, form a small local magnet which cause the magnetic particles in the powder or solution to gather there, effectively marking the crack. The cylinder head 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 uses fluorescent magnetic particles which glow under a "Black Light". Very fine cracks, especially on discolored or dark surfaces, that may be missed using the *Magnetic Particle Method* will be disclosed under the "Black Light".

Fluorescent Penetrant Method: A highly fluorescent liquid penetrant is applied to the area in question. Then, the excess penetrant is wiped off the surface and the part is dried. A developing powder is then applied which helps to draw the penetrant out of the flaws by capillary action. Inspection to find the crack is carried out using a "Black Light".

Non-Fluorescent Penetrant Method: The test area being inspected is sprayed with "Spotcheck" or Dye Check. Allow one to thirty minutes to dry. Remove the excess surface penetrant with clean cloths premoisened with cleaner/remover. DO NOT flush surface with cleaner/remover because this will impair sensitivity. Repeat this procedure with additional wipings until residual surface penetrant has been removed. Shake developer thoroughly until agaitator rattles. Invert spray can and spray short bursts to clear valve. Then, spray this developer film evenly over the test area being inspected. Allow developer film to dry completely before inspecting. Recommended developing time is 5 to 15 minutes.

The above four methods provide basic instructions. Specific details should be obtained from the supplier of the equipment or material.

Pressure Test Method: Cylinder head disassembled:

A. Seal off the water holes in the head with steel plates and suitable rubber gaskets secured in place with bolts and washers. Drill and tap one of the cover plates for an air hose connection.

B. Install scrap or dummy injectors to ensure proper 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 (27-34 Nm) torque.

C. Apply 40 psi (276 kPa) air pressure to the water jacket. Then, immerse the cylinder head in a tank of water, previously heated to 180-200° F or 82-93° C, for about twenty minutes to thoroughly heat the head. Observe the water in the tank for bubbles which indicate a leak or crack. Check for leaks at the top and bottom of the injector tubes, oil gallery, exhaust ports, fuel manifolds and the top or bottom of the cylinder head.

D. Relieve the air pressure and remove the cylinder head from the water tank. Then remove the plates,

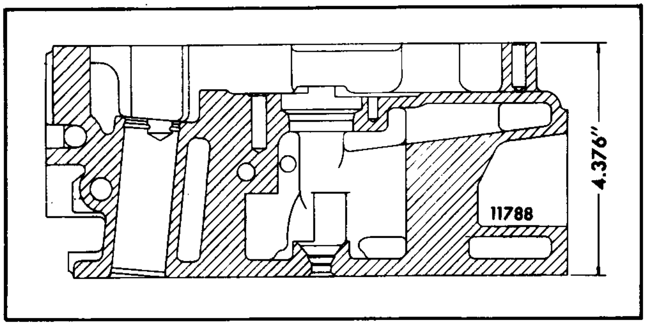


Fig. 4 - Minimum Distance Between Top and Bottom Faces of Cylinder Head

gaskets and injectors and dry the head with compressed air.

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

a. Use a heavy, accurate straight-edge and feeler gages, tool J 3172, to check for transverse warpage at each end and between all cylinders. Also, check for longitudinal warpage in six places (Fig. 3). Refer to Table 1 for maximum allowable warpage.

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

TABLE 1

b. Use the measurements obtained and the limits given in Table 1 as a guide to determine the advisability of reinstalling the head on the engine or of refacing it. The number of times a cylinder head may be refaced will depend upon the amount of stock previously removed.

c. If the head is to be refaced, remove the injector tubes prior to machining. Do not remove more metal from the fire deck of any cylinder head below the minimum distance of 4.376" (Fig. 4).

NOTE: When a cylinder head has been refaced, critical dimensions such as the protrusion of valve seat inserts, exhaust valves, injector tubes and injector spray tips must be checked and corrected. The push rods must also be adjusted to prevent the exhaust valves from striking the pistons after the cylinder head is reinstalled in the engine.

3. Install new injector tubes (Section 2.1.4) if the old tubes leaked or the cylinder head was refaced.

4. Inspect the exhaust valve seat inserts and valve guides (refer to Section 1.2.2).

5. Inspect the cam follower bores in the cylinder head for scoring or wear. Light score marks may be cleaned up with crocus cloth wet with fuel oil. Measure the bore diameters with a telescope gage and micrometer and record the readings. Measure the diameter of the cam followers with a micrometer. Record and compare the readings of the followers and bores to determine the cam follower-to-bore clearances. The clearance must not exceed .006" with used parts (refer to Section 1.0 for Specifications). If the bores are excessively scored or worn, replace the cylinder head.

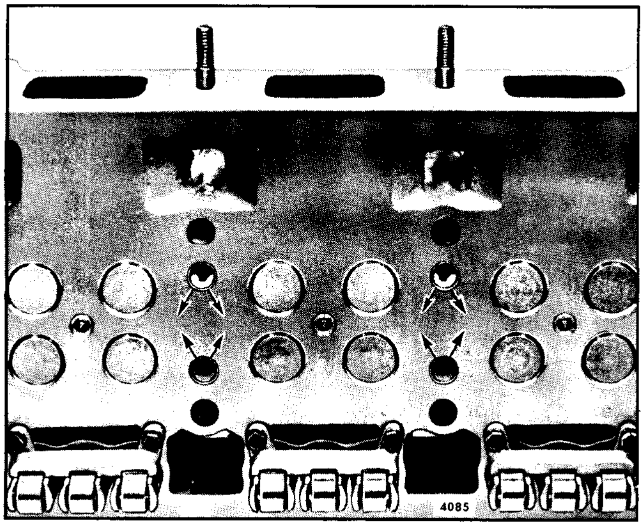


Fig. 5 - Correct Installation of Water Nozzles in Four-Valve Cylinder Head

6. Check the water hole nozzles (four-valve head only) to be sure they are not loose. If necessary, replace the nozzles as follows:

a. Remove the old nozzles.

b. Make sure the water inlet ports in the cylinder head are clean and free of scale. The water holes may be cleaned up with a 5/8" drill. Break the edges of the holes slightly.

c. Press the nozzles in place with the nozzle openings positioned as shown in Fig. 5. Press the nozzles flush to .0312" recessed below the surface of the cylinder head.

d. Check to make sure the nozzles fit tight. If necessary, use a wood plug or other suitable tool to expand the nozzles, or tin the outside diameter with solder to provide a tight fit. If solder is used, make sure the orifices in the nozzles are not closed with solder.

7. Replace broken or damaged exhaust manifold studs. Apply sealant to the threads and drive new studs to 25-40 lb-ft (34-54 Nm) torque (1.40"-1.50" height).

8. Inspect all other components removed from the cylinder head.

If a service replacement cylinder head is to be installed, it must be thoroughly cleaned of all rust preventive compound, particularly inside the integral fuel manifolds, before installing the plugs. A simple method of removing the rust preventive compound is to immerse the head in mineral spirits based solvent or fuel oil, then scrub the head and go through all of the openings with a soft bristle brush. A suitable brush for cleaning the various passages in the head can be made by attaching a 1/8" diameter brass rod to brush J 8152. After cleaning, dry the cylinder head with compressed air.

A service replacement cylinder head includes the exhaust valve guides, valve seat inserts, water nozzles, injector tubes and the necessary plugs.

Assemble Cylinder Head

After cleaning and inspection, assemble the cylinder head as follows:

1. Coat the threads of the plugs with Loctite Pipe Sealant with Teflon, then install the necessary plugs and tighten them to the specified torque (Section 1.0). Drive headless plugs flush to .0625" below the surface of the cylinder head. Use tool J 34650 to install the new sealant-coated 1/8"-27 pipe plugs.

2. After the following parts are cleaned and inspected, and replaced if necessary, reinstall them in the old cylinder head or transfer them to the new head:

a. Exhaust valves, valve seat inserts and springs (Section 1.2.2).

b. Cam followers, guides, push rods, springs, retainers, rocker arms, shafts, brackets and other related parts (Section 1.2.1).

c. Place new washers on the fuel connectors. Then, install the connectors and tighten them to 20-28 lb-ft (27-38 Nm) torque.

d. The fuel injectors, fuel pipes and injector control tube assembly can be installed at this time or after the cylinder head is installed on the engine.

Pre-Installation Inspection

Make the following inspections just prior to installing the cylinder head whether the head was removed to service only the head or to facilitate other repairs to the engine.

1. Check the cylinder liner flange heights with relationship to the cylinder block (Section 1.6.3).

2. Make sure the piston crowns are clean and free of foreign material.

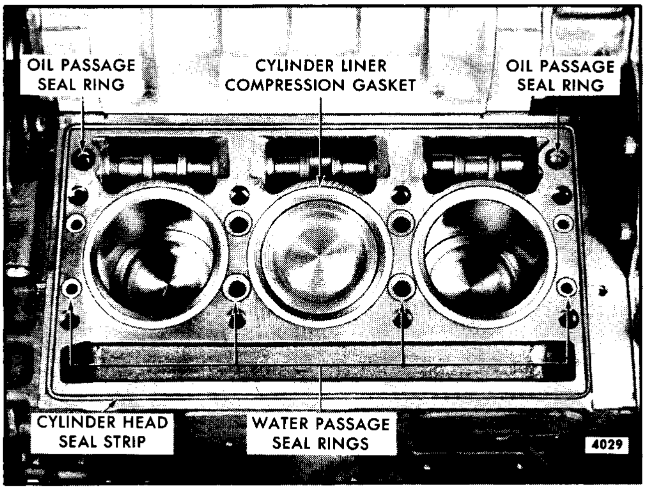


Fig. 6 - Cylinder Head Gaskets and Seals in Place on Cylinder Block

3. Make sure that each push rod is threaded into its clevis until the end of the push rod projects through the clevis. This is important since serious engine damage will be prevented when the crankshaft is rotated during engine tune-up.

4. Check the cylinder block and cylinder head gasket surfaces, counterbores and seal grooves to be sure they are clean and free of foreign material. Also, check to ensure that there are no burrs or sharp edges in the counterbores.

5. Inspect the cylinder head bolt holes in the block for accumulation of water, oil or any foreign material. Clean the bolt holes thoroughly and check for damaged threads.

Install Cylinder Head

1. Refer to Fig. 6 and install the water and oil seal rings and compression gaskets as follows:

NOTE: Never install used compression gaskets or seals.

a. Place a new compression gasket on top of each cylinder liner.

b. Place new seal rings in the counterbores of the water and oil holes in the cylinder block. Silicone-composition water hole seals can be damaged if they move out of position in the cylinder block counterbore during engine rebuild. In turn, damaged seals can allow engine coolant to contaminate lube oil and cause serious engine damage. To prevent this, a spray adhesive may be used to hold seals in place if the following precautions are taken:

1. Attach a mask or template to the cylinder block fire deck to minimize overspray.

2. Using a high-tack, spray type adhesive suitable for synthetic rubber seals (*3M Company Super-Tack Gasket Adhesive #8082,* or equivalent), spray a *light,* uniform coating of adhesive into the seal counterbores. Keep the adhesive off of adjacent block surfaces and wipe off any that gets on the fire deck or liner bores.

3. Allow the adhesive to dry to a high-tack consistency (stickiness) before installing the seal. This permits the evaporation of the liquid propellant used with the adhesive.

NOTE: Do not apply adhesive directly to the seal. The adhesive will coat the I.D. of the seal and the spray propellant may cause the seal to swell temporarily.

c. Install a new oil seal in the groove at the perimeter of the cylinder block. The seal must lay flat in the groove and *must not* be twisted or stretched when installed. Installing the seal strip in the groove with the colored stripe facing away from the cylinder bores can improve its sealing capabilities.

NOTE: 3M Company Super-Tack Gasket adhesive #8082 or equivalent may also be used to hold the peripheral head-to-block oil seals in place during engine rebuild.

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

3. Attach lifting fixture J 22062-01 to the cylinder head and lift the head into position above the cylinder block (Fig. 2).

4. Make a final visual check of the compression gaskets and seals to ensure that they are in place before the cylinder head is lowered. *This is a very important check.* Gaskets and seals which are not seated properly will cause leaks and "blowby" and result in poor engine performance and damage to the engine.

5. Wipe the bottom of the cylinder head clean. Then, lower the head until it is about 1/2″ from the surface of the cylinder block.

6. Apply a small quantity of International Compound No. 2, or equivalent, to the threads and underside of the head of each cylinder head attaching bolt. Then, install the bolts finger tight. On the In-line engines equipped with both six and twelve point 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. Continue to tighten the bolts as the head is lowered on the cylinder block.

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

7. After the head is in place, remove the guide studs and chain hoist and install the remaining bolts, running all bolts down snug tight with a speed handle (15-20 lb-ft or 20-27 Nm torque). However, *before* tightening the bolts, loosen the lifter bracket-to-cylinder head attaching bolts, otherwise the head may be prevented from seating properly on the cylinder block. A similar condition could exist if the exhaust manifold is attached to the cylinder head. Clearance must be assured between the exhaust manifold and the bosses on the cylinder block. On some engine models, these bosses serve as a rest for the exhaust manifold after the cylinder head has been installed on the cylinder block.

8. Tighten the bolts to 170-180 lb-ft (231-244 Nm) torque in 50 lb-ft (68 Nm) increments with a torque wrench, in the sequence shown in Fig. 7. Repeat the tightening sequence at least once, because the first bolts tightened in the sequence tend to lose significant clamp load during tightening of the remaining bolts. Apply a steady pressure for two or three seconds at the prescribed torque to allow the bolts to turn while the gaskets yield to their final designed thickness. *Begin on the cam follower side of the head* to take up tension in the push rod springs. Tighten the bolts to the high side of the torque specification, but do not exceed the limit or the bolts may stretch beyond their elastic limits. Attempting to tighten the bolts in one step may result in trouble and consequent loss of time in diagnosis and correction of difficulties, such as compression leaks, when the engine is put into operation.

NOTE: Tightening the cylinder head bolts will not correct a leaking compression gasket or seal. The head must be removed and the damaged gasket or seal replaced.

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

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

11. Tighten the rocker arm bracket bolts to 50-55 lb-ft (68-75 Nm) torque.

NOTE: The exhaust valves on a four-valve head may be damaged if the valve bridges are not resting on the ends of the exhaust valves when

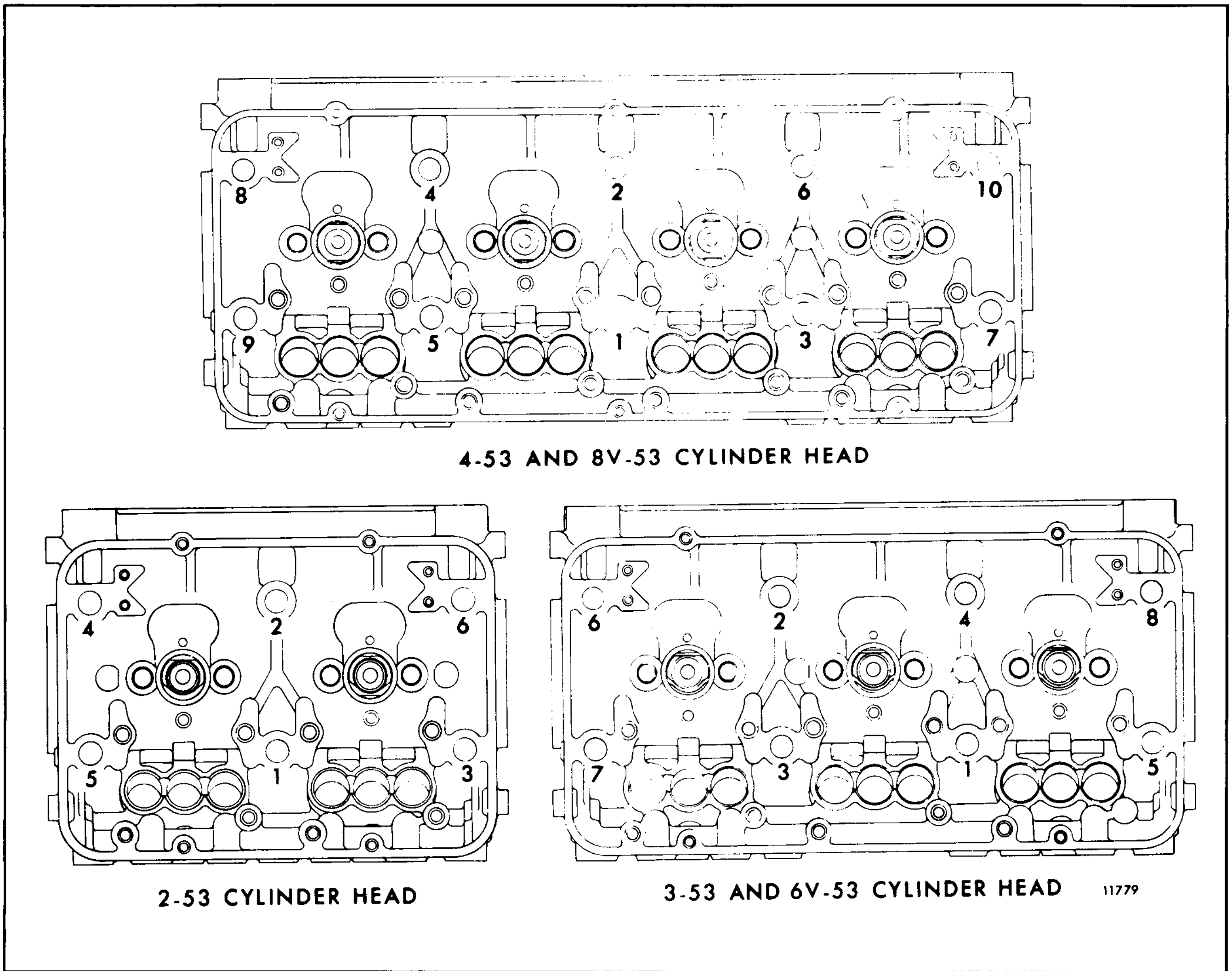


Fig. 7 - Cylinder Head Bolt Tightening Sequence

tightening the rocker arm bracket bolts (refer to Section 1.2.1 under *Install Rocker Arms and Rocker Arm Shaft*). Therefore, note the position of the valve bridges before, during and after tightening the bolts.

12. 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 (16-20 Nm) torque.

NOTE: 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 (refer to *Pressurize Fuel System - Check for Leaks* in Section 2.0).

13. Set the injector control tube assembly in place on the cylinder head and install the attaching bolts finger tight. When positioning the control tube, be sure 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 (14-16 Nm) torque.

14. After tightening the bolts, revolve the injector control tube to be sure 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 will remove any bind that may exist. The injector racks *must* return to the no-fuel position freely by aid of the return spring only. *Do not bend the spring.* If necessary, replace the spring.

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

16. Remove the covers from the drain holes in the cylinder head.

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

18. Install the thermostat housing and thermostat.

19. Install the air cleaner or air silencer.

20. Connect the fuel lines.

21. Install any other equipment that was previously removed.

22. Refer to Section 13.1 under *Preparation for Starting Engine First Time* and fill the cooling system and lubrication system.

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

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.

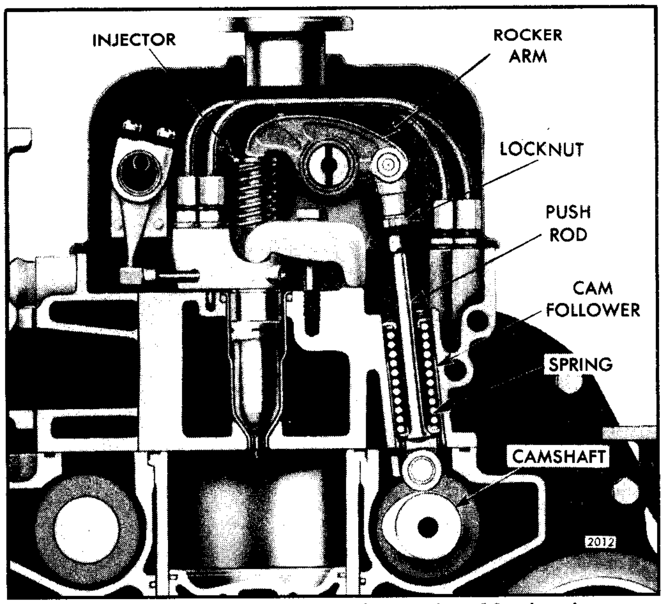


Fig. 1 - Valve and Injector Operating Mechanism

Each set of three rocker arms pivots on a shaft supported by two brackets. A single bolt secures each bracket to the top of the cylinder head. Removal of the two bracket bolts permits the rocker arm assembly for one cylinder to be raised, providing easy access to the fuel injector and the exhaust valve springs.

The rocker arms are operated by a 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 retain the cam followers in place and to align the cam follower rollers with the camshaft lobes.

A coil spring, inside of each cam follower, maintains a pre-determined load on the cam follower to ensure contact of the cam roller on the camshaft lobe at all times.

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 the main oil gallery in the cylinder block. Oil from this passage flows through drilled passages in the rocker shaft bracket bolts to the passages in the rocker arm shaft to lubricate the rocker arms.

Overflow oil from the rocker arms lubricates the exhaust valves and cam followers. The oil then drains from the top deck of the cylinder head through oil holes in the cam followers, into the camshaft pockets in the cylinder block and back to the oil pan.

The cam follower rollers are lubricated with oil from the cam followers, oil picked up by the camshaft lobes and by oil emitted under pressure from grooves in the camshaft bushing bores in the cylinder block.

Service

Some service operations may be performed on the valve and injector operating mechanism without removing the cylinder head:

1. Adjust valve clearance.
2. Replace a valve spring.
3. Replace a rocker arm.
4. Replace a rocker arm shaft or bracket.
5. Replace a fuel injector.

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

To replace the exhaust valves and valve seat inserts, the cylinder head must be removed (refer to Section 1.2).

Remove Rocker Arms and Shaft

1. Clean and remove the valve rocker cover. Discard the gasket(s).
2. Remove the fuel pipes from the injector and the fuel connectors.

NOTICE: Immediately after removing the fuel pipes, cover the injector fuel inlet and outlet openings with shipping caps to prevent dirt or foreign material from entering.

3. Turn the crankshaft, or crank the engine with the starting motor, to bring the injector and valve rocker arms in line horizontally.

NOTICE: Do not bar the crankshaft in a left-hand direction of rotation with a wrench or barring tool on the crankshaft bolt, because the bolt may be loosened.

4. Remove the two bolts which secure the rocker arm shaft brackets to the cylinder head. Also, remove the valve rocker cover hold-down bracket on engines equipped with a cast aluminum rocker cover. Then, remove the brackets and shaft.

NOTICE: When removing the rocker arm shaft, fold the three rocker arms back just far enough so the shaft can be removed. *Do not* force the rocker arms all the way back with the shaft in place as this may impose a load that could bend the push rods.

5. Loosen the locknuts at the upper ends of the push rods, next to the clevises, and unscrew the rocker arms from the push rods.

If the rocker arms and shafts from two or more cylinders are to be removed, tag them so they may be reinstalled in their *original* positions.

Inspection

Wash the rocker arms, shaft, brackets and bolts with clean fuel oil. Use a small wire to clean out the drilled oil passages in the rocker arms and rocker shaft bolts. Dry the parts with compressed air.

Inspect the rocker arm shaft, injector rocker arm bushings or valve rocker arm bores for wear. A maximum shaft-to-bushing (or bore) clearance of .004" is allowable with used parts (refer to Section 1.0). Service replacement injector rocker arm bushings must be reamed to size after installation.

Inspect the rocker arms for galling or wear on the pallets (valve or injector contact surfaces). If worn, the surface may be refaced up to a maximum of .010". However, proceed with caution when surface grinding to avoid overheating the rocker arm. Maintain the radius and finish as close to the original surface as possible. Also, inspect the valve bridges (four-valve head) for wear.

Remove Cam Follower and Push Rod (Cylinder Head on Engine)

When removing the cam followers and associated parts, tag them so they may be reinstalled in their original location.

To remove a push rod, spring, spring seats and cam follower from the top of the cylinder head, proceed as follows:

1. Remove the rocker arm shaft and brackets as outlined under *Remove Rocker Arms and Shaft.*
2. Loosen the locknut and unscrew the rocker arm from the push rod to be removed. Remove the locknut.
3. Install remover J 3092-01, a flat washer and the locknut on the push rod, with the lower end of the tool resting on the upper spring seat.
4. Thread the nut down to compress the spring.
5. Remove the spring seat retainer from the groove in the cylinder head (Fig. 2).
6. Unscrew the locknut to release the spring. Then, remove the nut, flat washer and tool from the push rod.
7. Pull the push rod, spring, spring seats and cam follower out of the cylinder head.

Remove Cam Follower and Push Rod (Cylinder Head Removed)

When removing the cam followers and associated parts, tag them so they may be reinstalled in their original location.

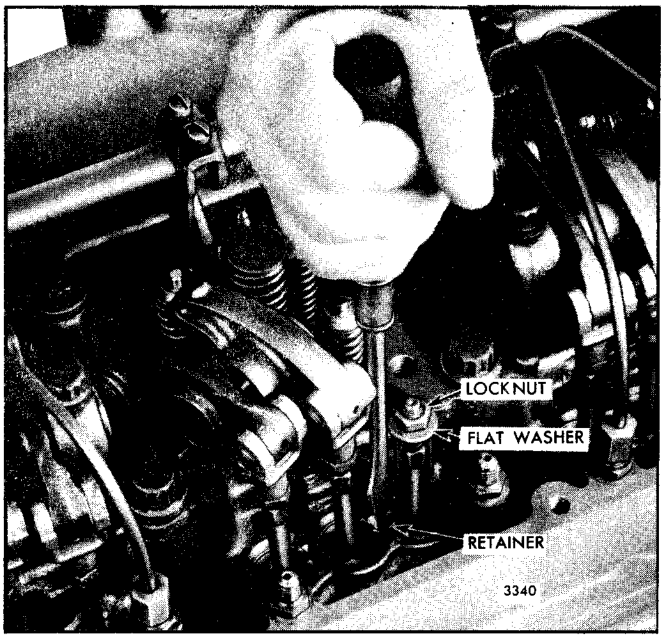


Fig. 2 - Removing Push Rod from Upper Side of Cylinder Head using Tool J 3092-01

1. Rest the cylinder head on its side and remove the cam follower guide (Fig. 3).
2. Pull the cam follower out of the cylinder head.
3. Remove the fuel pipes from the injector and the fuel connectors.

NOTICE: Immediately after removing the fuel pipes, cover the injector fuel inlet and outlet openings with shipping caps to prevent dirt or foreign material from entering.

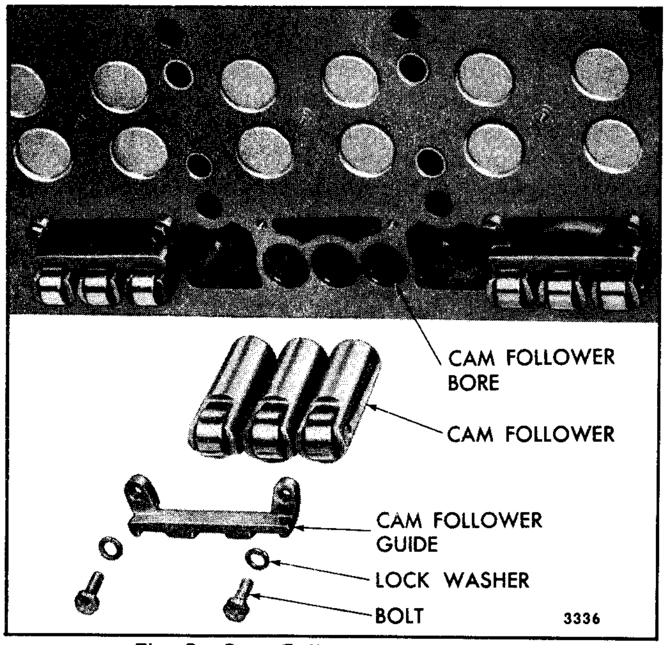


Fig. 3 - Cam Followers and Guide

4. Loosen the push rod locknut and unscrew the push rod from the rocker arm clevis.
5. Pull the push rod and spring assembly from the bottom of the cylinder head.
6. Remove the push rod locknut, spring and spring seats from the push rod.

If the cylinder head is to be replaced, remove the spring retainers and install them in the new head.

Inspection

Proper inspection and service of the cam follower is very necessary to obtain continued efficient engine performance. When any appreciable change in injector timing or exhaust valve clearance occurs during engine operation, remove the cam followers and their related parts and inspect them for excessive wear. This change in injector timing or valve clearance can usually be detected by excessive noise at idle speed.

Wash the cam followers with lubricating oil or Cindol 1705 and wipe dry. *Do not use fuel oil.* Fuel oil working its way in between the cam roller bushing and pin may cause scoring on initial start-up of the engine since fuel oil does not provide adequate lubrication. The push rods, springs and spring seats may be washed with clean fuel oil and dried with compressed air.

Examine the cam follower rollers for scoring, pitting or flat spots. The rollers must turn freely on their pins. Measure the total diametric clearance and side clearance. Install a new roller and pin if the clearances exceed those specified in Fig. 4. Cam followers stamped with the letter "S" on the pin, roller and follower body are equipped with an oversized pin and roller. The same clearances apply to either a standard or oversize cam follower assembly.

Examine the camshaft lobes for scoring, pitting or flat spots. Replace the camshaft, if necessary.

Measure the cam follower bores in the cylinder head with a telescope gage and micrometer and record the readings. Measure the diameter of the cam followers with a micrometer. Record the readings and compare the readings of the followers and bores to determine the cam follower-to-bore clearances (refer to Section 1.0 for Specifications).

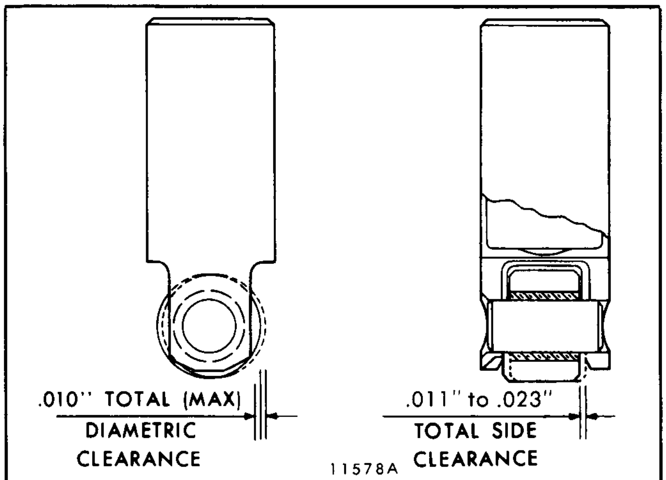


Fig. 4 - Cam Roller Clearances

If the push rod breaks or is damaged, the rocker arm should be suspect. Any wear or excessive movement in the rocker arm or clevis can put a side load on the push rod, resulting in fracture or damage. Before replacing the push rod, inspect the rocker arm for signs of wear or cracking. If wear or excessive movement of the rocker arm or clevis is noted, replace the rocker arm.

Inspect the push rods and spring seats for wear.

Examine the cam follower springs for wear or damage and check the spring load.

The current push rod spring (Fig. 5) is made from .1920" diameter wire and was first used only in the injector cam follower position. The former push rod spring was made from .1770" diameter wire.

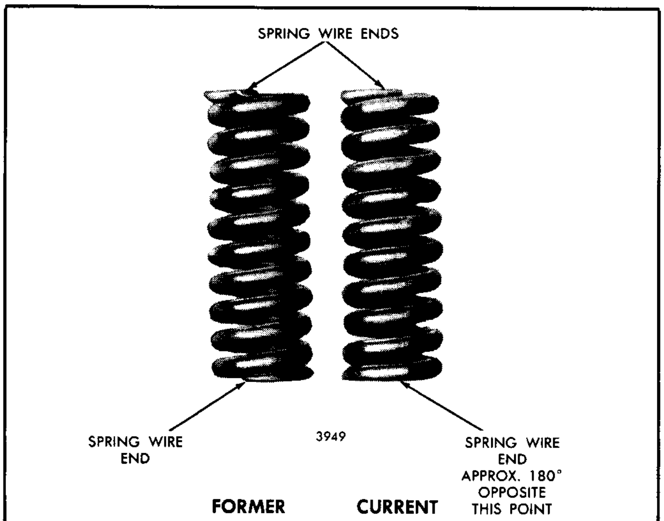


Fig. 5 - Spring Identification

Use spring tester J 22738-02 to check the spring load (Fig. 6). Replace the current type spring when a load of less than 250 pounds will compress it to a length of 2.1406". Replace the former type spring when a load of less than 172 pounds will compress it to a length of 2.1250".

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.

Replace Cam Roller and Pin

Do not attempt to bore out the legs of a standard cam follower for an oversized pin.

To replace a cam roller and pin, proceed as follows:

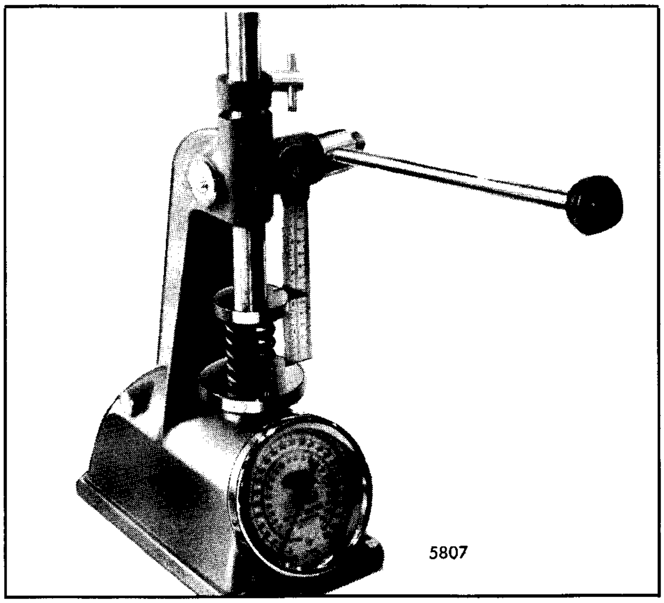


Fig. 6 - Testing Cam Follower Spring using Tool J 22738-02

DISASSEMBLE CAM FOLLOWER

1. Pull the adjustable sliding support out against its stop (Fig. 7).
2. Place the cam follower with follower pin resting on the spring-loaded guide pin in the fixture. Push the follower down until the lower leg engages the slot in the support plate. This supports the roller which in turn supports the upper follower leg. Then, push the follower in until contact is made with the roller stop screw. This should put the roller pin in alignment with the pressing ram.
3. Lower the handle to put pressure on the roller pin.
4. Push the adjustable sliding support in until resistance is felt. This causes the lower follower leg to be supported.
5. Press the pin from the cam follower.

ASSEMBLE CAM FOLLOWER

Before installing the new roller and pin, remove the preservative by washing the parts with clean lubricating oil or Cindol 1705 and wipe dry. *Do not use fuel oil.* After washing the parts, lubricate the roller and pin with Cindol 1705.

1. To install a new pin, pull the adjustable sliding support out and position the cam follower in the fixture (roller in place) as in Step 2 above.

When assembling the cam follower with flats on the outside of the legs, push adaptor J 33421-3 onto the pressing ram to the limit depth of the press to the correct dimension. When pressing the pin into the follower with rounded legs, depth of the press is determined by the operator. Adapter J 33421-3 has a

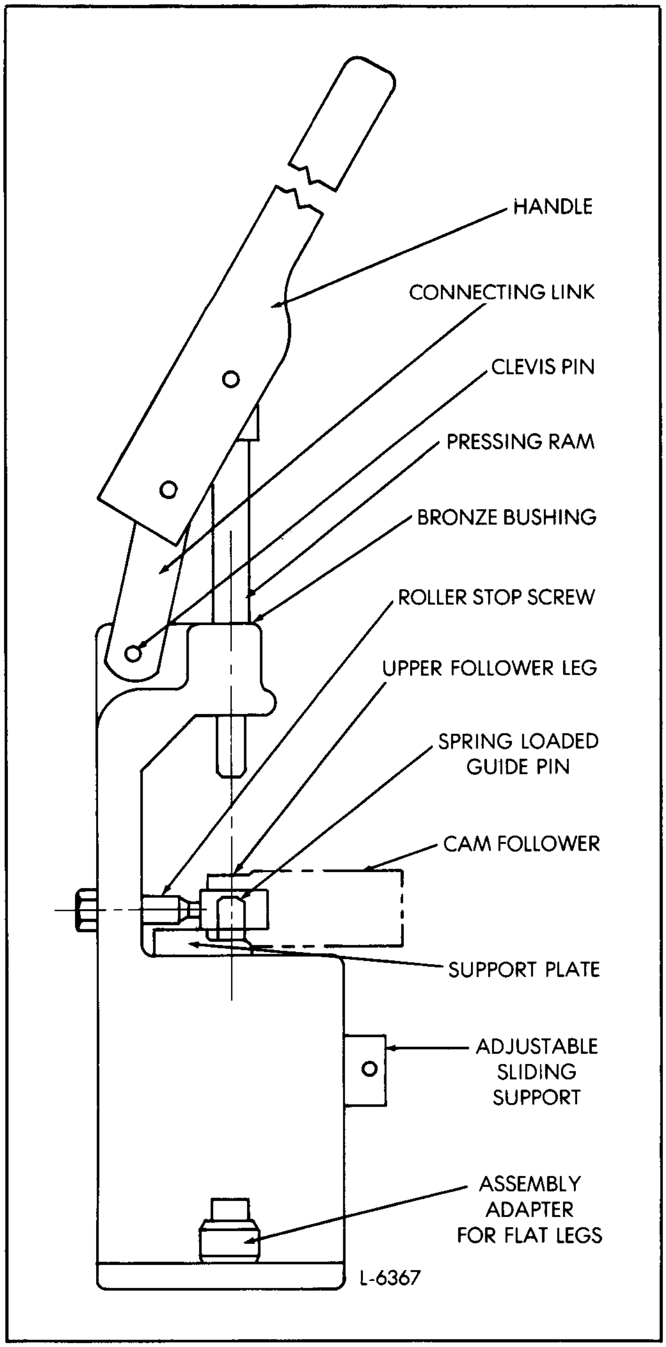


Fig. 7 - Removing or Installing Cam Follower Roller using Tool J 33421

spring-loaded plunger in the set screw and does not normally require any adjustment.

2. Align the pin over the follower leg, lower handle and place pressure on the pin.
3. To support the lower follower leg, push the adjustable sliding support in until resistance is felt.
4. Press the pin into place.
5. Remove the cam follower from the fixture and check the side clearance (Fig. 4). The clearance must be .011" to .023".

Install Cam Follower and Push Rod

If new cam follower assemblies are to be installed, remove the preservative by washing with Cindol 1705 and wipe dry. *Do not use fuel oil.*

Before cam followers are installed, immerse them in clean Cindol 1705 (heated to 100-125°F or 38-52°C) for at least one hour to ensure initial lubrication of the cam roller pins and bushings. Rotate the cam rollers during the soaking period to purge any air from the bushing-roller area. The heated Cindol oil results in better penetration as it is less viscous than engine oil and flows more easily between the cam roller bushing and pin. After the cam followers are removed from the heated Cindol 1705, the cooling action of any air trapped in the bushing and pin area will tend to pull the lubricant into the cavity.

NOTICE: Heat the Cindol 1705 in a small pail with a screen insert. The screen will prevent the cam followers from touching the bottom of the pail and avoid the possibility of contamination.

Install used cam followers and push rods in their original locations. Refer to Fig. 8 and proceed as follows:

CYLINDER HEAD ON ENGINE

1. Note the oil hole in the bottom of the cam follower. With the oil hole directed away from the exhaust valves, slide the cam follower in position in the cylinder head.
2. Assemble the *serrated* lower spring seat, spring and upper cup-shaped spring seat on the push rod.

The current cup-shaped upper spring seat can be used with either the former or current spring.

3. Place a flat washer over the upper spring seat and start the locknut on the push rod. Place tool J 3092-01 on the push rod between the washer and the upper spring seat and place the push rod assembly in the cam follower. Then, thread the locknut on the push rod until the spring is compressed sufficiently to permit the spring retainer to be installed. Then, install the spring retainer.
4. Remove the nut, flat washer and tool. Then, reinstall the locknut and thread it as far as possible on the push rod.

CYLINDER HEAD REMOVED FROM ENGINE

Refer to Fig. 8 and install the cam follower and push rod as follows:

1. Assemble the *serrated* lower spring seat, spring, upper cup-shaped spring seat and locknut on the push rod.

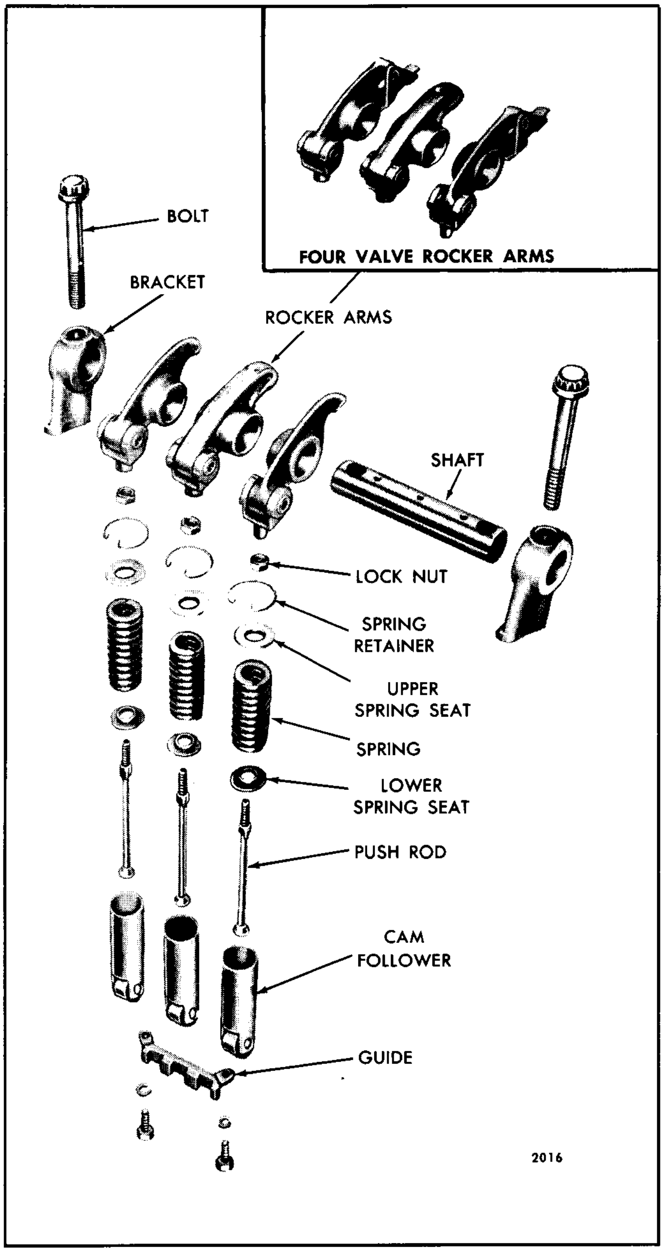


Fig. 8 - Valve and Injector Operating Mechanism and Relative Location of Parts

The current cup-shaped upper spring seat can be used with either the former or current spring.

2. With the spring retainer in place in the cylinder head, slide the push rod assembly in position from the bottom of the head.
3. Note the oil hole in the bottom of the cam follower. With the oil hole directed away from the exhaust valves, slide the cam follower in position from the bottom of the head.
4. Attach the follower guide to the cylinder head to hold the group of three cam followers in place. Tighten the guide bolts to 12-15 lb-ft (16-20 N·m) 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

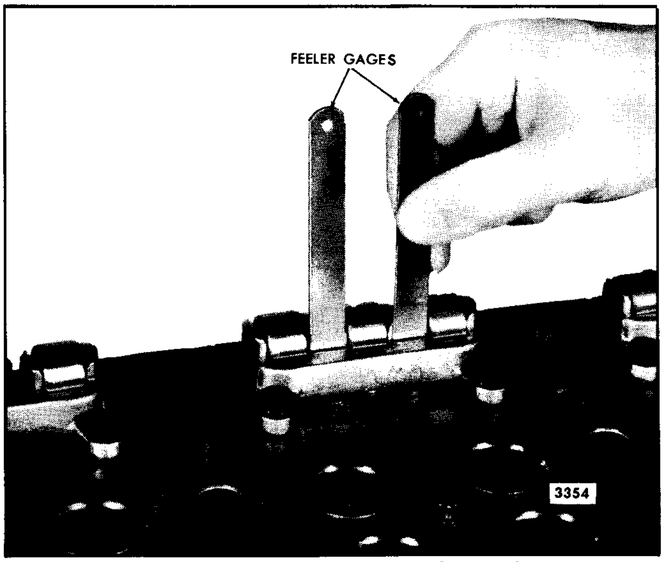


Fig. 9 - Checking Cam Follower to Guide Clearance

slightly and tap each corner of the guide with a brass rod (Fig. 10). Then, retighten the bolts to the specified torque.

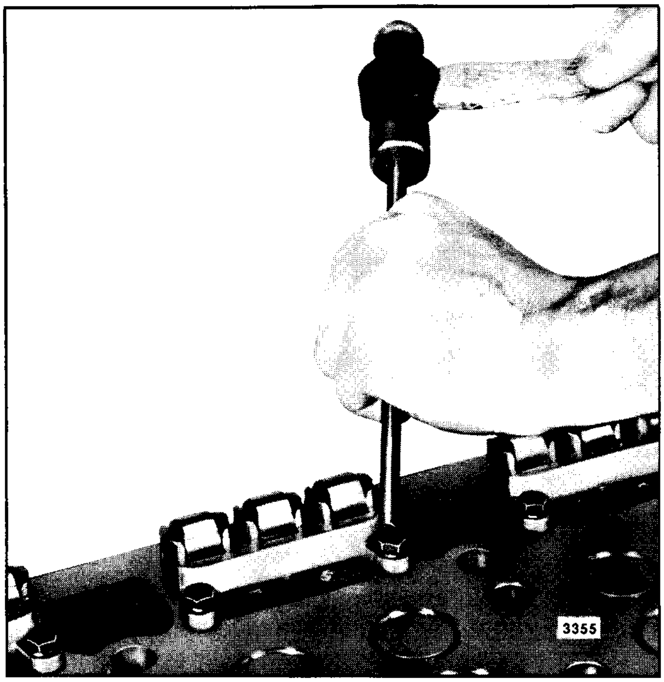


Fig. 10 - Adjusting Cam Follower Guide

NOTICE: It is important to use the correct bolts as prescribed in the parts books. The hardened bolt is necessary to obtain the proper torque and to withstand the stress imposed on it during engine operation.

Install Rocker Arms and Shaft

Note that the injector rocker arm (center arm of the group) is slightly different from the exhaust valve rocker arms; the boss for the shaft on the left and right-hand valve rocker arms is longer on one side. The extended boss of each valve rocker arm must face toward the injector rocker arm.

New injector rocker arm assemblies have an increased cross-sectional area between the pivot axis and pallet and the pivot axis and clevis. The former and current rocker arm assemblies are interchangeable and can be mixed in an engine. Only the new assemblies will be serviced.

NOTICE: If the rocker arm is damaged or breaks, the push rod should *always* be changed out when the new rocker arm is installed. A damaged rocker arm can cause side loading and weakening of the push rod. If reused, a side-loaded push rod can break.

1. Thread each rocker arm on its push rod until the end of the push rod is flush with or above the inner side of the clevis yoke. This will provide sufficient initial clearance between the exhaust valve and the piston when the crankshaft is turned during the valve clearance adjustment procedure.
2. If removed, install the cylinder head on the engine (refer to Section 1.2).
3. If removed, install the fuel injectors.
4. Apply clean engine oil to the rocker arm shaft and slide the shaft through the rocker arms. Then, place a bracket over each end of the shaft, with the finished face of the bracket next to the rocker arm.
5. Insert the rocker arm bracket bolts through the rocker cover hold-down bracket (if used) and through the brackets and the shaft (Fig. 11).

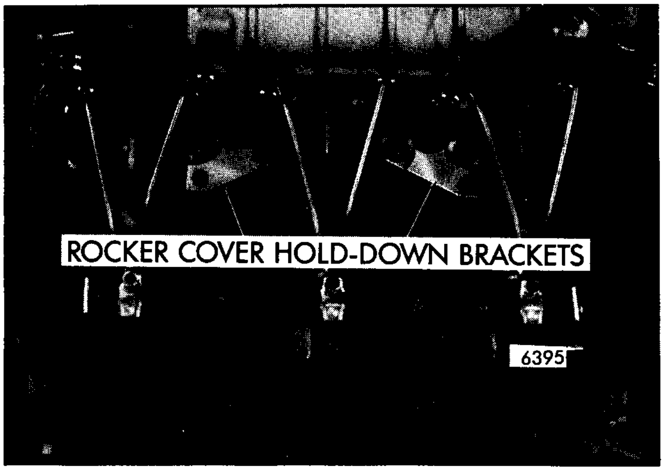


Fig. 11 - Rocker Cover Hold-Down Brackets Mounted on Rocker Arm Shaft Brackets

6. Tighten the rocker arm bracket bolts to the specified torque (refer to Section 1.0). Check to make sure there is some clearance between the rocker arms.

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

7. Align the fuel pipes and connect them to the injectors and the fuel connectors. Tighten the fuel pipe nuts to 12-15 lb-ft (16-20 N·m) torque using socket J 8932-01.

NOTICE: 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.

8. Fill the cooling system.
9. Adjust the exhaust valve clearance (Section 14.1) and time the injectors (Section 14.2).
10. If necessary, perform an engine tune-up.

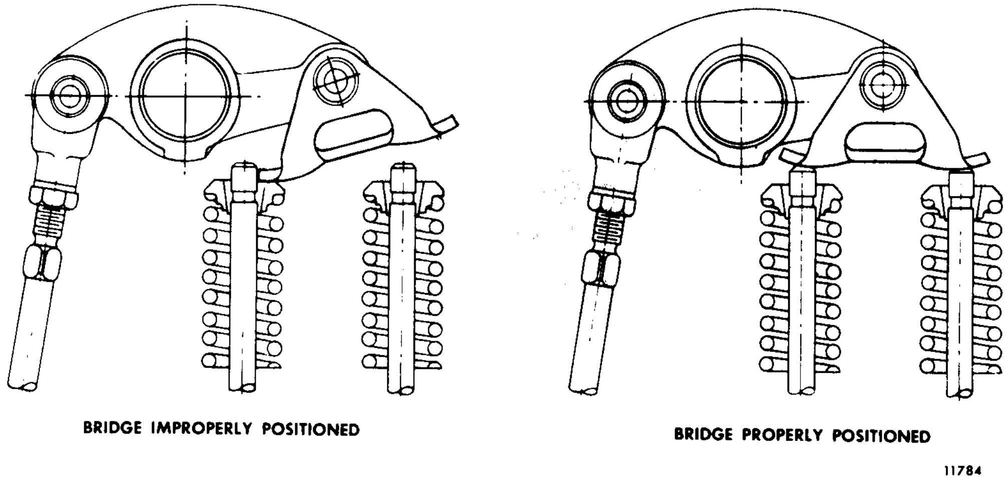


Fig. 12 - Relationship Between Exhaust Valve Bridge and Valve Stems

EXHAUST VALVES

Two or four exhaust valves are provided for each cylinder (Fig. 1), depending upon the engine model. 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 (two-valve head) or the exhaust valve bridge (four-valve head).

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 are ground to a 30° seating angle while the exhaust valve seat inserts are ground to a 31° 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.

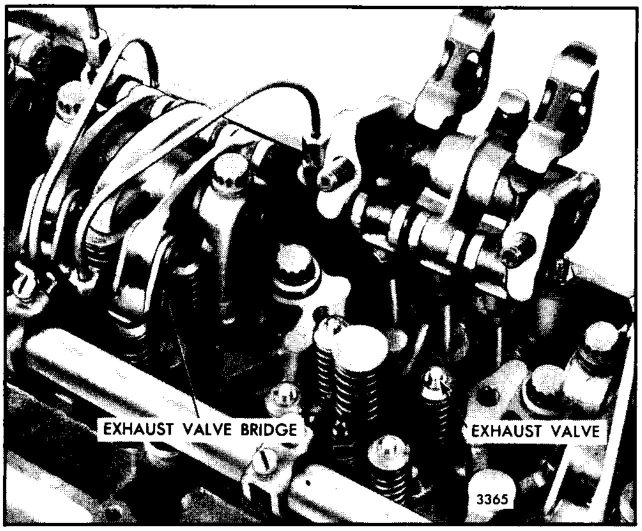


Fig. 1 - Location of Exhaust Valves

Proper maintenance and operation of the engine is important to long valve life. Normal engine operating temperatures should be maintained (see Section 13.2). 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 must be changed at the intervals shown in Section 15.1 to avoid the accumulation of sludge.

Valve sticking may also result from valve stems which have been scored due to foreign matter in the lubricating oil, leakage of 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 become bent or broken by being held in the open position and struck by the piston.

It is highly important that injector timing and valve clearance be accurately adjusted and checked periodically. Improperly timed injectors or tightly adjusted valves will have adverse effects upon combustion. Excessive valve clearance will result in noisy operation, increased valve face wear, valve and valve lock damage.

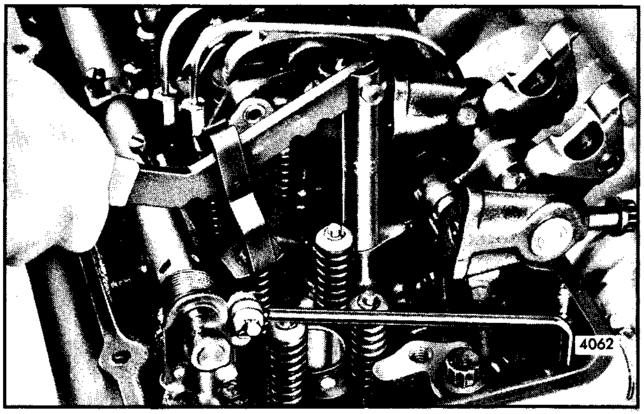


Fig. 2 - Removing Valve Spring using Tool J 7455

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.

NOTE: When using a wrench on the crankshaft bolt at the front of the engine, do not turn the crankshaft in a left-hand direction of rotation as this could loosen the bolt.

3. Disconnect and remove the fuel pipes from the injector and the fuel connectors.

NOTE: 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. Then, remove the brackets and shaft.

5. Remove the cylinder block air box cover so that piston travel may be observed, then turn the crankshaft until the piston is at the top of its stroke.

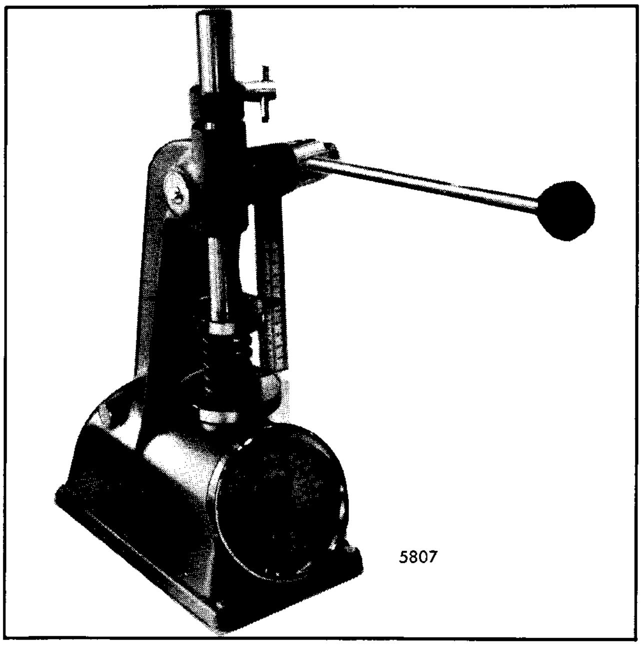


Fig. 3 - Testing Valve Spring using Tool J 22738-02

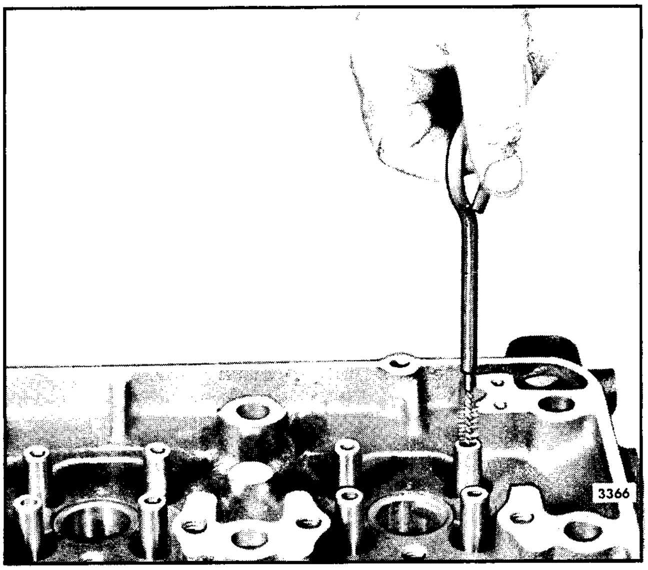


Fig. 4 - Cleaning Valve Guide

6. Thread the valve spring compressor adaptor tool J 7455-4 into one of the rocker arm bracket bolt holes in the cylinder head (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. Remove the fuel pipes from the injectors and the fuel connectors.

NOTE: 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. Then, remove the brackets and the shaft.

4. Remove the fuel injectors.

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 reinstallation in the same location. 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.

Use spring tester J 22738-02 to check the spring load (Fig. 3). 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.

NOTE: This test will not differentiate between high and low lift valve springs.

To eliminate exhaust valve spring surge, a new valve spring (.148″ wire diameter) is used in the 4-53 and 6V-53 engines. The change is effective with approximate engine serial numbers 4D-112278 and 6D-82217. The former spring was made from .135″ diameter wire.

NOTE: Low lift camshafts must use an exhaust valve spring with a .148″ wire diameter. High lift camshafts must use an exhaust valve spring with a .135″ wire diameter. A simple gage can be made by cutting a slot approximately .136″ to .138″ wide in a piece of thin steel stock. This will fit over the .135″ wire diameter coil of the high lift spring, but should not fit over the .148″ wire diameter coil of the low lift spring. With this gage, exhaust valve springs are identifiable regardless of color code.

The new spring can be used only in engines built after serial numbers 4D-112278 and 6D-60776 and use the present low-lift camshaft, or older engines which have these low-lift camshafts installed. The low-lift camshaft which provides a maximum valve cam lobe lift of .276″ is metal stamped V7L at both ends.

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

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 could indicate 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 heavy 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.

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.

Effective with four valve cylinder head engines built the second quarter of 1980, a new exhaust valve guide oil seal is being used. The new oil seal (Fig. 18) has a metal case and the slightly reduced inner diameter of the seal provides a press fit on the valve guide. The former oil seal was retained by a spring at the small end and a retainer at the large end. The former and current oil seals are interchangeable on a cylinder head.

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.

Clean the inside diameter of the valve guides with brush J 5437 (two-valve head), or brush J 7793 (four-valve head) - (Fig. 4). This brush will remove all gum or carbon deposits from the valve guides, including the spiral grooves.

Inspect the valve guides for fractures, chipping, scoring or excessive wear. Measure the valve guide inside diameter with a pin gage or inside micrometer and record the readings. After inspecting and cleaning the exhaust valves, measure the outside diameter of the valve stems with a micrometer and record the readings. Compare the readings to obtain the valve-to-guide clearance. If the clearance exceeds .006″ (two-valve head) or .005″ (four-valve head), replace the valve guides.

Replace Exhaust Valve Guide

Remove the exhaust valve guide as follows:

1. Remove and discard the oil seal, if used.

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

3. Drive the valve guide out of the cylinder head with valve guide remover J 6569 (two-valve head) or J 7775 (four-valve head) - (Fig. 5).

The current valve guides have a 45° chamfer at the top, replacing the former guides with a 15° chamfer. In addition, the guide for the four-valve cylinder head is machined for use of an oil seal (Fig. 6).

Install the exhaust valve guide as follows:

1. Place the cylinder head right side up on the bed of an arbor press.

2. Insert the internally threaded end of the valve guide in the proper valve guide installing tool (refer to the *Valve Guide Installing Tools* Chart (Fig. 7). When replacing the exhaust valve guides in a cylinder head, the current guide which is machined for use with an oil seal should be used in place of the 45° chamfered guide (Fig. 6). The current guide will facilitate field installation of valve guide oil seals.

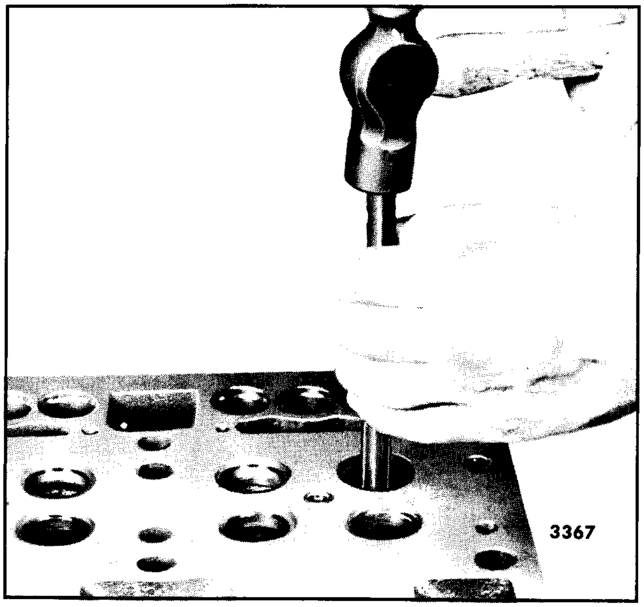


Fig. 5 - Removing Valve Guide

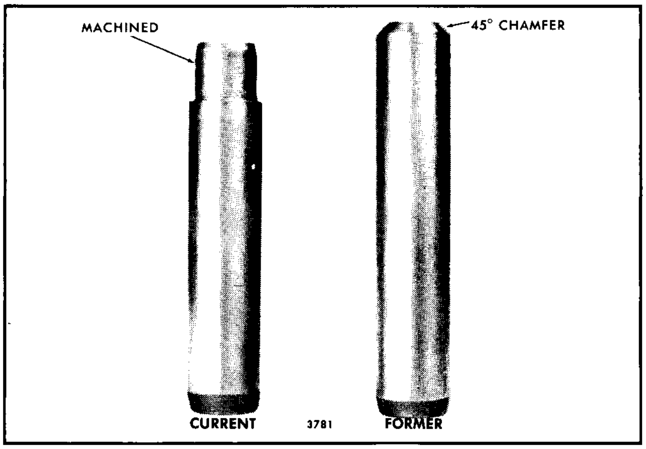


Fig. 6 - Former and Current Valve Guides

NOTE: Be sure to use the correct tool to avoid damage to the valve guide and to locate the valve guide to the proper dimension.

3. 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. 8). Then, press the guide in until the tool contacts the cylinder head (the bottom of the counterbore in the four-valve cylinder head).

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

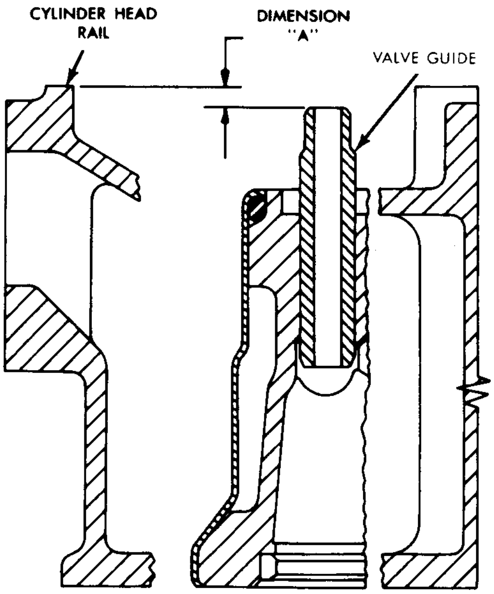
Inspect Exhaust Valve Seat Insert

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 (Fig. 9).



Tool No	Cyl. Head	DIMENSION "A"
J 7560	2 Valve	.010"-.040"
J24519	4 Valve	.150"-.018"

L-5489

Fig. 7 - Valve Guide Installing Tools

2. Place the collet of tool J 6974-01 (two-valve head) or 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.

NOTE: In addition to the above procedure, remover J 23479-15 and appropriate collet can be used to remove the exhaust valve insert from the cylinder head.

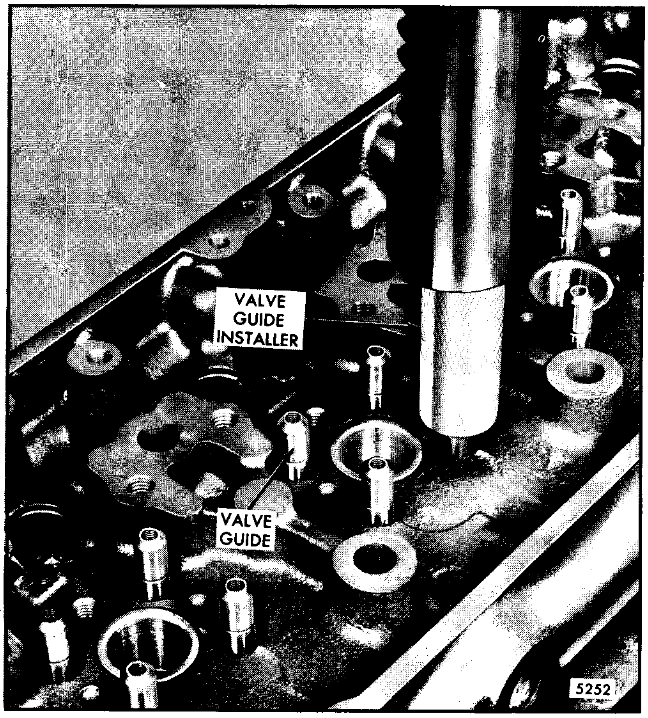


Fig. 8 - Installing Valve Guide

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.

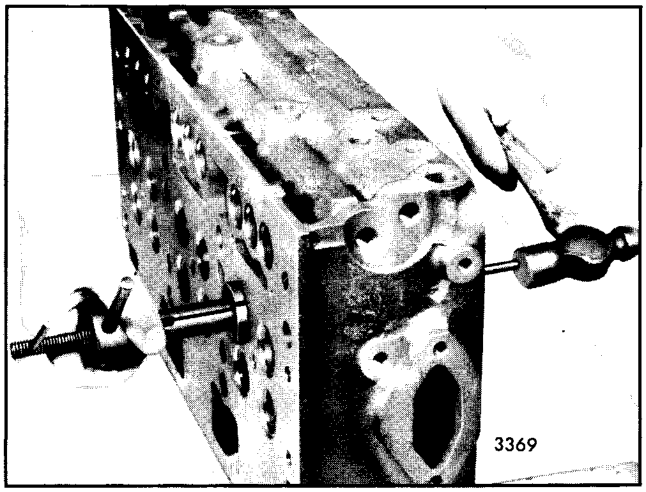


Fig. 9 - Removing Valve Seat Insert

Fig. 10 - Installing Valve Seat Insert

2. Inspect the counterbores for cleanliness, concentricity, flatness and cracks. The counterbores for the valve seat inserts in a two-valve head have a diameter of 1.439″ to 1.440″ and a depth of .294″ to .306″. The counterbores for the valve seat inserts 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″ oversize on the outside diameter are available, if required.

3. Immerse the cylinder head for at least 30 minutes in water heated to 180-200° F (82-93° C).

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) - (Fig. 10) until it seats solidly in the cylinder head.

6. Grind the old valve seat insert and check it for concentricity in relation to the valve guide as outlined below.

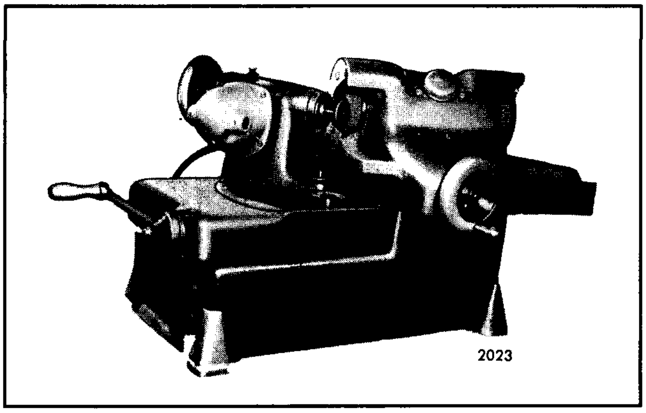


Fig. 11 - Refacing Exhaust Valve

NOTE: Because the new preground exhaust valve seat inserts are prefinished, they need only be checked for concentricity after proper installation. Grinding is required only if the runout exceeds .002″.

Recondition Exhaust Valve and Valve Seat Insert

An exhaust valve which is to be reused may be refaced, if necessary (Fig. 11). To provide sufficient valve strength and spring tension, the edge of the valve at the valve head must not be less than 1/32″ in thickness and must still be within the specifications shown in Figs. 13 and 14 after refacing.

Before either a new or used valve is installed, examine the valve seat in the cylinder head for proper valve seating. The proper angle for the seating face of the valve is 30° and for the valve seat insert, it is 31°.

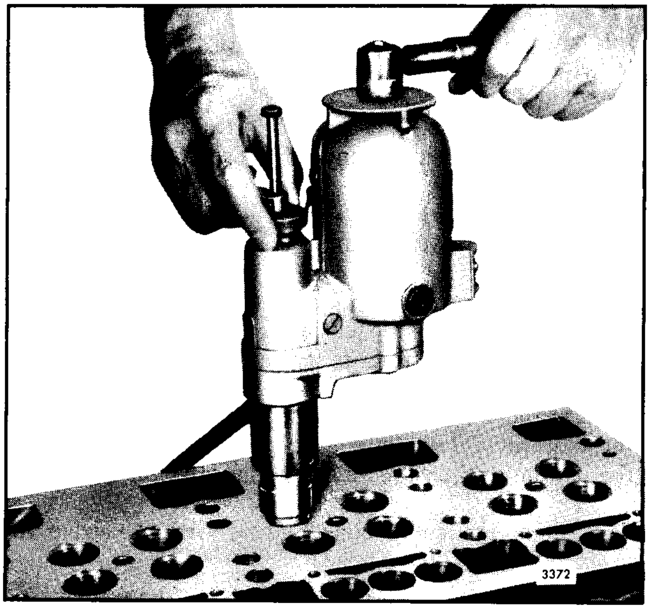


Fig. 12 - Grinding Valve Seat Insert

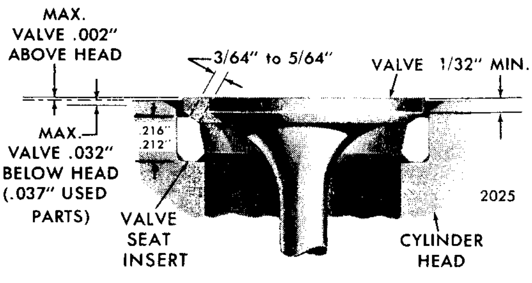


Fig. 13 - Relationship Between Exhaust Valve, Insert and Cylinder Head (Two-Valve Head)

When a new valve seat insert needs grinding or an old insert is refaced, the work must be done with a grinding wheel (Fig. 12).

The eccentric grinding method for reconditioning valve seat inserts is recommended. This method produces a finer, more accurate finish since only one point of the grinding wheel is in contact with the valve seat at any time. A micrometer feed permits feeding the grinding wheel into the work .001" at a time.

To grind the valve 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 (31°) 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 (31°) J 7792-3
6. Grinding Wheel (60°) J 7792-4

Grind the valve seat inserts as follows:

1. First apply the 31° 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" (Figs. 13 and 14). The 31° face of the insert may be adjusted relative to the center of the valve face with the 15° and 60° grinding wheels.

NOTE: 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 (Figs. 13 and 14). 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.

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. 15).

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 (Fig. 16) 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.

NOTE: The use of valve lapping compound is not recommended.

After the valve seat inserts have been ground and checked, thoroughly clean the cylinder head before installing the valves.

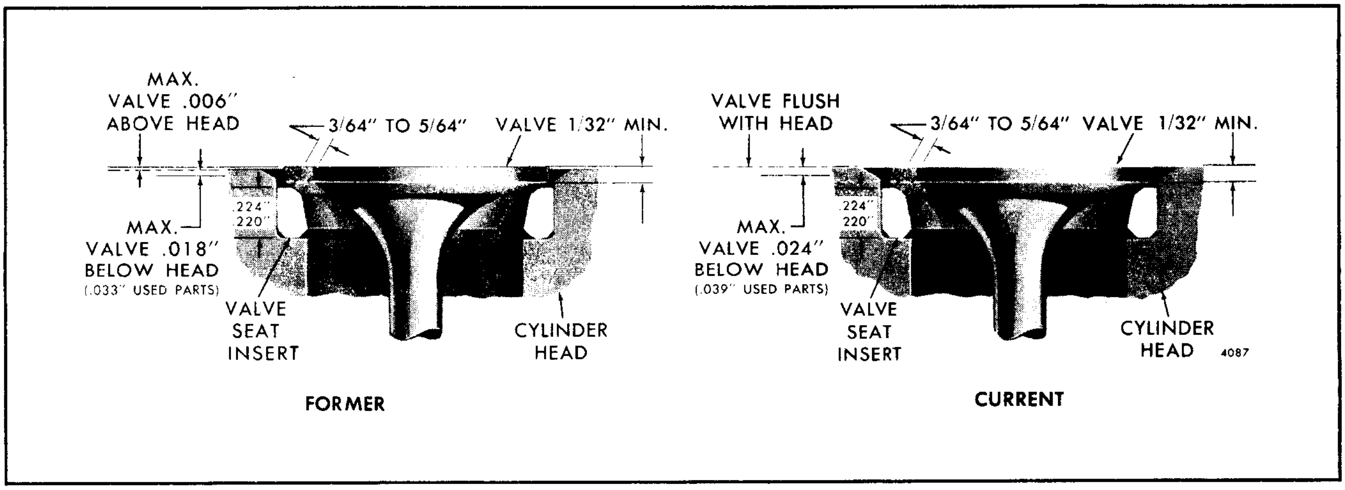


Fig. 14 - Relationship Between Exhaust Valve, Insert and Cylinder Head (Four-Valve Head)

Install Exhaust Valves and Springs

When installing exhaust valves, check to see that the valves are within the specifications (Figs. 13 and 14). 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 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 1.175" ±.015" in current design cylinder heads or 1.078" ±.015" in former design heads. The former head was discontinued in May, 1971.

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. 17). 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 springs 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.

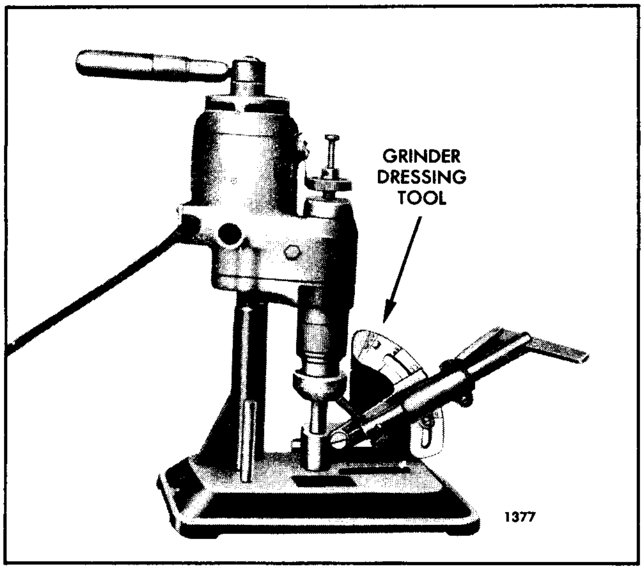


Fig. 15 - Grinding Wheel Dressing Tool of Set J 8165-1

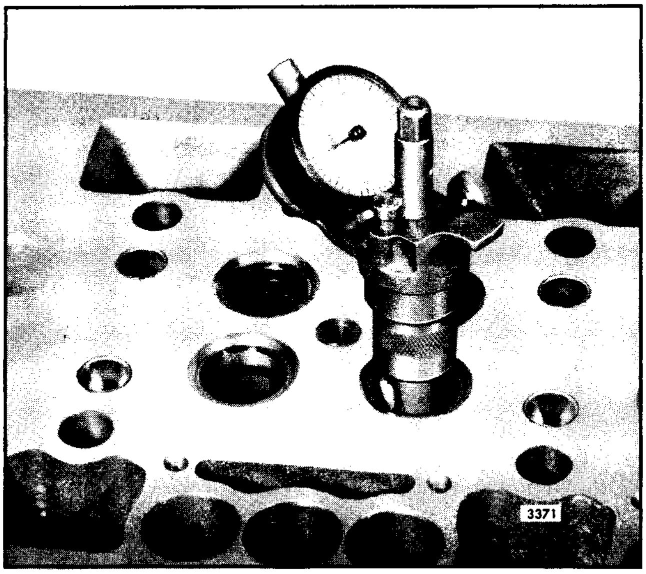


Fig. 16 - Checking Relative Concentricity at Valve Seat Insert with Relation to Valve Guide

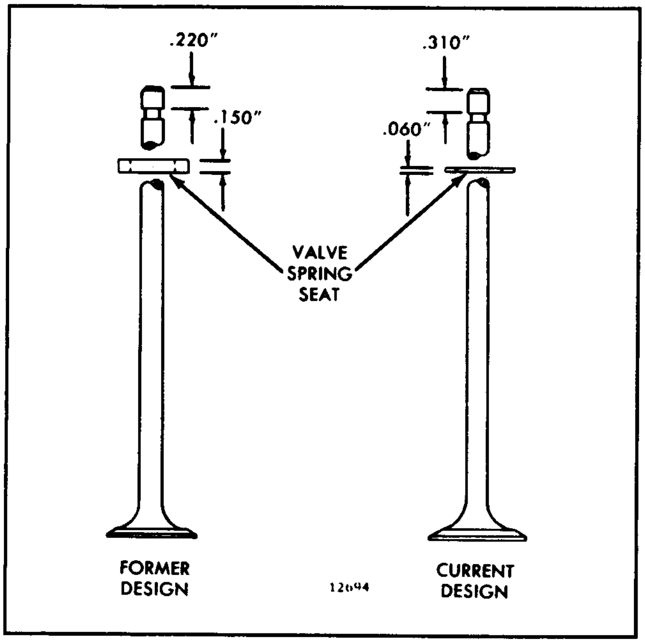


Fig. 17 - Former and Current Design Exhaust Valves (Four-Valve Head)

NOTE: 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:

Former Oil Seal (retained by a spring and retainer)

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.

Current Oil Seal (Fig. 18) (metal case and reduced inner diameter)

To properly install the current oil seal, use oil seal installer J 29579.

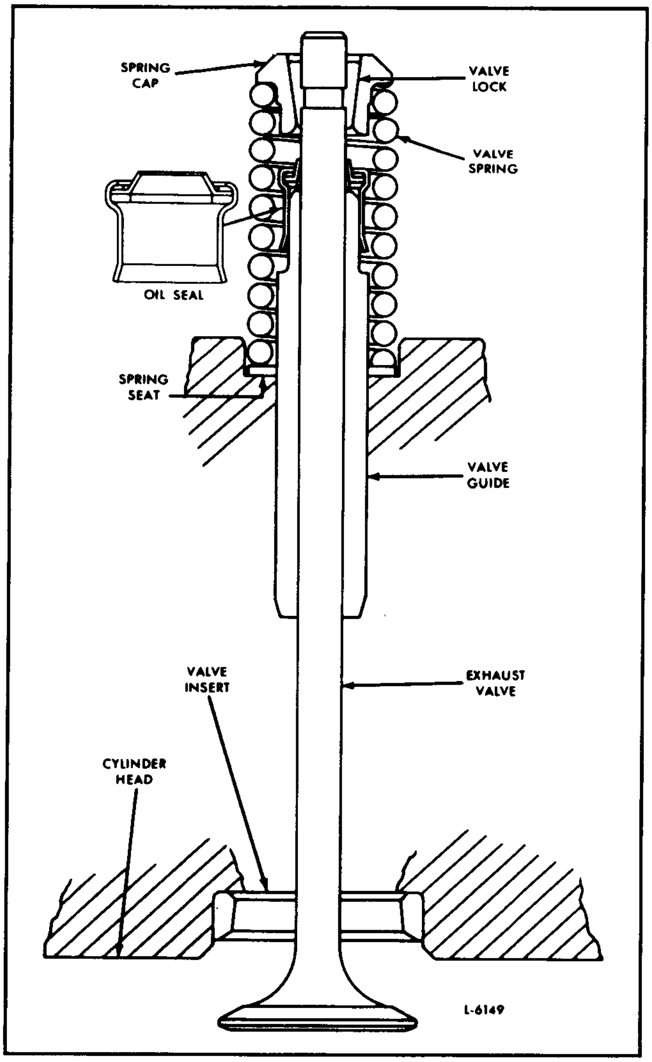


Fig. 18 - Current Valve Guide Oil Seal

a. Lubricate the oil seal and the valve stem with engine oil and start the oil seal carefully over the valve stem.

b. Using installer J 29579 drive the seal down slowly until the tool bottoms on the cylinder head (spring seat washer removed). Then, tap the tool with a mallet for final location and seating of the seal.

NOTE: The tool positions the seal so that it does not bottom out on the shoulder of the valve guide. If the oil seal is installed too far, it will be distorted and will not function as an effective seal.

c. Install the spring seat washer over the valve guide and let it drop into the valve counterbore (Fig. 18).

5. Install the valve springs and valve spring caps.

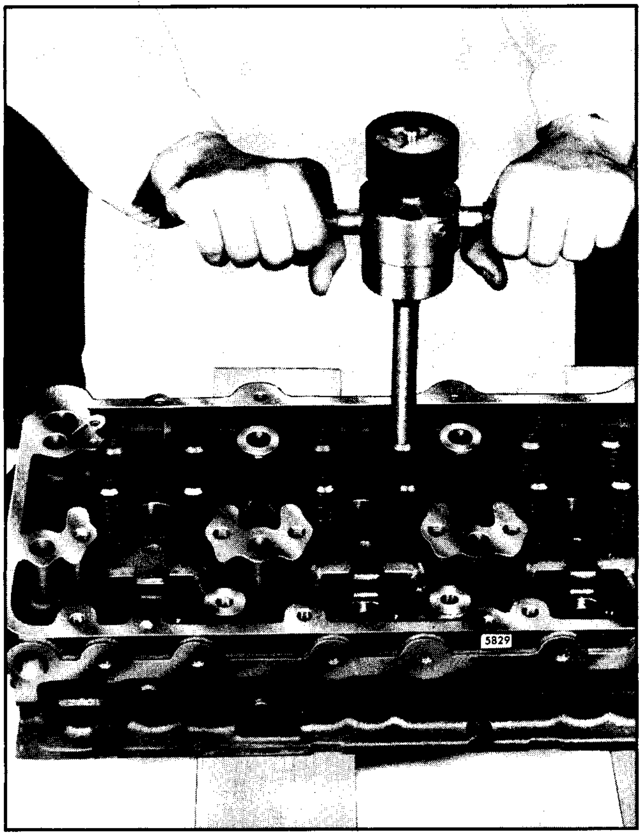


Fig. 19 - Checking Valve Opening Pressure with Gage J 25076-01

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.

> **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.

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 (Figs. 13 and 14).

10. Support the cylinder head at each end with wood blocks and remove the masking tape so that the exhaust valves are free. Then, give the ends of the valve stem a sharp tap with a plastic hammer to seat the valve locks. This will aid in the proper seating of the valve locks and reduce the chances of failure.

11. With the exhaust valves installed in the cylinder head, use spring checking gage J 25076-01 and note the gage reading the moment the exhaust valve starts to open (Fig. 19). 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.

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

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

14. Perform a complete engine tune-up.

VALVE ROCKER COVER

The valve rocker cover assembly completely encloses the valve and injector rocker arm compartment at the top of the cylinder head (Figs. 1 and 2). The top of the cylinder head is sealed against oil leakage by a gasket located in the flanged edge of the cover.

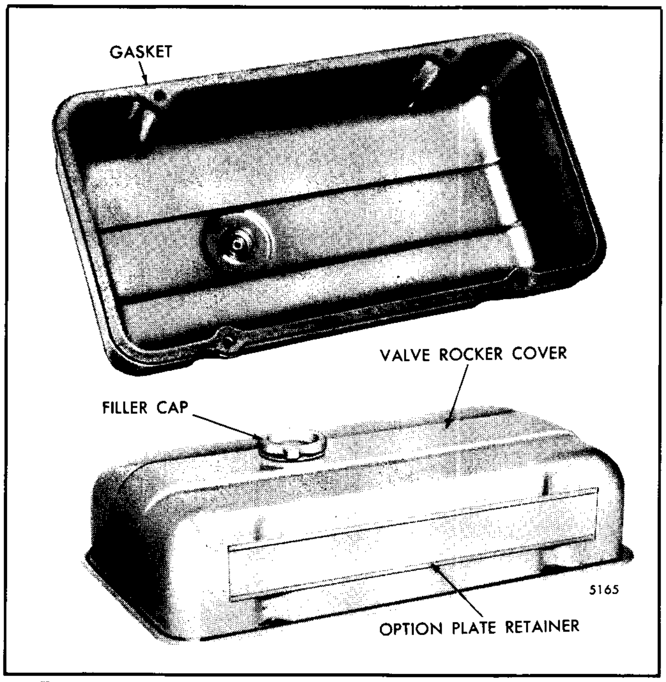


Fig. 1 - Typical Stamped Steel Valve Rocker Cover Assembly

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

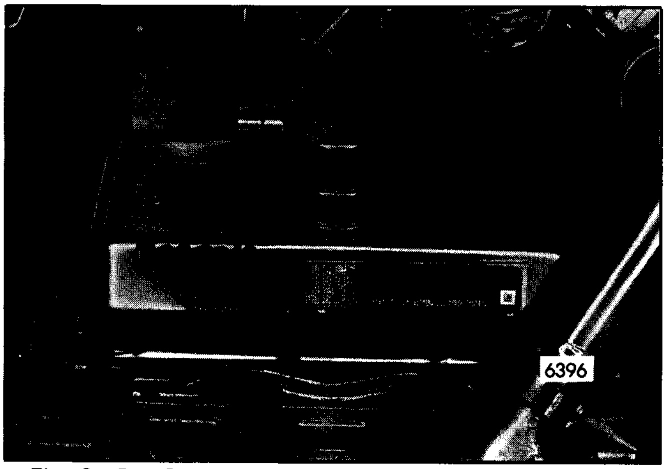


Fig. 2 - Die-Cast Aluminum Rocker Cover on 6V-53T Engine

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 valve rocker cover before removing it from the engine to avoid dust or dirt from entering the valve mechanism. Then, loosen the bolts (cast aluminum rocker cover) or the screws (stamped steel rocker cover) and lift the cover straight up from the cylinder head. Use a new gasket when reinstalling the cover.

Tighten the 3/8″-16 cast aluminum rocker cover hold-down bolts to 8-13 lb-ft (11-18 N·m) torque. Do not overtighten.

CRANKSHAFT

The crankshaft is a one-piece steel forging, heat-treated to ensure strength and durability (Figs. 1 and 2). All main and connecting rod bearing journal surfaces, oil seal surfaces and fillets on the 4-53 vehicle engine (since 4D-146948) and 6V crankshafts are induction hardened. All Series 53 engine crankshaft fillets are now induction hardened effective with 3D-187345 and 4D-201209 (non-vehicle engines).

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

The crankshaft end play 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 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.

The current 8V engine crankshaft no longer incorporates the two dowels in the flywheel end of the crankshaft. However, the former and current crankshafts are interchangeable.

In-line engine main bearing journals are 3.000" in diameter and the connecting rod journals are 2.500" in diameter. On the V-type engine, the main bearing journals are 3.500" in diameter and the connecting rod journals are 2.750" 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 2.500" 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 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

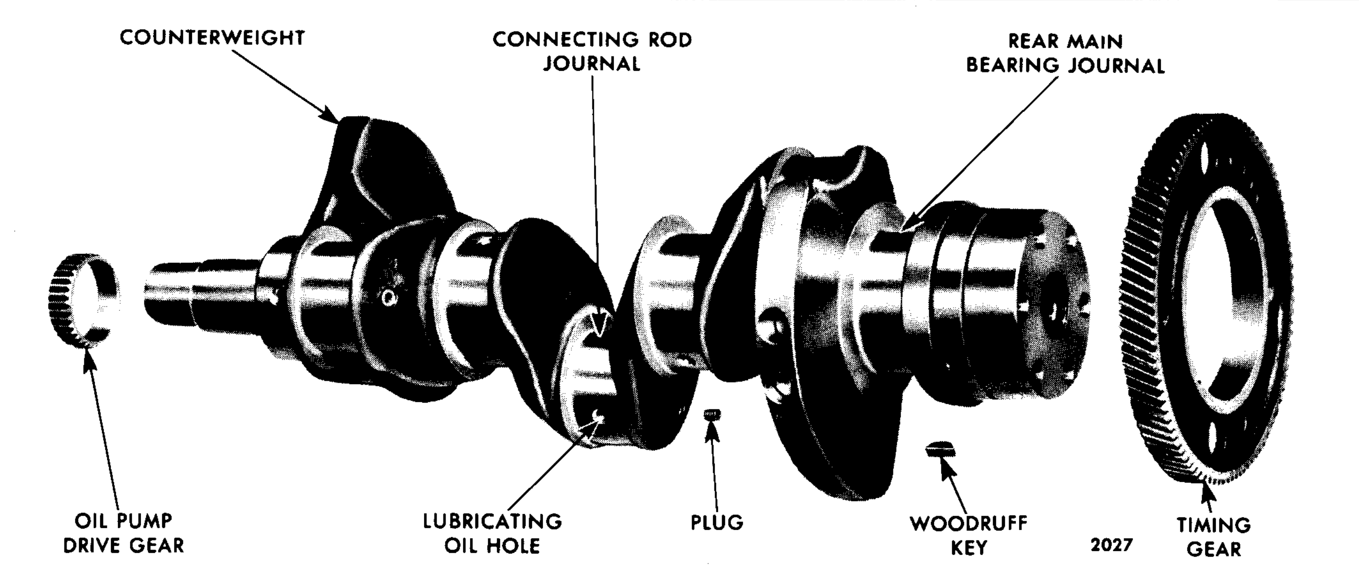


Fig. 1 - Crankshaft Details and Relative Location of Parts (3-53 Crankshaft Shown)

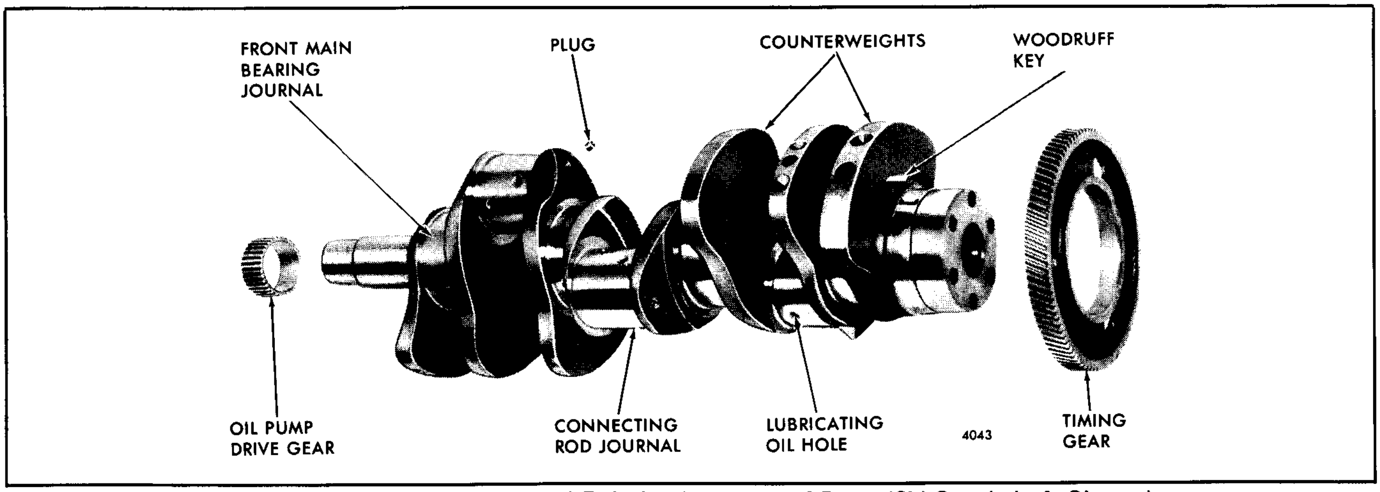


Fig. 2 - Crankshaft Details and Relative Location of Parts (6V Crankshaft Shown)

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.
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.

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 and torque to 10-12 lb-ft (14-16 N·m). Use tool J 34650 to install the new sealant-coated 1/8"-27 pipe plugs.

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

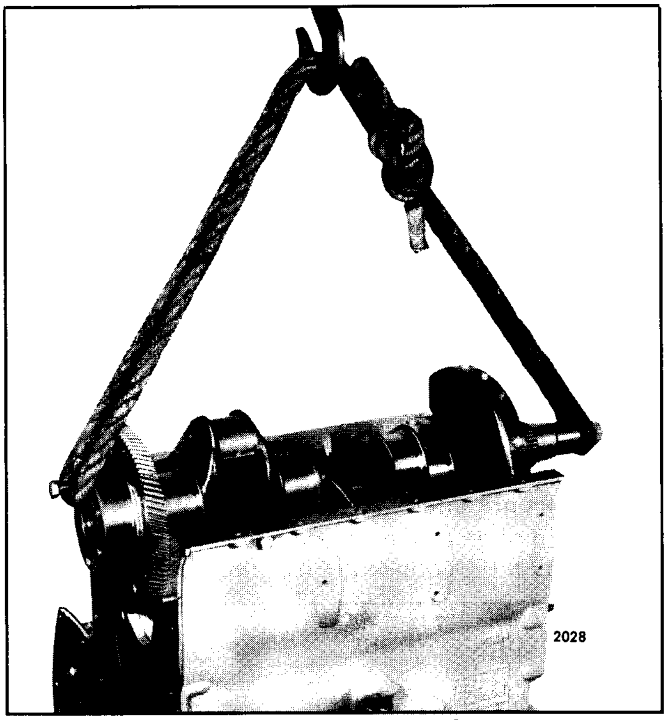


Fig. 3 - Removing or Installing Crankshaft

If the crankshaft shows evidence of excessive overheating, replace the crankshaft since the heat treatment has probably been destroyed.

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

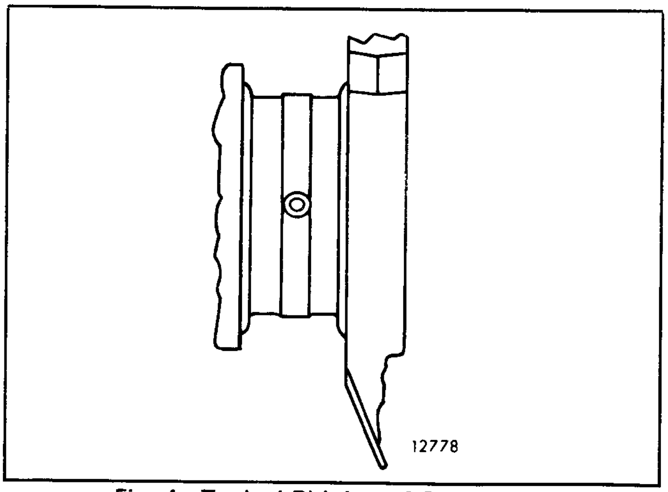


Fig. 4 - Typical Ridging of Crankshaft

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 surface 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 seal 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 .500" 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, in a lathe or the inverted engine block with only the front and rear upper bearing shells in place and check the alignment at the adjacent intermediate main journals with a dial indicator.

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

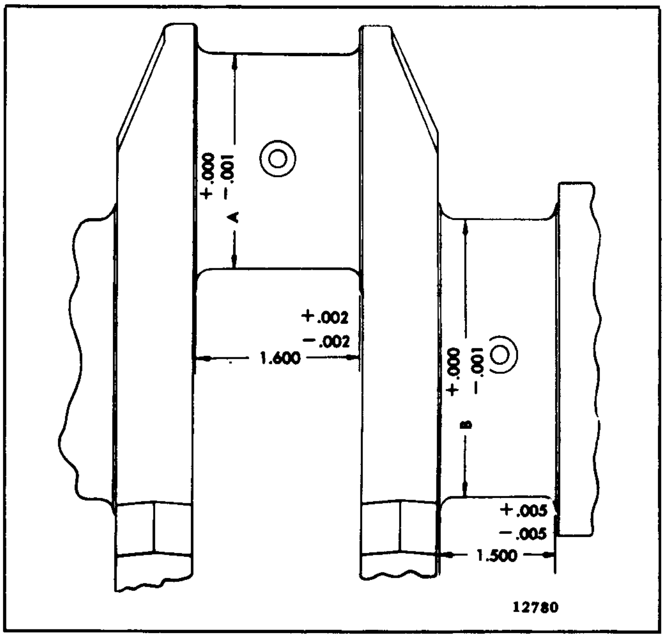


Fig. 5 - Dimensions of Crankshaft Journals - In-Line Engine

On an 8V 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 crankshaft, when the high spots of runout on the adjacent journals is in opposite directions, the sum must not exceed .003" total indicator reading. When the high spots of runout on the adjacent journals is in the same direction, the difference must not exceed .003" total indicator reading. When the 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 journals (Figs. 5 and 6). 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. Measurements of the crankshaft should be accurate to the nearest .0002". Also, if the journal taper or the out-of-round is greater than .003", the crankshaft must be reground.

Also, measure the crankshaft thrust surfaces (Fig. 7).

Inspection for Cracks

Carefully, check the crankshaft for cracks which start at an oil hole and follow the journal surface at an

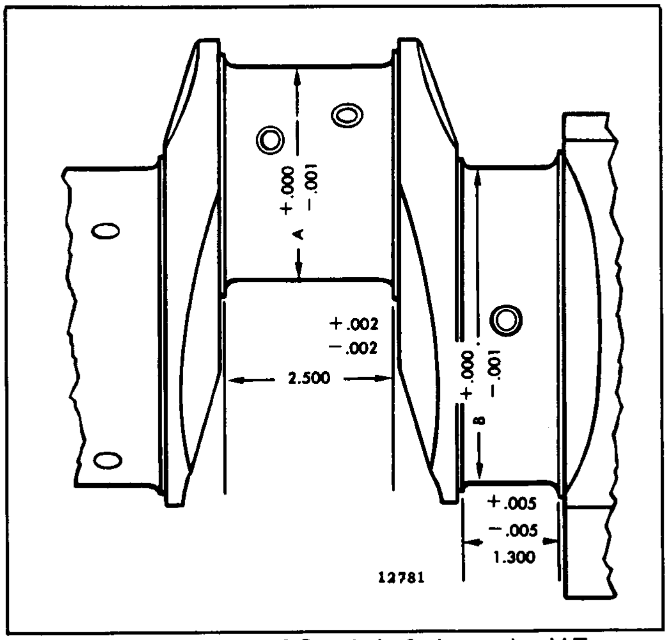


Fig. 6 - Dimensions of Crankshaft Journals - V-Type Engine

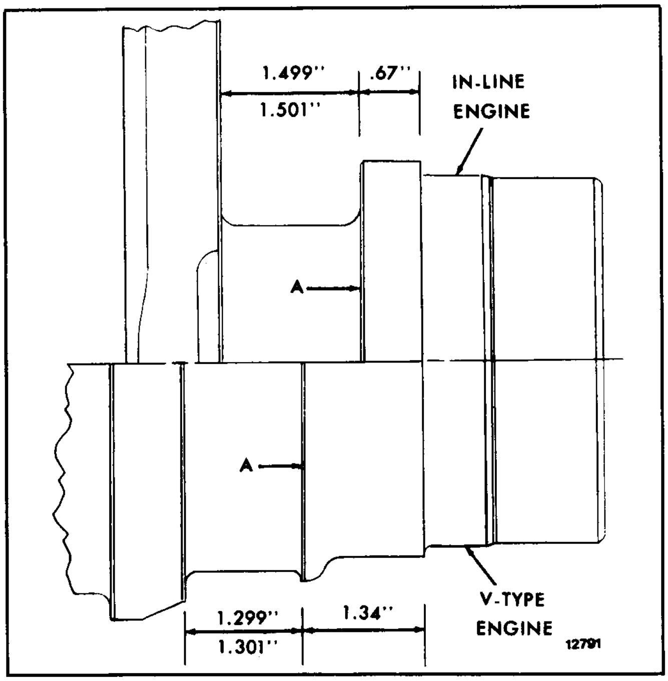


Fig. 7 - Standard Dimensions at Crankshaft Thrust Surfaces – In-Line and V-Type Engines

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 both *non-magnetic and magnetic* materials. A highly fluorescent liquid penetrant is applied to the part. Then, the excess penetrant is removed from the surface and the part is dried. A developing powder is then applied which helps to draw the penetrant out of the flaws by capillary action. Inspection is carried out under "black-light".

Non-Fluorescent Penetrant Method: The test area being inspected is sprayed with "Spotcheck" or Dye Check. Allow one to thirty minutes to dry. Remove the excess surface penetrant with clean cloths premoistened with cleaner/remover. DO NOT flush surface with cleaner/remover because this will impair sensitivity. Repeat this procedure with additional wipings until residual surface penetrant has been removed. Shake developerthoroughly until agaitator rattles. Invert spray can and spray short bursts to clear valve. Then, spray this even developer film evenly over the test area being inspected. Allow developer film to dry completely before inspecting. Recommended developing time is 5 to 15 minutes.

The above methods provide basic instructions. Specific details should be obtained from the supplier of the equipment or material.

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, sustain most of the load (Fig. 8).

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

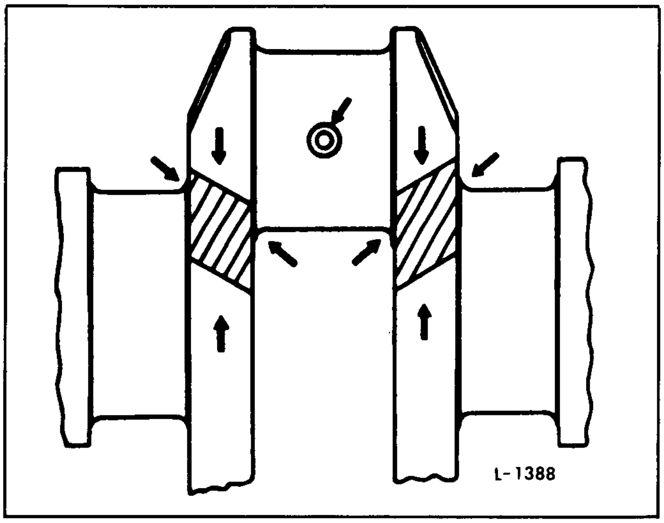


Fig. 8 - Critical Crankshaft Loading Zones

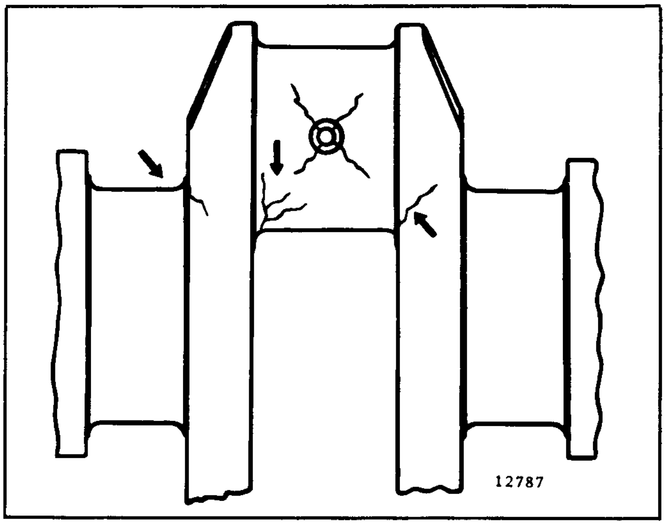


Fig. 9 - Crankshaft Fatique Cracks

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. 8.

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 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 oil holes (Fig. 9). 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. The .002" undersize bearings are used only to compensate for slight wear on crankshafts on which regrinding is unnecessary.

Crankshaft main bearing journals and/or connecting rod journals which exhibit discoloration due to excessive overheating from bearing failure are not acceptable for rework.

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. 5 or 6 and determine the size to which the journals are to be reground.

Bearing Size	Conn. Rod Journal Dia.	Main Bearing Journal Dia.
In-Line Engines		
Standard	2.499"/2.500"	2.999"/3.000"
.002" Undersize	2.497"/2.498"	2.997"/2.998"
.010" Undersize	*2.489"/2.490"	*2.989"/2.990"
.020" Undersize	*2.479"/2.480"	*2.979"/2.980"
.030" Undersize	*2.469"/2.470"	*2.969"/2.970"
V-Engines		
Standard	2.749"/2.750"	3.499"/3.500"
.002" Undersize	2.747"/2.748"	3.497"/3.498"
.010" Undersize	*2.739"/2.740"	*3.489"/3.490"
.020" Undersize	*2.729"/2.730"	*3.479"/3.480"
.030" Undersize	*2.719"/2.720"	*3.469"/3.470"

*Dimension of reground crankshaft

TABLE 1

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.

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. 10). 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.

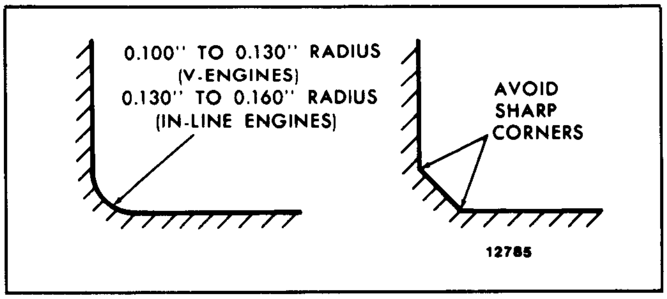


Fig. 10 - Crankshaft Journal Fillets

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 (Fig. 7) 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.
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.

For additional information refer to DDA Manual 6SE453.

Install Crankshaft

If a new crankshaft is to be installed, steam clean it to remove the rust preventive, blow out the oil passages with compressed air and install the plugs. Then, install the crankshaft as follows:

1. Assemble the crankshaft timing gear (Section 1.7.5) and the oil pump drive gear (Section 4.1) on the crankshaft.
2. Refer to Section 1.3.4 for main bearing details and install the upper *grooved* main 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. 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.
3. Apply clean engine oil 360° around all crankshaft bearing 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.* 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. 7 and Table 2.

Nominal Size	Thrust Washer Thickness	
	Min.	Max.
Standard	.1190"	.1220"
.005" Oversize	.1240"	.1270"
.010" Oversize	.1290"	.1320"

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.
6. Install the bearing caps and lower bearing shells as outlined under *Install Main Bearing Shells* in Section 1.3.4. 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 small (less than 12″) 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 .016″ 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.

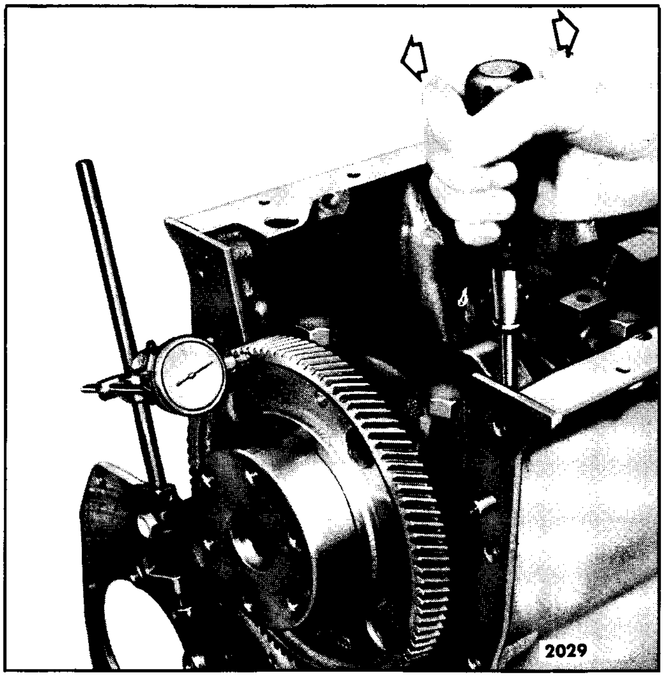


Fig. 11 - Checking Crankshaft End Play

8. Install the cylinder liner, piston and connecting rod assemblies (Section 1.6.3).
9. Install the cylinder head(s) (Section 1.2).
10. Install the flywheel housing (Section 1.5), then install the flywheel (Section 1.4).
11. Install the crankshaft lower engine front cover and 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 engines, install the oil pump, inlet pipe and screen assembly (Section 4.1).
15. Check the crankshaft for **distortion** (bending) at the rear connecting rod journal counterweights *before* and *after* installing a power takeoff assembly, marine gear, transmission or power generator. If improperly installed these components can distort the crankshaft and cause a crankshaft malfunction. Overtightened drive belts can also cause crankshaft distortion. See Section 15.1 for recommended belt tension.

   NOTICE: While in each case one must be guided by the individual circumstances and facts that evolve, generally speaking Detroit Diesel Allison cannot be responsible for system damage caused by engine-to-driven component interference and/or distortion. Consequently, the engine crankshaft end play check and crankshaft distortion check are **musts** .

   Check the crankshaft distortion as follows:

   a. Rotate the crankshaft clockwise until the crankshaft counterweights at the rear connecting rod journal are in the *six o'clock* position.
   b. Center punch a hole in the inside face of each counterweight cheek, one quarter of an inch from the lower end of each counterweight, to support the gage.
   c. Install a gage (Starrett Co. No. 696 dial gage, or equivalent) in the center punch holes in the cheek of each counterweight (Fig. 12).

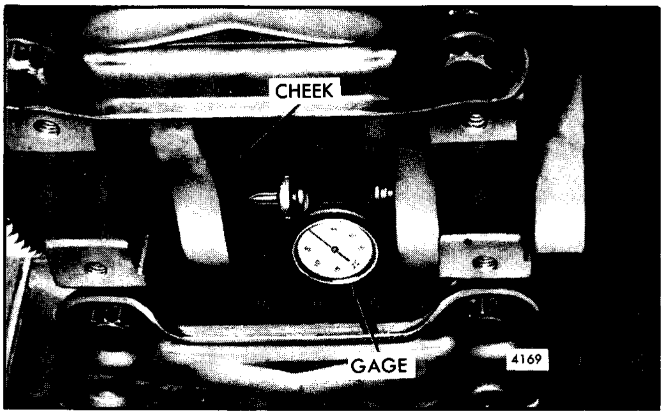


Fig. 12 - Crankshaft Distortion Measuring Gage Mounted on Crankshaft

   d. Set the dial indicator at zero, then rotate the crankshaft approximately 90° in both directions. Do not allow the gage to contact the connecting rod caps or bolts. Note and record the dial indicator readings at the *3, 6 and 9 o'clock crankshaft counterweight* positions. The maximum allowable variationis .0045" total indicator reading. Remove the tool that was used to rotate the crankshaft when taking the dial indicator readings.
   e. If the reading on the gage exceeds .0045", check the power takeoff assembly, transmission, marine gear or power generator for improper installation and realign, as necessary.
16. Affix a new gasket to the oil pan flange and install the oil pan.
17. 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.
18. Install all of the accessories that were removed.
19. After the engine has been completely reassembled, refer to the *Lubrication Specifications* in Section 13.3 and refill the crankcase to the proper level on the dipstick.
20. Close all of the drains and fill the cooling system.
21. After replacing the main or connecting rod bearings or installing a new or reground 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 retain the lubricating oil in the crankcase. The sealing lips of the oil seals are held firmly, but not tight, against the crankshaft sealing surfaces by a coil spring.

The front oil seal is pressed into the lower front cover on In-line and 6V-53 engines (Fig. 1). The seal is pressed into the front cover on early 8V-53 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 engines where there is oil on both sides of the oil seal; the lips of the seal face in opposite directions. The rear oil seal is pressed into the flywheel housing (Fig. 2).

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.

Remove Crankshaft Oil Seals

Remove the engine front cover (Section 1.3.5), outboard bearing support or the flywheel housing (Section 1.5) and remove the oil seals as follows:

1. 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.

2. Support the forward face of the flywheel housing on In-line or 6V-53 engines and the rear face of the flywheel housing on 8V-53 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.

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

When necessary, an oil seal 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. Remove the seal by prying against the washers with pry bars.

Inspection

Inspect the front and rear end of the crankshaft and the crankshaft front end oil seal sleeve (8V-53 engines) for wear due to the rubbing action of the oil seal, dirt build-up or fretting caused by action of the flywheel.

The crankshaft surface must be clean and smooth to prevent damaging the seal lip when a new oil seal is

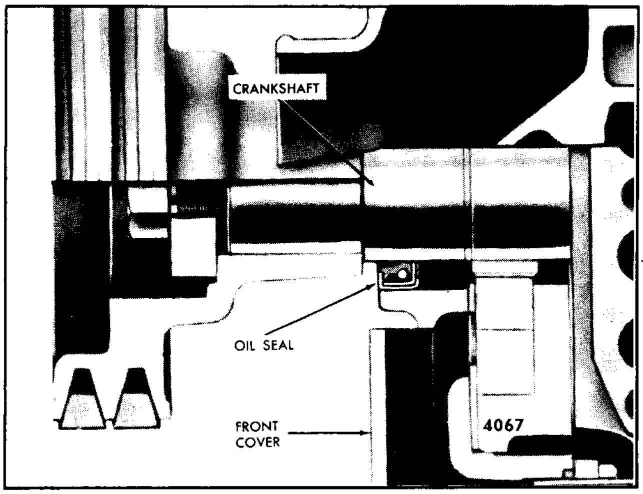


Fig. 1 - Crankshaft Front Oil Seal

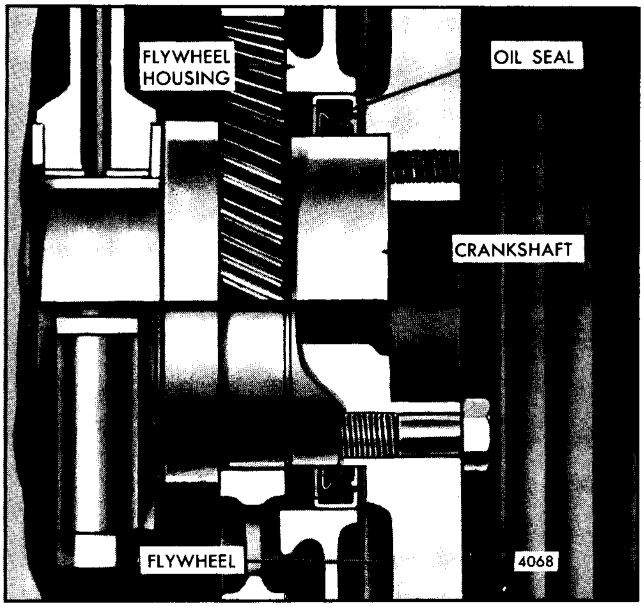


Fig. 2 - Crankshaft Rear Oil Seal (In-line and 6V-53 Engines)

installed. Slight ridges may be removed from the crankshaft as outlined under *Inspection* in Section 1.3.

On In-line or 6V-53 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-53 engines, if the crankshaft rear oil seal surface is grooved excessively, an oil seal spacer may be installed between the counterbore in the flywheel housing and the oil seal (Fig. 4). 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 type 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 which provides a replaceable wear surface for the lip-type oil seal (Figs. 3, 4 and 5). The oil seal sleeve may be used with either the single-lip or double-lip type oil seal, and can also be used in conjunction with the seal spacer. However, an oversize oil seal must be used with 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.

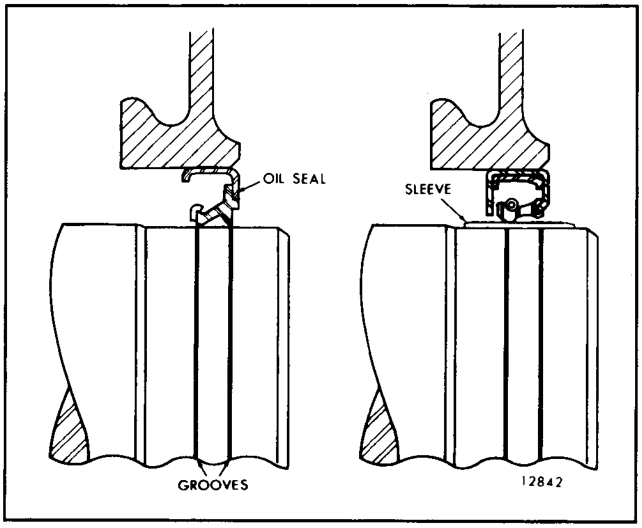


Fig. 3 - Use of Rear Oil Seal Sleeve on Grooved Crankshaft (In-line and 6V-53 Engines)

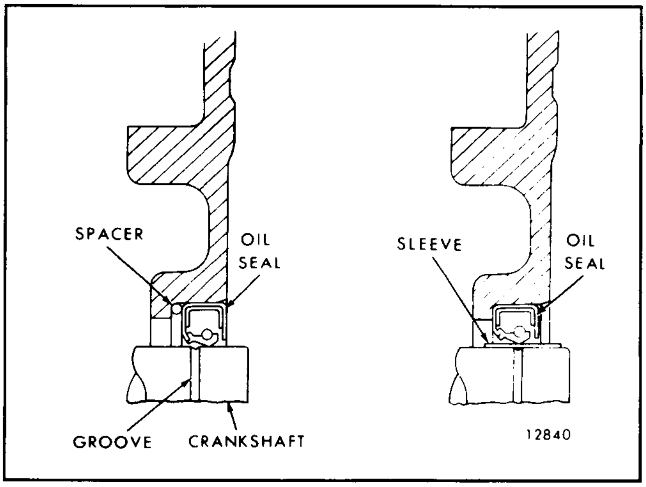


Fig. 4 - Use of Rear Oil Seal Spacer or Sleeve on Grooved Crankshaft (8V-53 Engines)

3. Drive the sleeve squarely on the shaft with crankshaft rear oil seal sleeve installer J 21277 (In-line or 6V-53 engines) or installer J 4194-01 (8V-53 engines).

4. Wipe off any excess sealant.

5. Coat the outside diameter of the sleeve with engine oil.

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

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

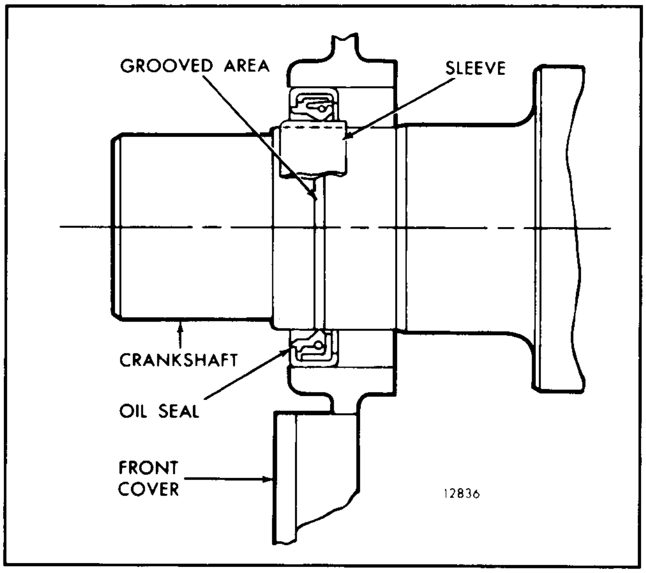


Fig. 5 - Use of Front Oil Seal Sleeve on Grooved Crankshaft

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

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

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

5. Wipe off any excess sealant.

6. Coat the outside diameter of the sleeve with engine oil.

To remove a worn sleeve, peen the outside diameter of the sleeve until it stretches sufficiently so it can be slipped off of the end of the crankshaft.

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.

The rear oil seal may have either an open or closed back. Both types are serviced.

Install Crankshaft Front Oil Seal

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

2. Coat the lip of the new oil seal lightly with grease or vegetable shortening. Then, position the seal in the cover or outboard bearing support with the lip of the seal pointed toward the inner face of the cover or bearing support.

3. On In-line and 6V-53 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 8V-53 engines, press the oil seal into the outboard bearing support with installer J 22153.

4. Remove any excess sealant.

5. Install the engine front cover (Section 1.3.5) or the outboard bearing support.

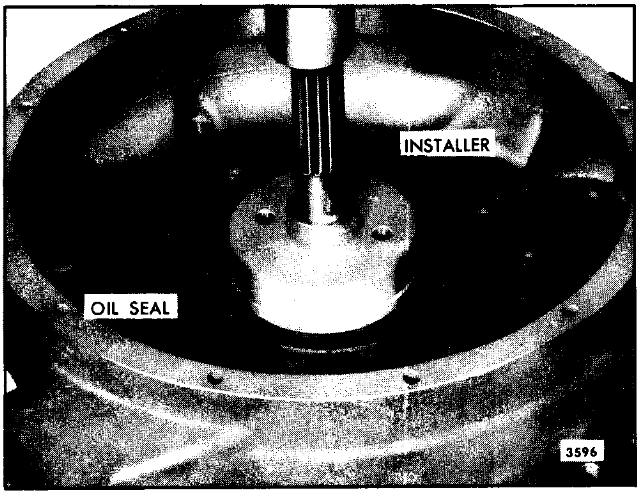


Fig. 6 - Installing Oil Seal in Flywheel Housing

Install Crankshaft Rear Oil Seal

A new, unidirectional Teflon rear crankshaft oil seal is being used in all right-hand rotating engines,. To help insure proper installation, the seal part number and the direction of shaft rotation are stamped on the seal case. The new seal is packaged around a special plastic sleeve which protects the Teflon lip of the seal during shipment and storage and functions as an installation tool. It is designed to be placed over the crankshaft end so that the seal can be easily slipped in place without damaging the lip.

> **NOTE:** Do not lubricate the new seal or the crankshaft end prior to seal installation. Unlike the silicone-lip seals they replace, Teflon-lip oil seals must be installed dry.

1. Support the inner face of the flywheel housing in an arbor press or on a flat surface.

2. If the new seal is not pre-coated, apply a non-hardening sealant to the periphery of the metal casing. Then, position the seal with the lip pointed toward the inner face of the housing.

3. Coat the lip of the 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.

4. On In-line and 6V-53 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 21278-01 (oversize seal) against the end of the crankshaft. Then, with the lip of the seal pointed toward the engine, 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 it is flush with the face of the housing.

5. On 8V-53 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 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 any excess sealant from the flywheel housing and the seal.

NOTE: 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, oil leakage will result.

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

CRANKSHAFT MAIN BEARINGS

The crankshaft main bearings shells are precision made and are replaceable without machining (Figs. 1 and 2). They consist of an upper bearing shell seated in each cylinder block main bearing support and a lower bearing shell seated in each main bearing cap. The upper and lower bearing shells are located in the respective block and bearing cap by a tang at the parting line at one end of each bearing shell. The tangs on the lower bearing shells are off-center and the tangs on the upper bearing shells are centered to aid correct installation.

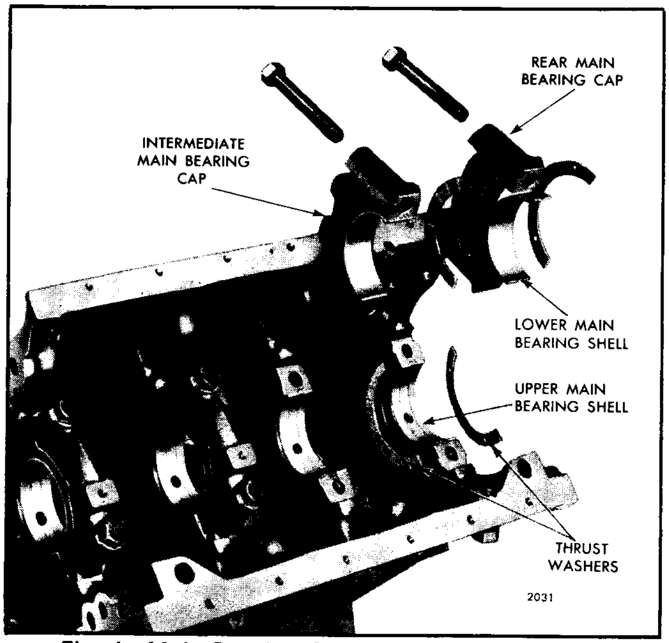


Fig. 1 - Main Bearing Shells, Bearing Caps and Crankshaft Thrust Washers – In-line Engines

On In-line and early V-type engines, a 7/16" oil hole in the groove of each upper bearing 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 oil gallery by way of the bearing shells to the drilled passages in the crankshaft, then to the connecting rods and connecting rod bearings.

On 6V marine engines effective with engine serial number 6D-11074 and all other 6V and 8V engines effective with serial numbers 6D-17960 and 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 improve piston cooling by allowing more oil, under pressure, to flow to the drilled passages in the crankshaft. 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.*

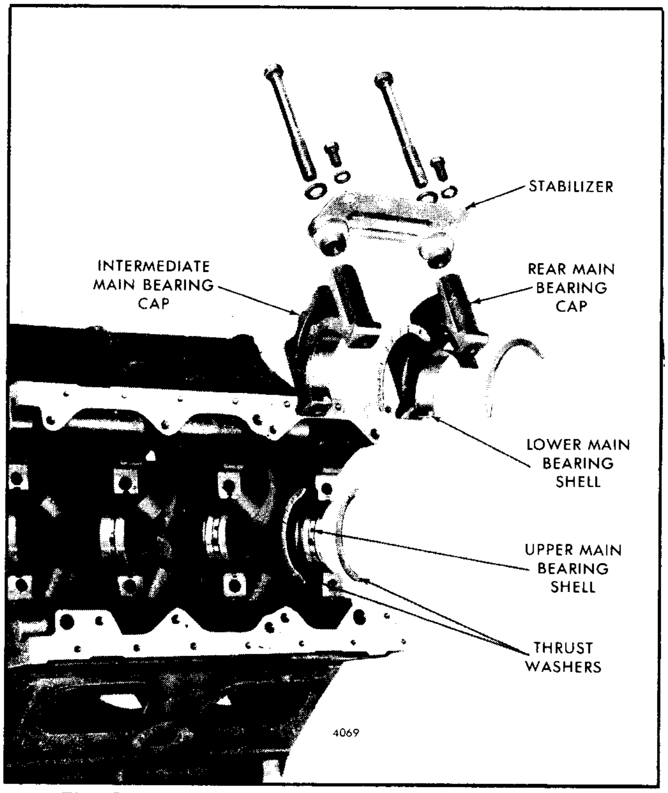


Fig. 2 - Main Bearing Shells, Bearing Caps and Crankshaft Thrust Washers – V-Type Engines

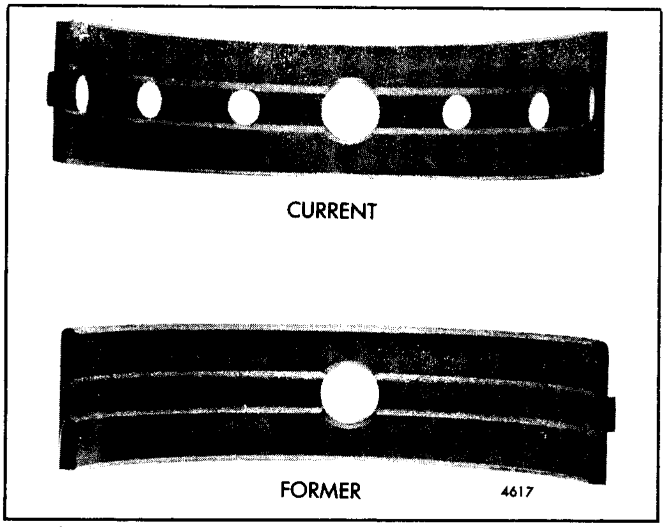


Fig. 3 - Old and New Upper Main Bearing Shells (V-Type Engines)

The lower main bearing shells have no oil grooves; therefore, the upper and lower bearing shells must not be interchanged.

On Brazil built engines the upper main bearing shell is slotted and the lower shell has grooved sides for continuous piston lubrication.

Thrust washers on each side of the rear main bearing, absorb the crankshaft thrust (Figs. 1 and 2). The lower halves of the two-piece washers are doweled to the bearing cap; the upper halves are not doweled.

All of the main bearing load is carried on the lower bearings; therefore, wear will occur on the lower bearing shells first. The condition of the lower 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)

The bearing caps are numbered 1, 2, 3, etc., indicating their respective positions and, when removed, must always be reinstalled in their original position.

All crankshaft main bearing journals, except the rear journal, are drilled for an oil passage. Therefore, the procedure for removing the upper bearing shells with the crankshaft in place is somewhat different on the drilled journals than on the rear journal.

Remove the main bearing shells as follows:

1. Drain and remove the oil pan to expose the main bearing caps.
2. Remove the oil pump and the oil inlet pipe and screen assembly. If shims are used between the oil pump (8V engine) and the main bearing caps, save the shims so that they may be reinstalled in exactly the same location.
3. Remove one main bearing cap at a time and inspect the bearing shells as outlined under *Inspection*. Reinstall each bearing shell and 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 (Fig. 4). The head of the bolt must not extend beyond the outside diameter of the bearing shell.
   b. Remove the rear main bearing upper shell by tapping on the edge of the bearing with a small curved rod, revolving the crankshaft at the same time to roll the bearing shell out (Fig. 5).
   c. The lower halves of the crankshaft thrust washers will be removed along with the rear main bearing cap. The upper halves of the washers can be removed for inspection by pushing on the ends of the washers with a small rod, forcing them around and out of the main bearing support.

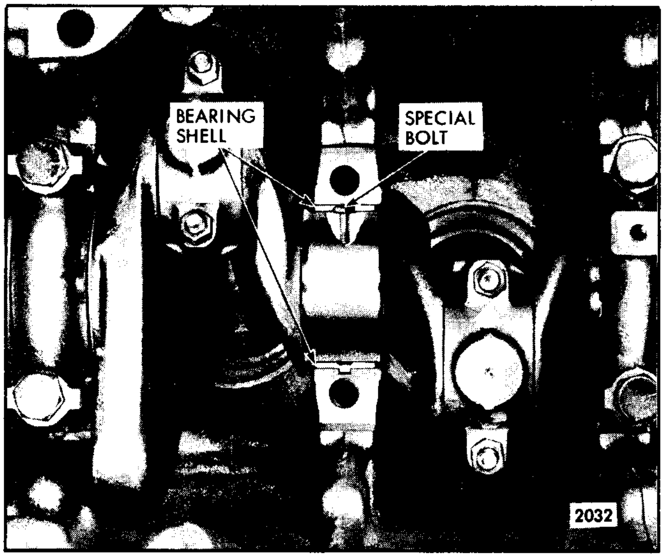


Fig. 4 - Removing Upper Main Bearing Shell (Except Rear Main)

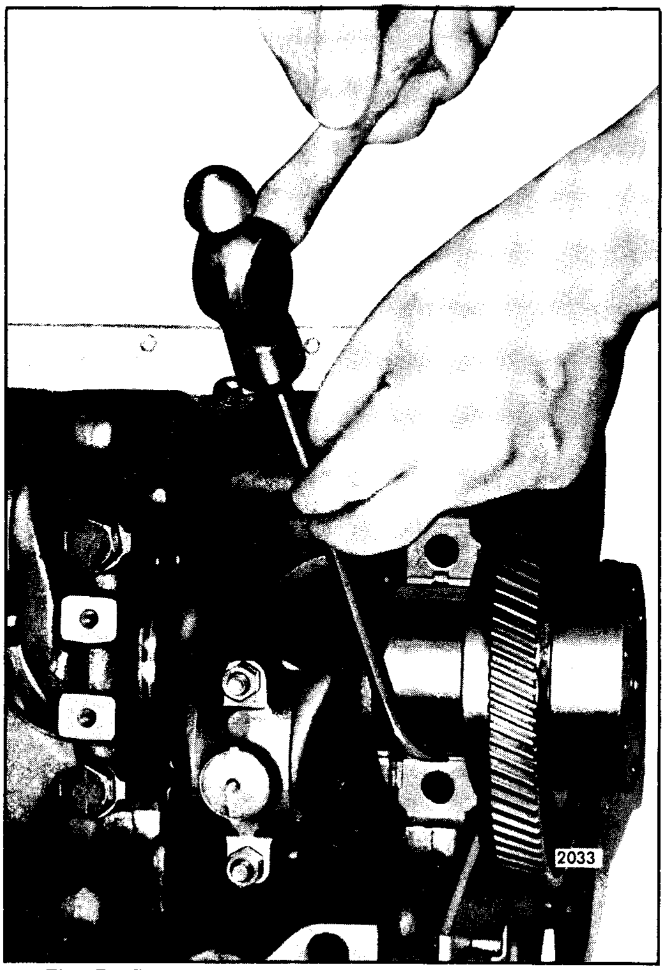


Fig. 5 - Removing Upper Rear Main Bearing Shell

Inspection

Bearing failures may result from deterioration (acid formation) or contamination of the oil or loss of oil. 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 bypass valve to make sure it is operating freely.

After removal, clean the bearings and inspect them for scoring, pitting, flaking, etching, loss of babbitt or signs of overheating (Fig. 6). The lower bearing shells, which carry the load, will normally show signs of distress before the upper bearing shells.

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

Measure the thickness of the bearing shells at point "C", 90° from the parting line (Figs. 7 and 8). Tool J 4757, placed between the bearing shell and a micrometer, will give an accurate measurement. The bearing shell thickness will be the total thickness of the steel ball in the tool and the bearing shell, less the diameter of the ball. This is the only practical method for measuring the bearing thickness, unless a special micrometer is available for this purpose. The minimum thickness of a worn standard main bearing shell is .1230" and, if any of the bearing shells are thinner than this dimension, replace all of the bearing shells. A new

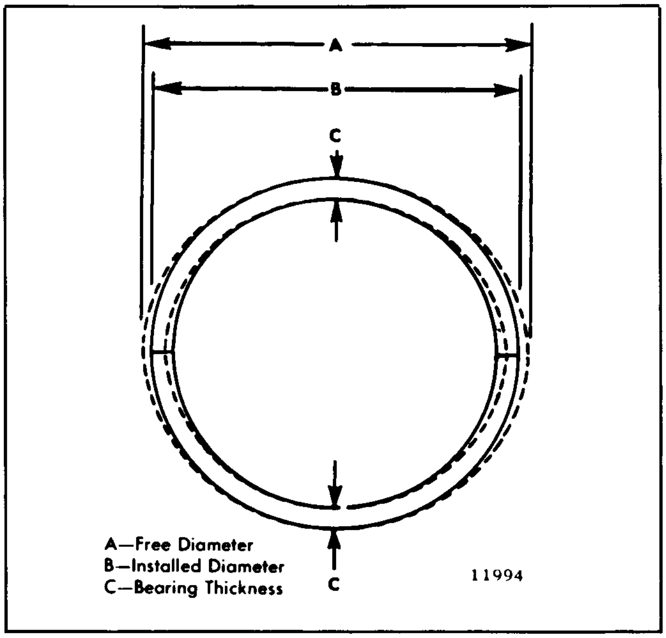


Fig. 7 - Main Bearing Measurements

standard bearing shell has a thickness of .1245" to .1250" (In-line engine) or .1240" to .1245" (V engine). Refer to Table 1.

In addition to the thickness measurement, check the clearance between the main bearings and the

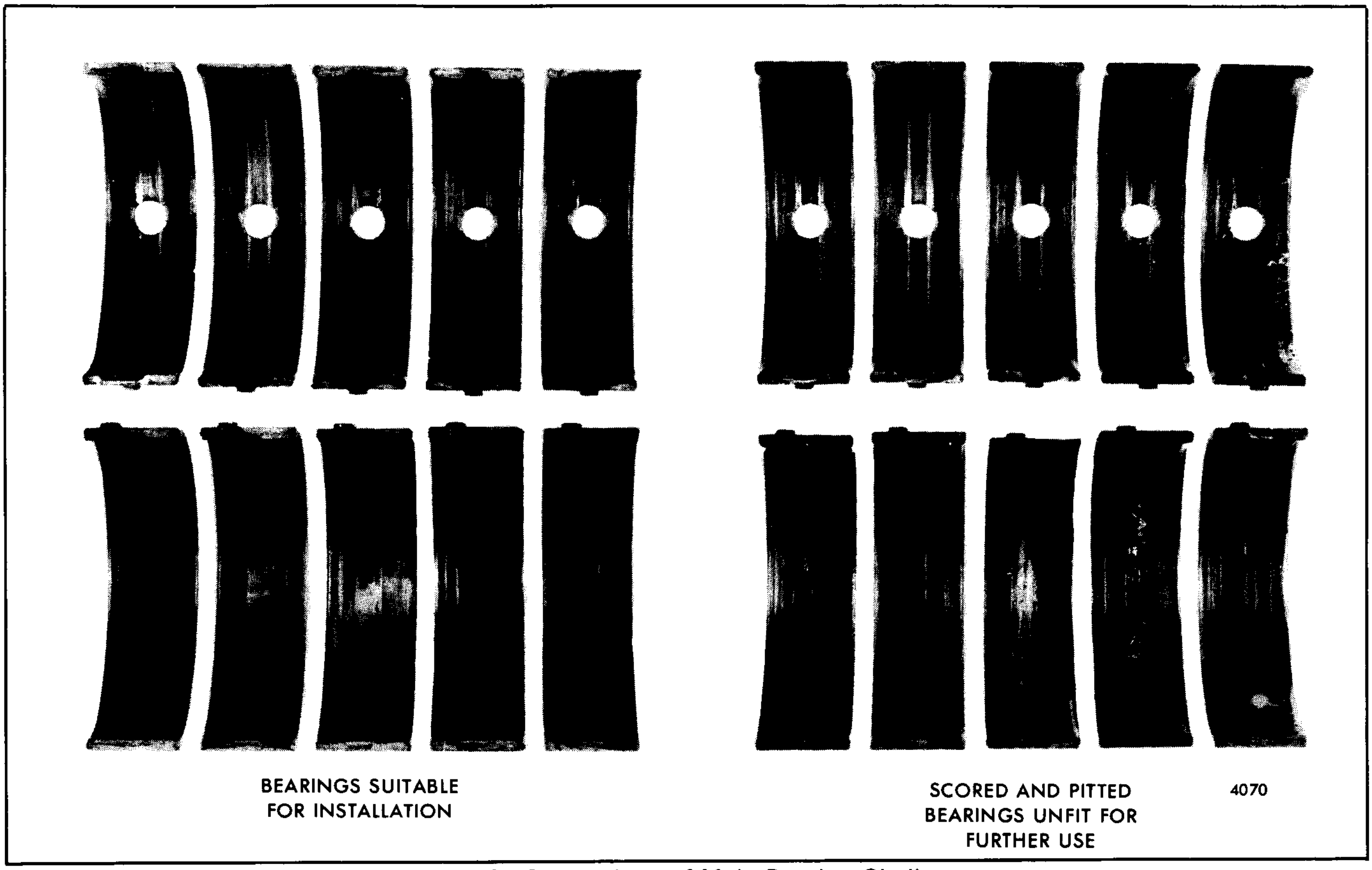


Fig. 6 - Comparison of Main Bearing Shells

Bearing Size	Bearing Thickness	Minimum Thickness
In-Line Engines		
Standard	.1245"/.1250"	.1230"
.002" Undersize	.1255"/.1260"	.1240"
.010" Undersize	.1295"/.1300"	.1280"
.020" Undersize	.1345"/.1350"	.1330"
.030" Undersize	.1395"/.1400"	.1380"
V-Type Engine		
Standard	.1240"/.1245"	.1230"
.002" Undersize	.1250"/.1255"	.1240"
.010" Undersize	.1290"/.1295"	.1280"
.020" Undersize	.1340"/.1345"	.1330"
.030" Undersize	.1390"/.1395"	.1380"

TABLE 1

crankshaft journals. This clearance 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 (refer to *Shop Notes* in Section 1.0). With the crankshaft removed, measure 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 bearing cap bolts. When installed, the bearing shells are .001" larger in diameter at the parting line than 90° from the parting line.

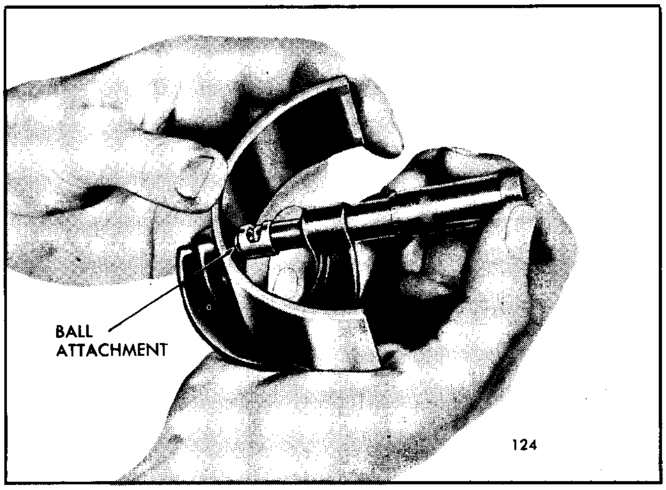


Fig. 8 - Measuring Thickness of Bearing Shell

The bearing shells do not form a true circle when not installed. When installed, the bearing shells have a squeeze fit in the main bearing bore and must be tight when the bearing cap is drawn down. This *crush* assures a tight, uniform contact between the bearing shell and bearing seat. Bearing shells that do not have sufficient crush will not have uniform contact, as shown by shiny spots on the back, and must be replaced. If the clearance between any crankshaft journal and its bearing shells exceeds .0060", all of the bearing shells must be discarded and replaced. This clearance is .0010" to .0040" with new parts.

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 the 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. Refer to Section 1.3 under *Crankshaft Inspection* for removal of ridges and inspection of the crankshaft.

Do not replace one main bearing shell alone. If one bearing shell requires replacement, install all new upper and lower bearing shells. Also, if a new or reground crankshaft is to be used, install all new bearing shells.

Bearing shells are available in .002", .010", .020" and .030" undersize for service with reground crankshafts. To determine the size bearings required, refer to *Crankshaft Grinding* in Section 1.3. Bearings which are .002" undersize are available to compensate for slight journal wear where it is unnecessary to regrind the crankshaft. Bearing shells are NOT reworkable from one undersize to another under any circumstances.

Oversize O.D. main bearing shells are also available in .010" and .020" oversize to salvage engine blocks which have experienced block bore wear or damage. The oversize bearing sets may be installed after the block bores have been line-bored to the oversized diameter (Section 1.0).

Do not mix main bearing shell kits on an engine. Use all oversize or all undersize bearing shells of the same size or use all standard main bearing shell kits.

Inspect the crankshaft thrust washers (Fig. 9). If the washers are scored or worn excessively or the crankshaft end play is excessive, they must be replaced. Improper clutch adjustment can contribute to excessive wear on the thrust washers. Inspect the crankshaft thrust surfaces. Refer to *Install Crankshaft* in Section 1.3. If, after dressing or regrinding the thrust surfaces, new standard size thrust washers do not hold the crankshaft end play within the specified limits, it may be necessary to install oversize thrust washers on one or both sides of the rear main bearing. A new standard size thrust washer is .1190" to .1220" thick. Thrust washers are available in .005" and .010" oversize.

The discovery of a crack in the rear main bearing cap of a 6V naturally aspirated or turbocharged engine does not automatically mean that the cap should be scrapped. The cap may be reused if the crack occurs on the bearing shell side of the dowel pin hole (Item 1 - Fig. 10). Fig. 10 shows the types of cracks which may be encountered on the 6V-53 rear main bearing cap. The reusability of the cap is defined as follows:

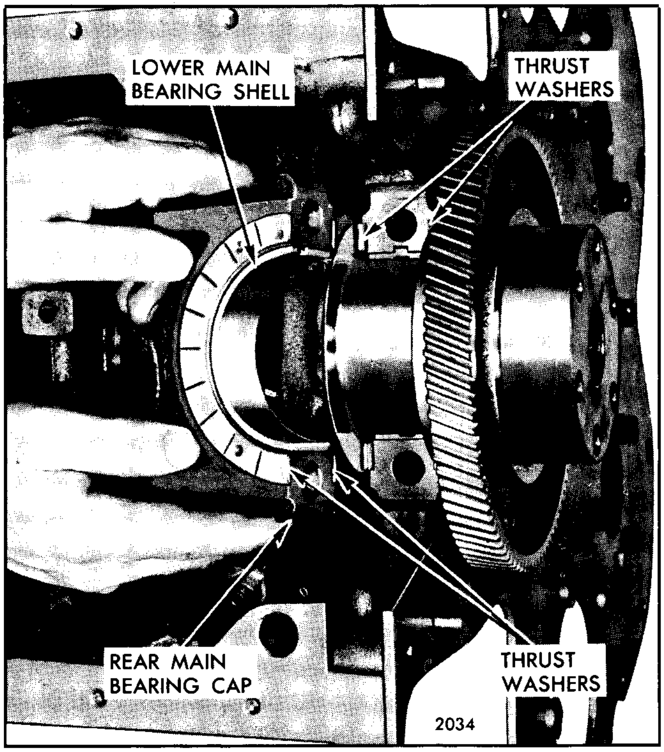


Fig. 9 - Crankshaft Thrust Washers in Place

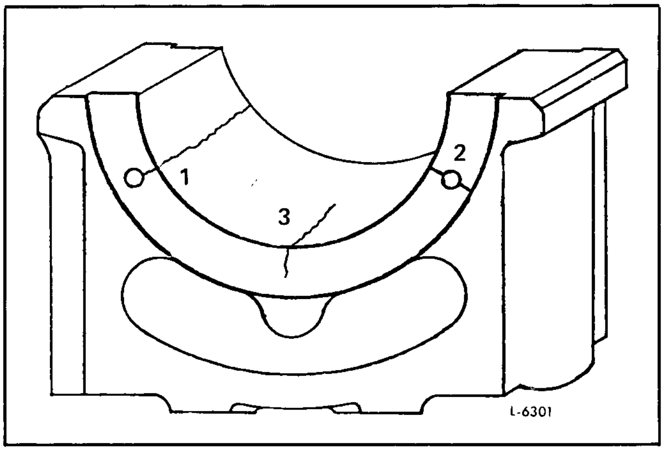


Fig. 10 - 6V Rear Main Bearing Cap Cracks

1. Cap *can* be reused. Crack occurs on the bearing shell side of the dowel pin hole.
2. Cap *cannot* be reused. Crack occurs on both sides of the dowel pin hole, extending toward the bearing shell area and the cap bolt hole.
3. Cap *cannot* be reused. Crack occurs at a location other than the dowel pin hole.

A pre-finished rear main bearing cap with machined thrust washer surface is available as a service part. After the bearing cap is replaced, the block must be line-bored to insure proper alignment (see Section 1.0).

Install Main Bearing Shells (Crankshaft in Place)

Make sure all of the parts are clean. Then, apply clean engine oil 360° around each crankshaft bearing journal and install the upper main bearing shells by reversing the sequence of operations given for removal.

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 bearing shell is grooved and drilled for lubrication -- the lower bearing shell is not. Be sure to install the grooved and drilled bearing shells in the cylinder block and the plain bearing shells in the bearing caps, otherwise the oil flow to the bearings and 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 an upper main bearing shell with the crankshaft in place, start the plain end of the bearing shell around the crankshaft journal so that, when the bearing is in place, the tang will fit into the groove in the bearing support.
2. Install the lower main bearing shell so that the tang on the bearing fits into the groove in the bearing cap.
3. Assemble the crankshaft thrust washers before installing the rear main bearing cap (Fig. 9). Clean both halves of each thrust washer carefully and remove any burrs from the washer seats -- the slightest burr or particle of dirt may decrease the clearance between the washers and the crankshaft beyond the specified limit. Slide the upper halves of the thrust washers into place. Then, assemble the lower halves over the dowel pins in the bearing cap. The main bearing caps are bored in position and stamped 1, 2, 3, etc. They must be installed in their *original* positions with the marked side of each cap facing the same side of the cylinder block that carried the engine serial number.

Bearing cap stabilizers are used at all 6V-53 engine main bearing cap positions. However, effective with engine serial number 6D-183126 the stabilizers were removed from the two front main bearing cap positions for the 6V naturally aspirated engines only.

Shorter bolts (9/16"-12 x 5.60") are now used at these two front main bearing cap positions that do not have the stabilizers. The longer 9/16"-12 x 6.24" bolt continues to be used with the stabilizers for the No. 3 and No. 4 main bearing caps. Refer to Fig. 11 for identification of bolts and Fig. 12 for modifications to the 6.24" bolt and washer.

NOTICE: Do not use the shorter bolt with a stabilizer, as this may result in insufficient bolt thread contact and possible engine damage.

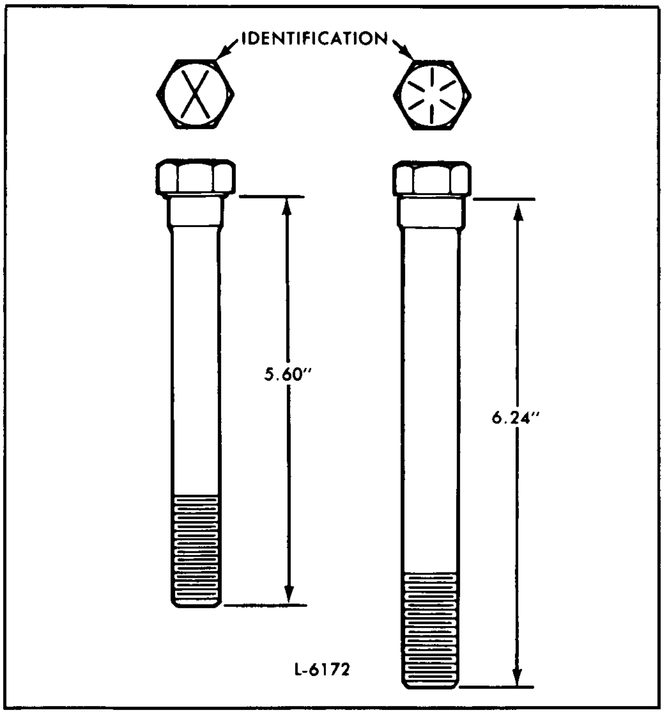


Fig. 11 - Identification of Stabilizer Bolts

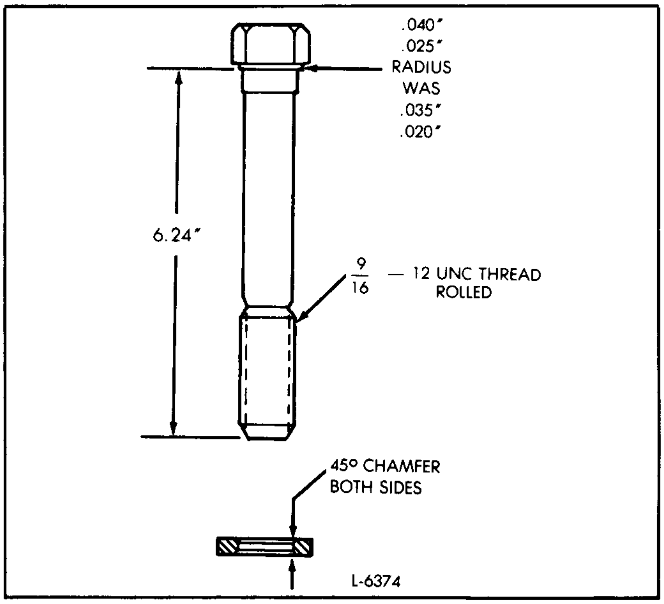


Fig. 12 - Modified 6V Main Bearing Cap Bolt and Washer

4. Apply a small quantity of International Compound No. 2, or equivalent, to the bolt threads and the bolt head contact area. Install the bearing caps and stabilizers (if used) and draw the bolts up snug. Then, rap the caps sharply with a soft hammer to seat them properly. Tighten all bolts (except the rear main bearing bolts) to 120-130 lb-ft (163-177 N·m) torque starting with the center bearing cap bolts and working alternately towards both ends of the block. Tighten the rear main bearing bolts to 40-50 lb-ft (54-68 N·m) torque. Strike both ends of the crankshaft two or three sharp blows with a soft hammer to insure proper positioning of the rear main bearing cap in the block saddle. Retorque all bearing bolts to 120-130 lb-ft (163-177 N·m). On a V-type engine, tighten the 7/16"-14 stabilizer bolts to 46-50 lb-ft (62-68 N·m) torque. If the bearings have been installed properly, the crankshaft will turn freely with all of the main bearing cap bolts drawn to the specified torque.
5. Check the crankshaft end play as outlined under *Install Crankshaft* in Section 1.3.
6. Install the lubricating oil pump and the oil inlet pipe assembly. If shims were used between the pump (8V engine) and the bearing caps, install them in their *original* positions.
7. Install the oil pan, using a new gasket.
8. Fill the crankcase to the proper level on the dipstick with *heavy-duty* lubricating oil of the recommended grade and viscosity (refer to *Lubrication Specifications* in Section 13.3).
9. 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.

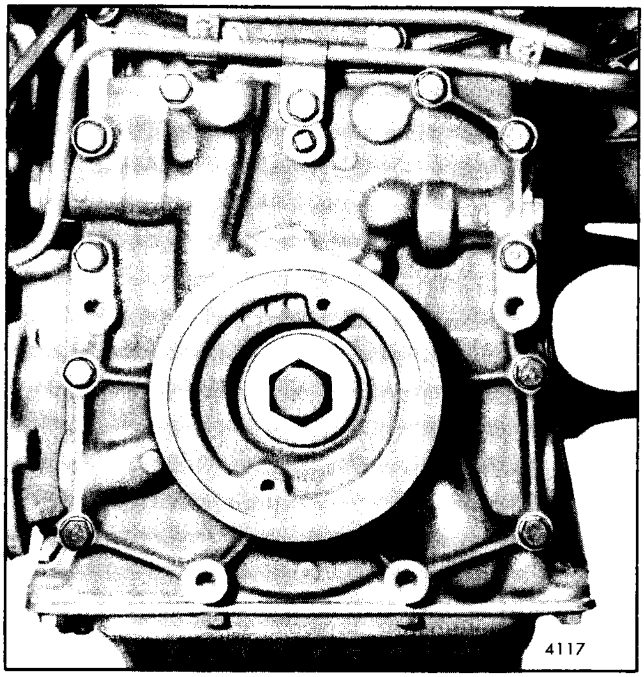


Fig. 1 - Engine Front Cover Mounting (Lower) -- In-Line Engine

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.

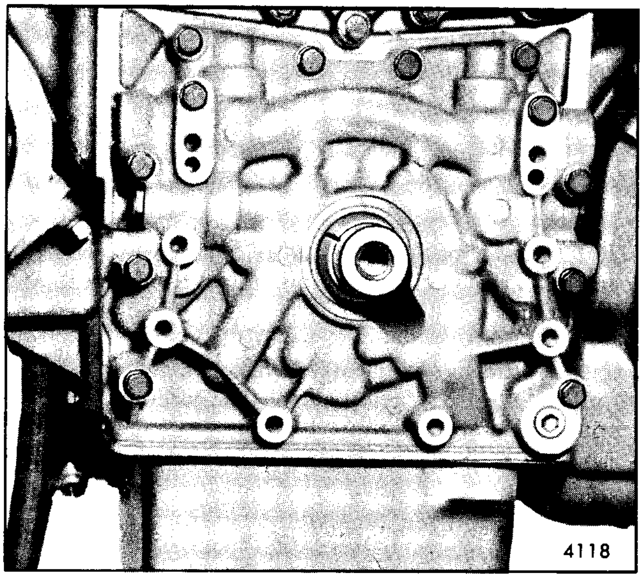


Fig. 2 - Engine Front Cover Mounting (Lower) -- 6V-Engine

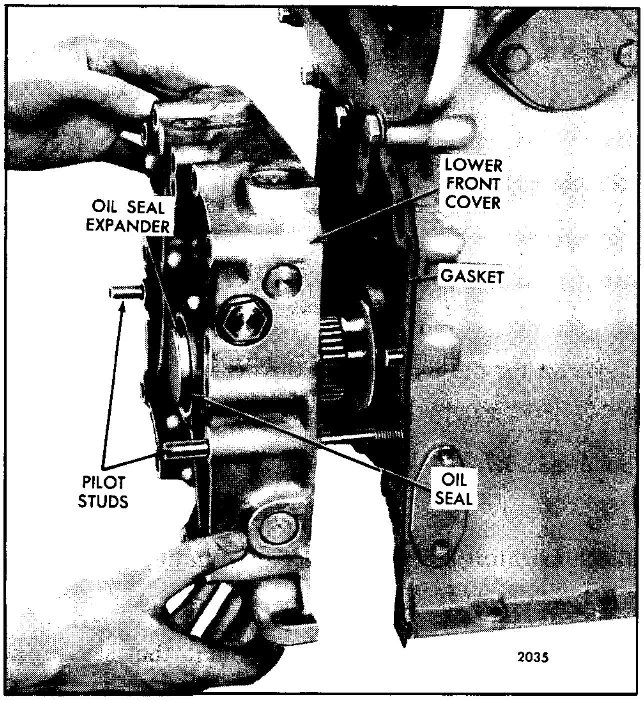


Fig. 3 - Installing Lower Engine Front Cover -- In-Line Engine

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 (41-47 Nm) 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 (18-23 Nm) 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 (18-23 Nm) 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.

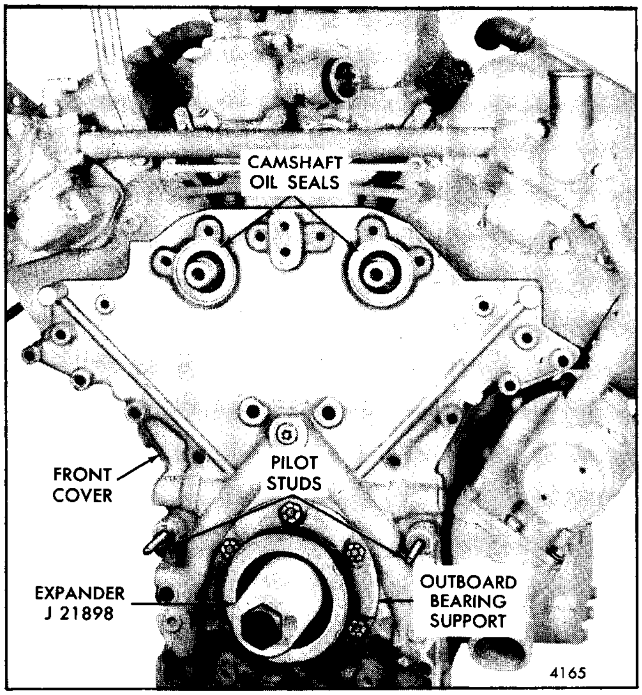


Fig. 4 - Installing Engine Front Cover - 8V-Engine

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 (41-47 Nm) 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 (102-115 Nm) 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 (41-47 Nm) 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 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

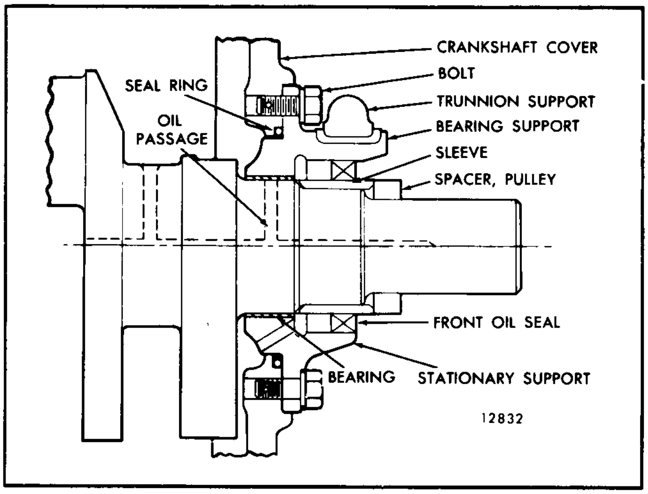


Fig. 1 - Outboard Bearing Support Assembly

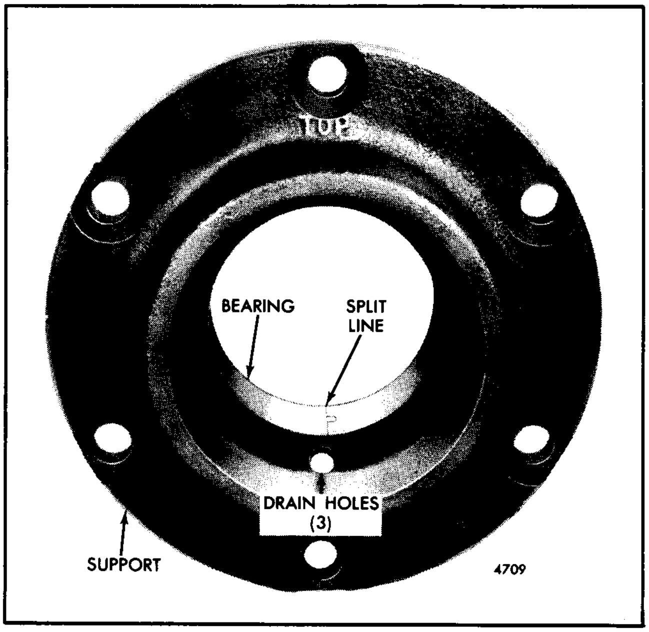


Fig. 2 - Location of Bearing in Support

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 24420 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.

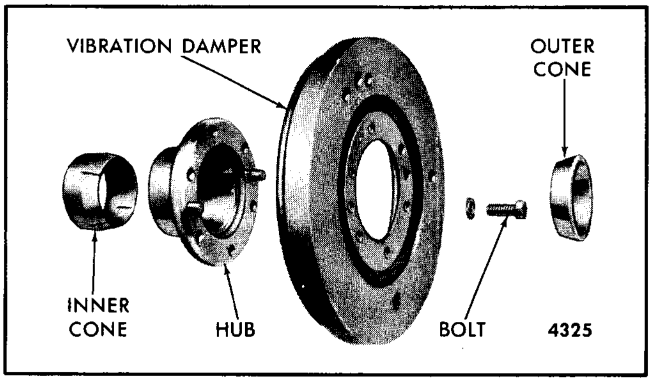


Fig. 1 - Vibration Damper Details and Relative Location of Parts

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.*

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, fluid leaks or bulges in the outer casing. Any indications of the above are sufficient cause for replacement of the damper. 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 in the damper has deteriorated and has 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.

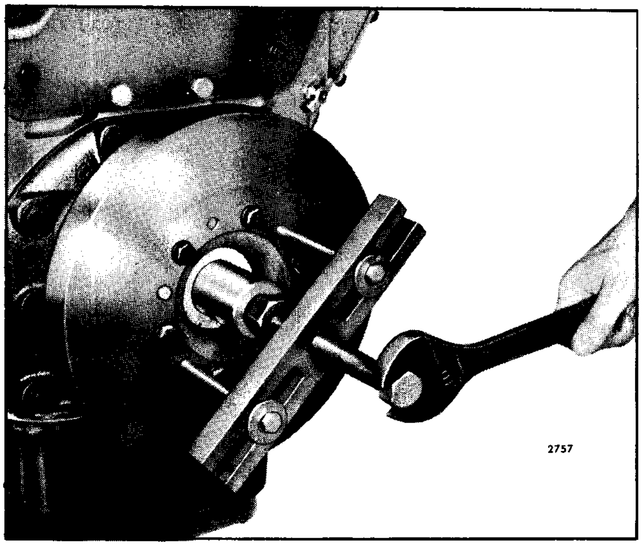


Fig. 2 - Removing Vibration Damper Outer Cone

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).

A loose engine mount could also damage the vibration damper by allowing the engine to move slightly during operation. Therefore, it is good practice to periodically inspect the engine mounts to be sure they are not loose, cracked or deteriorated.

Install Vibration Damper

IMPORTANT: All parts on the front of the crankshaft must be positioned without any noticeable interference.

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 (244 Nm) torque.

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

c. Tighten the bolt to 300 lb-ft (407 Nm) torque and strike the bolt again.

d. Retighten the bolt to 300 lb-ft (407 Nm) torque. *Do not hit the crankshaft end bolt after the last tightening of the bolt or the clamping effect will be reduced.*

IMPORTANT: The damper must be securely fastened to the crankshaft. When the bolt is drawn up to the specified torque, the cone will hold the damper rigidly in place. *Do not turn the crankshaft in a counterclockwise direction or the bolt may loosen, resulting in subsequent engine failure.*

CRANKSHAFT PULLEY

The crankshaft pulley is secured to the front end of the crankshaft by a special washer and a bolt. The engine application determines the type of crankshaft pulley to be used.

The appearance of the rubber bushing (if used) 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.

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 24420-A (Fig. 1). Then, force the pulley off the crankshaft by turning the puller center screw in.

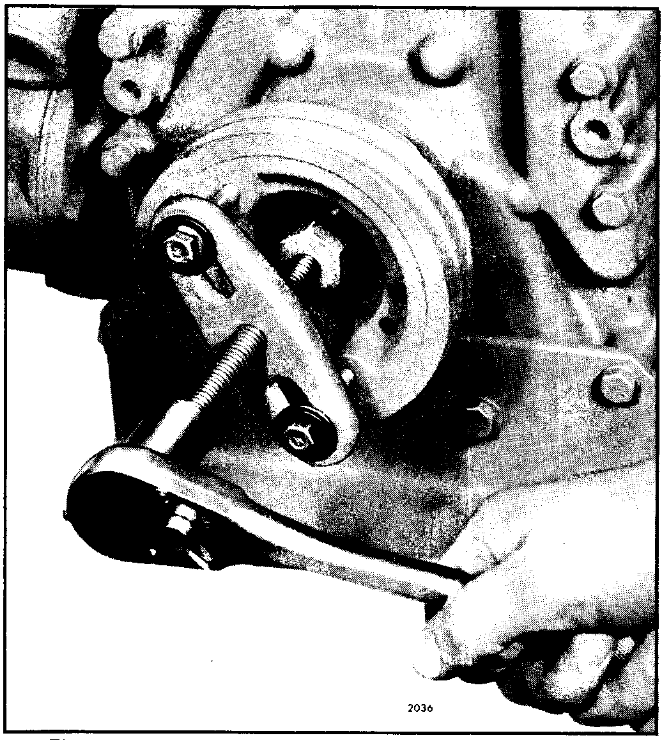


Fig. 1 - Removing Crankshaft Pulley Using Puller J 24420-A

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.

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.

Install Crankshaft Pulley

1. Lubricate the end of the crankshaft with engine oil to facilitate pulley installation.
2. Slide the inner cone (Fig. 2), if used, on the crankshaft.

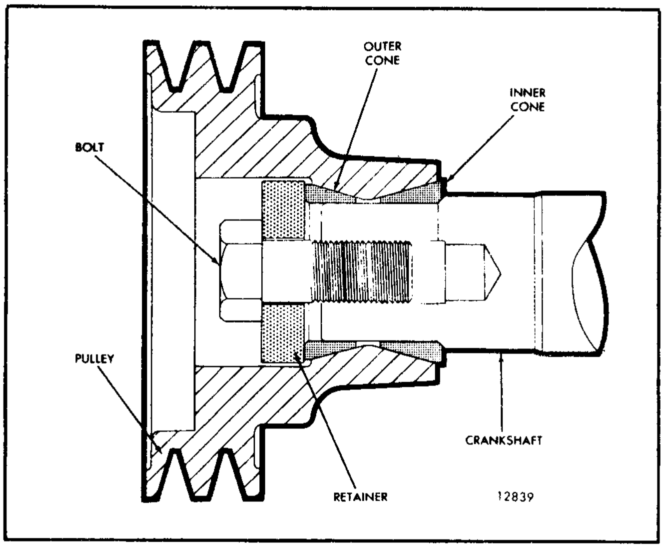


Fig. 2 - Cone Mounted Pulley

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.
5. Install a rigid type pulley on an In-line or 6V engine with installer J 7773 (Fig. 3). Then, remove the installer.

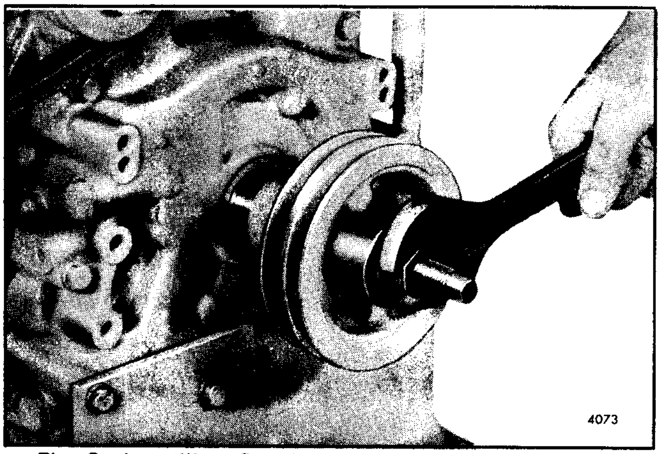


Fig. 3 - Installing Crankshaft Pulley Using Installer J 7773

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. 2), 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 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 (393-407 N·m) 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 (393-407 N·m) 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 (271-298 N·m) 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 (393-421 N·m) torque.
13. On 8V engines, tighten the 1"-14 crankshaft end bolt as follows:
    a. Tighten the bolt to 180 lb-ft (244 N·m) torque.
    b. Strike the end of the bolt a sharp blow with a 2 to 3 pound lead hammer.
    c. Retighten the bolt to 300 lb-ft (407 N·m) torque. *Do not hit the crankshaft end bolt after the last tightening of the bolt or the clamping effect will be reduced.*
14. Install and adjust the belts.

FLYWHEEL

The flywheel is attached to the rear end of the crankshaft with six self-locking bolts. On an 8V engine, two dowels are provided in the rear end of the crankshaft for locating the flywheel. A scuff plate is used between the flywheel and the bolt heads to prevent the bolt heads from scoring the flywheel surface.

A steel ring gear, which meshes with the starting motor pinion, is shrunk onto the rim of the flywheel.

The flywheel is machined to provide true alignment with the clutch or a power take-off driving ring, and the center bore provides for installation of a clutch pilot bearing. The clutch or power take-off driving ring is bolted 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 flywheels used with hydraulic couplings, clutches or Torqmatic converters.

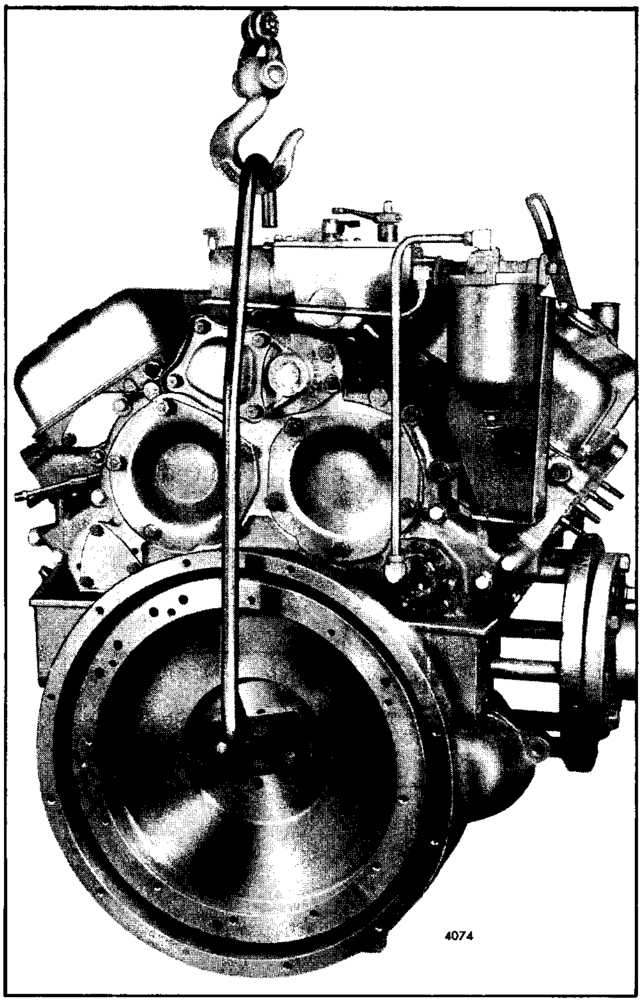


Fig. 1 - Removing Flywheel

The flywheel must be removed for service operations such as replacing the starter ring gear, crankshaft or flywheel housing. On torque converter units, the flywheel is part of the torque converter assembly and is covered in the applicable converter service manual.

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.

   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 or use tool J 25026.

   c. Attach a chain hoist to the lifting tool.

   d. Remove the remaining flywheel attaching bolt.

   e. Move the upper end of the lifting tool in and out to loosen the flywheel, then withdraw the flywheel from the crankshaft and the flywheel housing.

   f. Remove the clutch pilot bearing, if used, as outlined in Section 1.4.1.

   g. Remove the oil seal ring, if used.

Inspection

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

Replace the ring gear if the gear teeth are excessively worn or damaged.

Check the butt end of the crankshaft and flywheel contact surface. If necessary, lightly stone the crankshaft end and the flywheel contact surface to remove any fretting or brinnelling.

On crankshafts with dowels, be sure and check the dowel extension. Dowels must not extend more than 1/2" (13 mm) from the crankshaft.

Make sure that the crankshaft and flywheel contact surfaces and the bolt threads in the crankshaft end are clean and dry, to ensure proper metal-to-metal contact and maximum friction, before attaching the flywheel.

New bolts should be used to mount or remount the flywheel. However, if the original bolts are determined to be serviceable and are to be reused, clean them thoroughly before starting the assembly procedure.

Remove Ring Gear

Note whether the ring gear teeth are chamfered. The replacement gear must be installed so that the chamfer on the teeth faces the same direction with relationship to the flywheel as on the gear that is to be removed. Then remove the ring gear as follows:

1. Support the flywheel, crankshaft side down, on a solid flat surface or a hardwood block which is slightly smaller than the inside diameter of the ring gear.

2. Drive the ring gear off the flywheel with a suitable drift and hammer. Work around the circumference of the gear to avoid binding the gear on the flywheel.

3. If a clutch pilot bearing is used, inspect the bearing and replace it, if necessary.

Install Ring Gear

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 (204°C); excessive heat 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 these "crayons" will ensure 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 so that it is seated all the way around, remove it and apply additional heat, noting the above caution.

Install Flywheel

1. Install a new oil seal ring, if used.

2. Attach the flywheel lifting tool and, using a chain hoist, position the flywheel in the flywheel housing (use guide studs) or clutch housing. Align the flywheel bolt holes with the crankshaft bolt holes.

3. Install the clutch pilot bearing (if used).

4. Install two bolts through the scuff plate 180° from each other. Snug the bolts to hold the flywheel and scuff plate to the crankshaft. Remove the guide studs.

5. Remove the flywheel lifting tool.

6. Apply International Compound No. 2, or equivalent, to the threads and to the bolt head contact area (underside) of the remaining bolts. The bolt threads

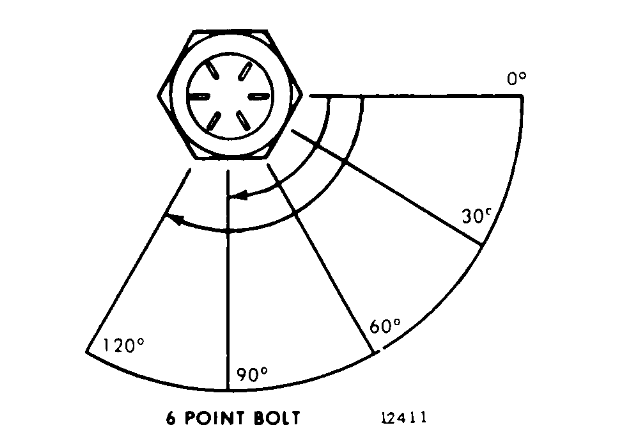


Fig. 2 - Torque-Turn Limits

must be completely filled with International Compound No. 2 and any excess wiped off.

> **NOTE:** International Compound No. 2 must never be used between two surfaces where maximum friction is desired, as between the crankshaft and the flywheel.

7. Install the remaining bolts and run them in snug.

8. Remove the two bolts used temporarily to retain the flywheel, apply International Compound No. 2 as described above, then reinstall them.

9. Use an accurately calibrated torque wrench and tighten the bolts to 50 lb-ft (68 Nm) torque.

10. Turn the bolts an additional 90°-120° (Fig. 2) to obtain the required clamping.

> **NOTE:** Since the *torque-turn method* provides more consistent clamping than the former method of flywheel installation, bolt torque values should be ignored.

> **IMPORTANT:** When a clutch pilot bearing is installed, index the flywheel bolts so that the corners of the bolt heads do not overlap the pilot bearing bore in the flywheel. Thus, one of the flats of each bolt head will be in line with the bearing bore. Always rotate bolts in the increased *clamp direction* to prevent underclamping.

11. Mount a dial indicator on the flywheel housing and check the runout of the flywheel at the clutch contact face. The maximum allowable runout is .001" total indicator reading per inch of radius (or .001 mm per millimeter 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 single-shielded ball type clutch pilot bearing should be packed with an all purpose grease such as Shell Alvania No. 2, or equivalent, if not previously packed by the manufacturer. A double-sealed clutch ball type pilot bearing is prepacked with grease and requires no further lubrication.

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 doweled to the crankshaft, except on an 8V engine.

2. With the clutch pilot bearing remover adaptor J 23907-2 attached to slide hammer J 23907-1, 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 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. Clean the other types of bearing thoroughly with clean fuel oil and dry them with compressed air.

Check the bearing for free rolling by holding the inner race and revolving the outer race *slowly* by hand. Rough spots in 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

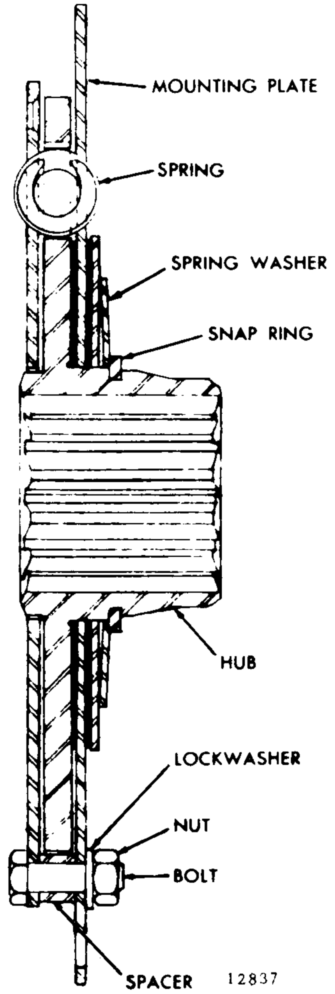


Fig. 1 - Engine Drive Shaft Flexible Coupling

The engine drive shaft flexible coupling (Fig. 1) 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.

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 compressed 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 (34-41 Nm) 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 cylinder block end plate, which provides a cover for the gear train and the flywheel. It also serves as a support for the starting motor and the 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. Mount the engine on an overhaul stand as outlined in Section 1.1.

2. Remove the starting motor from the flywheel housing or the clutch housing.

3. Remove the flywheel.

4. Remove the oil pan.

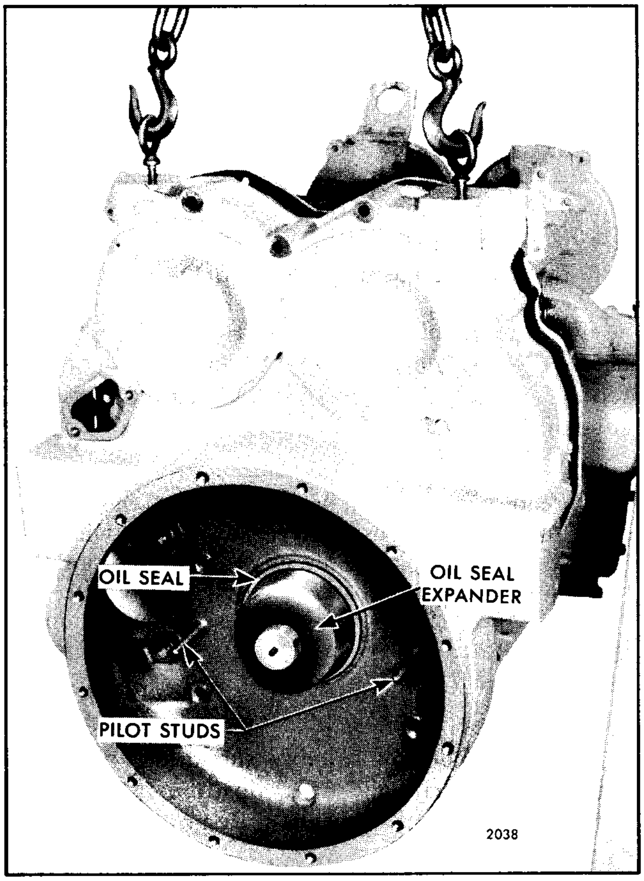


Fig. 1 - Removing or Installing Flywheel Housing

5. Remove the clutch housing, if used.

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 it 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 with a soft hammer to loosen and work it off the dowel pins.

Inspection

Clean the flywheel housing and inspect it for cracks or any other damage.

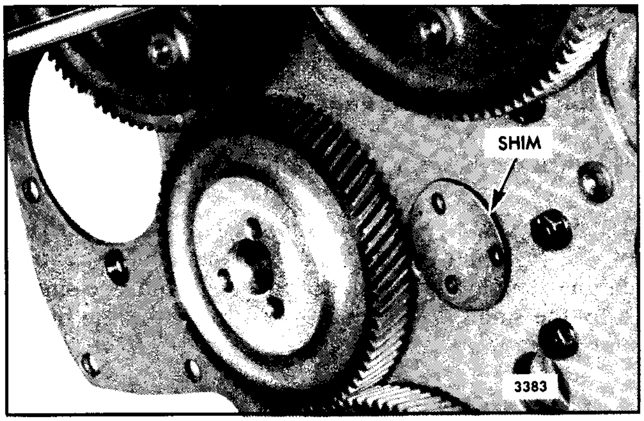
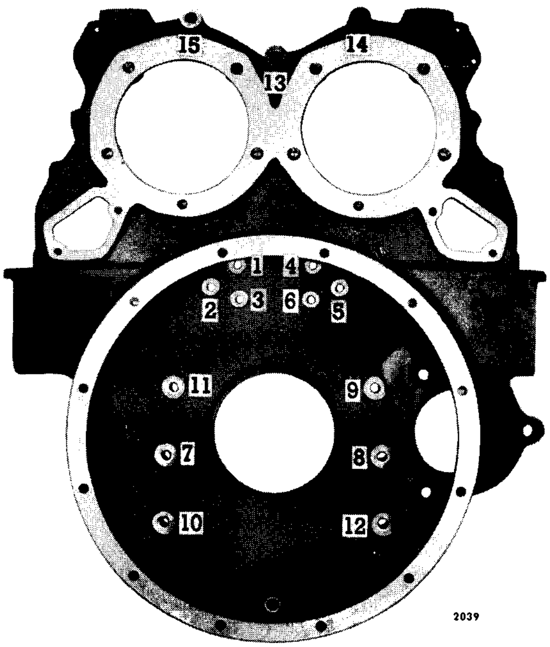
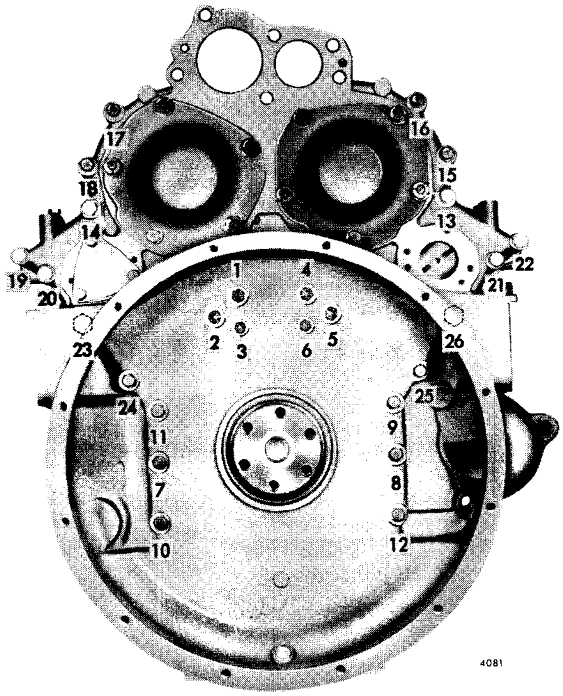


Fig. 2 - Location of Shim



Bolt Size	Location
5/16"-18x2 1/2"	3-6
3/8"-16x7/8"	1-2-4-5
3/8"-16x2 1/2"	7-8-9-10-11-12
3/8"-24x3 9/16"	13-14-15

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



Bolt Size	Location
5/16"-18x2 1/2"	3-6
3/8"-16x2 1/2"	1-2-4-5-7-8-9-10-11-12-24-25
3/8"-16x2 3/4"	23-26
3/8"-16x3 3/4"	13-14-19-20-21-22
3/8"-24x3 1/4"	15-16
3/8"-24x3 1/2"	17-18

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

It is very important that all old gasket material be thoroughly removed from the flywheel housing and the end plate, otherwise runout of the pilot and face of the housing may be affected when the housing is installed on the engine.

Remove and discard the crankshaft rear oil seal. Install a new 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.

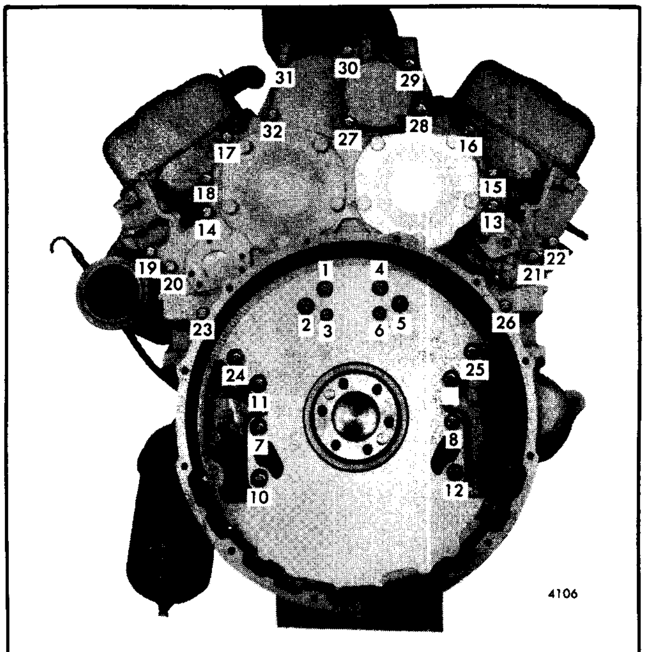
3. If the flywheel housing has an integral cast hub, install a flywheel housing-to-end plate shim (.015" thick). Use grease to hold the shim to the cylinder block rear end plate (Fig. 2).

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. Thread two pilot studs J 7540 into the cylinder block to guide the housing in place (Fig. 1). On In-line and 6V engines, to pilot the oil seal on the crankshaft successfully, use oil seal expander J 9769 (standard size seal) or J 21278-01 (oversize seal) on the end of the crankshaft. On 8V engines, use oil seal expander J 22425.

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

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



Bolt Size	Location
5/16"-18x2 1/2"	3-6
3/8"-16x2 1/2"	1-2-4-5
3/8"-16x2 3/4"	7-8-9-10-11-12-24-25
3/8"-16x3 1/2"	13-14
3/8"-16x3 3/4"	27-28-29-32
3/8"-16x4" Cad	19-20-21-22
3/8"-24x3 1/4"	15-16
3/8"-24x3 1/2"	17-18
3/8"-16x6 3/4"	23-26

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

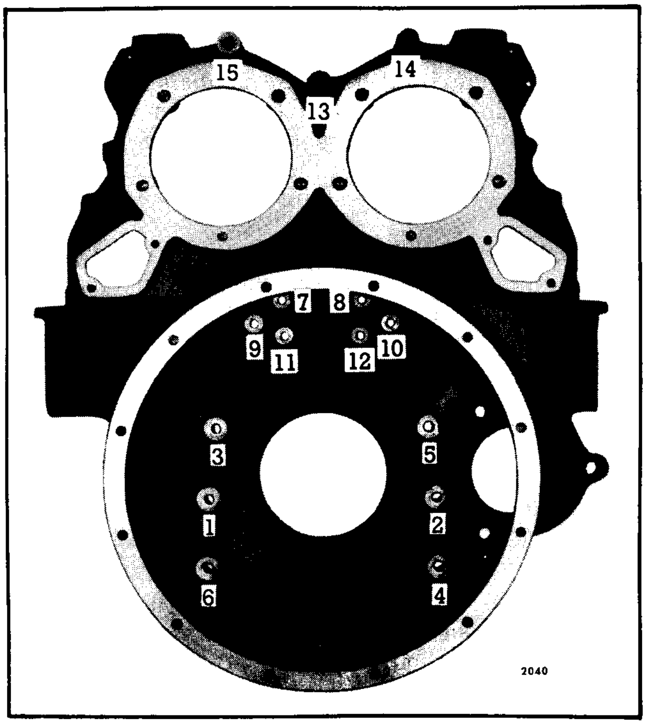


Fig. 6 - Flywheel Housing Bolt Tightening Sequence (Operation 2)--In-Line Engine

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 Figs. 4 and 5.

NOTE: On an 8V engine, when tightening the idler gear hub bolts, turn the engine crankshaft to prevent any bind or brinelling of the idler gear bearing. The crankshaft must be rotated for the flywheel housing bell bolt tightening also.

9. Refer to Fig. 6 for the final bolt tightening

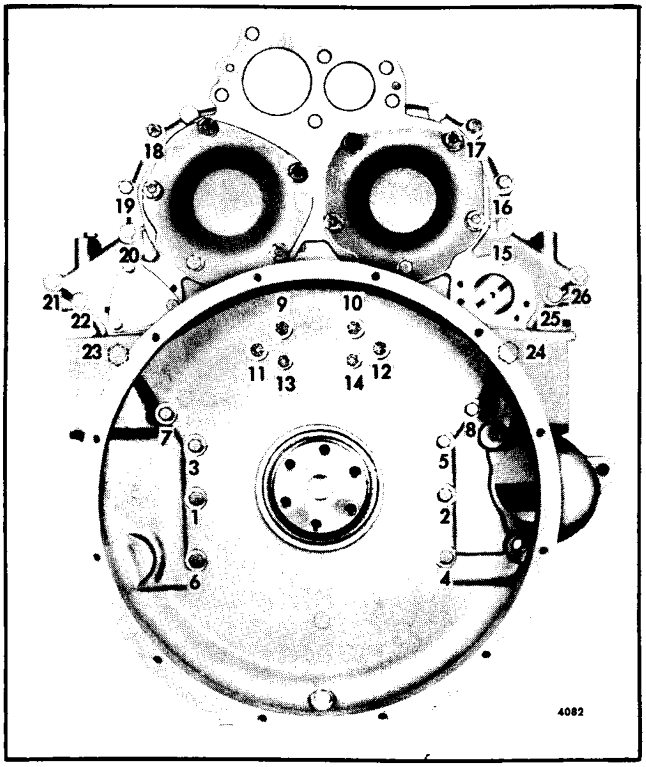


Fig. 7 - Flywheel Housing Bolt Tightening Sequence (Operation 2)--6V Engine

sequence on an In-line engine. Then start at No. 1 and tighten the bolts to the specified torque.

a. Tighten the 5/16"-18 bolts (numbers 11 and 12) to 19-23 lb-ft (26-31 Nm) torque and the 3/8"-16 bolts (numbers 7 through 10) to 40-45 lb-ft (54-61 Nm) torque. Tighten the remaining 3/8"-16 and 3/8"-24 bolts to 25-30 lb-ft (34-41 Nm) 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 (26-31 Nm) 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 (14-16 Nm) 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 (26-31 Nm) torque and the 3/8"-16 bolts (numbers 9 through 12) to 40-45 lb-ft (54-61 Nm) torque. Tighten the remaining 3/8"-16 and 3/8"-24 bolts to 25-30 lb-ft (34-41 Nm) torque. Be sure to rotate the crankshaft when tightening the idler gear hub bolts and flywheel housing bell bolt on an 8V engine.

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.

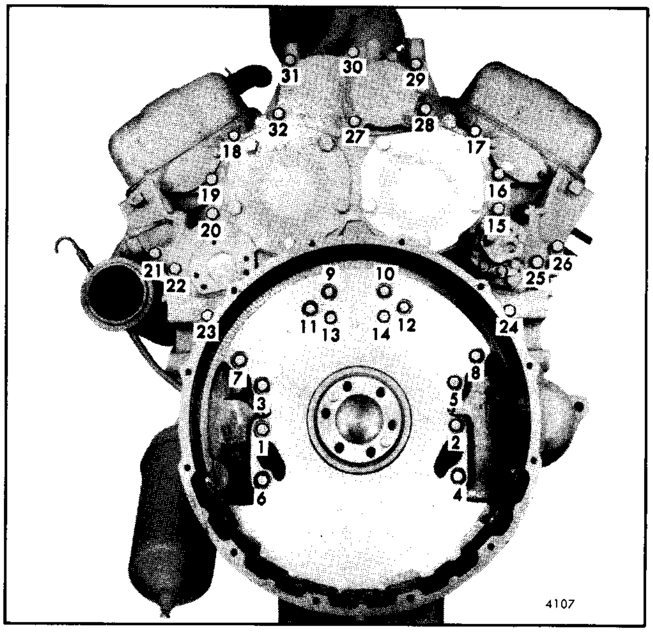


Fig. 8 - Flywheel Housing Bolt Tightening Sequence (Operation 2)--8V Engine

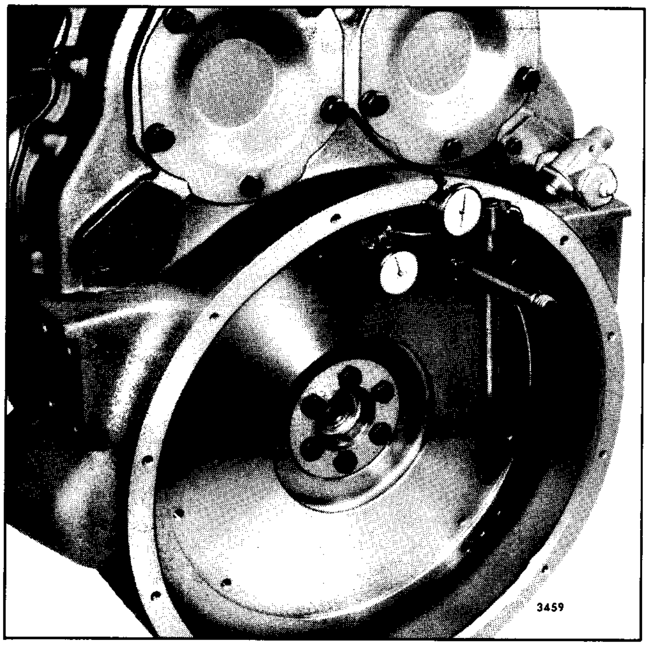


Fig. 9 - Checking Flywheel Housing Concentricity

12. Install the flywheel (Section 1.4).

13. Check the flywheel housing concentricity and bolting flange face runout with tool J 9737-C, 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.

b. Position the dial indicators straight and square with the flywheel housing bell face and inside bore of the bell. Make sure each indicator has adequate travel in each direction.

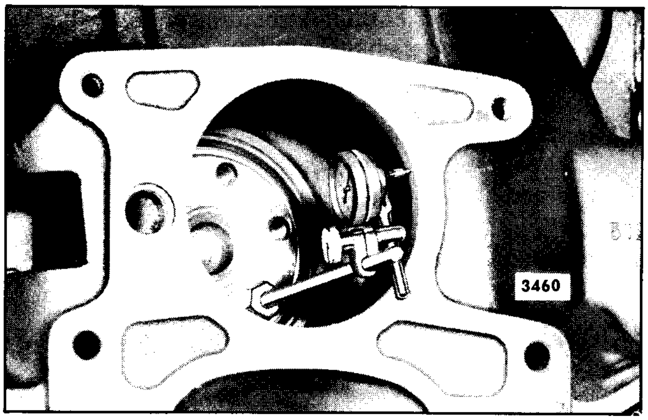


Fig. 10 - Checking Bore Runout

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

c. Pry the crankshaft toward one end of the block to ensure that end play is in one direction only.

d. *Adjust each dial indicator to read zero at the twelve o'clock position.* Rotate the crankshaft one full revolution, recording readings at 90° intervals (4 readings each for the bore and the bolting flange face). On "bossed" flywheel housings position the dial indicators at a location where clearance or obstruction is not a problem.

NOTE: The hex head of the front crankshaft bolt may be used to turn the crankshaft. However, the barring operation should ALWAYS be performed in a clockwise direction. It is very important to make certain that the bolt has not been loosened. Serious engine damage may result if the vibration damper or pulley is not securely fastened to the crankshaft.

e. Stop and remove the wrench or cranking bar before recording each reading to ensure accuracy. Record the readings and interpret as follows:

BORE and FACE RUNOUT

Check value at six o'clock (6:00) position. This value cannot exceed ±.013".

Check values at three o'clock (3:00) and nine o'clock (9:00) positions.

1. Both readings "+" or "–". The difference must not exceed .013".

3:00	9:00	EXAMPLES			
		Good		Bad	
+	+	+ .002"	+ .014"	+ .002"	+ .016"
		Difference =	.012"	Difference =	.014"
–	–	– .002"	– .014"	– .002"	– .016"
		Difference =	– .012"	Difference =	– .014"

2. Both readings different, "+/–" or "–/+". The total of dimensions must not exceed .013".

3:00	9:00	EXAMPLES			
		Good		Bad	
+	–	+ .002"	– .010"	+ .002"	– .012"
		Total =	.012"	Total =	.014"
–	+	– .002"	+ .010"	– .002"	+ .012"
		Total =	.012"	Total =	.014"

BORE DIAMETER

Verification of bore diameter is required when 3:00 and 9:00 o'clock readings are both "+" or both "–". The total of dimensions must not exceed .030".

3:00	9:00	EXAMPLES			
		Good		Bad	
+	+	+ .014"	+ .015"	+ .014"	+ .017"
		Total =	.029"	Total =	.031"
–	–	– .014"	– .015"	– .014"	– .017"
		Total =	.029"	Total =	.031"

f. If the bore or face runout 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.

g. Reinstall the flywheel housing and the flywheel and tighten the attaching bolts in the proper sequence and to the specified torque. Then recheck the bore and face runout and the bore diameter. If necessary, replace the flywheel housing.

14. Install the clutch housing, if used. Tighten the 3/8"-16 attaching bolts to 30-35 lb-ft (41-47 Nm) torque and the 3/8"-24 nuts to 35-39 lb-ft (47-53 Nm) 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 d 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 (41-47 and 47-53 Nm) torque respectively. Then recheck the runout.

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

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 complete assembly of the engine.

PISTON AND PISTON RINGS

TRUNK TYPE PISTON

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.

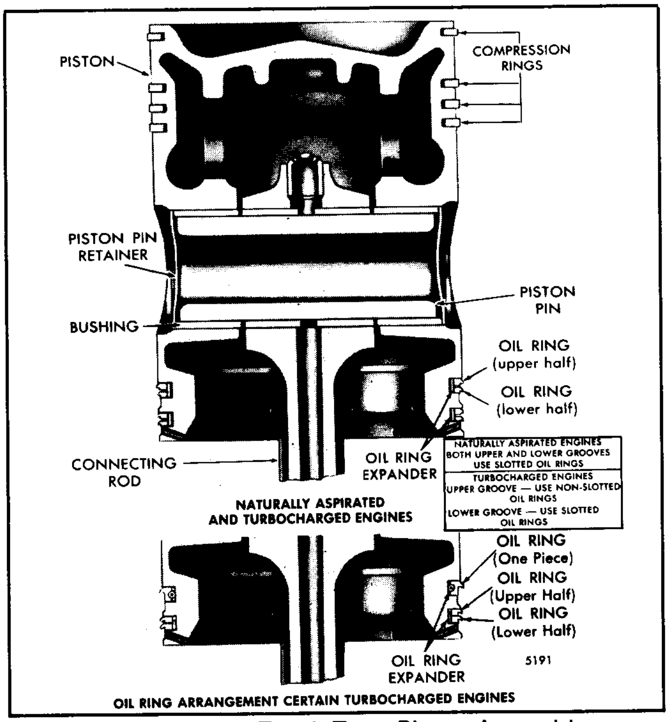


Fig. 1 - Typical Trunk Type Piston Assembly

Each piston is internally braced with fin-shaped ribs and circular struts, scientifically designed to draw heat rapidly from the piston crown and transfer it to the lubricating oil spray to ensure better control of piston ring temperature.

The piston is cooled by a spray of lubricating oil directed at the underside of the piston head from a nozzle in the top of the connecting rod, by fresh air from the blower to the top of the piston and indirectly by the water jacket around the cylinder.

Each piston is balanced to close limits by machining a balancing rib, provided on the inside at the bottom of the piston skirt.

Two bushings, with helical grooved oil passages, are pressed into the piston to provide a bearing for the hardened, floating piston pin (1.375" diameter). 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 sprayed underside of the piston head and working through the grooves in the piston pin bushings is prevented from reaching the cylinder walls.

The current piston pin retainer (formerly colored black) for the 1.375" diameter piston pin has a greater outside diameter (1.6110") and is now brass colored for identification. The former and new retainers are interchangeable in an engine. When rebuilding a turbocharged engine with the 1.375" diameter piston pin, use only the current retainer.

Effective with engine serial numbers 3D-170958, 4D-181763 and 6D-187523, turbocharged engines use a 1.500" diameter piston pin. With the use of the 1. 500" diameter piston pin, new piston assemblies, piston pin retainers and connecting rod assemblies are required. The former piston pin diameter is 1.375". The former and new piston and connecting rod assemblies differ only in that they have larger bushing bores to facilitate the installation of new, larger diameter bushings. The larger bushing inner diameter is necessary to accommodate the new, larger piston pin. Because of the larger pin diameter, former and new parts are not separately interchangeable. When it becomes necessary to replace any one of the three major cylinder components, it will be necessary to include the other two to assure interchangeability. Current piston assemblies and connecting rods can be mixed in an engine with the former piston assemblies and connecting rods.

Turbocharged engines incorporate pistons and connecting rod assemblies which utilize "vapor blasted" piston pin bushings. Vapor blasting is a surface finishing process which is applied to the bushing after it is installed and finished bored in the piston or rod. This process cannot be performed in the field. Piston pin bushings may not be replaced in turbocharged engines and when excessive wear exists it will be necessary to replace the piston and/or connecting rod assembly.

Each piston is fitted with compression rings and oil control rings (Fig. 1). Equally spaced drilled holes just below each oil control ring groove permits excess oil, scraped from the cylinder walls, to return to the crankcase.

A new fire ring (top compression ring), prestressed for increased durability, has been released for Series 53 naturally aspirated (NA) engines effective with 3D-189578, 4D-203354 and 6D-223676. The fire ring is identified with the word "TOP" stamped adjacent to the gap and a permanent oval mark on top to indicate prestressing. Current turbocharged engine fire ring (identified by a black oxide coating and a permanent oval mark on top to indicate prestressing) will continue to be available to service turbocharged engines. The chrome facing on both the new NA engine fire ring and the current turbocharged engine fire ring has been increased for improved wear characteristics.

The upper drain holes in the oil ring groove and the "J" relief are omitted on Brazil built engines. The piston bushings are vapor blasted and the piston pins are polished and drilled for positive piston pin bushing lubrication.

Inspect Piston Rings

When an engine is hard to start, runs rough or lacks power, worn or sticking compression rings may be the cause. Replacing the rings will aid in restoring engine operation to normal.

The compression rings may be inspected through the ports in the cylinder liners after the air box covers have been removed. If the rings are free and are not worn to the extent that the plating or grooves are gone, compression should be within operating specifications. Refer to Section 15.2 for the procedure for checking compression pressure.

Remove Piston and Connecting Rod

1. Drain the cooling system.
2. Drain the oil and remove the oil pan.
3. Remove the oil pump and inlet and outlet pipes, if necessary (Section 4.1).
4. Remove the cylinder head (Section 1.2).
5. Remove the carbon deposits from the upper inner surface of the cylinder liner.
6. Remove the bearing cap and the lower bearing shell from the connecting rod. Then, push the piston and rod assembly out through the top of the cylinder block. The piston cannot be removed from the bottom of the cylinder block.
7. Reassemble the bearing cap and lower bearing shell to the connecting rod.

Disassemble Piston and Connecting Rod

Note the condition of the piston and rings. Then, remove the rings and connecting rod from the piston as follows:

1. Secure the connecting rod in a vise equipped with soft jaws and remove the piston rings with tool J 8128 (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, then remove the connecting rod.
4. Drive the remaining piston pin retainer out from the inside with a brass rod or other suitable tool.

Clean Piston

Clean the piston components with fuel oil and dry them with compressed air. If fuel oil does not remove the carbon deposits, use a chemical solvent (Fig. 3) that will not harm the piston pin bushings or the tin-plate on the piston.

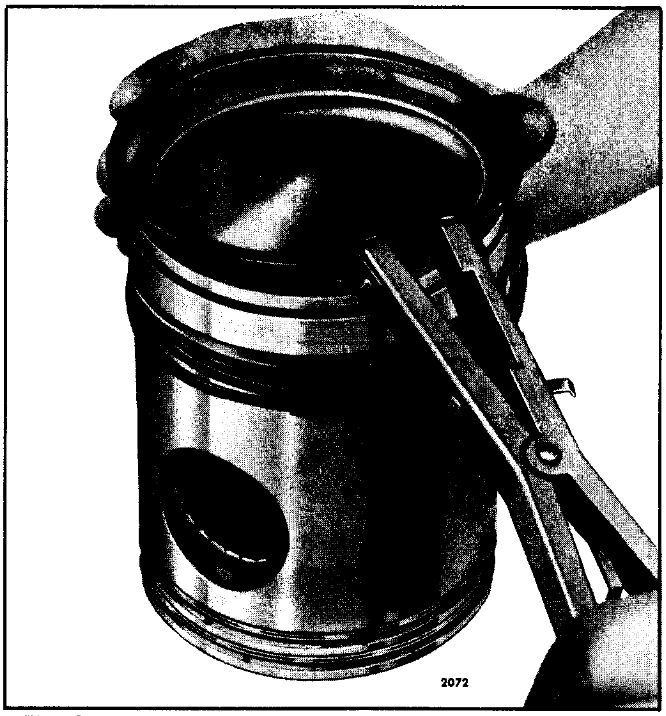


Fig. 2 - Removing or Installing Piston Ring using Tool J 8128

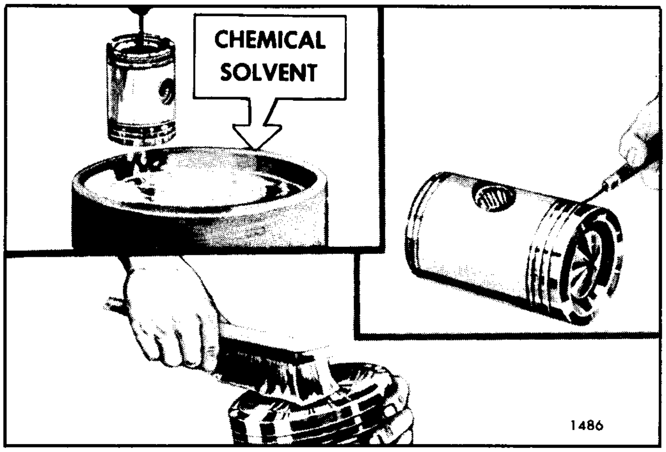


Fig. 3 - Cleaning Piston

The upper part of the piston, including the compression ring lands and grooves, is not tin-plated and may be wire-brushed to remove any hard carbon. However, use care to avoid damage to the tin-plating on the piston skirt. Clean the ring grooves with a suitable tool or a piece of an old compression ring that has been ground to a bevel edge.

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

Inspection

If the tin-plate on the piston and the original grooves in the piston rings are intact, it is an indication of very little wear.

Excessively worn or scored pistons, rings or cylinder liners may be an indication of abnormal maintenance or operating conditions which should be corrected to avoid recurrence of the failure. The use of the correct types and 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 reduce the rate of wear.

Long periods of operation at idle speed and the use of improper lubricating oil or fuel must be avoided, otherwise a heavy formation of carbon may result and cause the rings to stick.

Keep the lubricating oil and engine coolant at the proper levels to prevent overheating of the engine.

Examine the piston for score marks, cracks, damaged ring groove lands or indications of overheating. A piston with light score marks which may be cleaned up and reused (Fig. 4). Any piston that has been severely scored or overheated must be replaced. Indications of overheating or burned spots on the piston may be the result of an obstruction in the connecting rod oil passage.

Replace the piston if cracks are found across the internal struts.

Check the cylinder liner and block bore for excessive out-of-round, taper or high spots which could cause failure of the piston (refer to Section 1.0 for Specifications).

Inspection of the connecting rod and piston pin are covered in Section 1.6.1.

Other factors that may contribute to piston failure include oil leakage into the air box, oil pull-over from the air cleaner, dribbling injectors, combustion blow-by and low oil pressure (dilution of the lubricating oil).

Inspect and measure the 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.

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.

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 (non-turbocharged engines) with the bushing remover J 4972-4 and handle J 1513-2 (Fig. 5).

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. 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.
6. The bushings must withstand an end load of 1,800 pounds without moving after installation.
7. Ream the bushings to size as follows:

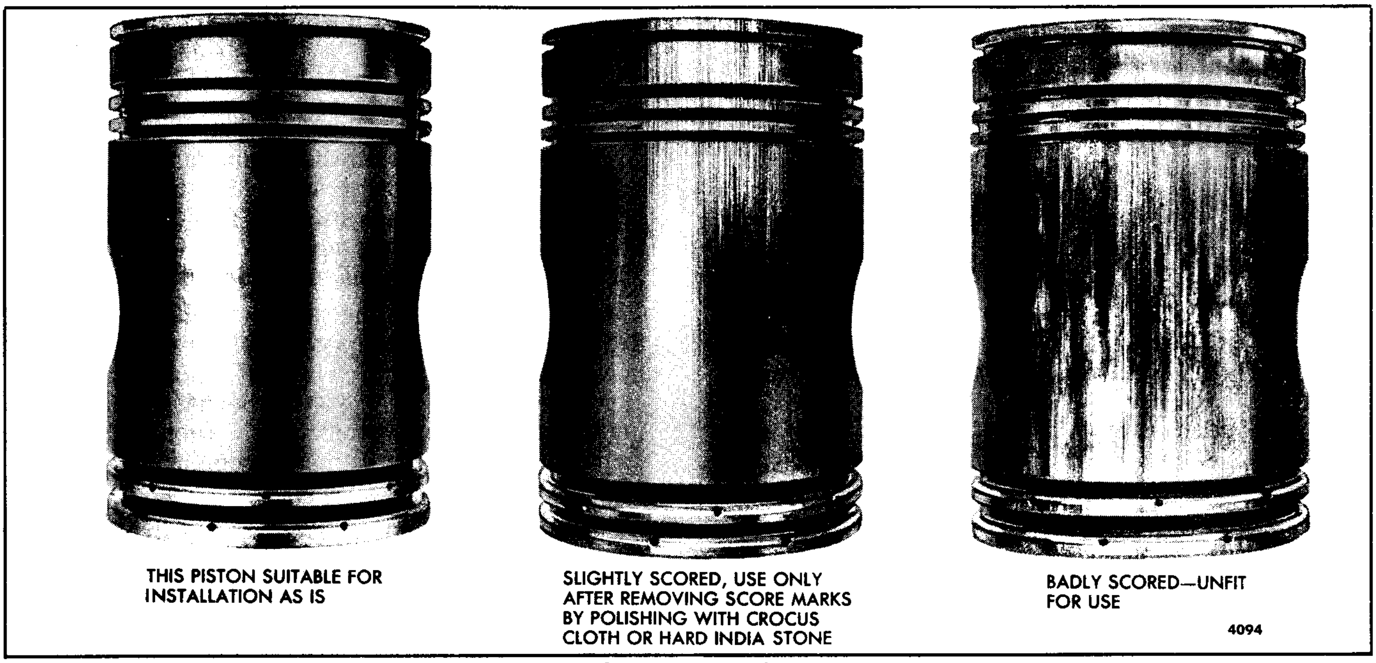


Fig. 4 - Comparison of Pistons

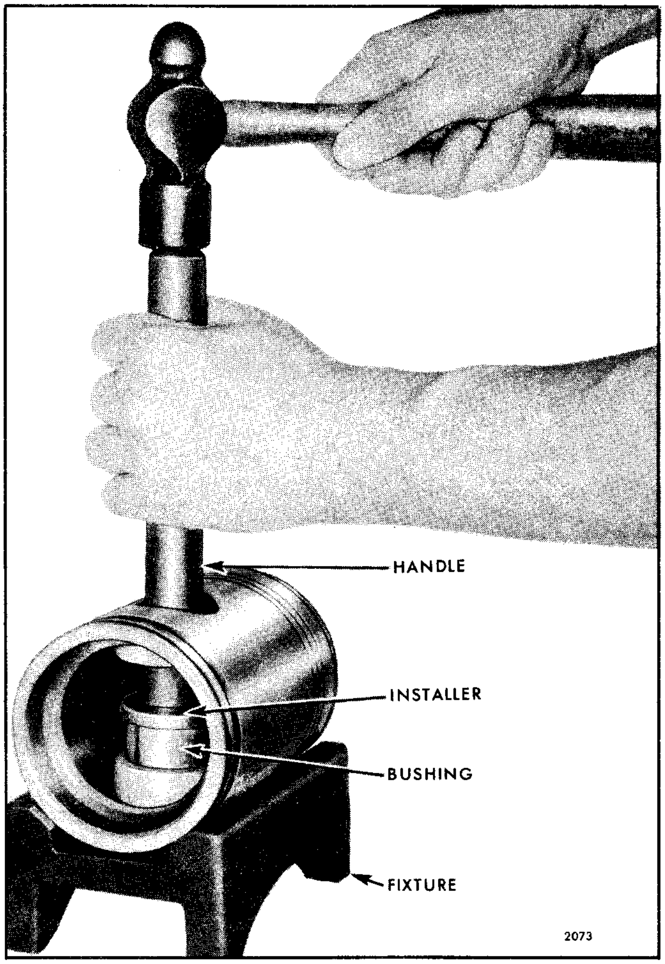


Fig. 5 - Removing or Installing Piston Pin Bushings

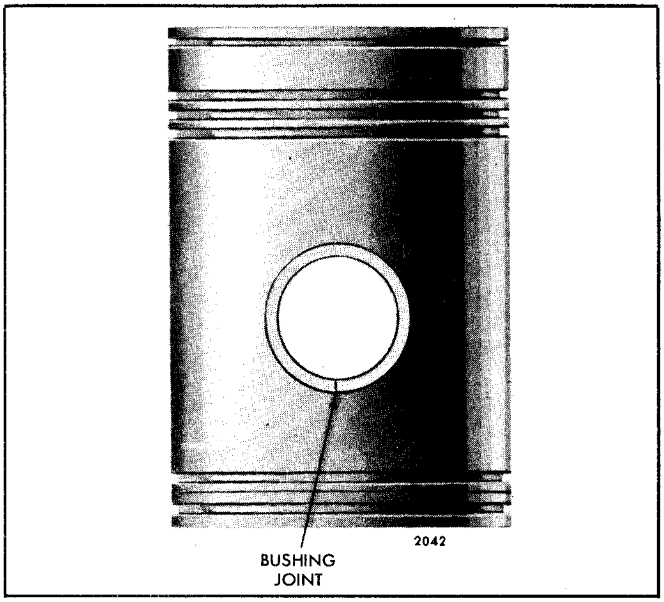


Fig. 6 - Location of Joint in Piston Pin Bushings

a. 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.

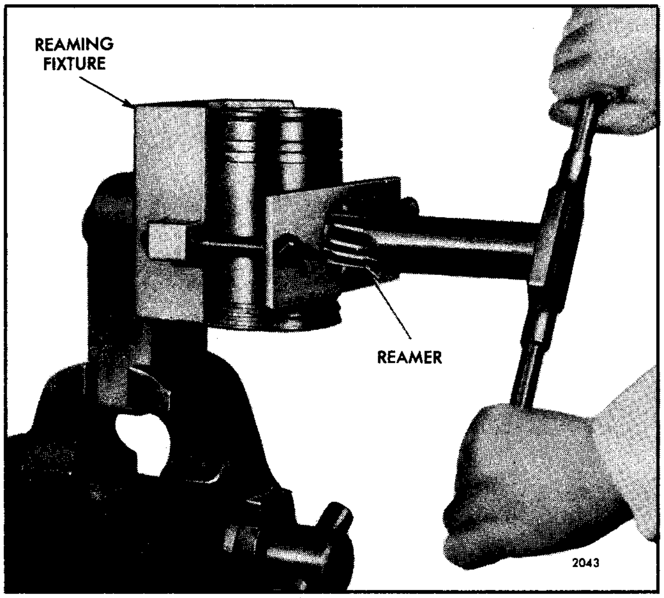


Fig. 7 - Reaming Piston Pin Bushings

b. Place the piston in the fixture and insert the pilot end of the reamer J 4970-4 through the clamping bar, bushings and into the guide bushing.

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

d. Ream the bushings (Fig. 7). Turn the reamer in a clockwise direction only, when reaming or withdrawing the reamer. For best results, use only moderate pressure on the reamer.

e. Withdraw the reamer and remove the piston from the fixture. Blow out the chips and measure the inside diameter of the bushings. The diameter must be 1.3775″ to 1.3780″.

Fitting Piston

Measure the piston skirt diameter lengthwise and crosswise of the piston pin bore. Measurements should be taken at room temperature (70°F or 21°C). The taper and out-of-round must not exceed .0005″. Refer to Section 1.0 for piston diameter Specifications.

A new cylinder liner has an inside diameter of 3. 8752″ to 3.8767″. The piston-to-liner clearance, with new parts, is .0027″ to .0068″ (non-turbocharged engines) or .0047″ to .0088″ (turbocharged engines). A maximum clearance of .010″ (non-turbocharged engines) or .012″ (turbocharged engines) is allowable with used parts.

With the cylinder liner installed in the cylinder block, hold the piston upside down in the liner and check the clearance in four places 90° apart (Fig. 8).

Use feeler gage set J 5438-01 to check the clearance. The spring scale, attached to the proper feeler gage, is used to measure the force in pounds required to withdraw the feeler gage.

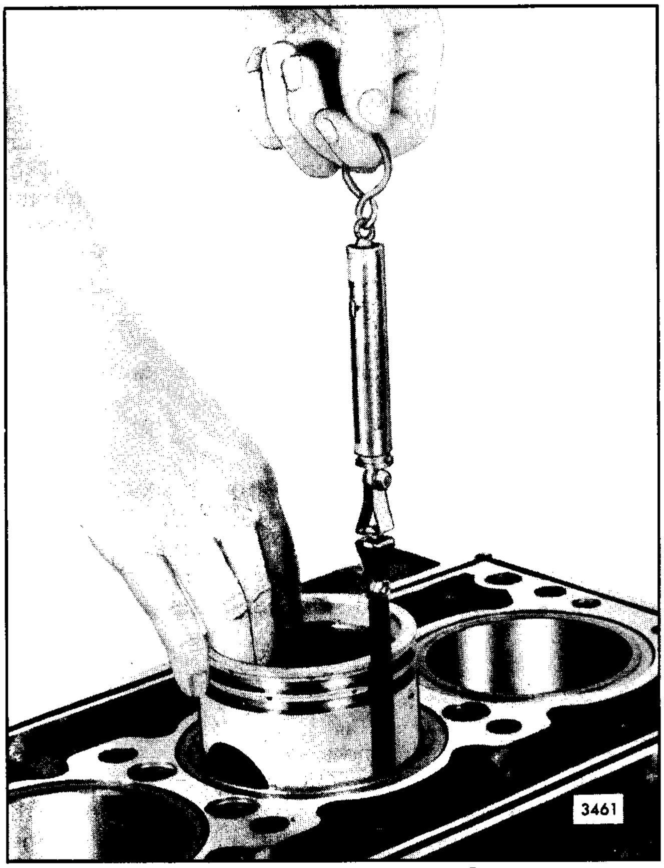


Fig. 8 - Measuring Piston-to-liner Clearance

Select a feeler gage with a thickness that will require a pull of six pounds to remove. The clearance will be .001″ greater than the thickness of the feeler gage used, i.e., a .004″ feeler gage will indicate a clearance of .005″ when it is withdrawn with a pull of six pounds. The feeler gage must be perfectly flat and free of nicks and bends.

If any bind occurs between the piston and the liner, examine the piston and liner for burrs. Remove burrs with a fine hone (a flat one is preferable) and recheck the clearance.

Fitting Piston Rings

Each piston is fitted with a fire ring, three compression rings and two oil control rings (Fig. 1).

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.

A two-piece oil control ring is used in both oil ring grooves in the pistons for non-turbocharged (naturally aspirated) engines. A one-piece oil control ring is used in the upper ring groove and a two-piece ring in the lower ring groove in the pistons for turbocharged engines. Brazil built engines use non-slotted upper oil control rings and low tension expanders.

All new piston rings must be installed whenever a piston is removed, regardless of whether a new or used piston or cylinder liner is installed.

Insert one ring at a time inside of the cylinder liner and far enough down 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 (Fig. 9). Refer to Section 1.0 for ring gap specifications.

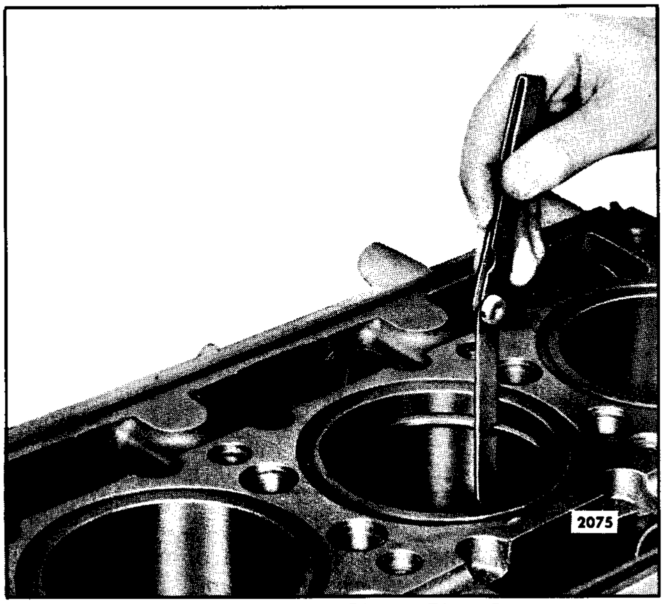


Fig. 9 - Measuring Piston Ring Gap

If the gap on a compression ring is insufficient, it may be increased by filing or stoning the ends of the ring. File or stone both ends of the ring so the cutting action is from the outer surface to the inner surface. This will prevent any chipping or peeling of the chrome plate on the ring. The ends of the ring must remain square and the chamfer on the outer edge must be approximately .015″.

Check the ring side clearance (Fig. 10). Ring side clearances are specified in Section 1.0.

Install Piston Rings

Before installing the piston rings, assemble the piston and rod as outlined under *Assemble Connecting Rod to Piston* in Section 1.6.1. Then, refer to Fig. 1 and install the piston rings. Lubricate the piston rings and piston with engine oil before installing the rings.

COMPRESSION RINGS

1. Starting with the bottom ring, install the compression rings with tool J 8128 (Fig. 2). To avoid breaking or overstressing the rings, do not spread them any more than necessary to slip them over the piston. When installing the top compression (fire) ring with the tapered face, be sure the side marked "TOP" is toward the top of the piston.

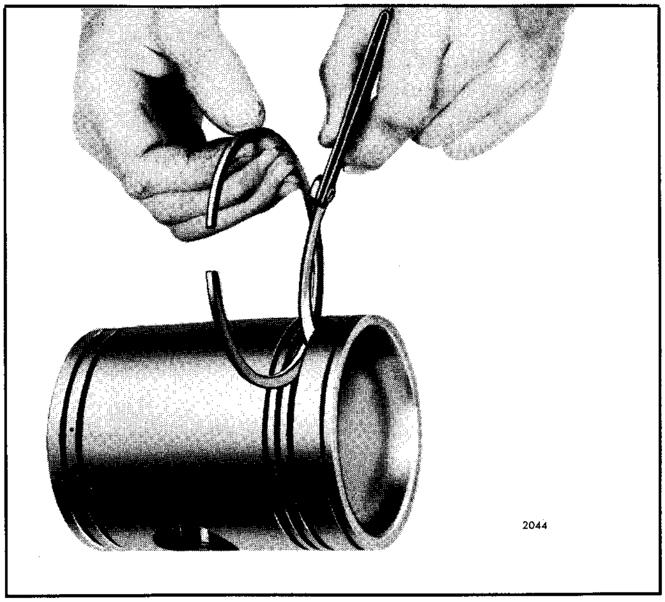


Fig. 10 - Measuring Piston Ring Side Clearance

2. Stagger the ring gaps around the piston.

OIL CONTROL RINGS

The upper and lower oil control rings used on pistons for *naturally aspirated and turbocharged* engines consist of two halves (upper and lower). The upper oil control ring used on pistons for certain *turbocharged* engines is a one-piece ring while the lower ring is a two-piece ring (upper and lower halves). Install the oil control rings as follows:

1. Install the ring expanders in the oil control ring grooves in the piston.

   NOTICE: When installing the oil control rings, use care to prevent overlapping the ends of the ring expanders. An overlapped expander will cause the oil ring to protrude beyond allowable limits and will result in breakage when the piston is inserted in the ring compressor during installation in the cylinder liner. Do not cut or grind the ends of the expanders to prevent overlapping. Cutting or grinding the ends will decrease the expanding force on the oil control rings and result in high lubricating oil consumption.

2. To install the one-piece ring on certain turbocharged engines, position it over the upper ring groove, using tool J 8128, with the gap 180° from the gap in the expander and the scraper edge facing down. Press the ring against the gap side of the expander to prevent the ends of the expander from overlapping, then align the ring with the groove and release the tension on the tool, permitting the ring to slip in position.

Install the upper and lower halves of the lower oil control ring by hand. Install the upper half with the gap 180° from the gap in the expander. Then, install the lower half with the gap 45° from the gap in the upper half of the ring. Make sure the scraper edges are facing down (toward the bottom of the piston). The scraper edges of all oil control rings must face downward (toward the bottom of the piston) for proper oil control.

3. Install the upper and lower halves of both oil control rings (naturally aspirated and turbocharged engines) as outlined above.

If there is a noticeable resistance during installation of the piston, check for an overlapped ring expander.

CROSS-HEAD TYPE PISTON

The cross-head piston (Figs. 11 and 12) is a two-piece piston consisting of a crown and skirt. A fluoroelastomer oil seal ring is used between the crown and skirt which are held together by the piston pin. Ring grooves are machined in the piston crown for a fire ring and two compression rings. The crown is also machined to accept a 150° slipper type bushing (bearing). The piston skirt incorporates two oil control ring grooves, piston pin holes and piston pin retainer counterbores. Equally spaced drain holes are located in the oil ring groove area to permit excess oil, scraped from the cylinder walls, to return to the crankcase. A lubricating oil hole is drilled through the solid piston pin. Two bolts and spacers are used to attach the connecting rod to the piston pin.

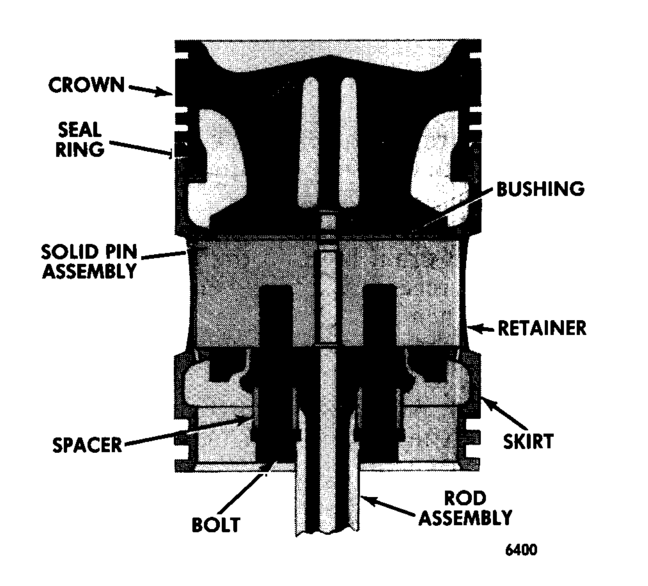


Fig. 11 - Cross-Head Piston and Connecting Rod Assembly

Internal parts of the piston are lubricated and cooled by the engine lubricating oil. Oil is pressure-fed up the drilled passage in the connecting rod, through the oil tube in the piston pin, then through the center hole in the bushing to the underside of the piston crown. A portion of the oil flows along the grooves in the bushing to lubricate the piston pin.

During engine operation, gas loads pushing down on the piston crown are taken directly by the piston pin and bushing. The piston skirt, being separate, is free from vertical load distortion; thermal distortion is also reduced as the piston crown expands. As the connecting rod swings to one side during downward travel of the piston, the major portion of the side load is taken by the piston skirt.

In cross-head piston equipped engines, a complete new balance weight system is used. When replacing trunk-type pistons with cross-head pistons, new camshaft front pulleys (integral weight) plus new

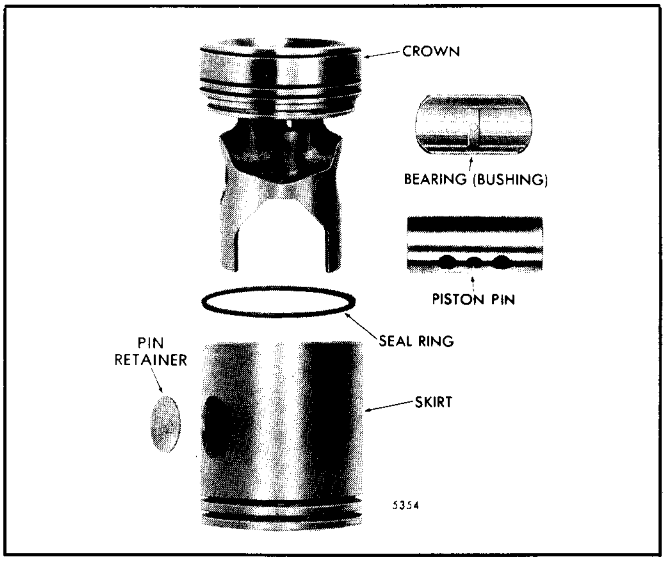


Fig. 12 - Cross-Head Piston and Connecting Rod Components

bolt-on weights on the rear camshaft gears (Sections 1.7.2 and 1.7.3) must be used.

NOTICE: Cross-head pistons and trunk-type pistons must not be used together in an engine. The difference in weight of the pistons will affect engine balance.

Inspect Piston Rings

When an engine is hard to start, runs rough or lacks power, worn or sticking compression rings may be the cause. Replacing the rings will aid in restoring engine operation to normal.

The compression rings may be inspected through the ports in the cylinder liners after the air box covers have been removed. If the rings are free and are not worn to the extent that the plating or grooves are gone, compression should be within operating specifications. Refer to Section 15.2 for the procedure for checking compression pressure.

Remove Piston and Connecting Rod

1. Drain the cooling system.
2. Drain the oil and remove the oil pan.
3. Remove the oil pump inlet pipe, if necessary (Section 4.1).
4. Remove the cylinder head (Section 1.2).
5. Remove the carbon deposits from the upper inner surface of the cylinder liner.
6. Remove the bearing cap and the lower bearing shell from the connecting rod. Then, push the piston and rod assembly out through the top of the cylinder block. The piston cannot be removed from the bottom of the cylinder block.
7. Reassemble the bearing cap and lower bearing shell to the connecting rod.

Disassemble Piston and Connecting Rod

Piston assembly components should be match-marked during disassembly to ensure that they are reassembled in the same position. Note the condition of the piston and rings. Then, remove the rings and disassemble the piston, as follows:

1. Secure the connecting rod in a vise equipped with soft jaws and remove the piston rings with tool J 8128 (Fig. 13).

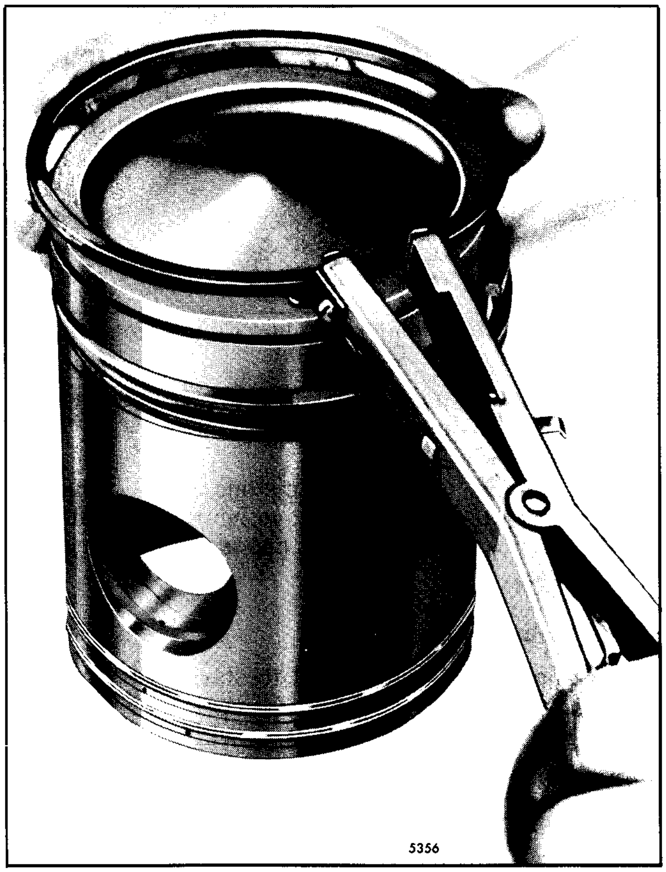


Fig. 13 - Removing or Installing Piston Rings with Tool J 8128

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 bushing. Remove the opposite retainer in the same manner.
3. Loosen the two bolts which secure the connecting rod to the piston pin. Then, remove the rod and piston assembly from the vise and place the assembly on the bench. Remove the two bolts and spacers and remove the connecting rod.
4. Withdraw the piston pin.
5. Separate the piston skirt from the piston crown. Tool J 33048 may be used to aid in disassembling the dome from the skirt, of piston assemblies using fluoroelastomer seal rings. The piston assembly should be grasped by the skirt, and the pin area of the dome brought down onto the neoprene head of the tool with sufficient force to separate the dome from the skirt. The neoprene-padded base of the tool will absorb the impact of any dropped piston skirt.

CAUTION: To reduce the risk of personal injury when disassembling the piston dome from the skirt, keep fingers out of the piston pin hole and wear steeltoed shoes.

6. Remove the seal ring from the piston crown.
7. Remove the piston pin bushing (bearing).

Cleaning

Clean the piston components with fuel oil and dry them with compressed air. If fuel oil does not remove the carbon deposits, use an approved chemical solvent that will not harm the tin-plate on the piston skirt. Do not use chemical solvent on the bushing.

The piston crown, including the compression ring grooves, is not tin-plated and may be wire-brushed to remove any hard carbon. *Do not wire-brush the piston skirt.* Clean the ring grooves with a suitable tool or a piece of an old compression ring that has been ground to a bevel edge.

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

Glass beading can be used to clean a piston crown. Mico Bead Glass Shot MS-M (.0029" - .0058") is recommended. Allowable air pressure is 80-100 psi (552-689 kPa). After cleaning, do not leave glass beads in the piston crown.

NOTICE: Do not attempt to clean the piston skirt by glass beading, as it will remove the tin-plating.

Use crocus cloth wet with fuel oil to remove any trace of fretting and/or corrosion on the connecting rod saddle-to- piston pin contact surface. Do not use crocus cloth on the bushing side of the pin. Polishing or refinishing the piston pin on the bushing side is not recommended.

Inspection

If the tin-plate on the piston skirt and the original grooves in the piston rings are intact, it is an indication of very little wear.

Excessively worn or scored piston skirts, rings or cylinder liners may be an indication of abnormal maintenance or operating conditions which should be corrected to avoid recurrence of the failure. The use of the correct types and 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 reduce the rate of wear.

Long periods of operation at idle speed and the use of improper lubricating oil or fuel must be avoided, otherwise, a heavy formation of carbon may result and cause the rings to stick.

Keep the lubricating oil and engine coolant at the proper levels to prevent overheating of the engine.

Examine the piston skirt and crown for score marks, cracks, damaged ring groove lands or indications of overheating. Any piston that has been severely scored or overheated must be replaced. Indications of overheating or burned spots may be the result of an obstruction in the connecting rod oil passage.

Check the cylinder liner and block bore for excessive out-of-round, taper or high spots which could cause failure of the piston (refer to Section 1.0 for Specifications).

Inspection of the connecting rod, piston pin and piston pin bushing are covered in Section 1.6.1.

Other factors that may contribute to piston failure include oil leakage into the air box, oil pull-over from the air cleaner, dribbling injectors, combustion blow-by and low oil pressure (dilution of the lubricating oil).

Assemble Piston and Connecting Rod

1. Refer to Section 1.0 (Shop Notes and Specifications) on reusing piston assembly components.
2. Install the bearing (bushing) in the piston crown. It should slide into the piston crown without force. With new parts, there is .0005" to .0105" clearance between the edge of the bushing and the groove in the piston crown. The bearing must be installed before assembling the piston skirt and crown.
3. Lubricate the seal ring with engine oil and install in the groove on the piston crown. Allow time for the seal to return to its original shape before installing the skirt. *Excessive stretching should be avoided.* .
4. The fluoroelastomer seal ring can be compressed by hand when the skirt is pushed into position on the piston crown. Lubricate the seal with engine oil. Before completely assembling the piston, check to make sure the seal ring does not roll out of the groove during assembly. This condition can cause the skirt to cock with respect to the dome. This may result in premature piston wear or the inability to install the piston in the liner. This condition is evidenced by the non-uniform clearance between the dome and the skirt after assembly. This condition may be corrected by cleaning the skirt counterbore with crocus cloth the remove any tin or sharp edge that may be pulling the seal out of the groove.
5. Lubricate the piston pin with clean engine oil and install it (Fig. 14).

NOTICE: Line up the piston pin opening in the piston skirt with the bearing (bushing) opening in the piston crown to prevent damage to the pin or bushing.

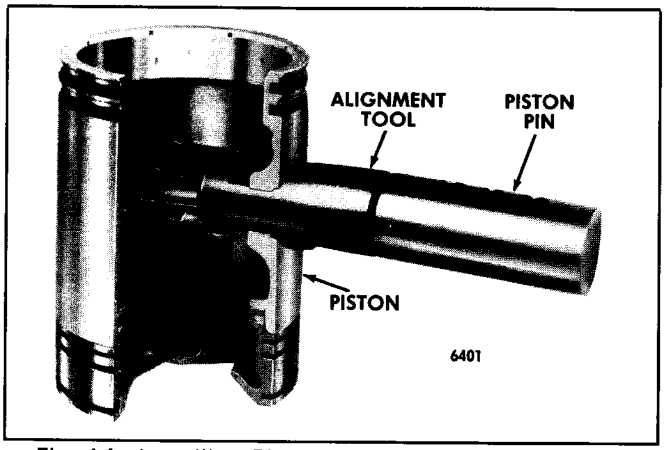


Fig. 14 - Installing Piston Pin using Alignment Tool J 35619

6. Install the spacers on the two 3/8"-24 x 1.88" connecting rod to piston pin attaching bolts.
7. Apply a small amount of International Compound No. 2, or equivalent, to the bolt threads and bolt head contact contact surfaces.
8. Install and tighten the bolts finger tight. Then, clamp the connecting rod in a vise and tighten the bolts to 30-35 lb-ft (41-47 N·m) torque (Fig. 15). Do not exceed this torque.

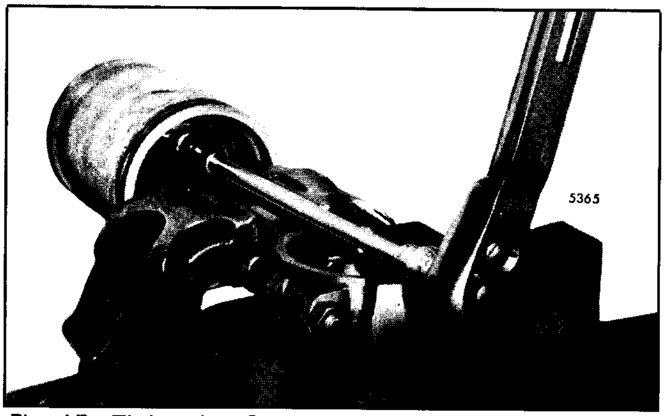


Fig. 15 - Tightening Connecting Rod to Piston Pin Bolts

9. Place a new piston pin retainer in position. Then, place the crowned end of installer J 23762-A against the retainer and strike the tool just hard enough to deflect the retainer and seat it evenly in the piston (Fig. 16).
10. Install the second piston pin retainer in the same manner. Due to the size of the counterbore in the piston skirt, be careful when installing the piston pin retainers and inspect them to be sure they are not buckled and that they are fully seated in the counterbores. The width of the land should be even around the retainer.
11. 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 bushing,

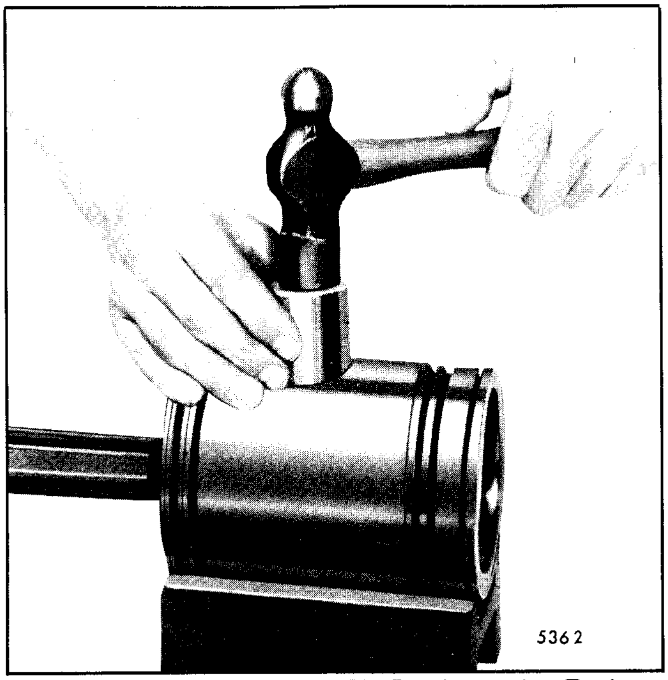


Fig. 16 - Installing Piston Pin Retainer using Tool J 23762-A

from reaching the cylinder walls. Check each retainer for proper sealing with leak detector J 23987-01 (Fig. 17). Place the suction cup over the retainer and hand operate the lever to pull a vacuum of ten inches on the gage. A drop in the gage reading indicates air leakage at the retainer.

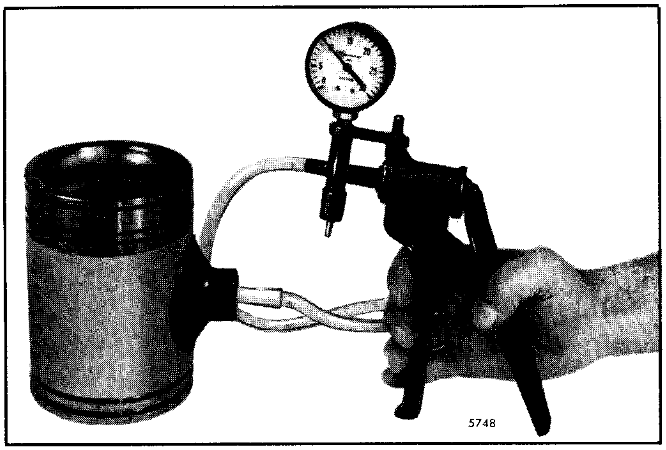


Fig. 17 - Checking Piston Pin Retainer for Proper Sealing with Tool J 23987-01

Fitting Piston

Measure the piston skirt diameter lengthwise and crosswise of the piston pin bore. Measurements should be taken at room temperature (70°F or 21°C). Refer to Section 1.0 for Specifications.

The piston-to-liner clearance, with new parts, will vary with the particular piston and cylinder liner (refer to Section 1.0). A maximum clearance of .012" is allowable with used parts.

With the cylinder liner installed in the cylinder block, hold the piston skirt upside down in the liner

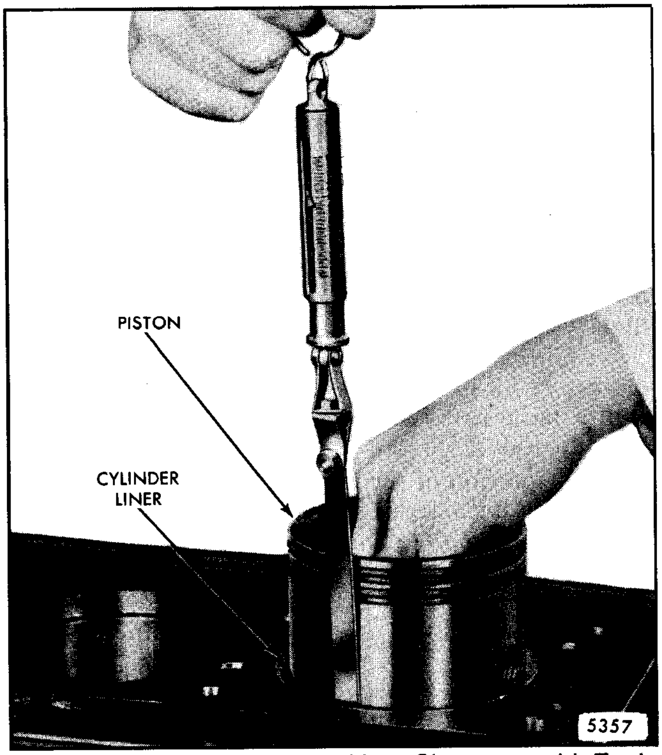


Fig. 18 - Measuring Piston-to-Liner Clearance with Tool J 5438-01

and check the clearance in four places 90° apart (Fig. 18).

Use feeler gage set J 5438-01 to check the clearance. The spring scale, attached to the proper feeler gage, is used to measure the force in pounds required to withdraw the feeler gage.

Select a feeler gage with a thickness that will require a pull of six pounds to remove. The clearance will be .001" greater than the thickness of the feeler gage used, i.e., a .004" feeler gage will indicate a clearance of .005" when it is withdrawn with a pull of six pounds. The feeler gage must be perfectly flat and free of nicks and bends.

If any bind occurs between the piston and the liner, examine the piston and liner for burrs. Remove burrs with a fine hone (a flat one is preferable) and recheck the clearance.

Fitting Piston Rings

Each piston is fitted with a fire ring, two compression rings and two oil control rings (Fig. 19).

The top (fire) ring is pre-stressed. It is identified by a small indentation mark on the top side.

A new "wide gap" prestressed fire ring and a new one piece new upper oil control ring and expander are being used on cross-head pistons. The fire rings differ only in their width dimensions. The trunk type piston ring has a .0804"-.0820" width. The cross-head piston ring has a .1034"-.1050" width.

A one-piece oil control ring in the upper ring groove and a two-piece ring in the lower ring groove

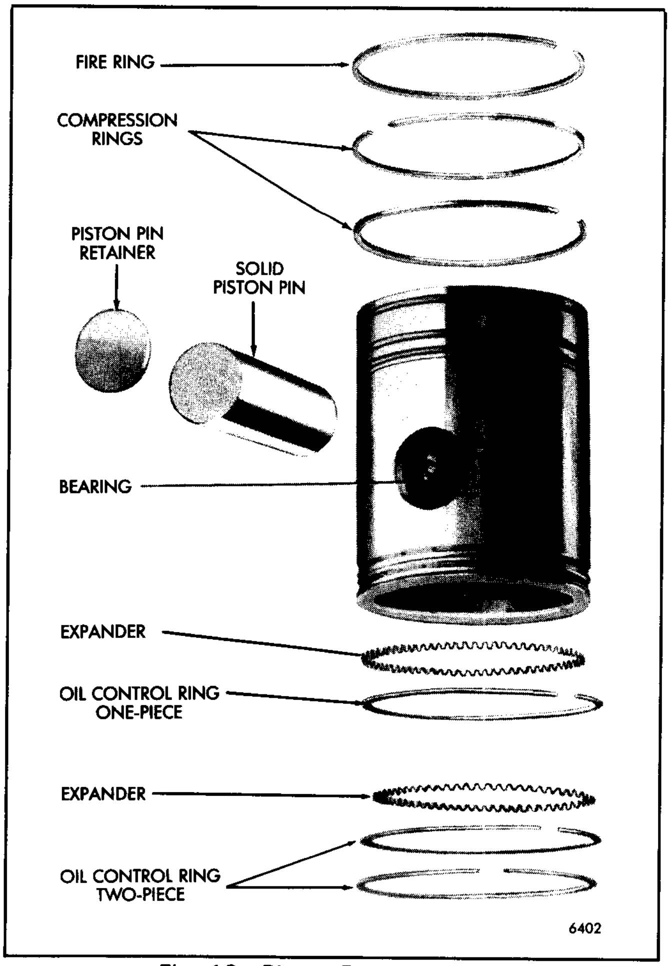


Fig. 19 - Piston Ring Location

are used in the cross-head pistons for *turbocharged* engines (Fig. 22).

The former and new fire rings, upper groove oil control rings and expanders are not functionally interchangeable. The new components must be used together on cross-head piston equipped turbocharged engines. The former fire ring will continue to be used in production and service for engines with trunk type pistons. The former oil control ring and expander will continue to be used in the upper oil control ring groove of trunk type pistons.

All new piston rings must be installed whenever a piston is removed, regardless of whether a new or used piston or cylinder liner is installed. Refer to the parts catalog or microfiche to select the current piston rings for a particular engine.

Insert one ring at a time inside of the cylinder liner and far enough down to be within the normal area of ring travel. Use a piston skirt 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 (Fig. 20). Refer to Section 1.0 for ring gap specifications.

If the gap on a compression ring is insufficient, it may be increased by filing or stoning the ends of the

Fig. 20 - Measuring Piston Ring Gap

ring. File or stone both ends of the ring so the cutting action is from the outer surface to the inner surface. This will prevent any chipping or peeling of the chrome plate on the ring. The ends of the ring must remain square and the chamfer on the outer edge must be approximately .015″.

Check the ring side clearance (Fig. 21). Ring side clearances are specified in Section 1.0.

Install Piston Rings

Lubricate the piston rings and piston with engine oil before installing the rings.

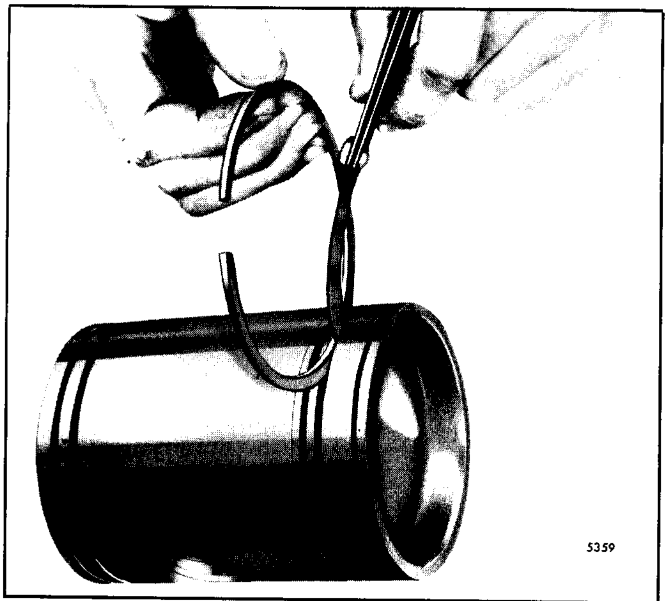


Fig. 21 - Measuring Piston Ring Side Clearance

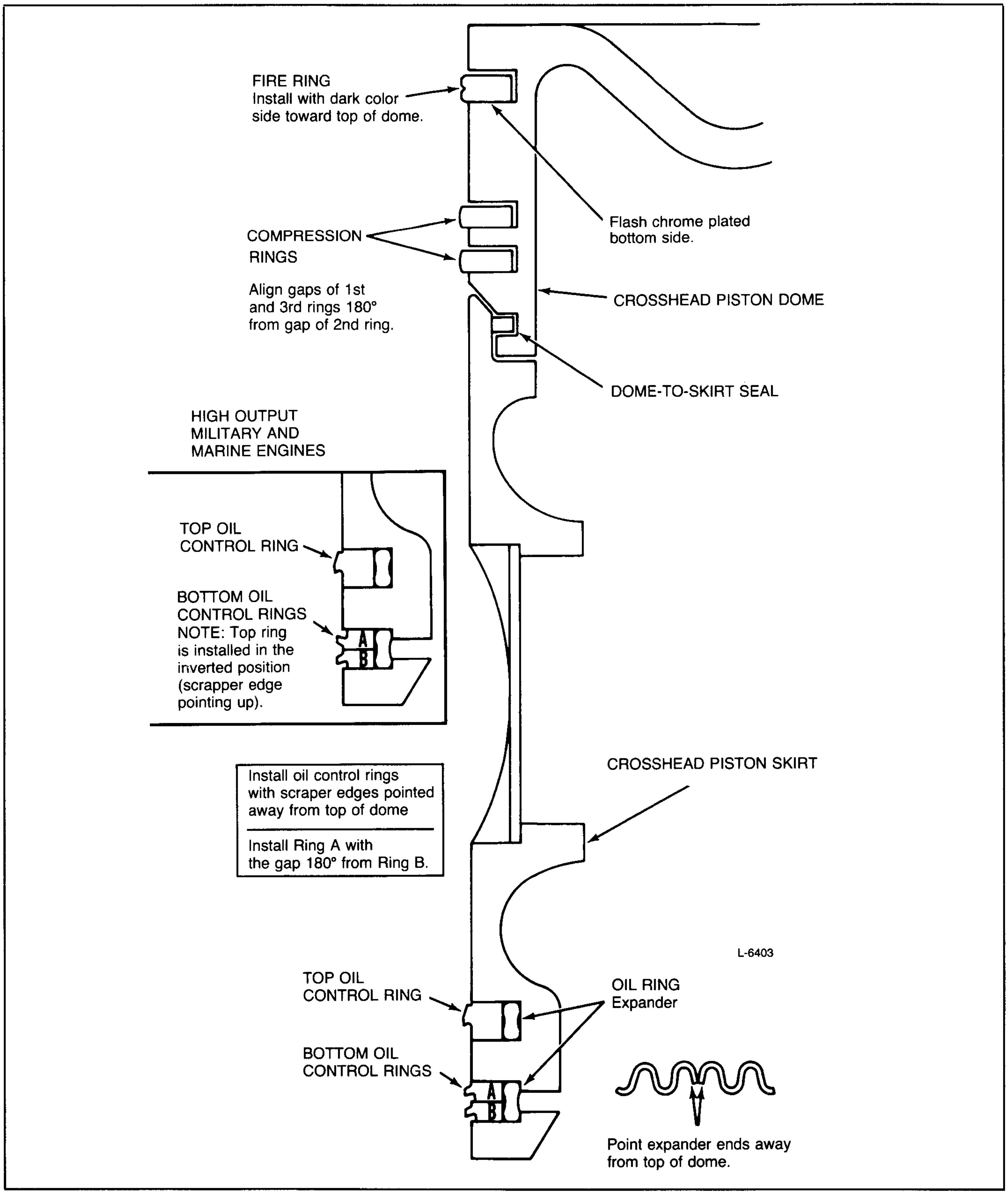


Fig. 22 - Piston Ring Installation Instructions

COMPRESSION RINGS

1. Starting with the bottom ring, install the compression rings with tool J 8128 (Fig. 13). To avoid breaking or overstressing the rings, do not spread them any more than necessary to slip them over the piston. Refer to Fig. 22 for ring identification and location.
2. Stagger the ring gaps around the piston.

OIL CONTROL RINGS

Refer to Fig. 22 for the type and location and install the oil rings as follows:

1. Install the ring expanders in the oil control ring grooves in the piston skirt. When installing the oil control rings, use care to prevent overlapping the ends of the ring expanders. An overlapped expander will cause the oil ring to protrude beyond allowable limits and will result in breakage when the piston is inserted in the ring compressor during installation in the cylinder liner. Do not cut or grind the ends of the expanders to prevent overlapping. Cutting or grinding the ends will decrease the expanding force on the oil control rings and result in high lubricating oil consumption. When peripheral abutment type ring expanders are used, install them with the legs of the free ends toward the bottom of the piston. Noticeable resistance will be encountered during installation of the piston if the ends of the expander are overlapped. Corrective action should be taken to prevent ring breakage before this occurs.
2. Install the oil control rings by hand. Start with the top oil ring and align the gaps as indicated in Fig. 22. The scraper edges of all oil control rings must face downward (toward the bottom of the piston) for proper oil control, except on high output military and marine engines (Fig. 22).

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

CONNECTING ROD

TRUNK TYPE PISTON

Each connecting rod is forged to an "I" section with a closed hub at the upper end and a bearing cap at the lower end (Figs. 1 and 2). The connecting rod is drilled to provide lubrication to the piston pin at the upper end and is equipped with a nozzle to spray cooling oil to the underside of the piston head on engines equipped with an oil cooler. Engines that are not equipped with an oil cooler do not use nozzle type connecting rods. An orifice is pressed into a counterbore at the lower end of the oil passage (in rods equipped with a spray nozzle) to meter the flow of oil.

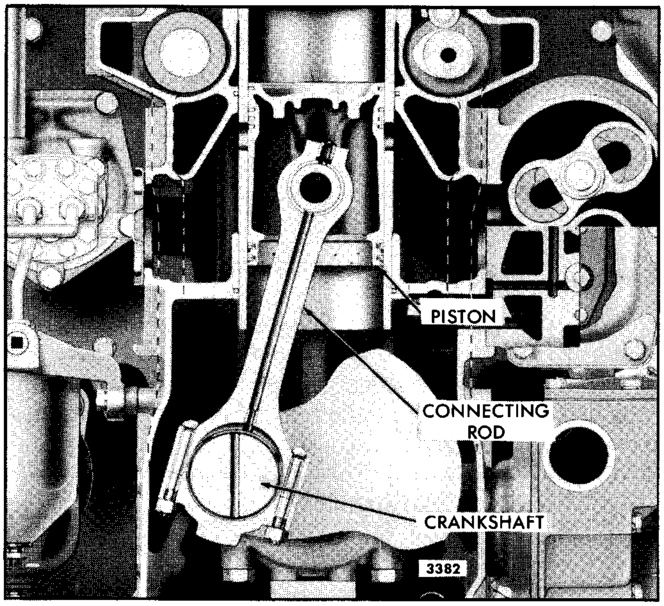


Fig. 1 - Connecting Rod Mounting

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. The cavity between the inner ends of these bushings registers with the drilled oil passage in the connecting rod and forms a duct around the piston pin. Oil entering this cavity lubricates the piston pin bushings and is then forced out the spray nozzle to cool the piston. The piston pin floats in the bushings of both the piston and the connecting rod.

The turbocharged engine connecting rods include vapor blasted bushings and increased width oil grooves.

A service connecting rod includes the bearing cap, bolts, nuts, spray nozzle (if used), orifice and the piston pin bushings pressed in place and bored to size.

The replaceable connecting rod bearing shells are covered in Section 1.6.2.

Effective with engine serial numbers 3D-170958, 4D-181763 and 6D-187523, turbocharged engines use

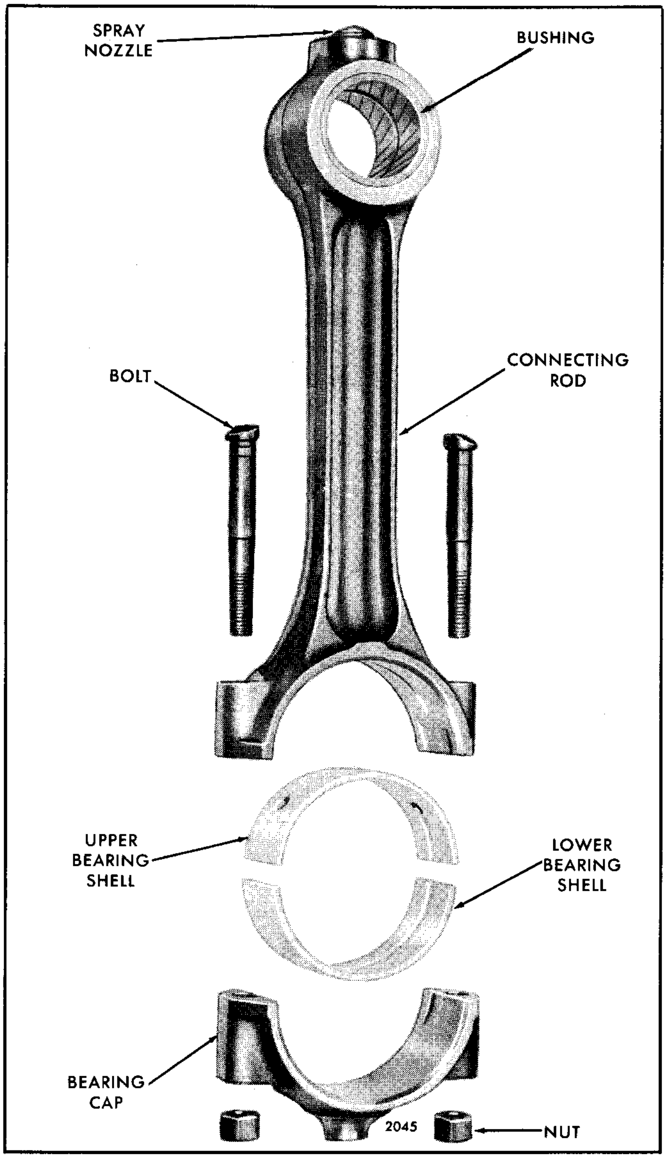


Fig. 2 - Connecting Rod Details and Relative Location of Parts

a 1.500″ diameter piston pin. With the use of the 1.500″ diameter piston pin, new piston assemblies, piston pin retainers and connecting rod assemblies are required. The former piston pin diameter is 1.375″. The former and new piston and connecting rod assemblies differ only in that they have larger bushing bores to facilitate the installation of new, larger diameter bushings. The larger bushing inner diameter is necessary to accommodate the new, larger piston pin. Because of the larger pin diameter, former and new parts are not separately interchangeable. When it becomes necessary to replace any one of the three major cylinder components, it will be necessary to include the other two to assure interchangeability. Current piston assemblies and connecting rods can be mixed in an engine with the former piston assemblies and connecting rods.

Disassemble Connecting Rod from Piston

With the rod and piston assembly removed from the engine, disassemble the piston and connecting rod, as outlined in Section 1.6.

Inspection

Clean the connecting rod and piston pin with fuel oil and dry them with compressed air. Blow compressed air through the drilled oil passage in the connecting rod to be sure the orifice, oil passage and spray holes are not clogged.

Visually, check the connecting rod for twist or bending. Check for cracks (Fig. 3) by the magnetic particle method outlined in Section 1.3 under *Crankshaft Inspection.*

If a new service connecting rod is required, stamp the cylinder number on the connecting rod and cap (refer to Section 1.6.3).

Clean the rust preventive from a service replacement connecting rod and blow compressed air through the drilled oil passage to be sure the orifice, oil passage and spray holes are not clogged. Also, make sure the split line (cap to rod) is thoroughly cleaned to avoid trapped contaminants from adversely affecting bearing shell "crush".

Check the connecting rod bushings for indications of scoring, overheating or other damage. Bushings that have overheated may become loose and creep together, thus blocking off the supply of lubricating oil to the piston pin, bushings and spray nozzle.

Turbocharged engines with trunk type pistons use two different diameter piston pins with a special surface finish. Engines built prior to 3D-170958, 4D-181763 and 6D-187523 have a 1.375" diameter piston pin. Those built after have a 1.500" diameter piston pin, except marine applications which continue to use the 1.375" diameter piston pin.

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

Since it is subjected to downward loading only, free movement of the piston pin is desired to secure perfect alignment and uniform wear. Therefore, the piston pin is assembled with a full floating fit in the connecting rod and piston bushings, with relatively large clearances. Worn piston pin clearances up to .010" are satisfactory.

Remove Bushings

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

Do not remove the bushings from the connecting rods used in turbocharged engines because they are not serviced separately.

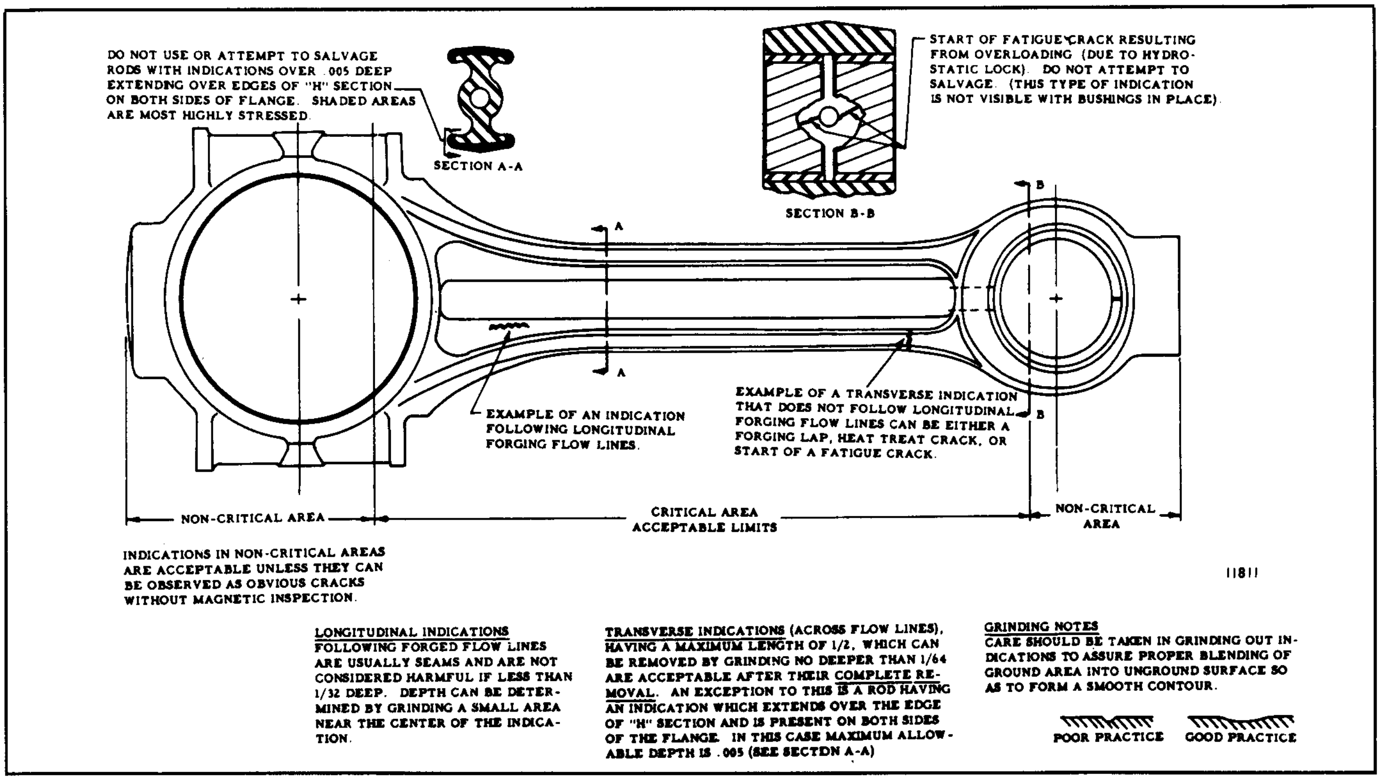


Fig. 3 - Magnetic Particle Inspection Limits for Connecting Rod

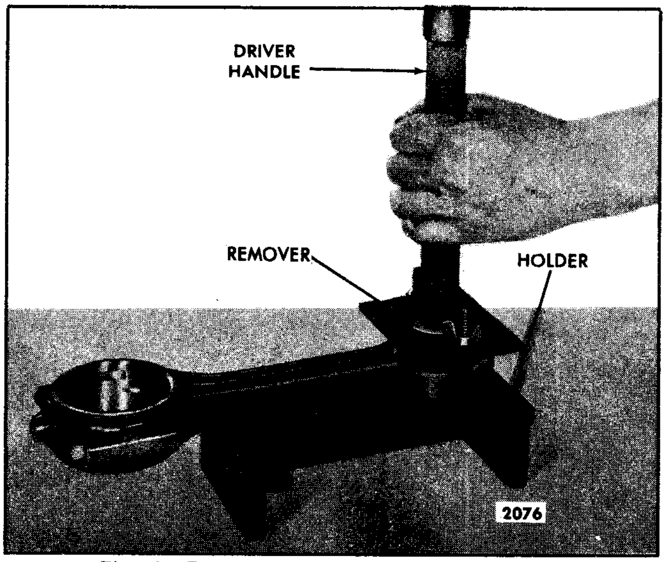


Fig. 4 - Removing or Installing Bushings

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. Place 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

The connecting rod bushings must be removed before the spray nozzle can be replaced. The orifice in the lower end of the drilled passage in the connecting rod is not serviced and it is not necessary to remove it when replacing the spray nozzle.

Replace the spray nozzle, as follows:

1. Remove the connecting rod bushings (non-turbocharged engines only).
2. Insert spray nozzle remover J 8995 through the upper end of the connecting rod and insert the pin, in the curved side of the tool, in the opening in the bottom of the spray nozzle.
3. Support the connecting rod and tool in an arbor press (Fig. 5).
4. Place a short sleeve directly over the spray nozzle. Then, press the nozzle out of the connecting rod.
5. Remove the tool.
6. Start the new spray nozzle straight into the counterbore in the connecting rod.
7. Support the connecting rod in the arbor press, place a short 3/8" I.D. sleeve on top of the nozzle and press the nozzle into the connecting rod until it bottoms in the counterbore.
8. Install new bushings in the connecting rod.

Install Bushings

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 (Fig. 4).
2. Start a new bushing straight into the bore of the connecting rod, with the bushing joint at the top of the rod (Fig. 6).

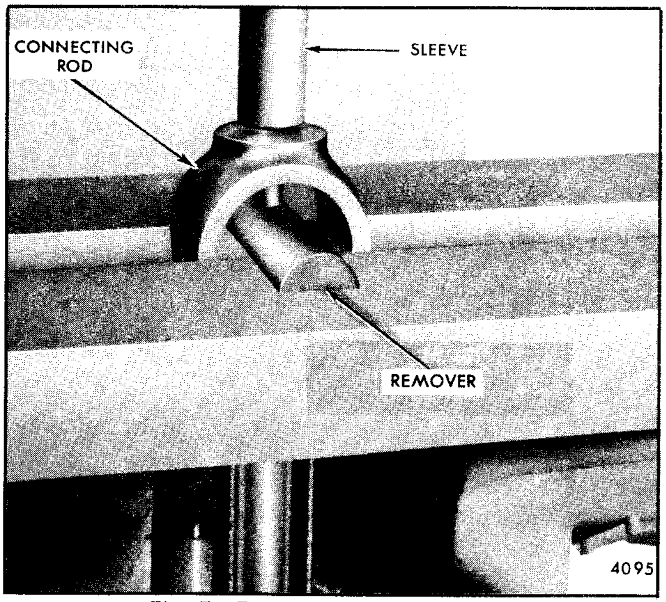


Fig. 5 - Removing Spray Nozzle

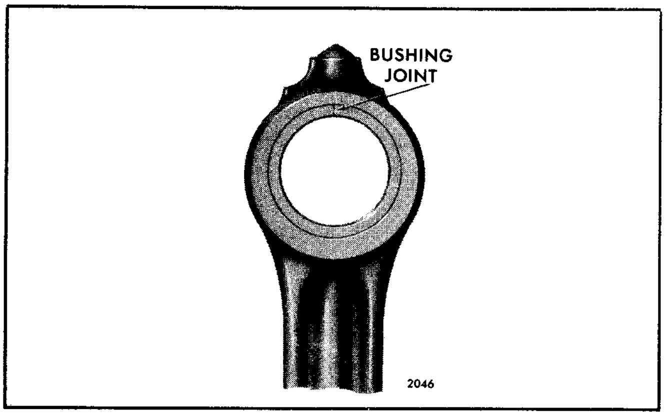


Fig. 6 - Location of Bushing Joint

3. Insert installer J 4972-2 in the bushing, then insert handle J 1513-2 in the installer and drive the bushing in until the flange of the installer bottoms on the connecting rod.
4. Turn the connecting rod over in the holder and install the second bushing in the same manner.
5. The bushings must withstand an end load of 2,000 pounds without moving after installation.
6. Ream the bushings to size as follows:
   a. Clamp reaming fixture J 7608-4 in a bench vise.
   b. Slide sleeve J 7608-5 on the arbor of the fixture (for V-type engine connecting rod).
   c. Place the crankshaft end of the connecting rod on the arbor of the fixture (Fig. 7). Tighten the nuts on the 3/8"-24 bolts

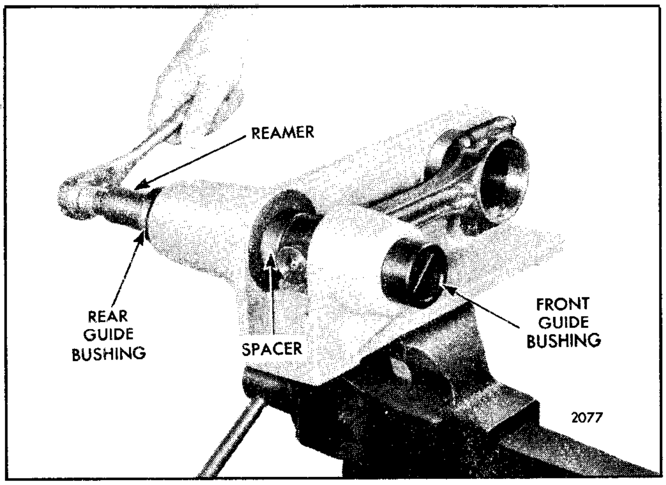


Fig. 7 - Reaming Bushings

(In-line and V-type engines) to 40-45 lb-ft (54-61 N·m) torque. Tighten the nuts on the 5/16"-24 bolts (early 6V engines) to 24-28 lb-ft (33-38 N·m) torque.

d. Slide the front guide bushing J 4971-6 (with the pin end facing out) in the fixture.
e. Install spacer J 7608-3 in the fixture.
f. Align the upper end of the connecting rod with the hole in the reaming fixture.
g. Install the rear guide bushing J 1686-5 on the reamer J 7608-21, then slide the reamer and bushing into the fixture.
h. Turn the reamer in a clockwise direction only, when reaming or withdrawing the reamer. For best results, use only moderate pressure on the reamer.

NOTICE: Do not at any time turn the reamer counterclockwise as this will dull the cutting edges of the reamer.

i. 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 must be 1.3760" to 1.3765". This will provide a piston pin-to-bushing clearance of .0010" to .0019" with a new piston pin. A new piston pin has a diameter of 1.3746" to 1.3750". On the 6V-53T the inside diameter of the bushings must be 1.5025" to 1.5030". This will provide a piston pin-to-bushing clearance of .0025" to .0034" with a new piston pin. A new piston pin has a diameter of 1.4996" to 1.5000".

Assemble Connecting Rod to Piston

Apply clean engine oil to the piston pin and bushings. Refer to Fig. 2 and assemble the connecting rod to the piston as follows:

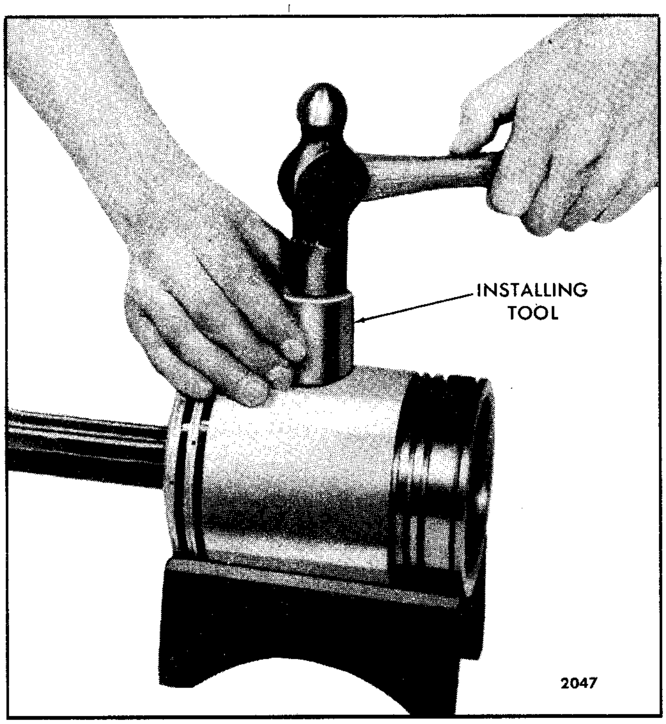


Fig. 8 - Installing Piston Pin Retainer using Holder J 1513-02

1. Place the "N" piston in the holding fixture (Fig. 8).
2. Place a new piston pin retainer in position. Then, place the crowned end of installer J 23762-A against the retainer and strike the tool just hard enough to deflect the retainer and seat it evenly in the "N" piston.

If you have a turbo-trunk type piston, use tool J 24107-01 to seat the piston pin retainer. Do not drive the retainer in too far or the piston bushing may be moved inward and result in reduced piston pin end clearance.

3. Place the upper end of the connecting rod between the piston pin bosses and in line with the piston pin holes. Then, slide the piston pin in place. If the piston pin-to-bushing clearances are within the specified limits, the pin will slip into place without use of force.
4. Install the second piston pin retainer as outlined in Steps 1 and 2.
5. After the piston pin retainers have been installed, check for piston pin end clearance by *cocking* the connecting rod and shifting the pin in its bushings.
6. 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 each retainer for proper sealing with leak detector J 23987-01 (Fig. 9). Place the suction cup over the retainer and hand operate the lever to pull a

vacuum of ten inches on the gage. A drop in the gage reading indicates air leakage at the retainer.

7. Install the piston rings on the piston, as outlined in Section 1.6.

8. Install the piston and connecting rod assembly in the engine, as outlined in Section 1.6.3.

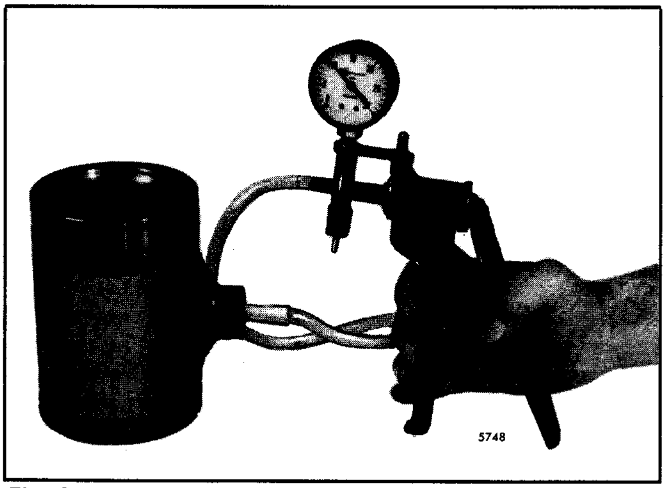


Fig. 9 - Checking Piston Pin Retainer for Proper Sealing using Tool J 23987-01

CROSS-HEAD TYPE PISTON

The connecting rod is forged to an "I" section with an open or saddle type contour at the upper end and a bearing cap at the lower end (Fig. 10). The bearing cap and connecting rod are forged in one piece and bored prior to separation.

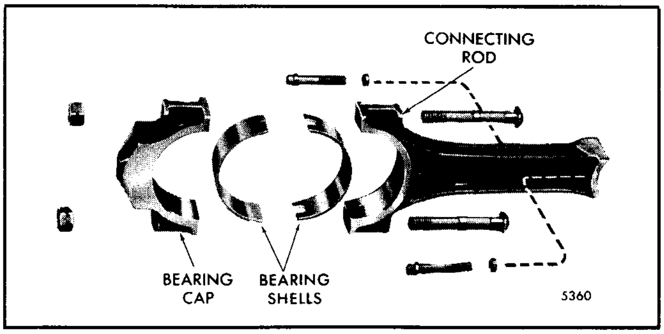


Fig. 10 - Connecting Rod Details

The upper end of the connecting rod is machined to match the contour of the piston pin. The piston pin is secured to the connecting rod with two bolts and spacers. The bearing cap is secured to the connecting rod by two specially machined bolts and nuts.

Lubricating oil is forced through a drilled oil passage in the connecting rod to the piston pin and bushing.

A service connecting rod includes the bearing cap and the attaching bolts and nuts. The replaceable connecting rod bearing shells are covered in Section 1.6.2.

Disassemble Connecting Rod from Piston

With the rod and piston assembly removed from the engine, disassemble the piston and connecting rod, as outlined in Section 1.6.

Inspection

Clean the connecting rod and piston pin with a suitable solvent and dry them with compressed air. Blow compressed air through the oil passage in the connecting rod to be sure it is clear of obstructions. Use crocus cloth, wet with fuel oil, to remove any trace of fretting and/or corrosion on the connecting rod saddle and piston pin contact surface with the rod before reassembly. Never use crocus cloth on the bearing side of the pin.

Connecting rods being removed from an original build engine can be reused as is, after considering the following:

1. Check for visual damage (bent).
2. A previous bearing(s) or related failure.
3. The connecting rod is blue at the top or bottom end.
4. Fretting at split line between the connecting rod and cap.
5. Excessive pound-in of the bolt head or nut.

If the connecting rod has been subjected to any of the above, it should be scrapped.

In qualifying a used connecting rod from a source other than an original build engine, the following checks should be made in addition to the above.

1. Check for cracks (Fig. 11) by the magnetic particle method outlined in Section 1.3 under *Crankshaft Inspection.*
2. Determine average bore diameter of the rod, using a dial bore gage and master ring as follows (Fig. 15):
   a. Install the connecting rod cap on the connecting rod and tighten the bolt nuts to 60-70 lb ft (81-95 N·m) torque.

   NOTICE: Do not over torque the connecting rod bolt nuts. Over torque may permanently distort the connecting rod cap.

   b. Measure diameter A and B (Fig. 12).
   c. Obtain the average of A and B to obtain size at split line.
   $\frac{A + B}{2} = X$ -- which is the average of A + B.
   d. Measure C. The difference in the results of the measurements X and C gives average bore out-of-round and can be .005" maximum.
   e. Add C with X and average to obtain average bore size.
   $\frac{C + X}{2} =$ Average diameter of bore.

   Must be within 2.7515" to 2.7525" (In-line) or 3.0015" to 3.0025" (V-type) engines.

If the crosshead connecting rod bore is not to specifications, the rod must be scrapped and cannot be machined.

3. Determine taper as follows (Fig. 12):
   a. Substract D1 from D2 to find the difference.
   b. The difference can be .0005" maximum.
4. Determine length by finding the distance between E1 and E2 (Fig. 12).

   Specifications: 8.799" to 8.801".

   The length of the rod can be measured on connecting rod measurement fixtures marketed by B. K. Sweeney, Tobin Arp or equivalent.

Remove any nicks or burrs from the connecting rod bolt holes to ensure proper seating of the underside of the bolt head.

If a new service connecting rod is required, stamp the cylinder number on the connecting rod and cap (refer to Section 1.6.3).

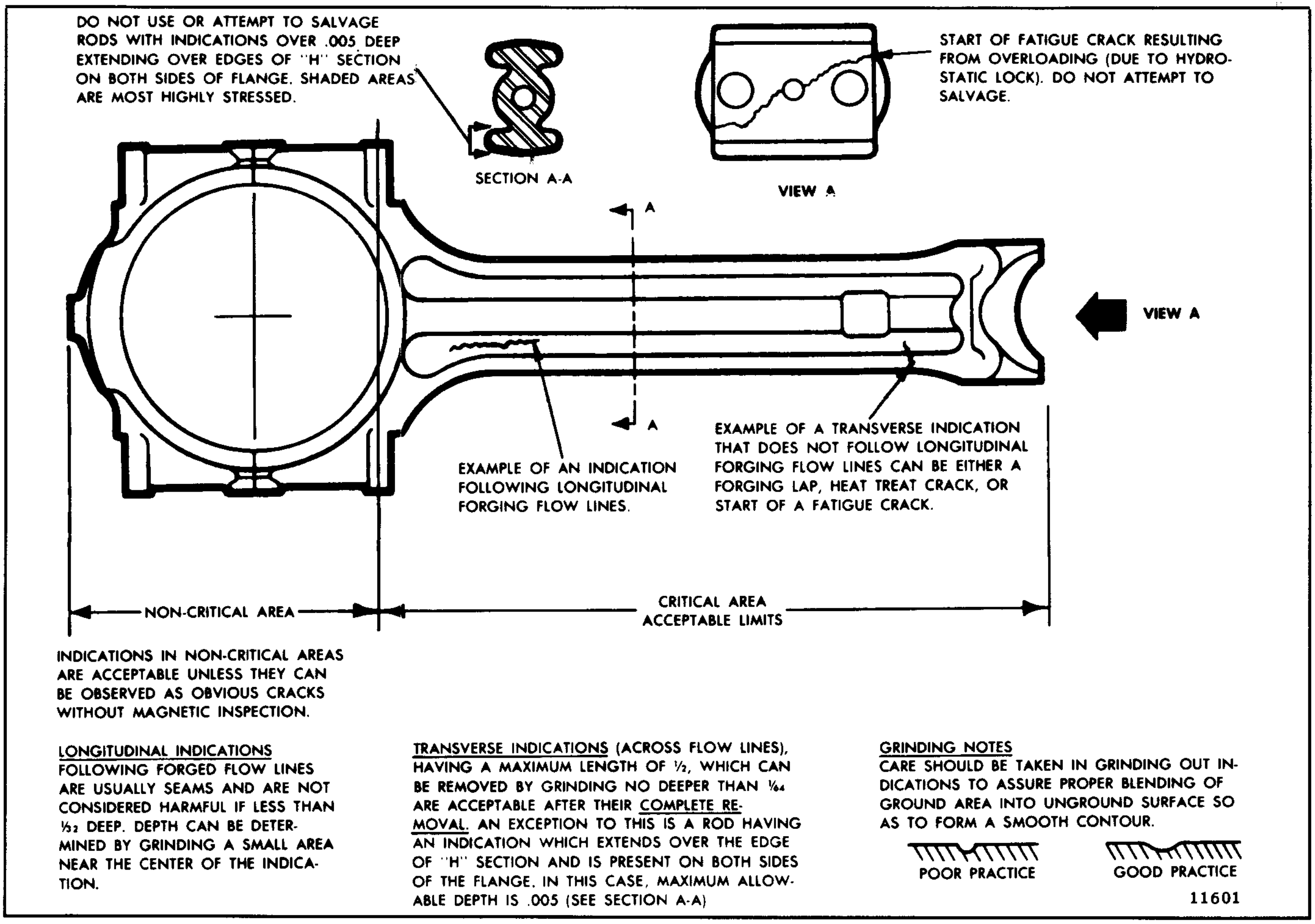


Fig. 11 - Magnetic Particle Inspection Limits for Connecting Rod

NOTICE: Clean the rust preventive from a service replacement connecting rod and blow compressed air through the drilled oil passage to be sure it is clear of obstructions. Also, make sure the split line (cap to rod) is thoroughly cleaned to avoid trapped contaminants from adversely affecting bearing shell "crush".

Inspect the bearing (bushing) for indications of scoring, overheating or other damage. Measure the thickness of the bushing along the center. Replace the bushing if it is damaged or worn to a thickness of .085" or less. A new bushing is .086" to .087" thick.

Inspect the piston pin for signs of fretting. When reusing a piston pin, the highly polished and lapped surface of the pin must not in any way be refinished. Polishing or refinishing the piston pin is not recommended as it could result in very rapid bushing wear. A new piston pin has a diameter of 1.3746" to 1.3750". Replace the piston pin if it is worn to a diameter of 1.3730" or less.

Assemble Connecting Rod to Piston

Refer to *Assemble Piston* in Section 1.6 for assembly of the connecting rod to the piston.

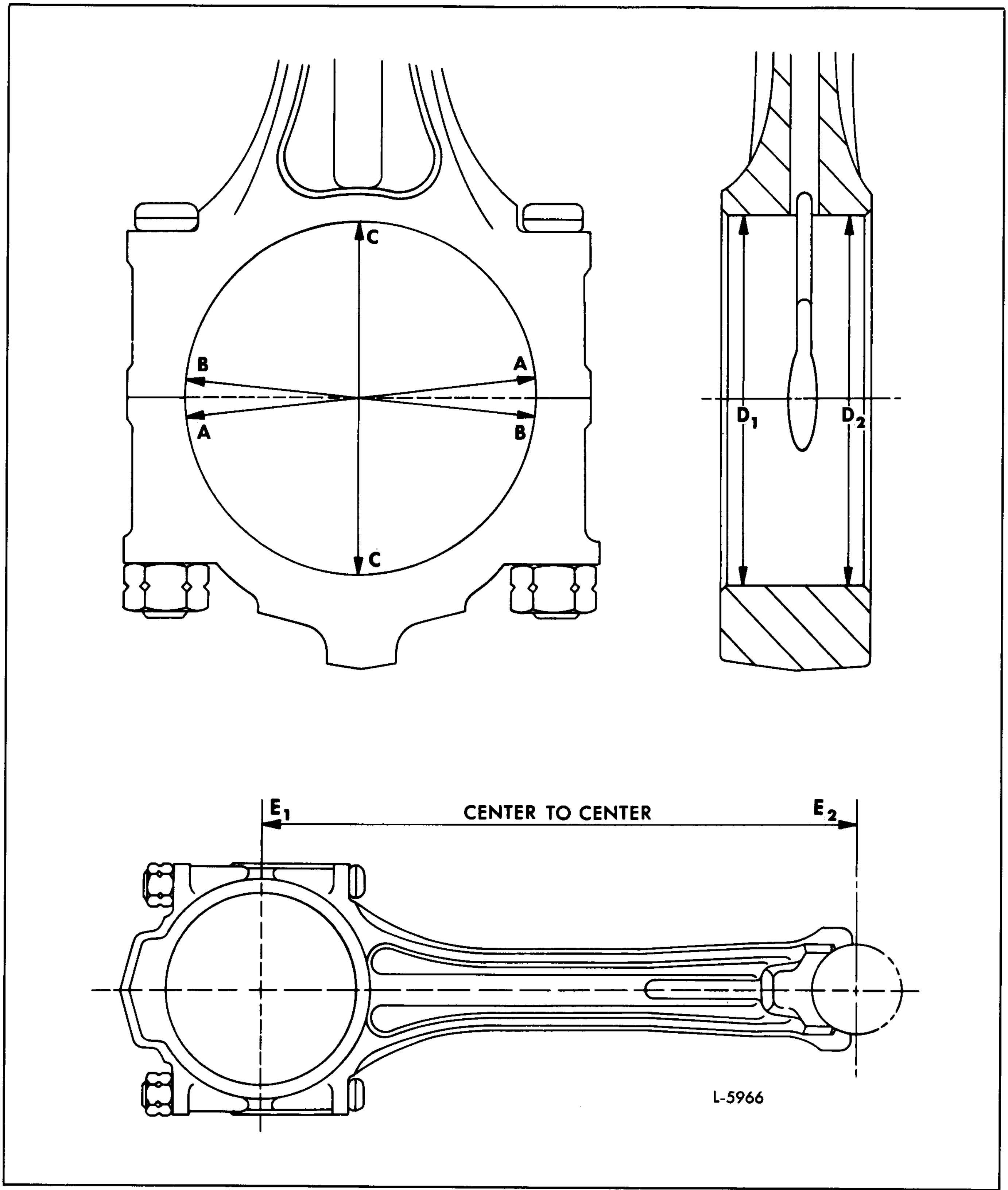


Fig. 12 - Dimensional Inspection of Cross-Head Piston Connecting Rods

CONNECTING ROD BEARINGS

The connecting rod bearing shells (Fig. 1) are precision made and are replaceable without shim adjustments. They consist of an upper bearing shell seated in the connecting rod and a lower bearing shell seated in the connecting rod cap. The upper and lower bearing shells are located in the connecting rod by a tang at the parting line at one end of each bearing shell. The current connecting rod bearing shells used in the V-type engines incorporate a relief groove at each end of each bearing shell to provide clearance for the 3/8" connecting rod bolts.

The upper and lower connecting rod bearing shells are different and are not interchangeable. The upper bearing shell has two short oil grooves and two oil holes; each groove begins at the end of the bearing 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 a continuous registry with the oil hole in the crankshaft connecting rod journal, thereby providing a constant supply of lubricating oil to the connecting rod bearings, piston pin bushings and spray nozzle through the oil passage in the connecting rod.

The Brazilian built engine connecting rod bearings include a slotted upper shell.

Remove Bearing Shells

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 rods. When removed, each bearing cap and the bearing shells must always be reinstalled on the original connecting rod.

Remove the connecting rod bearings, as follows:

1. Drain the oil and remove the oil pan.

2. Remove the oil inlet pipe and screen assembly.

   NOTE: Remove the oil pump on 8V engines and save the shims, if used, so that they may be reinstalled in exactly the same location.

3. 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 bearing shell with a sharp tool.

4. Inspect the upper and lower bearing shells as outlined under *Inspection*.

5. Install the bearing shells and bearing cap before another connecting rod bearing cap is removed.

Inspection

Bearing failures may result from deterioration (acid formation) or contamination of the oil or loss of oil. 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.

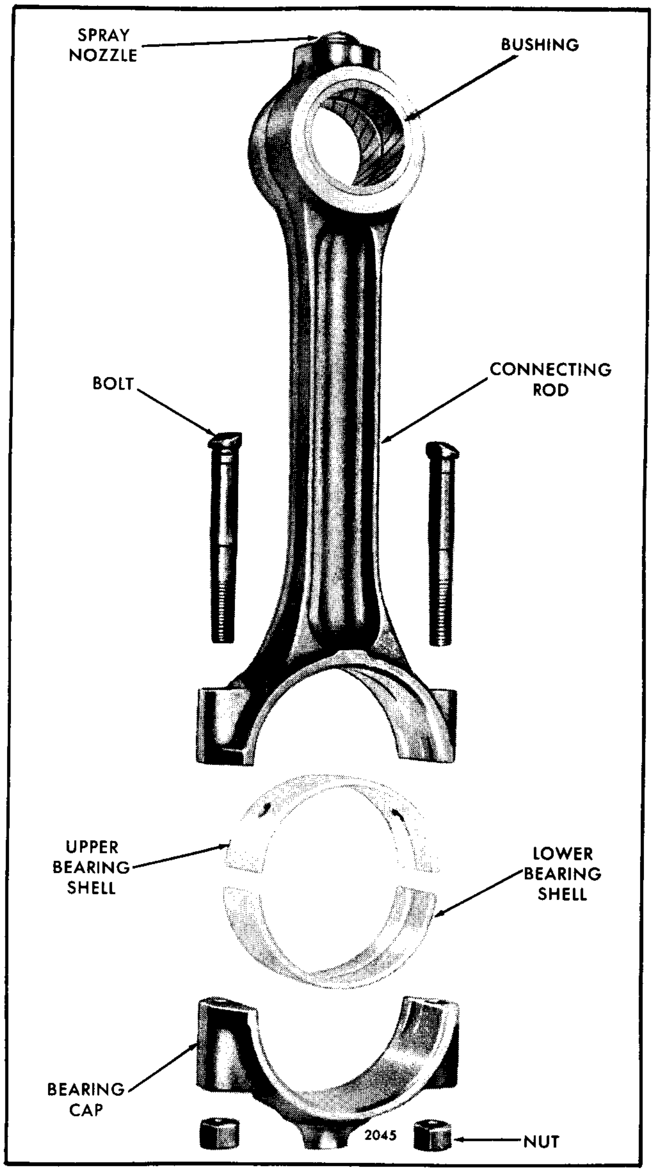


Fig. 1 - Connecting Rod and Bearing Shells

After removal, clean the bearings and inspect them for scoring, pitting, flaking, etching or signs of overheating. If any of these defects are present, the bearings must be discarded. The upper bearing shells, which carry the load, will normally show signs of distress before the lower bearing shells do.

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

Measure the thickness of the bearing shells, using a micrometer and ball attachment J 4757, as described under *Inspection* in Section 1.3.4. The minimum thickness of a worn standard connecting rod bearing shell should not be less than .1230" and, if either bearing shell is thinner than this dimension, replace both bearing shells. A new standard bearing shell has a thickness of .1245" to .1250" (In-line engine) or .1247" to .1252" (V-engine). Refer to Table 1.

Bearing Size	*New Bearing Thickness	Minimum Worn Thickness
In-Line Engines		
Standard	.1245"/.1250"	.1230"
.002" Undersize	.1255"/.1260"	.1240"
.010" Undersize	.1295"/.1300"	.1280"
.020" Undersize	.1345"/.1350"	.1330"
.030" Undersize	.1395"/.1400"	.1380"
V-Type Engines		
Standard	.1247"/.1252"	.1230"
.002" Undersize	.1257"/.1262"	.1240"
.010" Undersize	.1297"/.1302"	.1280"
.020" Undersize	.1347"/.1352"	.1330"
.030" Undersize	.1397"/.1402"	.1380"

*Thickness 90° from parting line of bearing.

TABLE 1

In addition to the thickness measurement, check the clearance between the connecting rod bearing shells and the crankshaft journal. This clearance may be checked by means of a soft plastic measuring strip which is squeezed between the journal and the bearing (refer to *Shop Notes* in Section 1.0). The maximum connecting rod bearing-to-journal clearance with used parts is .006".

Before installing the bearings, inspect the crankshaft journals (refer to *Inspection* in Section 1.3).

Do not replace one connecting rod bearing shell alone. If one bearing shell requires replacement, install both new upper and lower bearing shells. Also, if a new or reground crankshaft is to be used, install all new bearing shells.

Bearing shells are available in .002", .010", .020" and .030" undersize for service with reground crankshafts. To determine the size bearings required, refer to *Crankshaft Grinding* in Section 1.3. Bearings which are .002" undersize are available to compensate for slight journal wear where it is unnecessary to regrind the crankshaft.

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

Install Connecting Rod Bearing Shells

With the crankshaft and the piston and connecting rod assembly in place, install the connecting rod bearings as follows:

1. Rotate the crankshaft until the connecting rod journal is at the bottom of its travel, then 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 bearing shell fits in the groove in the connecting rod.

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

4. Note the numbers stamped on the connecting rod and the bearing cap and install the lower bearing shell -- the one with the continuous oil groove -- in the bearing cap, with the tang on the bearing shell in the groove in the bearing cap.

5. Install the bearing and cap and tighten the nuts on the 3/8"-24 bolts (In-line and "V" engines) to 40-45 lb-ft (54-61 Nm) torque. Tighten the nuts on the former 5/16"-24 bolts (6V engine) to 24-28 lb-ft (33-38 Nm) torque.

NOTE: Be sure the connecting rod bolt has not turned in the connecting rod before torque is applied to the nut.

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

NOTE: On the 8V engine, if shims were used between the oil pump body and the main bearing caps, install the shims in exactly the same location from which they were removed.

7. Install the oil pan, using a new gasket.

8. Refer to the *Lubrication Specifications* in Section 13.3 and fill 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 liner (Fig. 1) is of the replaceable wet type, made of hardened alloy cast iron, and is a slip fit in the cylinder block. The liner is inserted in the cylinder bore from the top of the cylinder block. The flange at the top of the liner rests on a counterbore in the top of the block.

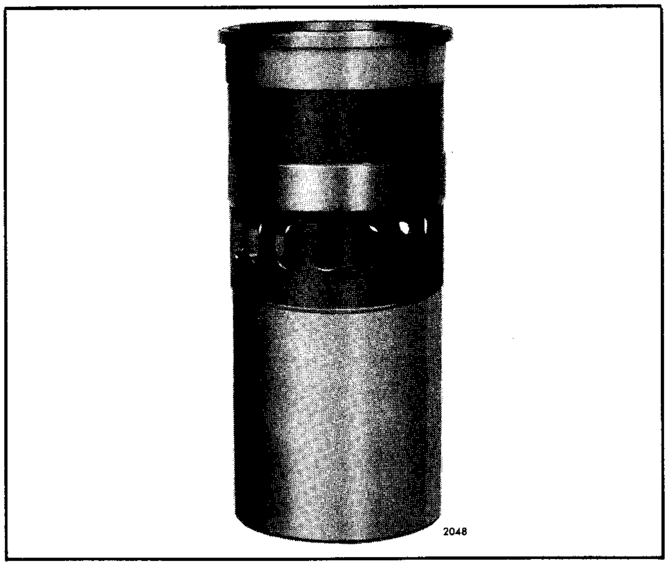


Fig. 1 - Cylinder Liner

Two silicone seal rings, 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 equally spaced ports. On 6V (aluminum) and 8V 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 except those with cross-head pistons.

When rebuilding a turbocharged engine with cross-head pistons, always make sure that the correct cylinder liner is installed. The cross-head piston liner has a .74" port height, while the standard liner has a .84" port height. If the standard liner is installed in place of the cross-head piston liner, a small loss in power and an increase in smoke will result.

The .74" port height liner can be identified as follows:

1. The part number is stamped on the outside diameter of the liner.
2. The liner has an identification groove machined around the outside diameter surface just below the ports.

The air inlet ports in the liner are machined at an angle to create a uniform swirling motion to the 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.

Remove Cylinder Liner

It is very important that the proper method is followed when removing a cylinder liner. *Do not* attempt to push the liner out by inserting a bar in the liner ports and rotating the crankshaft, otherwise the piston may be damaged or the upper ring groove may collapse.

To remove a cylinder liner, refer to Fig. 2 and proceed as follows:

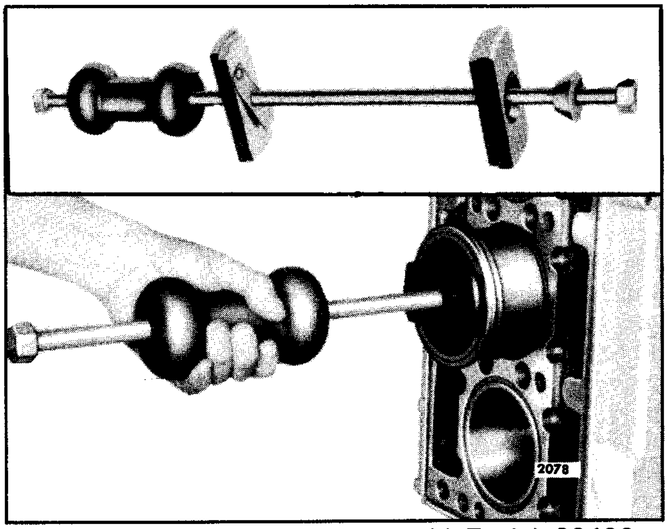


Fig. 2 - Removing Cylinder Liner with Tool J 22490

1. Remove the piston and connecting rod assembly as outlined in Section 1.6.
2. Remove the cylinder liner with tool set J 22490 as follows:
   a. Slip the lower puller clamp up on the puller rod and off the tapered seat. Cock the clamp so it will slide down through the liner. The clamp will drop back on the tapered seat after it clears the bottom of the liner. Then, slide the upper puller clamp down against the top edge of the liner.
   b. 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.

c. Remove the tool from the liner. Then, remove the liner from the cylinder block.
d. Remove and discard the cylinder liner seal ring from the groove in the cylinder block bore.

NOTICE: After removing liners from an engine and prior to installing liners, always store them in an upright position until ready for use. Liners left on their side for any length of time can become egg-shaped and distorted, making installation in cylinder bores difficult or impossible.

If tool J 22490 is unavailable, tap the liner out with a hardwood block and hammer.

Inspect 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
- Outside diameter
- Out-of-round
- Taper

A cracked or excessively scored liner must be discarded. A slightly scored liner may be cleaned-up and reused.

When removing the preservative from new liners, do not steam-clean. Instead, stand the liners upright in a metal basket and immerse in a suitable cold tank containing pure mineral spirits or fuel oil. Steam cleaning may cause internal engine parts to water spot and corrode. Placing liners on their sides for cleaning can lead to liner distortion.

Excessive liner-to-block clearance or block bore distortion will reduce heat transfer from the liner to the block and to the engine coolant.

Examine the outside diameter of the liner for fretting below the ports. Fretting is the result of a slight movement of the liner in the block bore during engine operation, which causes material from the block to adhere to the liner. These metal particles may be removed from the surface of the liner with a coarse, flat stone.

Measure the block bore (Section 1.1) and the outside diameter of the liner (refer to Section 1.0 for Specifications).

A new .020" oversize O.D. cylinder liner has been released to service Series 53 engines. To ensure serviceability, a new liner-to-block seal ring (identified by two yellow stripes) has also been released for use with the new liner. The standard seal ring has no paint identification and is used only with standard and .010" oversize O.D. liners. These are available for both standard and short port liner replacement.

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 seating of the piston rings.

A used cylinder liner must be honed for the following reasons:

1. To break the glaze (Fig. 3) due to the rubbing action of the piston rings after long periods of operation. Unless this glaze is removed, the time required to seat new piston rings will be lengthened.

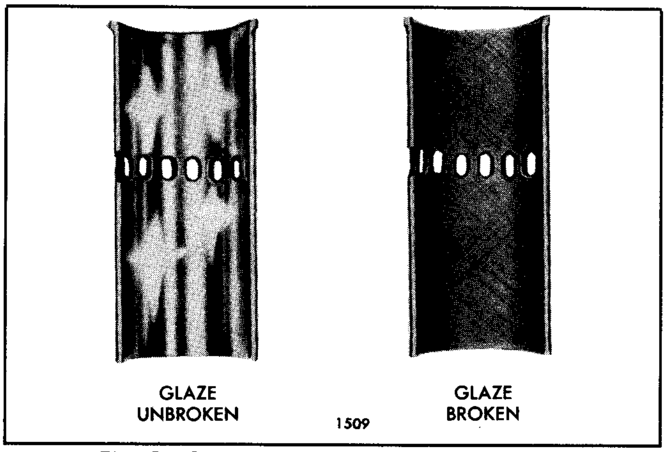


Fig. 3 - Glazed Surface of Cylinder Liner

2. To remove the ridge (Fig. 4) formed at the top by the piston ring travel. Otherwise, interference with the travel of the new compression rings may result in ring breakage.

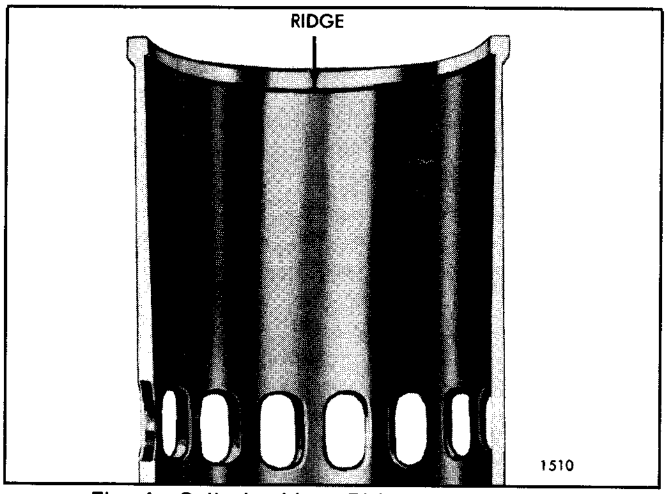


Fig. 4 - Cylinder Liner Ridge Due to Wear

Therefore, even though the taper and out-of-round are within the specified limits, the glaze and ridge must be removed by working a hone up and down the full length of the liner a few times.

Place the liner in a fixture (a scrap cylinder block makes an excellent honing fixture). However, if it is necessary to hone a liner in the cylinder block that is to be used in building up the engine, the engine must be dismantled and then, after honing, the cylinder block and other parts must be thoroughly cleaned to ensure that all abrasive material is removed.

The hone J 5902-01, equipped with 120 grit stones J 5902-14, should be worked up and down (at 300-400 rpm) the full length of the liner a few times in a criss-cross pattern that produces hone marks on the 45° axis.

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 (Section 1.0).

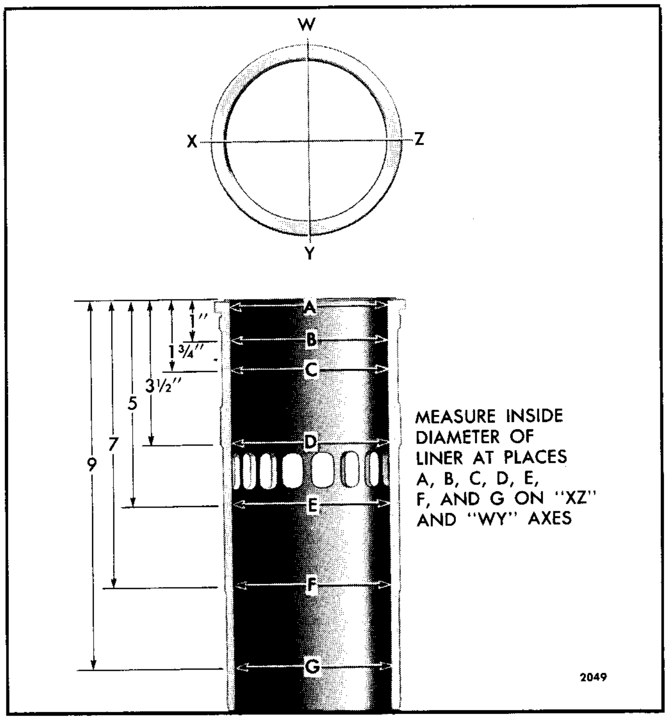


Fig. 5 - Cylinder Liner Measurement Diagram

Install the liner (new or used) in the proper bore of the cylinder block and measure the inside diameter at the various points shown in Fig. 5. Use cylinder bore gage J 5347-B (Fig. 6), which has a dial indicator calibrated in .0001" increments. Set the cylinder bore gage on zero in master ring gage J 8385-01. Also, check the liner for taper and out-of-round. Dial bore gage master setting fixture J 23059-01 may be used in place of the master ring gage.

The piston-liner clearance must be within the specified limits (Section 1.0). Also, the taper must not exceed .002" and the out-of-round must not exceed .003" on a used liner. The taper must not exceed .001" and the out-of-round must not exceed .002" on a new liner.

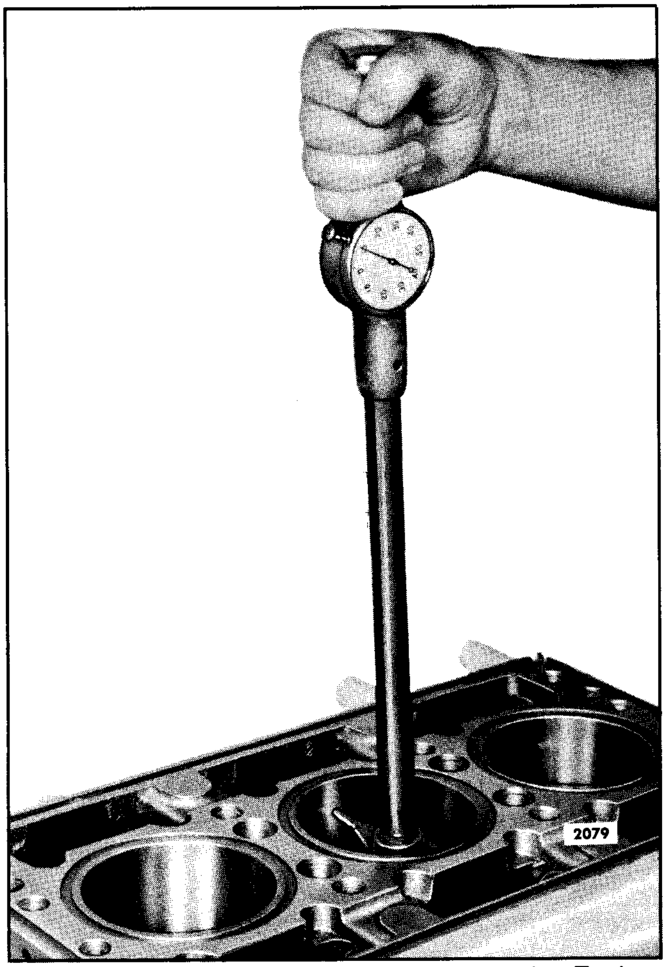


Fig. 6 - Checking Bore of Cylinder Liner using Tool J 5347-B

New service liners have an *inside* diameter of 3.8752" to 3.8767".

Fitting Cylinder Liner in Block Bore

1. Wipe the inside and outside of the liner clean and make sure the block bore and counterbore are clean.
2. Slide the liner into the block until the flange rests on the bottom of the counterbore in the block. Do not drop or slam the liner flange against the bottom of the counterbore in the block.
3. Tap the liner lightly with a soft hammer to make certain the liner flange seats on the bottom of the counterbore.
4. Install a cylinder liner hold-down clamp as illustrated in Fig. 7.
5. Measure the distance from the top of the liner flange to the top of the block with a dial indicator (Fig. 7). The liner flange must be .0465" to .0500" below the top of the block. However, even though all of the liners are within these specifications, there must not be over .002" difference between any two adjacent liners when measured along the cylinder longitudinal center

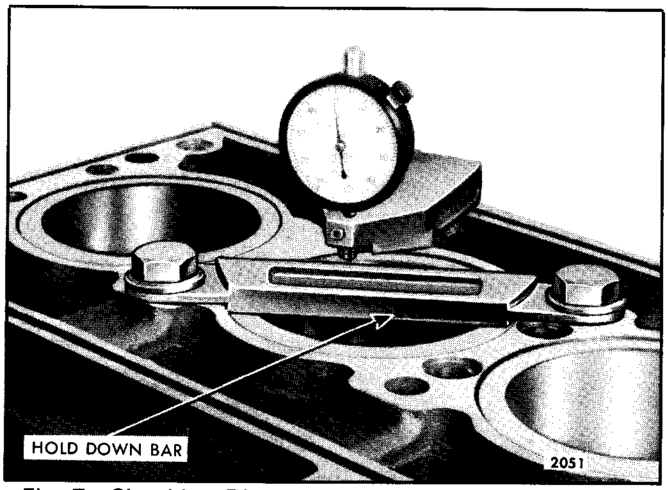


Fig. 7 - Checking Distance of Liner Flange Below Top Face of Block using J 22273-01 and Hold-Down Tool J 21793-B

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

6. Matchmark the liner and the cylinder block with a felt pen so the liner may be reinstalled in the same position in the same block bore. Place the matchmarks on the engine serial number side of the block (In-line engine) or on the outer edge of the block (V-type engine).
7. Remove the hold-down clamp and the cylinder 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 surface of the piston ring compressor J 6883-01.

NOTICE: 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, with the tapered end of the ring compressor facing up.
3. Position (stagger) the piston ring gaps properly on the piston. Make sure the ends of 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 ("Operation 1" of Fig. 8).
5. Note the position of the matchmark and place the liner, with the flange end down, on the wood block.
6. Place the ring compressor and the piston and connecting rod assembly on the liner so the numbers on the rod and cap are aligned with the matchmark on the liner ("Operation 2" of Fig. 8). 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 in the same location as on the connecting rod that was replaced.

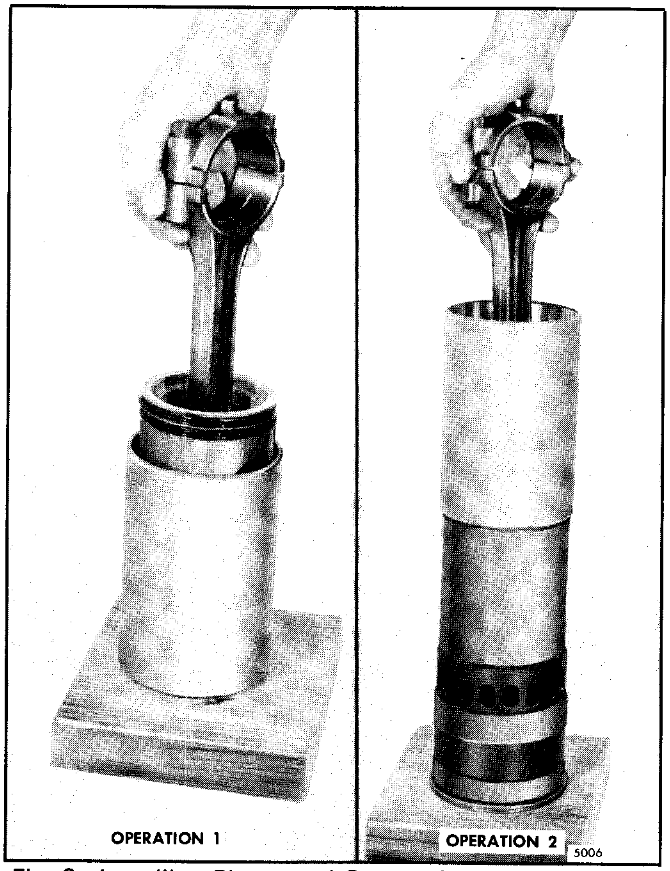


Fig. 8 - Installing Piston and Connecting Rod Assembly in Ring Compressor and Cylinder Liner

7. Push the piston and connecting rod assembly down into the liner until the piston is free of the ring compressor.

NOTICE: 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 must be taken during the loading operation to prevent ring breakage.

8. Remove the connecting rod cap and the ring compressor. Then, push the piston down until the compression rings pass the cylinder liner ports.

Install Cylinder Liner, Piston andConnecting Rod Assembly

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

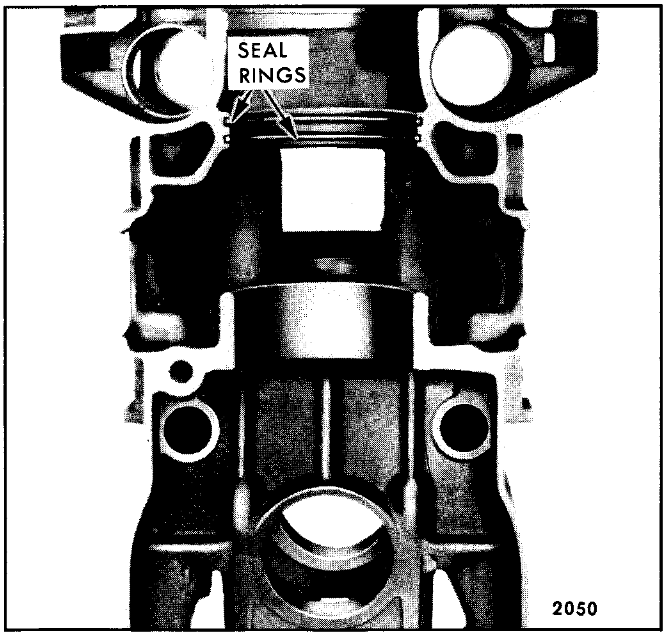


Fig. 9 - Cylinder Liner Seal Ring Location in Cylinder Block Bore

1. Make sure the seal ring grooves in the cylinder block bore are clean. Then, install two new seal rings (Fig. 9).
2. Apply hydrogenated vegetable type shortening or ethylene glycol base antifreeze to the inner surface of the seal rings.
3. If any of the pistons and liners are already in the engine, use hold-down clamps 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 oil groove at each parting line -- in the connecting rod. Lubricate the bearing shell with clean engine oil.
6. Position the piston, rod and liner assembly in line with the block bore (Fig. 10) so that 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 the block. Then, slide the entire assembly into the block bore being careful not to damage the seal rings.
7. Push or pull the piston and connecting rod into the liner until the upper bearing shell is firmly seated on the crankshaft journal.

NOTICE: On a V-type 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.

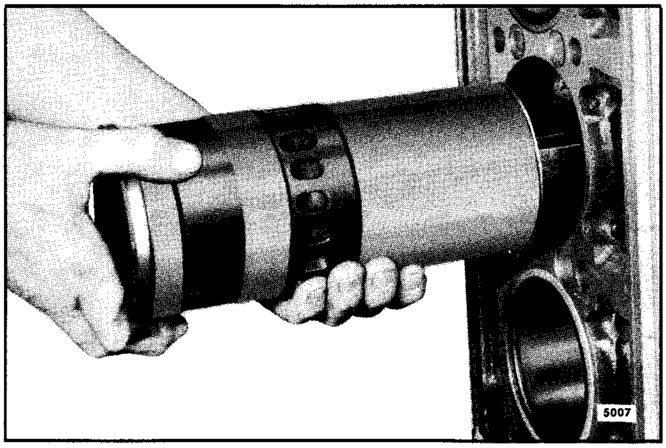


Fig. 10 - Installing Piston, Rod and Liner Assembly in Cylinder Block

8. Place the lower bearing shell -- the one with the continuous oil groove from one parting line to the other -- in the connecting rod cap, with the tang on the bearing shell in the notch in the connecting rod bearing cap. Lubricate the bearing shell with clean engine oil.
9. Install the bearing cap and the bearing shell on the connecting rod with the identification 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 (54-61 N·m) torque. Tighten the nuts on the 5/16"-24 bolts (early 6V engines) to 24-28 lb-ft (33-38 N·m) torque. Be sure the connecting rod bolt has not turned in the connecting rod before torque is applied to the nut. The new 6V rod assembly with 3/8" bolts should be used for replacement at the time of normal overhaul. Rework of an old 6V rod assembly to utilize 3/8" bolts is not recommended.
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 engine or .008" to .016" clearance between the connecting rods on a V-type engine.
11. Install the remaining liner, piston and rod assemblies in the same manner. Use hold-down clamps to hold each liner in place.
12. After all of the liners and pistons have been installed, remove the hold-down clamps.
13. Install new compression gaskets and water and oil seals as outlined in Section 1.2. Then, install the cylinder head and any other parts which were removed from the engine.
14. After the engine has been completely reassembled, refer to the *Lubrication 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.

Effective with engine serial numbers 3D-193526, 4D-209292 and 6D-229545 new camshaft front pulleys and weights are used with new bolt-on balance weights which are attached to the rear camshaft gears. When replacing the trunk type pistons with cross-head type pistons in an engine, the new camshaft front pulleys and heavier weights must be used.

When the cross-head pistons are to be installed in an engine built prior to serial numbers 3D-193526, 4D-209292 or 6D-229545, and an in-frame overhaul is desired, a new bolt-on rear balance weight must be used in addition to the existing balance weight attached to the flywheel housing side of each rear camshaft gear. Refer to Section 1.0 for the installation procedure.

Remove Front Balance Weights

1. Remove the nut at each end of both shafts as outlined in Section 1.7.2.
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 (Fig. 1).

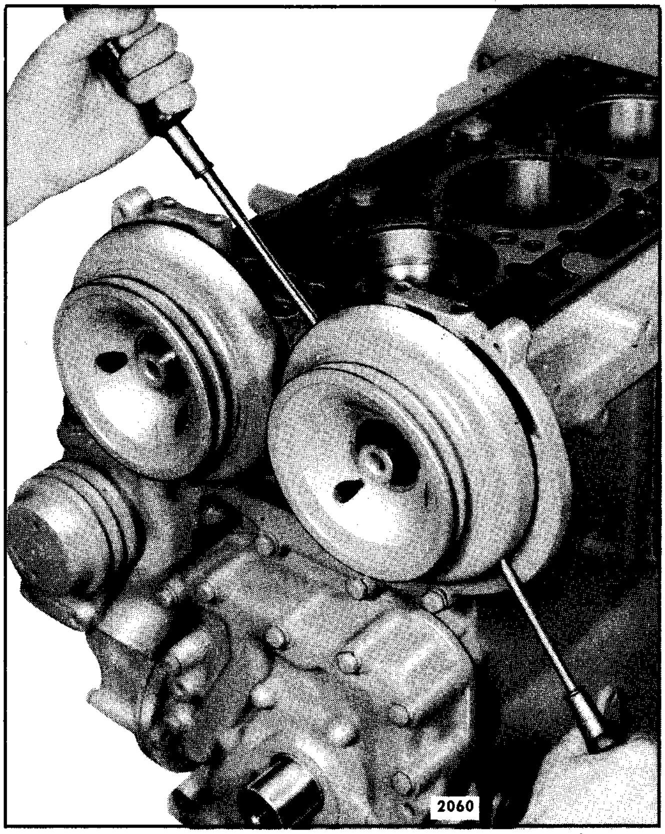


Fig. 1 - Removing Front Balance Weight (Pulley Type)

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 (41-47 N·m) torque. Install the other weight in the same manner.

3. Wedge a clean rag between the gears. Refer to Section 1.7.2 and tighten the gear retaining nuts to 300-325 lb-ft (407-441 N·m) torque. Then, tighten the front balance weight retaining nuts to 300-325 lb-ft (407-441 N·m) torque. Remove the rag from the gears.

GEAR TRAIN AND ENGINE TIMING

GEAR TRAIN

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 engine.

The gear train on an In-line engine consists of a crankshaft gear, an idler gear, a camshaft gear and a balance shaft gear (Fig. 1). 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.

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. This is effective with engine serial numbers 3D-170683, 4D-180939 and 6D-196535.

This reduction in noise level has been accomplished by changing the gear pitch from 14 to 16 and the pressure angle from 20° to 16°. Identification of the new and former gears can be made by counting the number of teeth in the gears (Table 1).

The former individual 20° angle main gear train gears (crankshaft, idler, balance and camshaft gears) will be available for service until stock is exhausted. Then, when any one gear requires replacement, all of the gears in the gear train must be changed to the 16° angle gears. The former governor, fuel pump, blower rotor and blower drive gears will continue to be serviced, as well as the new gears.

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.

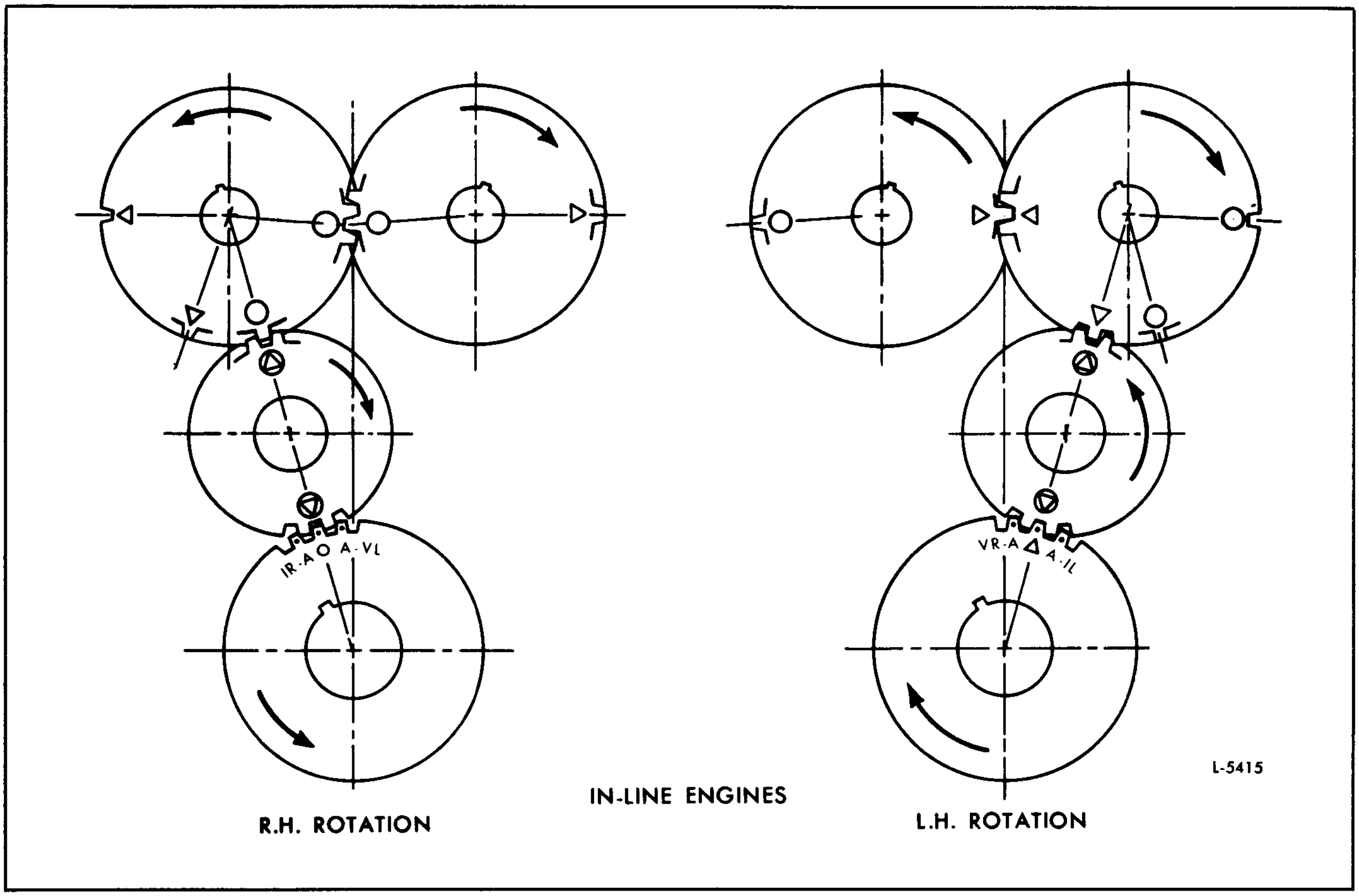


Fig. 1 - In-Line Engine Gear Train Timing Mark (Standard Timing Shown)

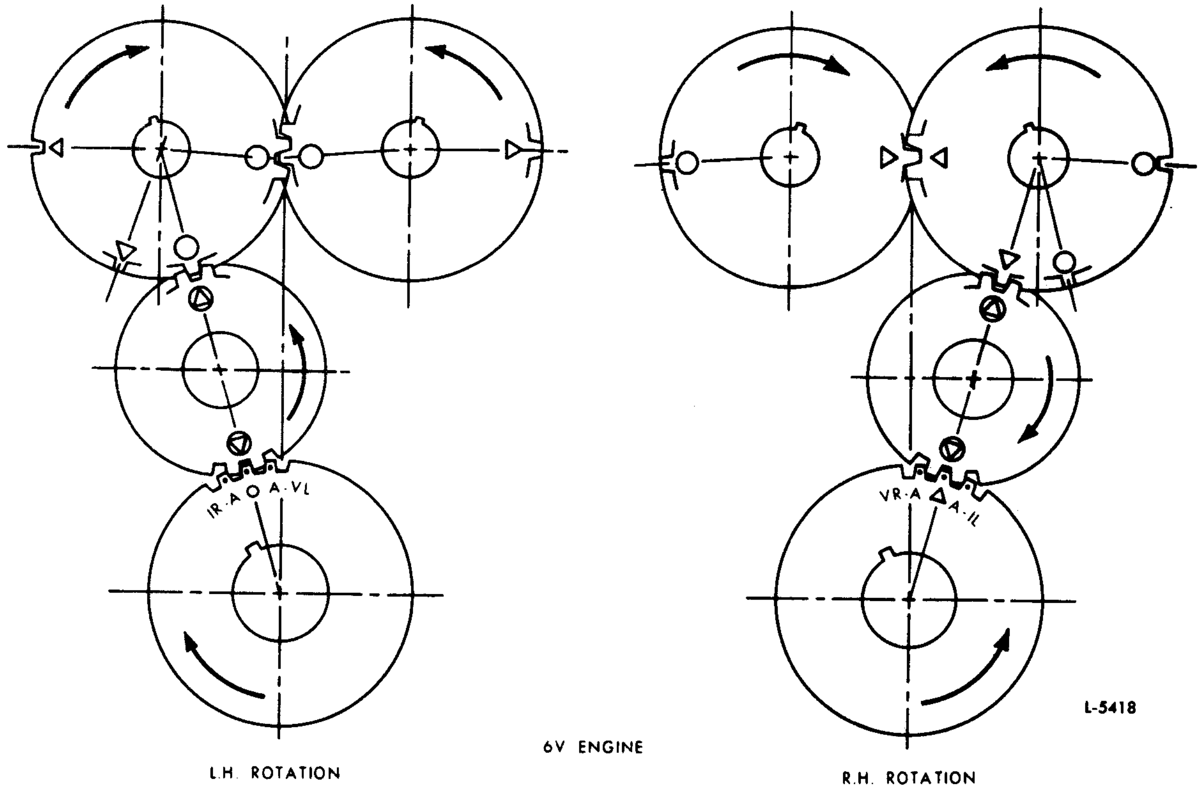


Fig. 2 - 6V Engine Gear Train Timing Marks (Standard Timing Shown)

Gear	Number of Teeth	
	Former	New
Crankshaft	97	111
Balance and Cam	97	111
Idler	72	82
Blower Drive	39	45
Blower Rotor	39	45
Governor Drive	49	56
Fuel Pump Drive	49	56

TABLE 1

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.

Do not mix the former and the current hardened gears on the same engine. Mixing the gears will result in excessive gear wear and may lead to serious engine damage. The hardened gears are used on 3-53 turbocharged industrial and 6V turbocharged automotive engines. This change became effective with engine serial numbers 3D-193516 and 6D-229616.

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.

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.

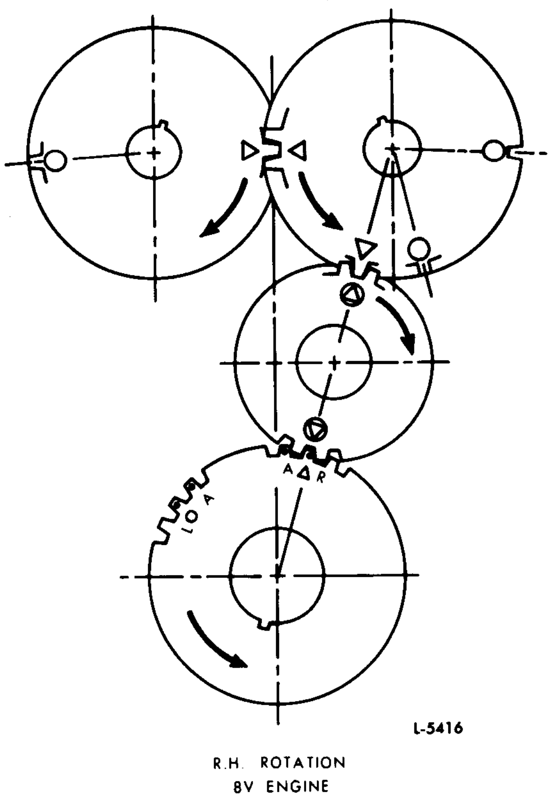


Fig. 3 - 8V Engine Gear Train Timing Marks (Standard Timing Shown)

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 side of the circle timing mark for a right-hand rotation engine (Fig. 1). 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 for a right-hand rotation engine (Fig. 2). 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 for a left-hand rotation engine (Fig. 2). 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 (former and current) 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 the 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 (Figs. 1, 2 and 3).

Preignition, 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. Discard the gasket(s).
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 one inch. Provide an extension for the indicator spindle. The extension must be long enough to contact the piston just before it reaches the end of its upward stroke. Also, select suitable mounting attachments for the indicator so it can be mounted over the injector tube in the cylinder head.
6. Mount the indicator over the injector tube. Check to 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".
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.

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 camshaft with no designation on the ends or a "7" stamped on the ends is a high-velocity high-lift camshaft. A camshaft metal stamped with a "V" or "V7" is a low-velocity high-lift camshaft. Effective with engines 4D-112278 and 6D-60777, new camshafts metal stamped "V7L" are used, intermittenly in the 4-53 and 6V engines. These are low velocity low-lift camshafts. Note the indicator reading and compare it with the dimensions listed in Table 2 for the particular camshaft in the engine.
19. Remove the dial indicator. Also, remove the pointer attached to the front of the engine.
20. Use new gasket(s) and install the valve rocker cover.

Engine	*INDICATOR READING		
	Correct	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 2

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 accurately ground cams ensure efficient, quiet cam follower roller action. They are also heat treated to provide a hard wear surface.

Both ends of 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 4-53 and 8V-53 engines to support the camshafts. The camshafts in the 3-53 and 6V-53 engine are supported by two end bearings and two intermediate bearings.

To facilitate assembly, letters signifying the engine models in which a shaft may be used are metal 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 metal stamped with a "V" or "V7" is a low-velocity high-lift camshaft. Effective with engines 4D-112278 and 6D-60777, new camshafts metal stamped "V7L" are used intermittenly in the 4-53 and 6V-53 engines. These are low-velocity low-lift camshafts.

On 4-53 and 6V-53 engines the present low-lift camshaft must be used in conjunction with the new exhasut valve springs. Failure to change the exhaust valve springs could result in broken springs and engine failure. Refer to Section 1.2.2.

The low-lift camshaft which provides a maximum valve cam lobe lift of .276" is stamped "V7L" on both ends.

To provide proper camshaft end thrust, a new front camshaft pulley spacer is being used and the oil slinger has been eliminated, effective with engine serial numbers 3D-158108, 4D-164682 and 6D-180763. Engines built prior to 1968 were built with an oil slot broached in the camshaft end bearing. With pressure oil from this slot flowing directly on the upper front cover oil seal, the seal required the protection of an oil slinger. Even though the slot was eliminated in 1968 the use of the slinger was continued. With the elimination of the oil slinger, a new .025" longer spacer is used to make up for the removal of the slinger. Therefore, when removing the oil slinger(s) from an engine built prior to the above serial numbers, it will be necessary to replace the shorter spacer(s) with the new .025" longer spacer. Removal of the oil slinger on former engines is not mandatory. The former short spacer and slinger are for engines built prior to 1968 (engine serial numbers 2D-23442, 3D-44069, 4D-48900 and 6D-41029).

The new spacer is identified with a black oxide finish, the same part number also incorporates an optional material (powered metal) which is identified with an indent in the top surface below the chamfer.

A method of identifying a camshaft with the cylinder head still installed is as follows:

1. Put a dial indicator on the rocker arm clevis.
2. Bar the engine over 360° and the indicator will give a reading directly relative to the maximum amount of lift on the high point of the camshaft exhaust lobe.
   a. The 4-53 low-lift camshafts have a .276 maximum lift.
   b. The 4-53 high-lift camshafts have a .327 maximum lift.

3. The above can be accomplished with the cylinder head removed by placing the dial indicator directly on the exhaust valve lobe of the camshaft. A reading of the maximum camshaft lift can be taken at the high point of the lobe.

Lubrication

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 replacing, remove the shafts from the engine as follows:

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 (See Section 1.1).
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 and remove the nuts from each end of both shafts with a socket wrench (Fig. 1).

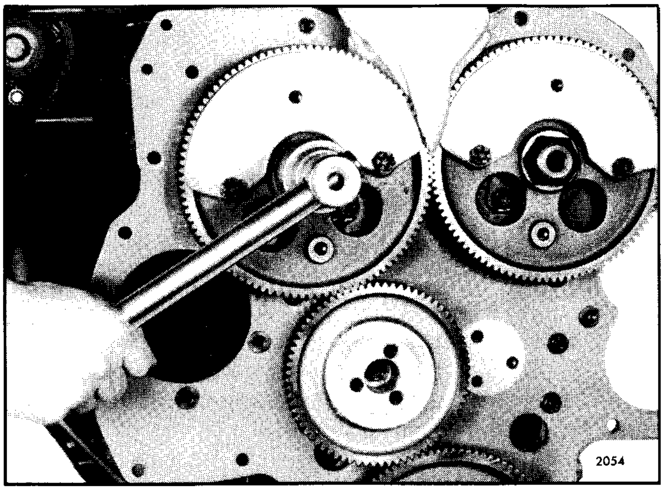


Fig. 1 - Removing or Installing Nut on Camshaft or Balance Shaft

8. Remove the balance pulleys 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 (Fig. 2).

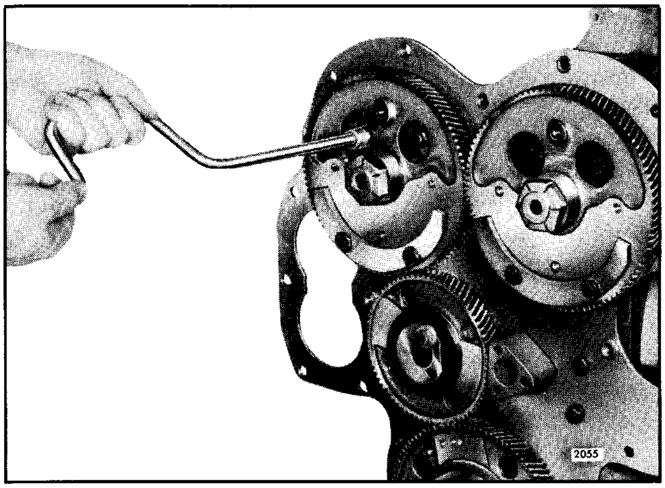


Fig. 2 - Removing or Installing Thrust Washer Retaining Bolts

12. Withdraw the shaft, thrust washer and gear as an assembly from the rear end of the cylinder block.

Remove Camshaft (Flywheel Housing and Transmission in Place)

A camshaft may be removed and replaced without removing the flywheel housing and disconnecting the transmission, if there is space enough to slide the shaft out through the front of the engine.

1. Drain the cooling system.
2. Remove the accessories and assemblies with their attaching parts that are necessary to facilitate the removal of the flywheel housing hole cover over the camshaft and the upper engine front cover (if used).
3. Remove the cylinder head.
4. Remove the gear nut retainer plates (if used).
5. Wedge a clean rag between the gears and remove the gear retaining nut from each end of the camshaft (Fig. 1).
6. Remove the camshaft front balance pulley.
7. Remove the upper engine front cover (if used).
8. Remove the woodruff key from the camshaft and then remove the oil slinger.
9. Install the camshaft gear puller J 1902-01, four spacers J 6202-2 and camshaft gear puller adaptor plate J 6202-1 on the camshaft gear (Fig. 3).

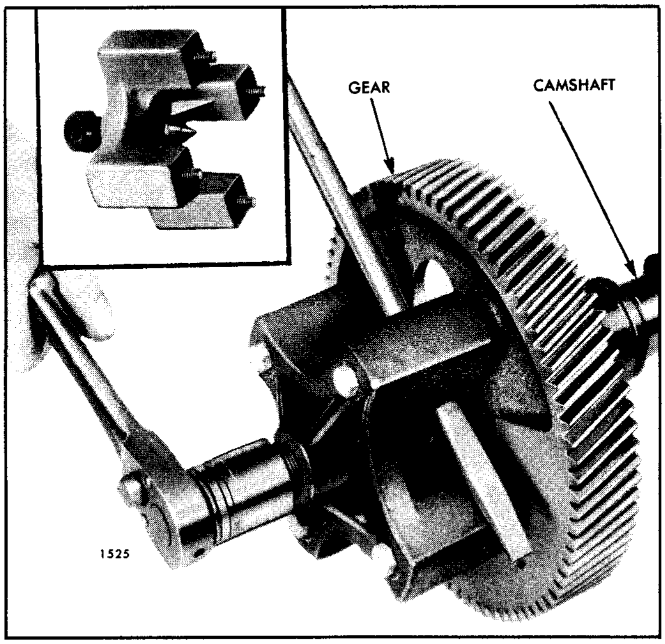


Fig. 3 - Removing Camshaft Gear with Tool J 1902-01

10. Turn the center screw of the puller clockwise to disengage the camshaft gear. Do not remove the puller or the adaptor plate until the camshaft is reinstalled. The adaptor plate, secured to both the flywheel housing and the camshaft gear will hold the gear securely in place and in alignment which will aid in the reinstallation of the camshaft.

11. Pull the camshaft from 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 6471-2 into the plug. Then, attach a slide hammer J 2619-5 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.

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 gears, 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.

If there is a doubt as to the acceptability of the camshaft for further service determine the extent of cam lobe wear as follows:

The camshaft can be in or out of the engine during this inspection.

1. With a tapered leaf set of feeler gages (.0015"-.0100") and a piece of square hard material 1/8" x 3/8" x 1" measure the flat on the injector rise side of the cam lobes (Fig. 4).
2. If the flats measure less that .003" in depth and there are no other defects the camshaft is satisfactory for service.

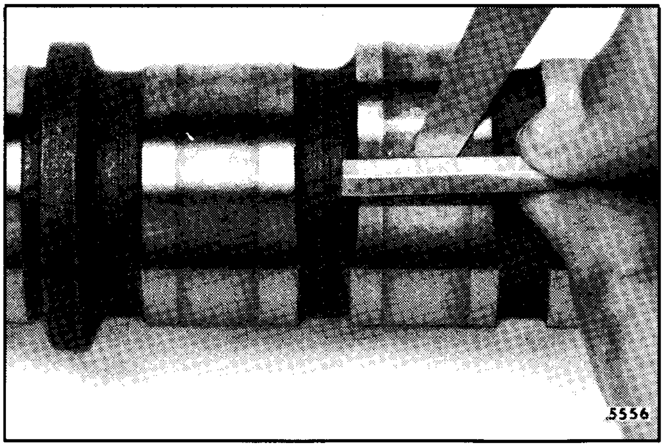


Fig. 4 - Checking Cam Lobe Wear

3. A slightly worn lobe still within acceptable limits, may be stoned and smoothed over with a fine crocus cloth.

Check the runout at the center bearing with the camshaft mounted on the end bearing surfaces. Runout should not exceed .002".

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. If a new camshaft is to be installed, thoroughly clean it to remove the rust preventive and blow out the oil passages with compressed air.

The clearance between new shafts and new bearings is .0035" to .007", 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.

Remove Bearings

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

NOTICE: 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.

CAMSHAFT AND BALANCE SHAFT CYLINDER BLOCK BORE MACHINING CHART

(Oversize Camshaft Bearings)

Engine	Bearing Location	Dimension	
		Minimum	Maximum
2,3,4,6V & 8V	End	2.385"	2.386"
2,3,4,6V & 8V	Intermediate*	2.375"	2.376"
4 & 8V	Center	2.365"	2.366"

*Center Bearing 2-53 Engine Only

TABLE 1

1. Remove all accessories and assemblies with their attaching parts as is necessary so that tool set J 7593-03 may be used as shown in Fig. 5 and in A of Fig. 6.

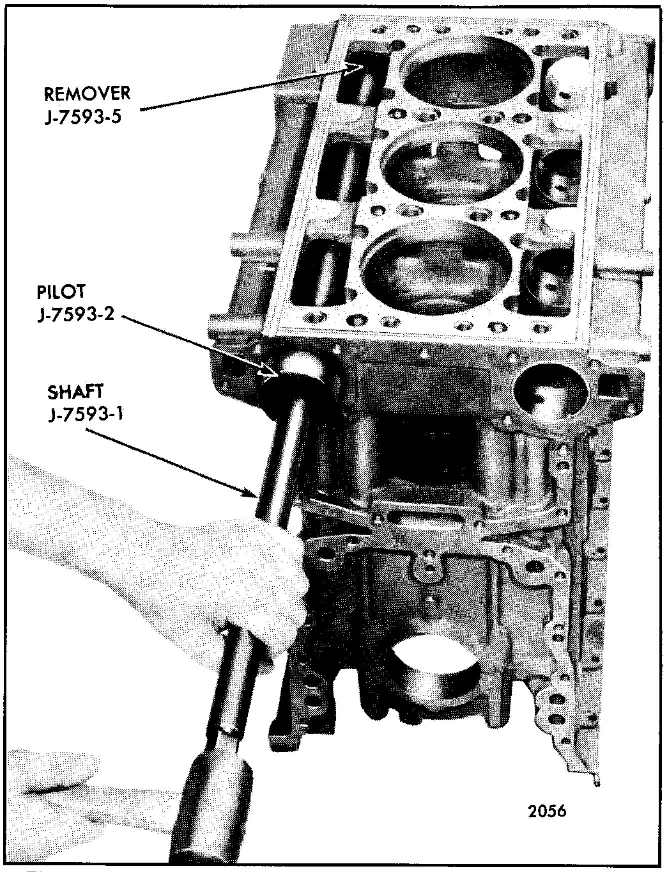


Fig. 5 - Removing End Bearing with Tools J 7593-1, J 7593-2 and J 7593-5

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 the camshaft bore and is used when removing the other end bearing and any remaining bearings.

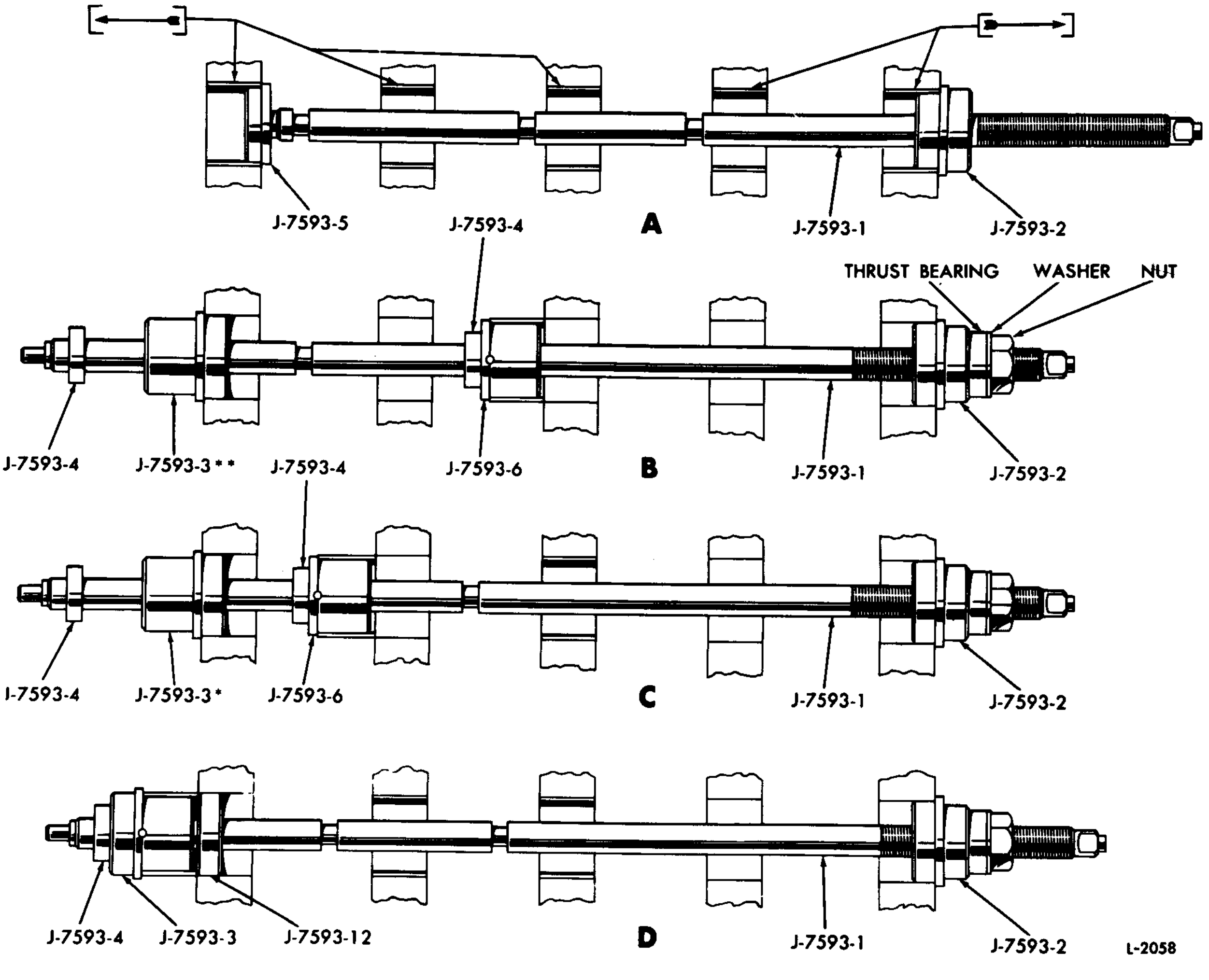
Install Intermediate and/orCenter Camshaft Bearings

Camshaft center and intermediate bearings must be installed prior to installing the camshaft end bearings. On the 4-53 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 3-53 and 6V engine except that there is no center bearing. Current bearings incorporate lubrication grooves on the inner bearing surface (Fig. 7).

To properly install the camshaft and balance shaft bearings, refer to Fig. 8 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 (Table 2).

1. Insert pilot J 7593-2 in the bore of the block (Fig. 9). Use the small end of the pilot if an end bearing has been installed. Refer to B and C of Fig. 6.
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. 6.
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. 9, is used on the 3-53 and 6V blocks.
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.



*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. 6 - Removing and Replacing Camshaft or Balance Shaft Bearings with Tool Set J 7593-03

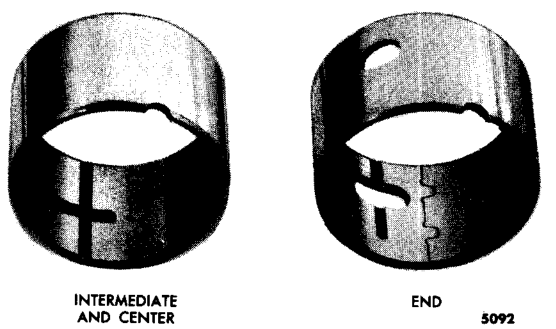


Fig. 7 - Camshaft and Balance Shaft Bearing Identification

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. 9. 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.

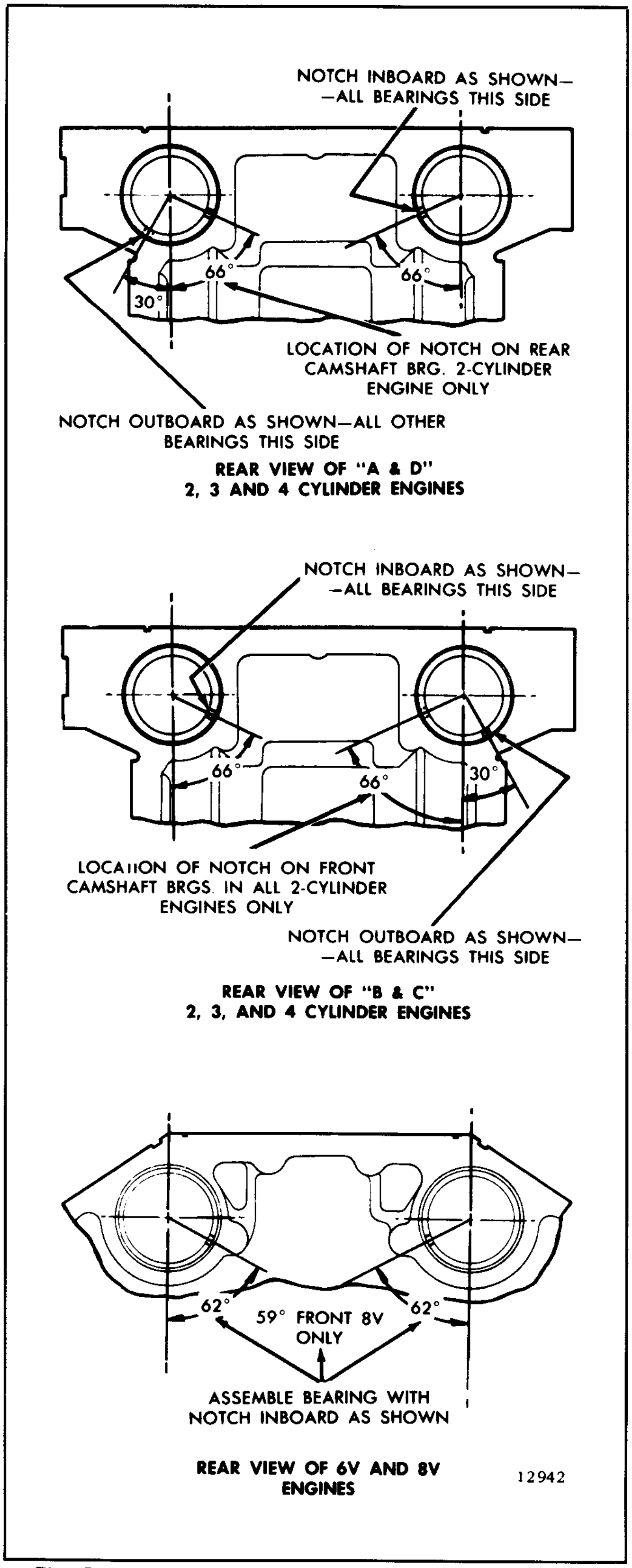


Fig. 8 - Location of Notch in Relation to Shaft Bore Centerline

CAMSHAFT AND BALANCE SHAFT BEARING COLOR CODE CHART

Bearing Position	Color Code Current	Color Code Former	Outside Diameter	Inside Diameter
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

4. Place "C" washer J 7593-4 in the end notch in the shaft; pull the shaft back until the washer butts against the installer.
5. Next, place a spacer (if required), thrust washer, plain washer and hex nut over the threaded end of the shaft as shown in "D" of Fig. 6 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 set 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 4-53 and 8V cylinder block is 10.94" from the rear face of the block. The intermediate bearings for the 3-53 and 4-53 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.

Assemble and Install Camshaft and Balance Shaft

Refer to Fig. 10 and assemble the camshaft and balance shaft.

1. Coat the sides of the camshaft plugs with a light coating of Permatex Hi-Tack® or equivalent.
2. Install new end plugs in the camshaft. Press the plugs in to a depth of 1.940" to 2.060" (Fig. 11).
3. Install the gears and thrust washers on their respective shafts as outlined in Section 1.7.3.

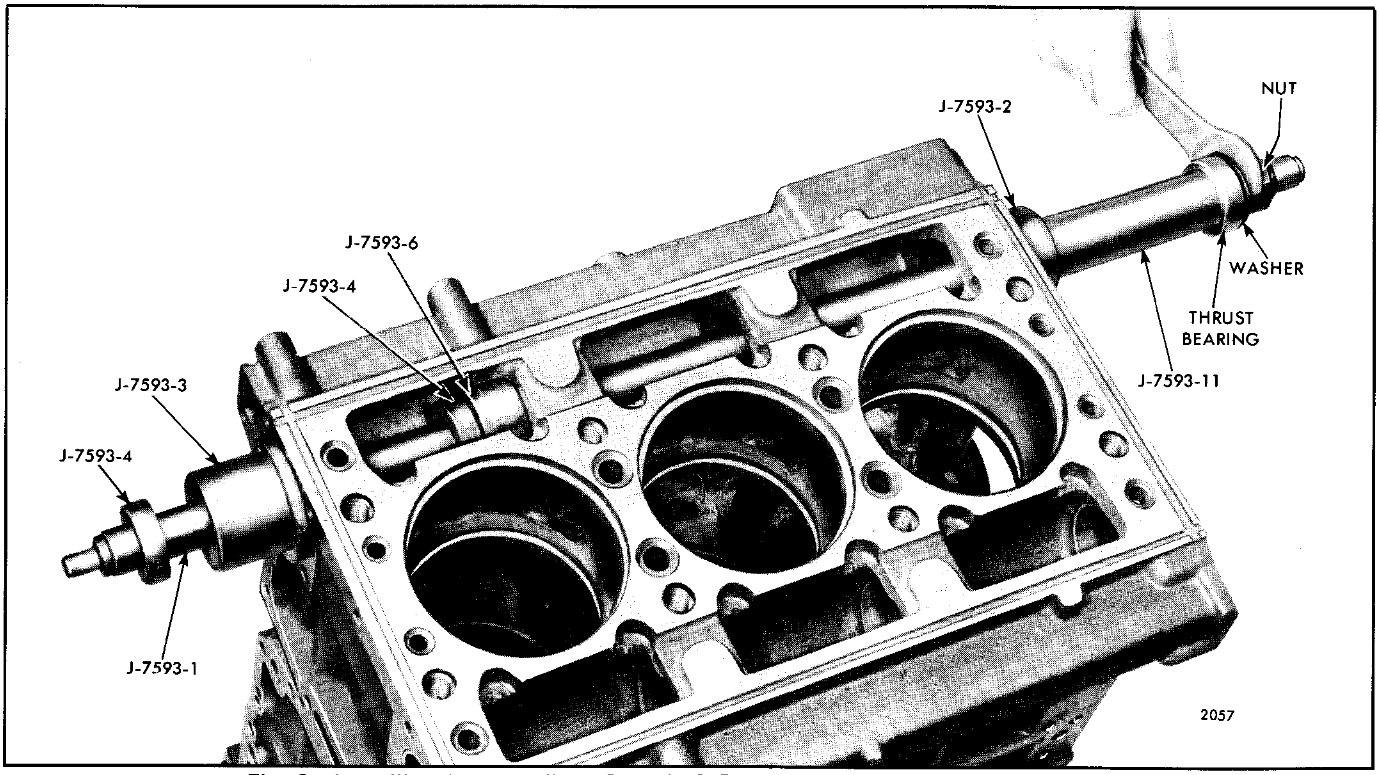


Fig. 9 - Installing Intermediate Camshaft Bearing using Tool Set J 7593-03

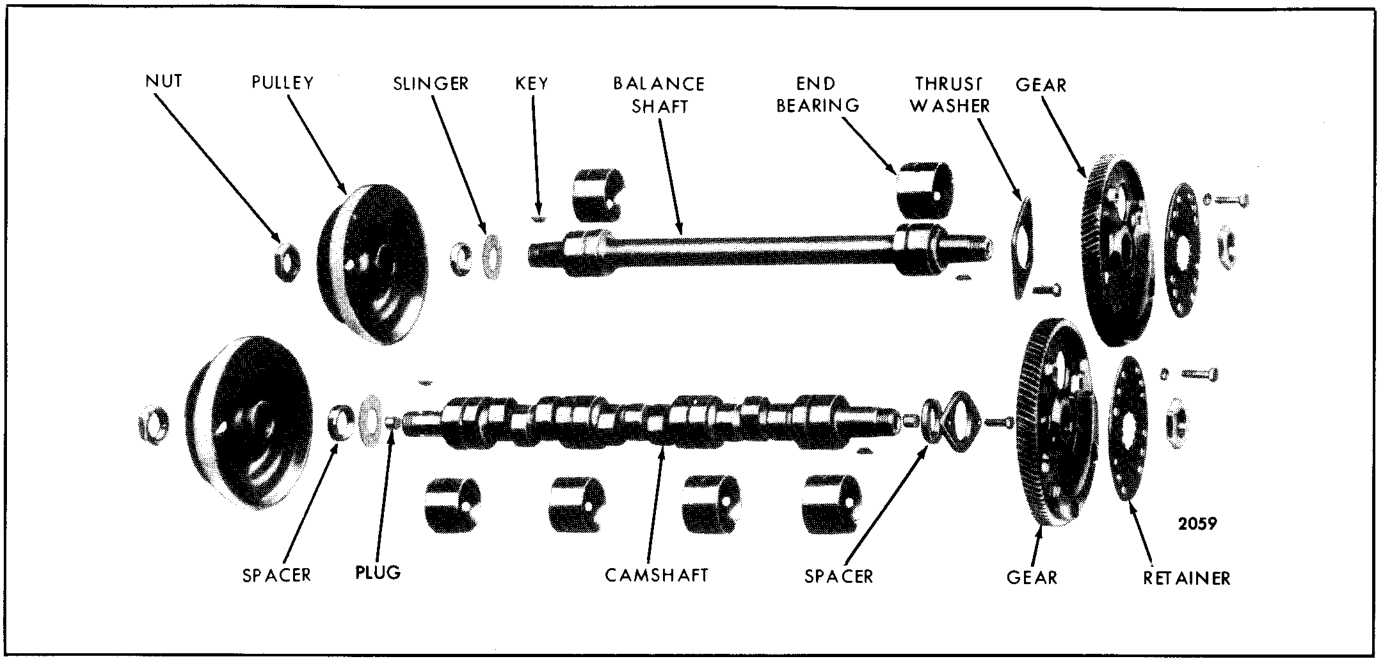


Fig. 10 - Camshaft and Balance Shaft Details and Relative Location of Parts

4. 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.

5. Slide an oil slinger on the front end of both shafts.

6. Install the upper engine front cover, if used, (Section 1.7.8).

7. Secure the thrust washers in place (Fig. 2) and tighten the bolts to 30-35 lb-ft (41-47 N·m) torque.

8. Install the front balance weights (Section 1.7).

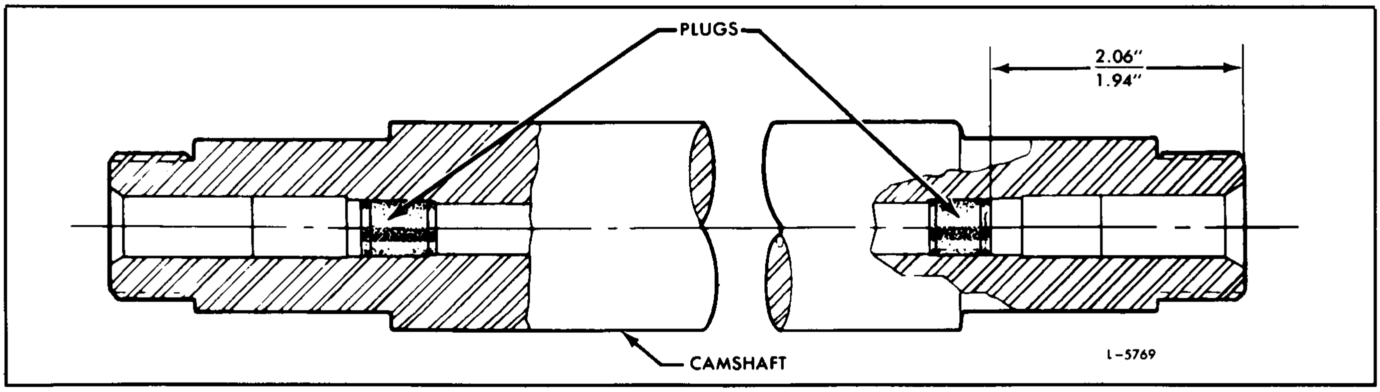


Fig. 11 - Camshaft Plug Installation

9. 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 (47-53 N·m) torque.
10. 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.
11. Check the backlash between the mating gears. The backlash should be .0005" to .005" and should not exceed .007" between used gears.
12. Install the flywheel housing and other parts or assemblies that were removed from the engine as outlined in their respective sections of this manual.

Install Camshaft (Flywheel Housing and Transmission in Place)

1. Place the rear camshaft spacer over the end of the camshaft and install the wooruff key in the gear end of the camshaft. Insert this end into position from the front of the engine. Push the shaft in until it slides into the end bearing.

2. Align the key in the shaft with the keyway in the camshaft gear and start the shaft into the gear. Tap the shaft into the gear with a soft (plastic or rawhide) hammer.

3. Remove the camshaft gear puller, spacers and adaptor plate. Finger tighten the gear retaining nut on the shaft.

4. Install the oil slinger on the front end of the camshaft.

5. Install the upper front cover, if used, and slide the spacer over the end of the camshaft and into the oil seal in the cover.

6. Install the camshaft front balance pulley. Finger tighten the pulley retaining nut.

7. With the clean rag wedged between the gears to prevent their rotation, tighten the nut on each end of the camshaft to 300-325 lb-ft (407-441 N·m) torque.

8. Install the gear nut retainers with bolts and lockwashers. Tighten the bolts to 35-39 lb-ft (47-53 N·m) torque.

9. Install the accessories and assemblies that were removed and refill the cooling system.

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 for gear train timing and identification of the new quiet gears and former gears).

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 (61-68 N·m) torque.

Do not mix the former and the current hardened gears on the same engine. Mixing the gears will result in excessive gear wear and may lead to serious engine damage. The hardened gears are used on 3-53 turbocharged industrial and 6V turbocharged automotive engines. This change became effective with engine serial numbers 3D-193516 and 6D-229616.

When cross-head pistons are to be installed in a turbocharged Series 53 engine built prior to serial numbers 3D-193526, 4D-209292, 6D-229545 and an in-frame overhaul is desired, new bolt-on balance weights must be used.

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 (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 on the end of the camshaft and press the camshaft out of the camshaft gear.

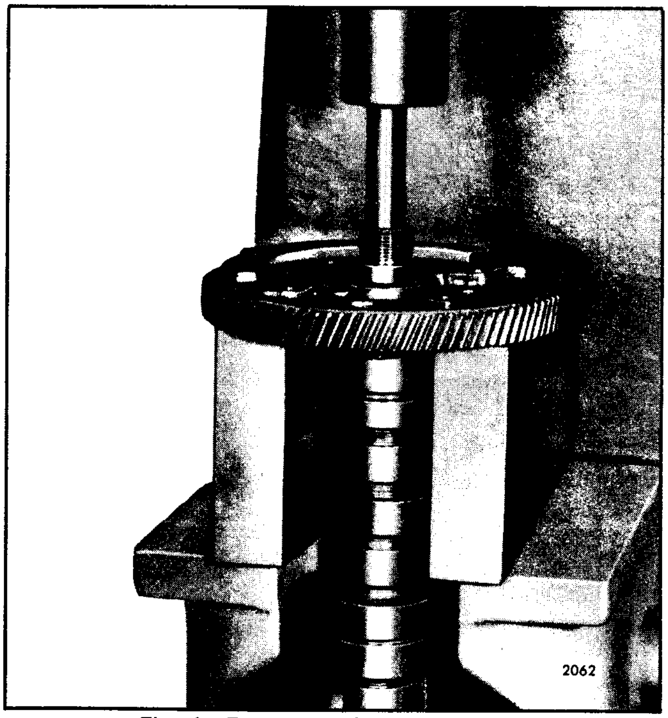


Fig. 1 - Removing Camshaft Gear

5. Remove the thrust washer, Woodruff key and spacer from the camshaft.
6. Remove the gear from the balance shaft in a similar manner.

Inspection

Clean the gears with fuel oil and dry them with compressed air. Then, examine the gear teeth for evidence of scoring, pitting and wear. Replace the gears, if necessary.

Examine both faces of the camshaft and balance shaft thrust washer 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.

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 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 1.7.2.

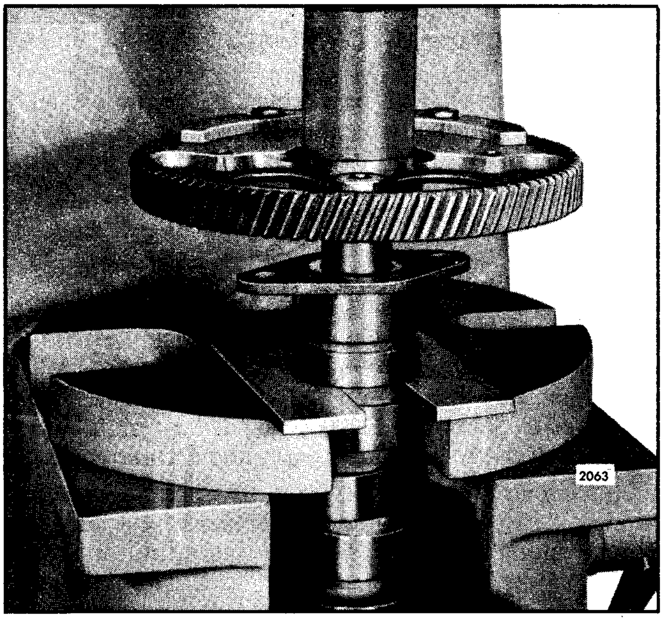


Fig. 2 - Installing Camshaft Gear

IDLER GEAR AND BEARING ASSEMBLY

IN-LINE AND 6V-53 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).

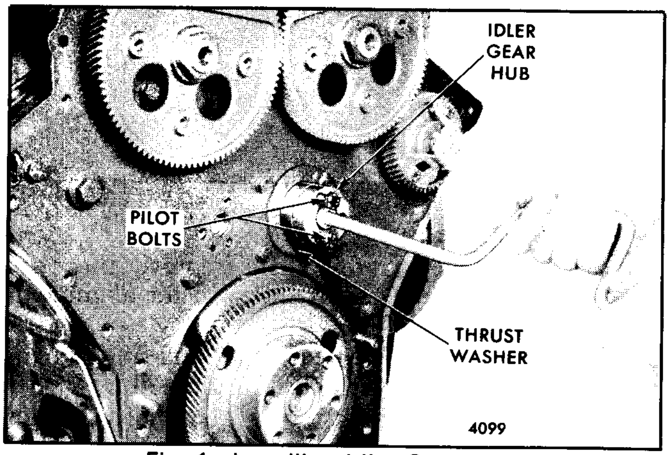


Fig. 1 - Installing Idler Gear Hub

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" - 1.234" and the standard thickness of the two thrust washers is .236" to .240". Therefore, 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. 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 *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.

Do not mix the former and the current hardened gears on the same engine. Mixing the gears will result in excessive gear wear and may lead to serious engine damage. The hardened gears are used on 3-53 turbocharged industrial and 6V turbocharged automotive engines. This change became effective with engine serial numbers 3D-193516 and 6D-229616.

Remove Idler Gear and Bearing Assembly (Flywheel Housing Removed)

1. Remove the idler gear outer thrust washer from the idler gear hub (Fig. 2).
2. Slide the idler gear straight back off of the idler gear hub.
3. Remove the bolt which secures the idler gear hub to the cylinder block. Then, remove the idler gear hub and the idler gear inner thrust washer 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 or 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 (bushing) is installed in the idler gear, it must not protrude beyond the gear face on either side and must sustain an axial load of 2,000 pounds minimum without pushing out of the gear.

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 (Fig. 1), to be sure the bolt holes will be in alignment when the flywheel housing is installed.
4. Insert the 3/8"-16 x 1-3/4" 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

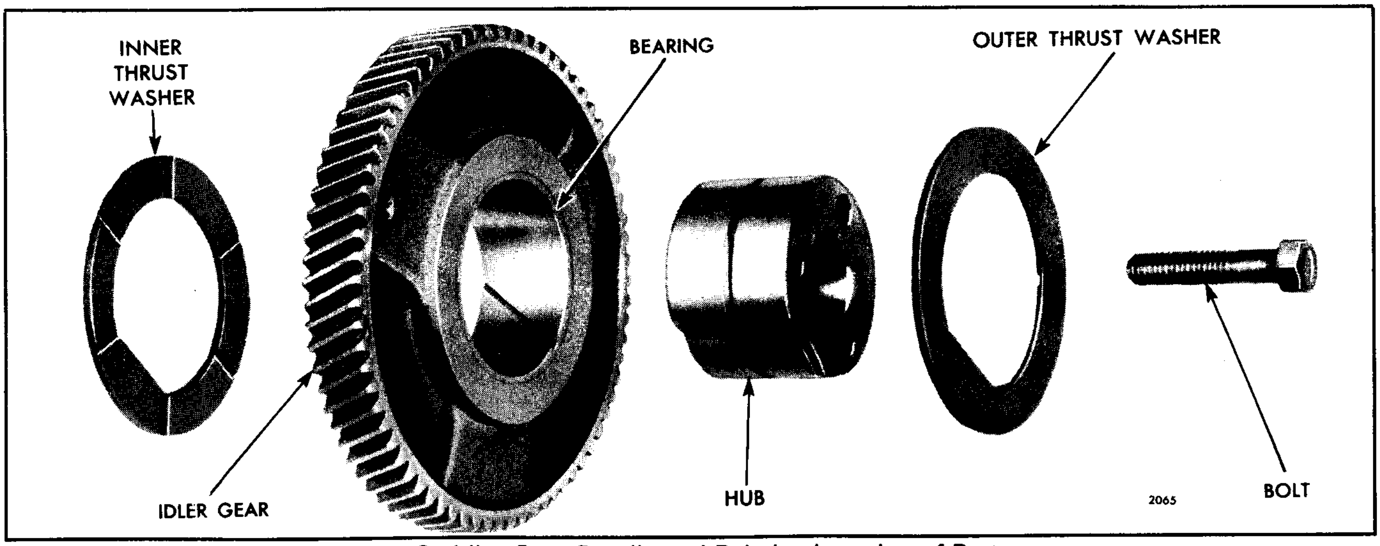


Fig. 2 - Idler Gear Details and Relative Location of Parts

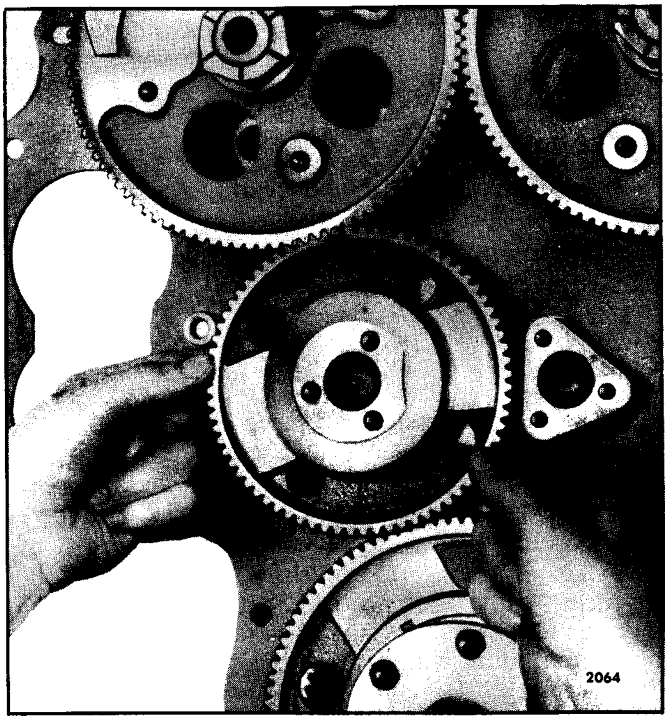


Fig. 3 - Installing Idler Gear

(54-61 N·m) 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 and to Table 1 in Section 1.7.1 for identification of the new quiet gears and the former gears.
7. With these timing marks in alignment, install the idler gear (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 .0005" to .005" between new gears and should not exceed .007" between used gears.

8V-53 ENGINE

Fig. 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.

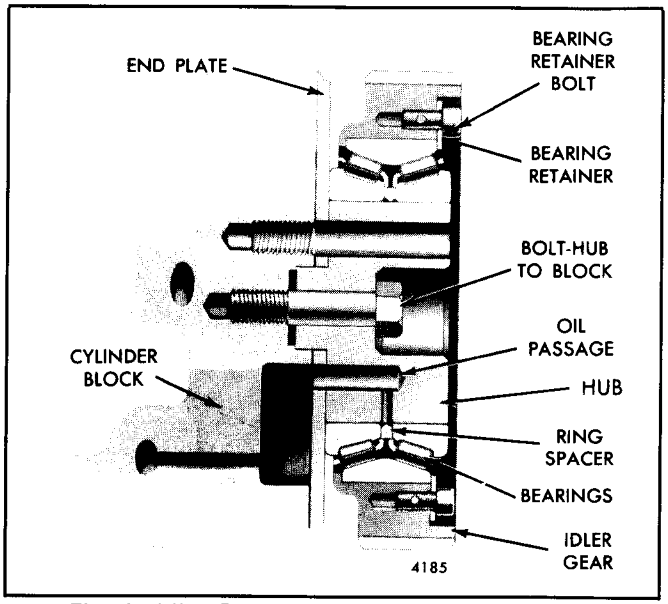


Fig. 4 - Idler Gear Mounting (Former Bearing)

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 on 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, Huband Bearing Assembly (Flywheel Housing Previously Removed)

Remove the hub to cylinder block bolt and withdraw the assembly from the cylinder block rear end plate.

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.

Component parts of the idler gear bearing are mated. Therefore, matchmark 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 (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 (Figs. 6 and 7).

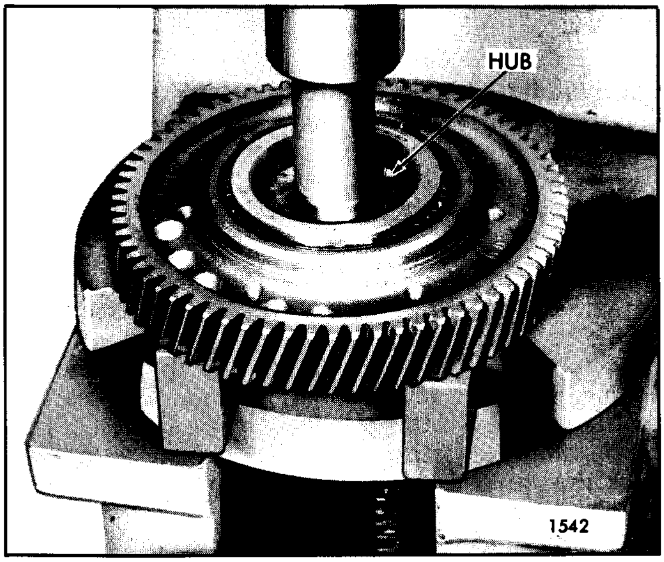


Fig. 5 - Pressing Hub Out of Bearing

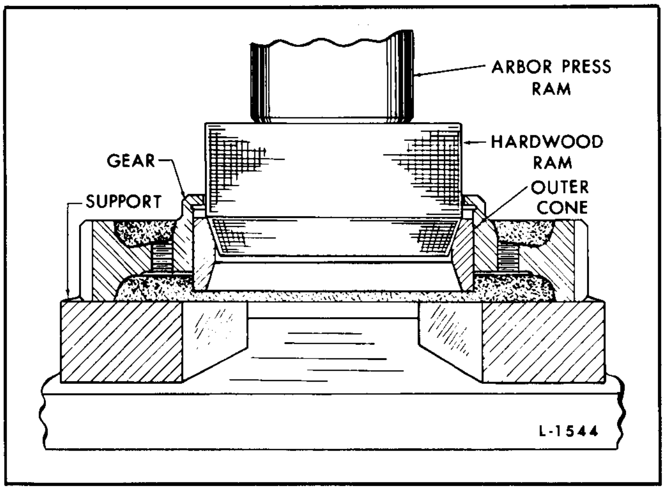


Fig. 6 - Hardwood Ram for Pressing Outer Bearing Race from Gear

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 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 or wear. If severely damaged or worn, replace the gear. Also, inspect the other gears in the gear train.

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:

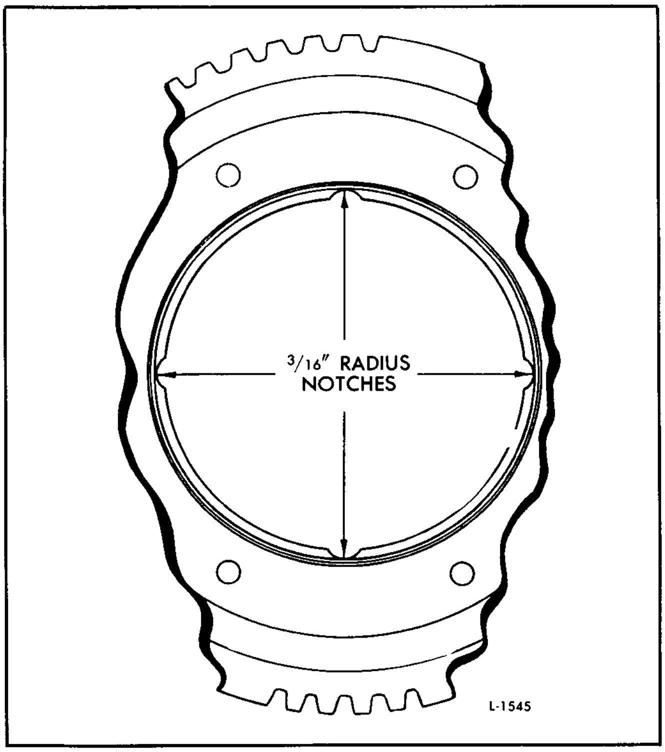


Fig. 7 - Location of Notches in Idler Gear

The current idler gear bearing is a matched assembly. *Do not* mix the components with those of another gear.

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

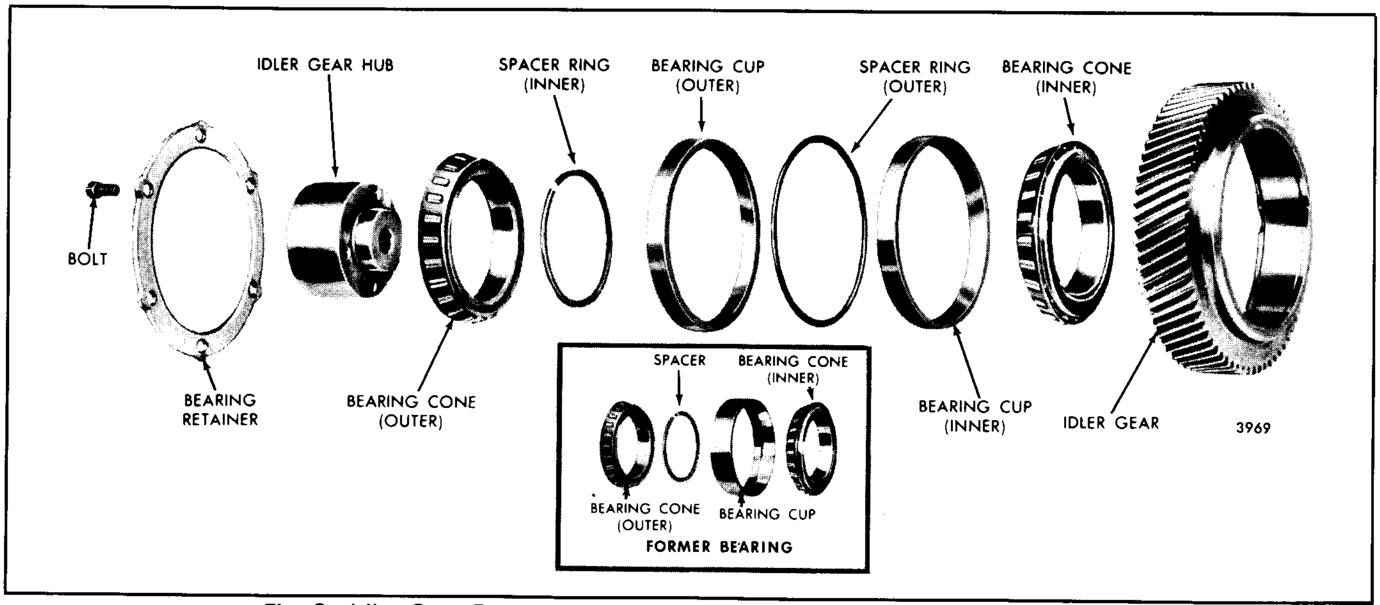


Fig. 8 - Idler Gear Details and Relative Location of Parts (Current Bearing)

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.
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).

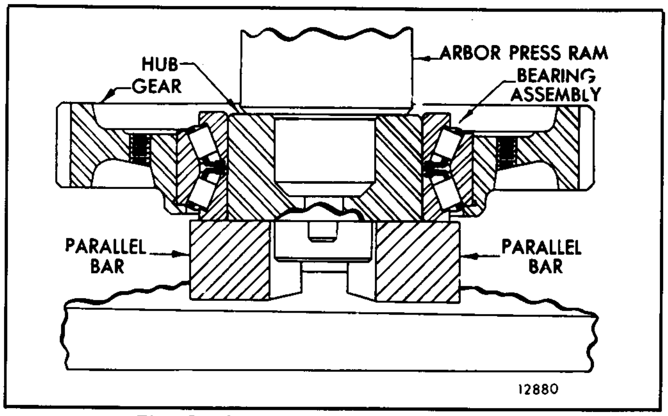


Fig. 9 - Pressing Hub into Bearing

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 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 (54-61 N·m) torque.
3. Place the steel plate (lower plate shown in Fig. 10) 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 (54-61 N·m) torque and the 5/16″-18 bolt to 19-23 lb-ft (26-31 N·m) 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. 11). 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 with two plates (Figs. 10 and 12). 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 nuts to 40-45 lb-ft (54-61 N·m) torque.

Check the pre-load as follows:

1. Clamp the idler gear between the two plates (Fig. 12). Insert the bolts and tighten the three 3/8″-16 bolts and nuts to 40-45 lb-ft (54-61 N·m) torque.

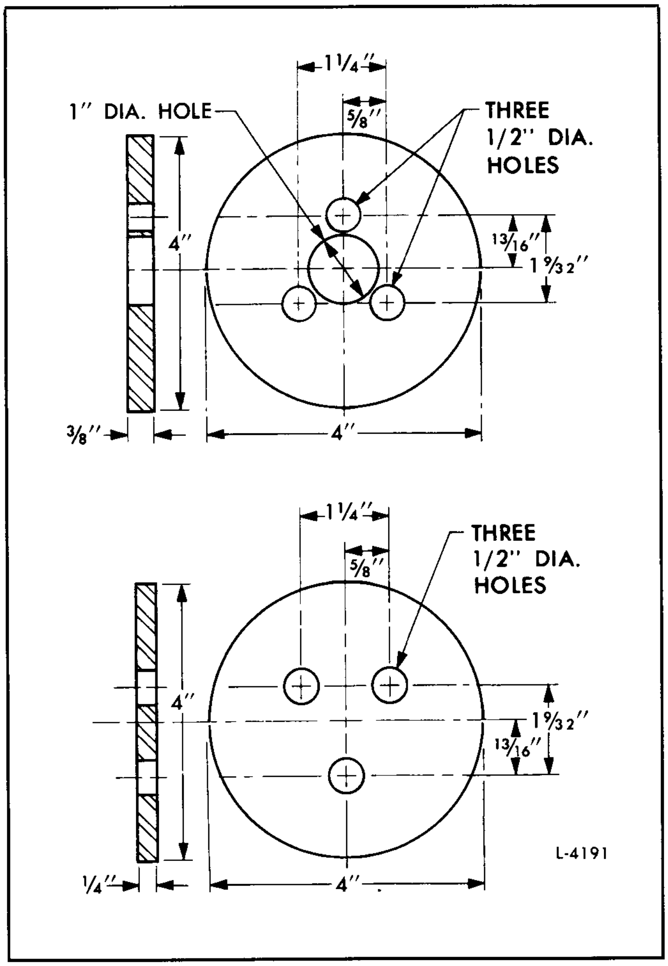


Fig. 10 - Plates for Bearing Test Fixture

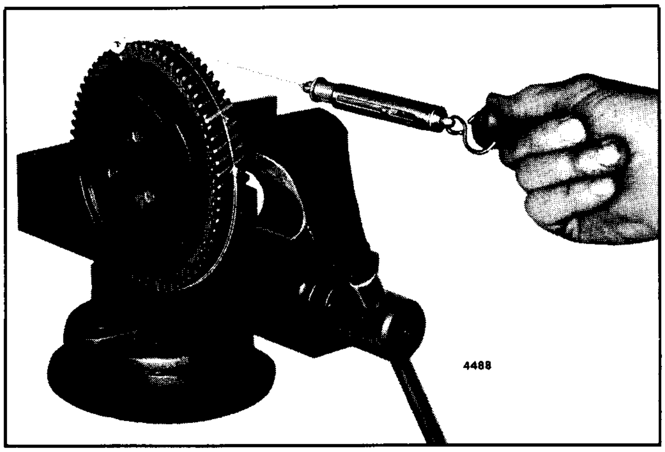


Fig. 11 - Checking Pre-Load of Idler Gear Bearing

2. Clamp the idler gear assembly and fixture in a vise (Fig. 10).
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

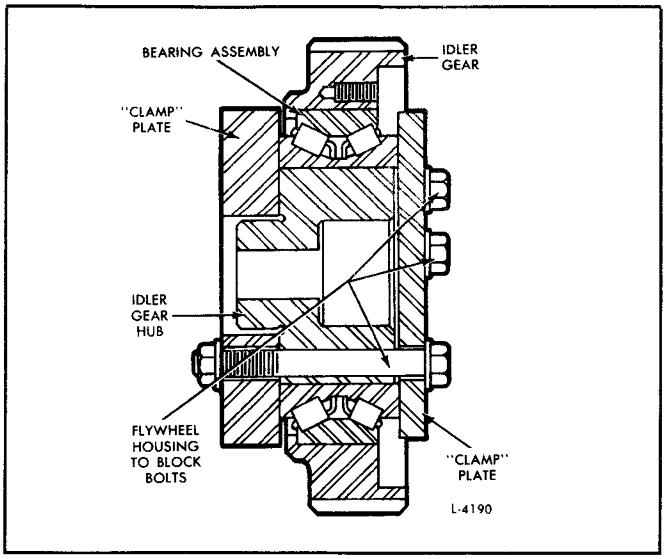


Fig. 12 - Fixture for Testing Bearing Pre-Load

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. 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 (16-20 N·m) 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 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 (54-61 N·m) 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 .0005" to .005" between new gears and should not exceed .007" between used gears.

CRANKSHAFT TIMING GEAR

IN-LINE AND 6V-53 ENGINES

The crankshaft timing gear is keyed and pressed on the crankshaft and drives the camshaft gear (In-line or 6V-53 engines) or balance shaft gear (In-line engines) through an idler gear. A quiet gear train was introduced in 53 Series engines effective with engines 3D-170683, 4D-180939 and 6D-196535.

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 for gear train timing and identification of the new quiet gears and the former gears).

Remove Crankshaft Timing Gear (Flywheel Housing Removed)

The former crankshaft timing gear is a .001" to .003" press fit on the crankshaft. The current 111 toothed gear is a .0015" to .0035" press fit on the crankshaft. The crankshaft diameter at this point is 4.060" to 4.061". 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 (Fig. 1).

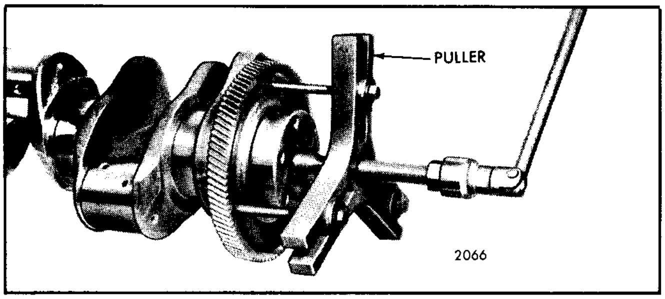


Fig. 1 - Removing Crankshaft Timing Gear with Puller J 4871

4. Turn the center screw of the puller to pull the crankshaft gear off of the crankshaft.

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

Before the crankshaft timing gear is installed, measure the inside diameter of the gear and outside diameter of the butt end of the crankshaft to assure the correct press fit.

> The inside diameter of the current 111 tooth gear is 4.0575" to 4.0585". The former 97 tooth gear inside diameter is 4.0580" to 4.0590".
>
> The outside diameter of the butt end of the crankshaft is 4.060" to 4.061".

If either the crankshaft or gear are beyond specifications, replace the gear or the crankshaft.

Do not mix the former and the current hardened gears on the same engine. Mixing the gears will result in excessive gear wear and may lead to serious engine damage. The hardened gears are used on 3-53 turbocharged industrial and 6V turbocharged automotive engines. This change became effective with engine serial numbers 3D-193516 and 6D-229616.

1. If removed, install the Woodruff key in the keyway in the crankshaft.

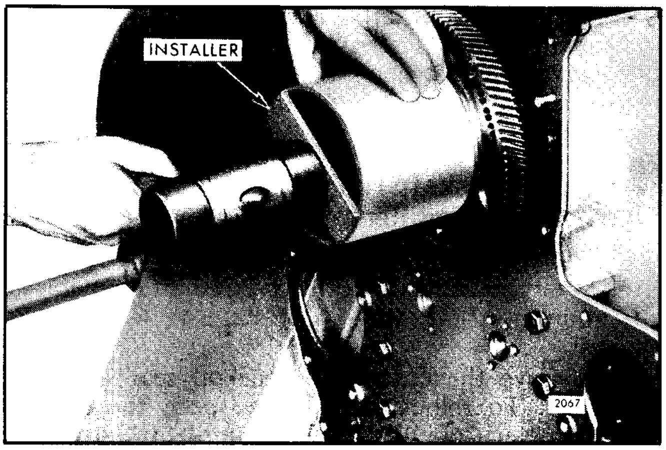


Fig. 2 - Installing Crankshaft Timing Gear using Installer J 7557

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).

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 drive the gear up against the shoulder on the crankshaft (Fig. 2).

5. Check the backlash between the mating gears. The backlash must be .0005" to .005" between new gears and should not exceed .007" between used gears.
6. Install a new crankshaft rear oil seal sleeve, if required, as outlined in Section 1.3.2.

8V-53 ENGINE

The crankshaft timing gear on an 8V-53 engine is keyed and fastened to the crankshaft with three 3/8"-24 x 3/4" socket head bolts (Fig. 3).

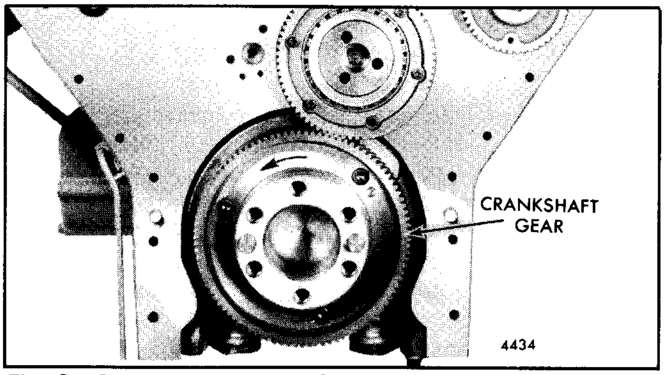


Fig. 3 - Crankshaft Timing Gear Mounting (R.H. Rotation Engine Shown)

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. The crankshaft diameter at this point is 4.060" to 4.061". 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 (J 4871).

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).

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 (47-53 N·m) torque.
5. Check the backlash between the mating gears. The backlash must be .0005" to .005" between new gears and should not exceed .007" between 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 ENGINES

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 on 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).

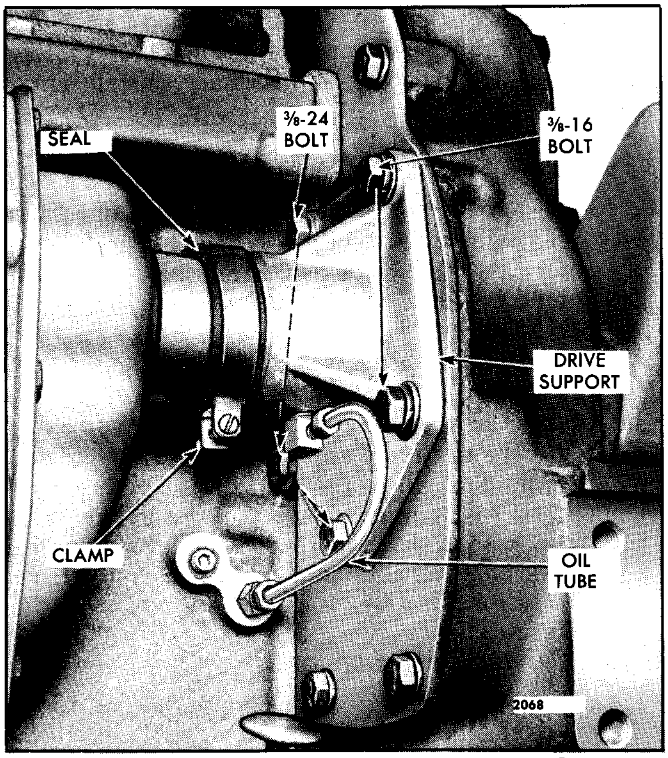


Fig. 1 - Blower Drive Support Mounting on 4-53 In-line Engine

Effective with engine serial numbers 4D-201579 and 6D-220736, new carbonitride-hardened blower drive shaft and a new steel induction-hardened blower coupling cam are being used in naturally aspirated and turbocharged engines. Carbontride hardening results in added resistance to shaft and coupling spline wear. To distinguish the new shafts from the former, one end of each new shafts is stamped with the letter "H". The non-counterbored face of the new cam is stamped with the letter "S". The former and the new components are not interchangeable, and only the new components will be serviced.

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).

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.

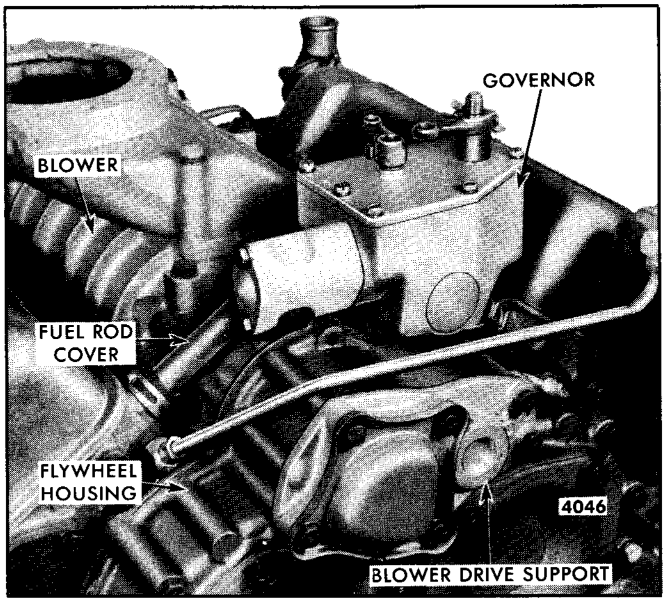


Fig. 2 - Blower Drive Support Mounting on 6V-53 Engine

Do not mix the former and the current hardened gears on the same engine. Mixing the gears will result in excessive gear wear and may lead to serious engine damage. The hardened gears are used on 3-53 turbocharged industrial and 6V turbocharged automotive engines. This change became effective with engine serial numbers 3D-193516 and 6D-229616.

Remove and Install Blower Drive Shaft

1. Remove the air inlet housing from the blower (refer to Section 3.3).
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 procedure.

Remove Blower Drive Support

1. Remove the blower and the blower drive shaft as outlined above.
2. Disconnect the lubricating oil tube from the blower drive support (Fig. 1).
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

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).

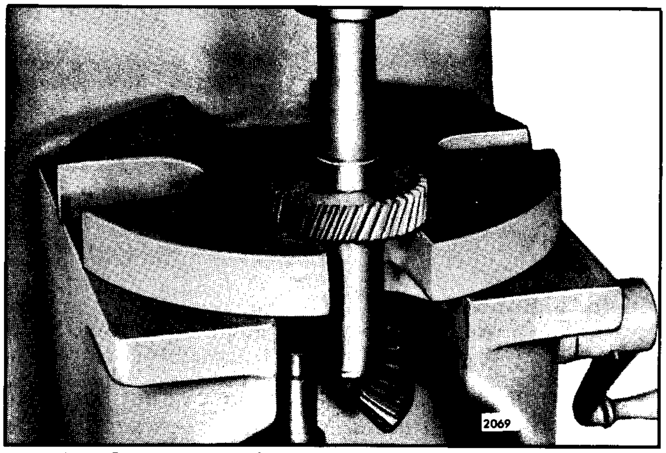


Fig. 3 - Pressing Blower Drive Gear From Shaft

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 or wear. If necessary, install a new gear.

Assemble Blower Drive Support

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 .012" (Fig. 5).

Install Blower Drive Support

1. Affix a new blower drive support gasket to the cylinder block rear end plate.

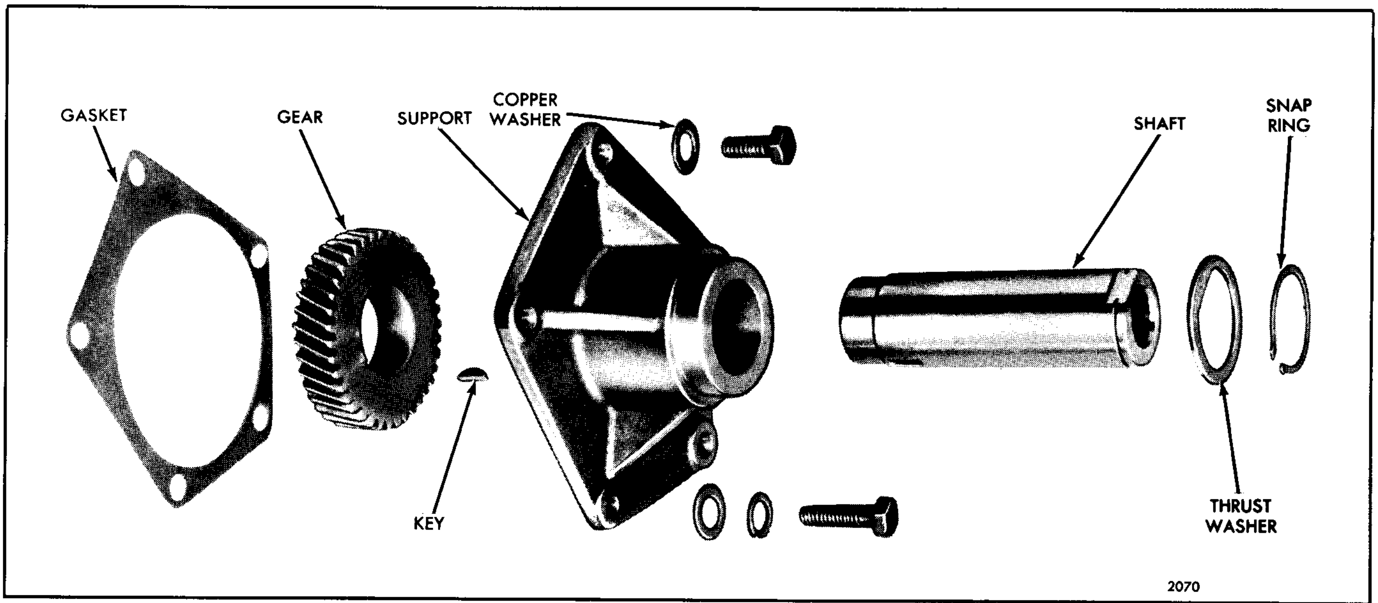


Fig. 4 - Blower Drive Gear and Support Assembly Details and Relative Location of Parts (In-line Engine)

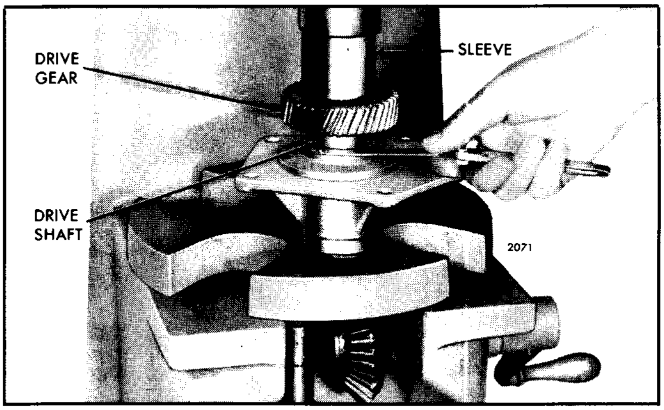


Fig. 5 - Pressing Blower Drive Gear On Shaft

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 (47 N·m) torque.

8V-53 ENGINE

The blower drive gear is driven by the right-bank camshaft gear. The drive gear is pressed on 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

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:

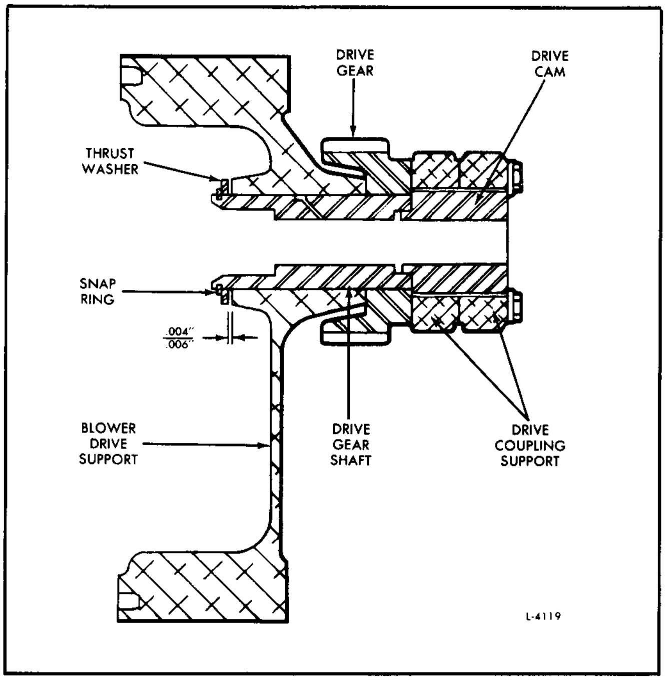


Fig. 6 - Blower Drive Support Assembly

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.

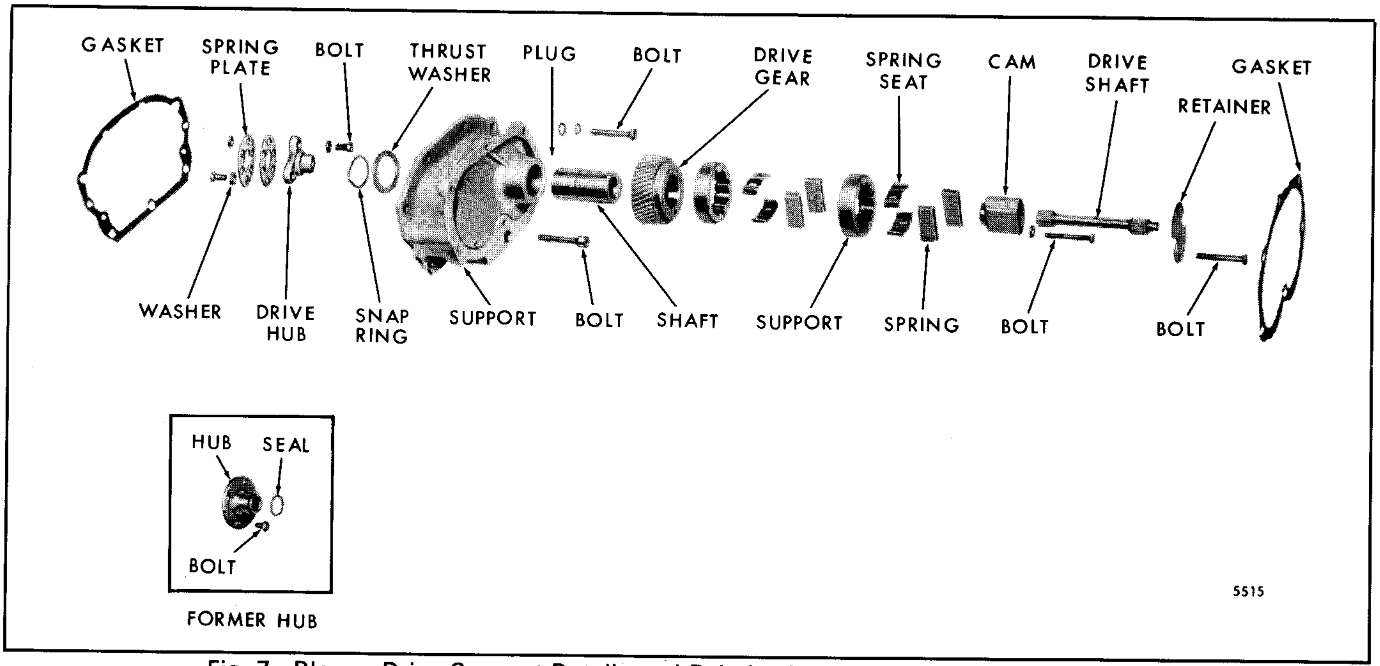


Fig. 7 - Blower Drive Support Details and Relative Location of Parts (8V-53 Engine)

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 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 or wear. If necessary, install a new gear.

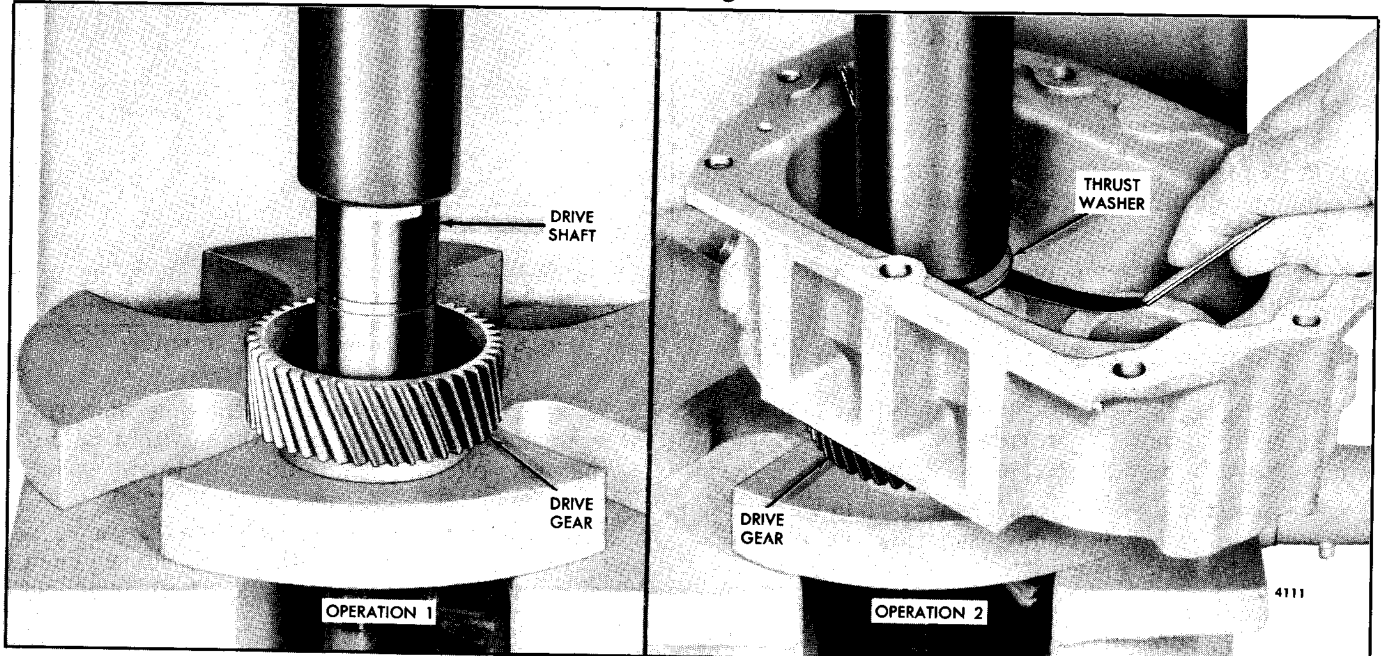


Fig. 8 - Installing Blower Drive Gear Shaft in Drive Gear

Assemble Blower Drive Support

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 (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 (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" to .012" (Fig. 6).

Install Blower Drive Support

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 (27-33 N·m) 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.

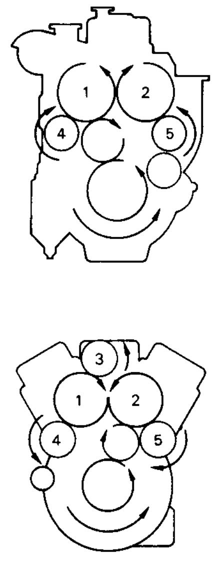
For the possible accessory drive locations and rotation of the drive at a particular position, refer to Fig. 1.

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



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

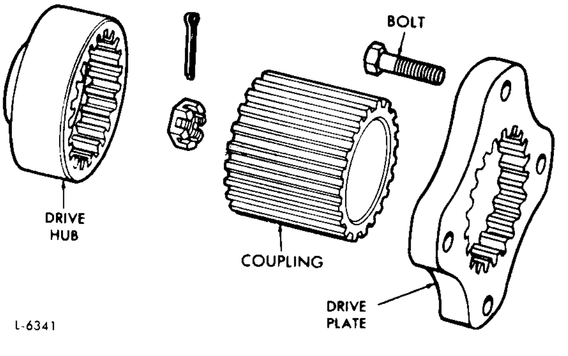


Fig. 2 - Air Compressor Drive

pulley (Fig. 4), or a spacer, accessory drive plate, accessory drive shaft, accessory drive retainer assembly and pulley (Fig. 5).

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.

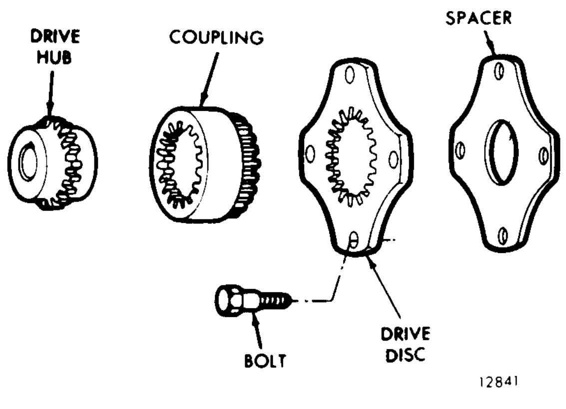


Fig. 3 - Hydraulic Pump Drive

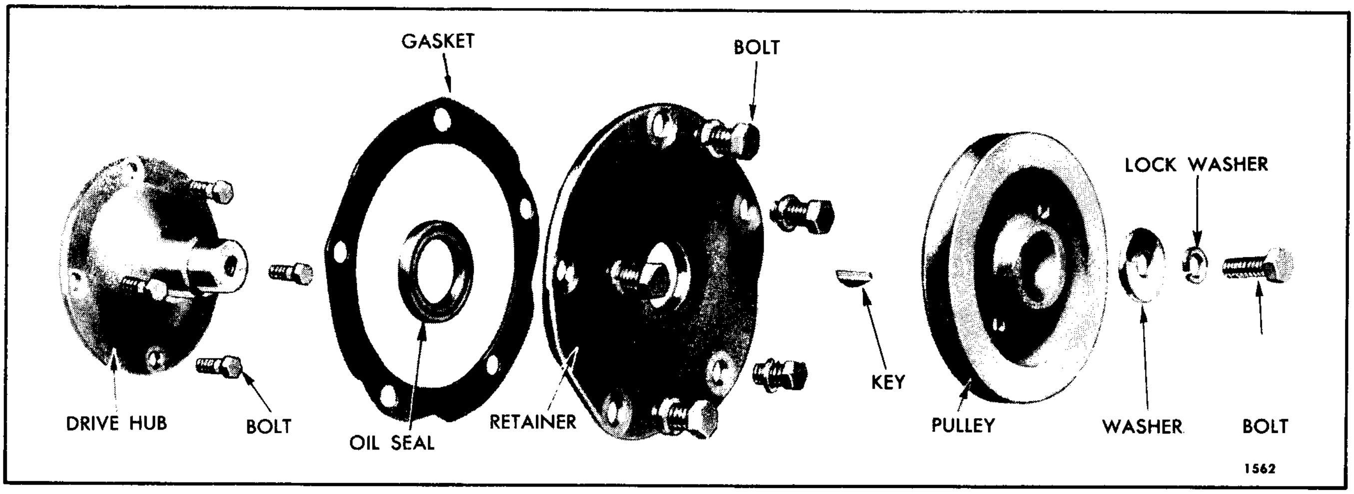


Fig. 4 - Components of Accessory Drive for Belt-Driven Accessory (Drive Hub Type)

Remove Accessory Drive

Remove the direct gear-driven type accessory drive as follows:

1. Remove any external piping or connections to the accessory.

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:

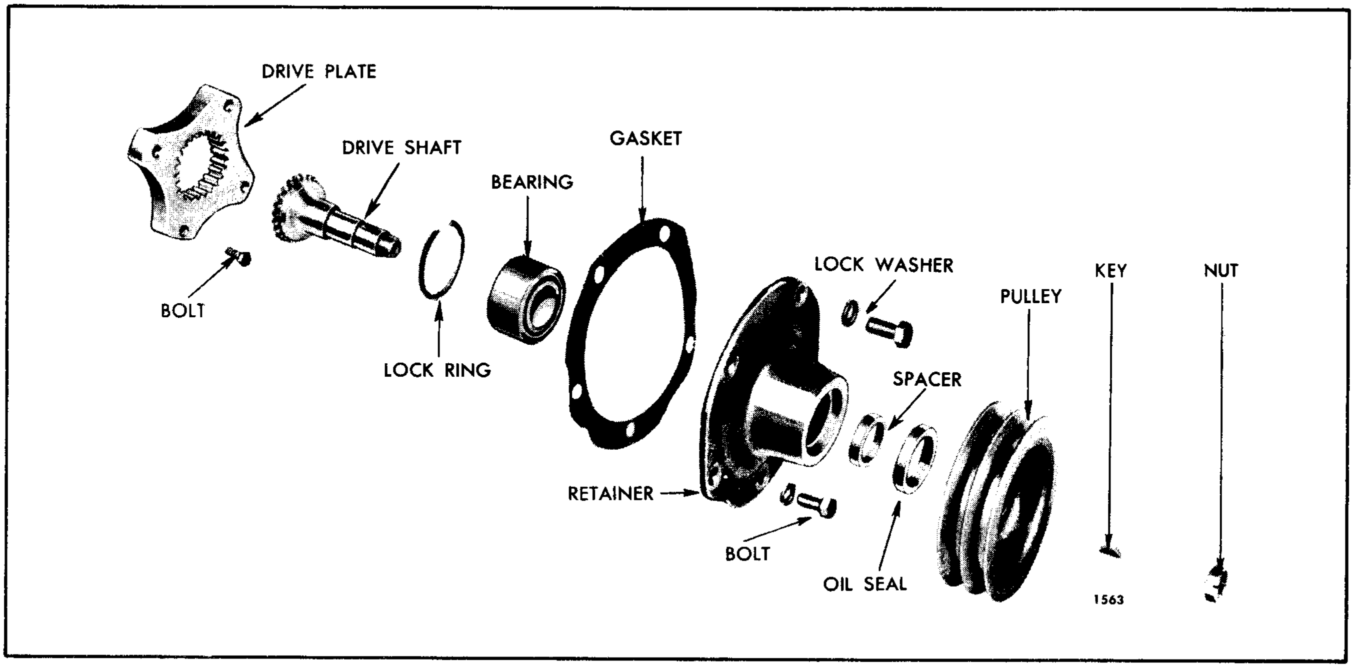


Fig. 5 - Components of Accessory Drive for Belt-Driven Accessory (Drive Plate Type)

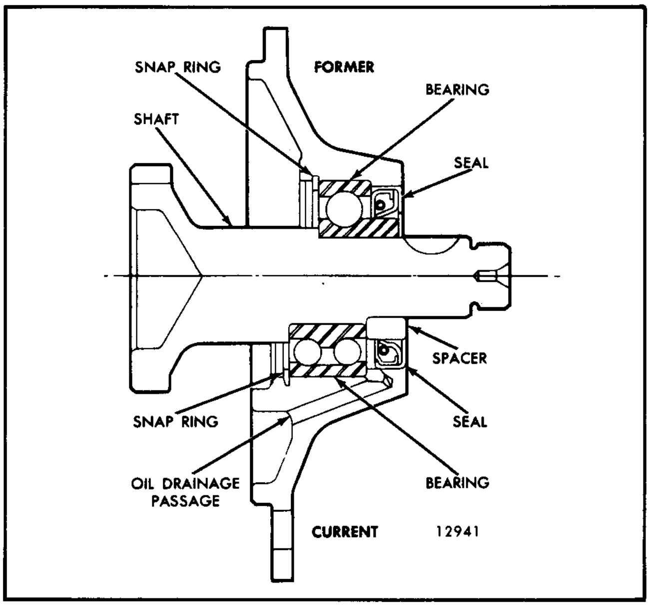


Fig. 6 · Former and Current Drive Plate Type Accessory Drive

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.

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.

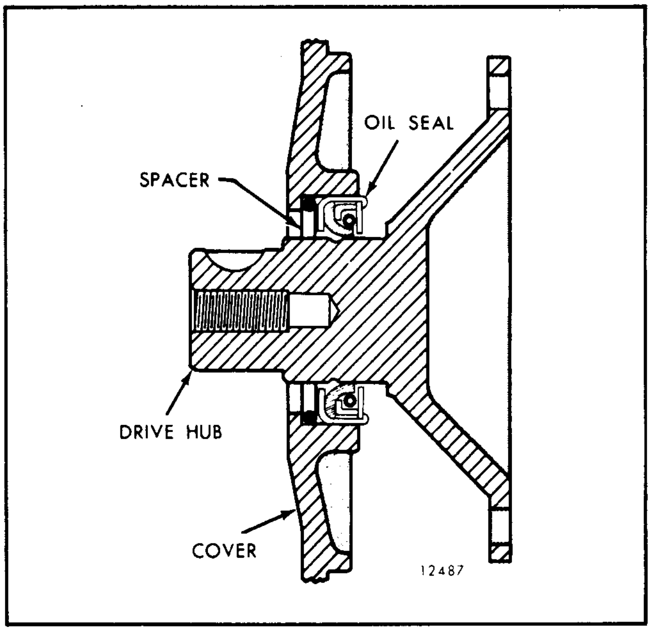


Fig. 7 · Location of Oil Seal Spacer

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. 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. *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, then:

NOTE: When replacing the drive hub on the accessory shaft, drive the hub squarely on the shaft (refer to Section 12.4).

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.

NOTE: 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 Nm) 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.

NOTE: When installing or adjusting an accessory drive belt(s), be sure the bolt at the accessory adjusting pivot point is properly tightened, as well as the bolt in the adjusting slot.

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.

NOTE: When installing or adjusting an accessory drive belt(s), be sure the bolt at the accessory adjusting pivot point is properly tightened, as well as the bolt in the adjusting slot.

ENGINE FRONT COVER (Upper)

In-Line and 6V Engines

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.

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 sub-assemblies 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.

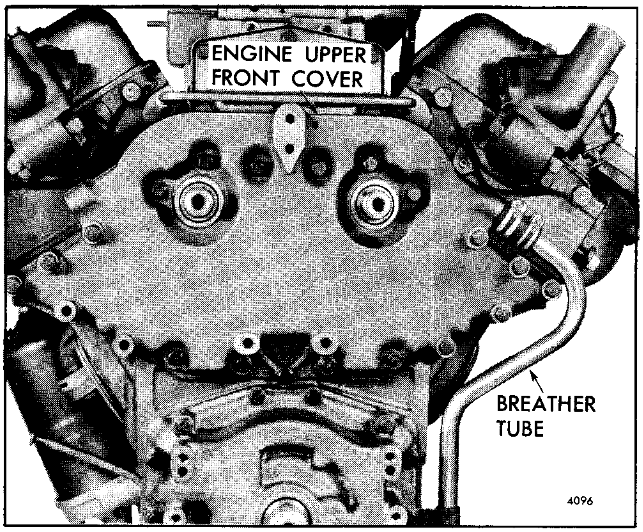


Fig. 1 - 6V Engine Upper Front Cover Mounting

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.

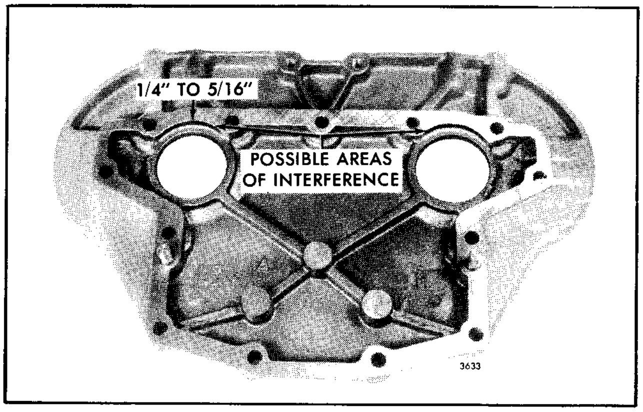


Fig. 2 - In-Line Engine Upper Front Cover

3. Position a new oil seal in the cover with the lip of the seal pointing toward the inner face of the cover.

> **CAUTION:** 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 Nm) torque.

3. Apply cup grease to the outside diameter of the oil seal spacers, then slide them on the shafts.

> **NOTE:** 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 Nm) torque.

SHOP NOTES - TROUBLESHOOTING - SPECIFICATIONS SERVICE TOOLS

SHOP NOTES

CHECKING BEARING CLEARANCES

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.

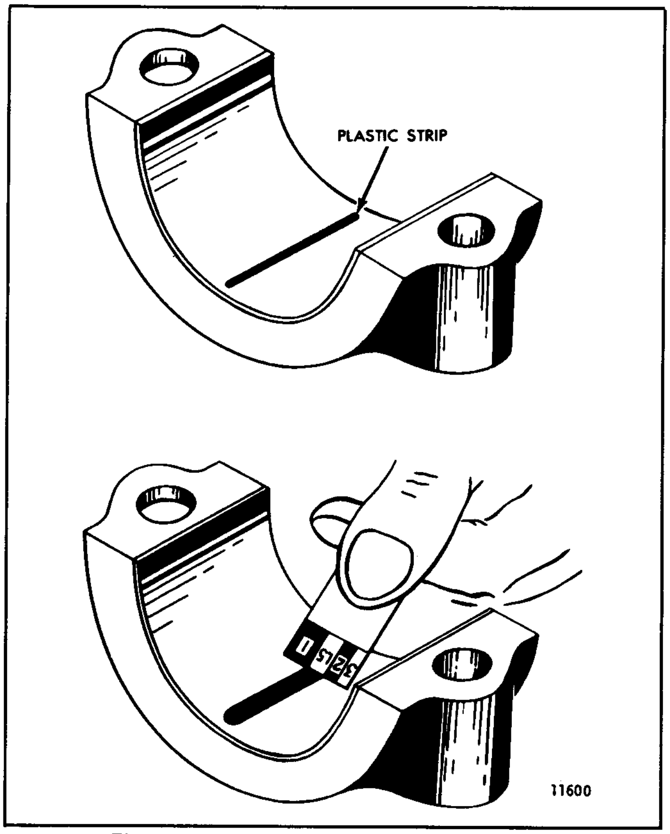


Fig. 1 - Using Plastic Strip to Measure Bearing-to-Crankshaft Clearance

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 than the other. 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").

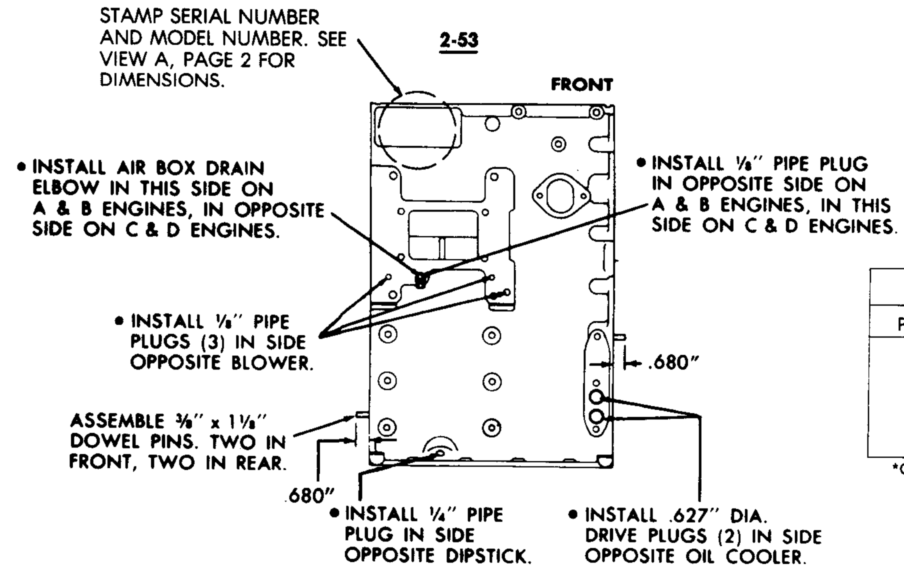
After installing oversize O.D. main bearing shells, always check bearing clearances before putting the engine back in service. Use the procedure found in this section.

REUSING CROSS-HEAD 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 cross-head 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 cross-head piston assembly components, see "wear limits" in the Specifications portion of this Section.

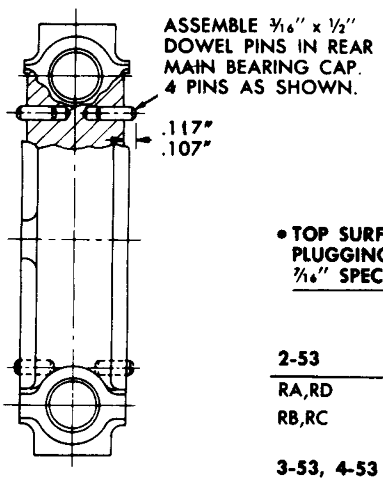
CYLINDER BLOCK PLUGGING INSTRUCTIONS (IN-LINE ENGINES)



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



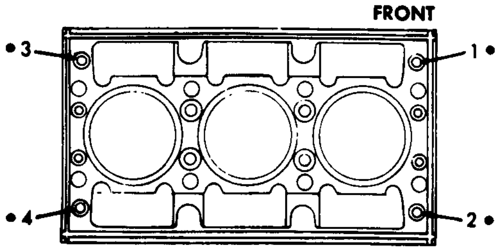
NOTES

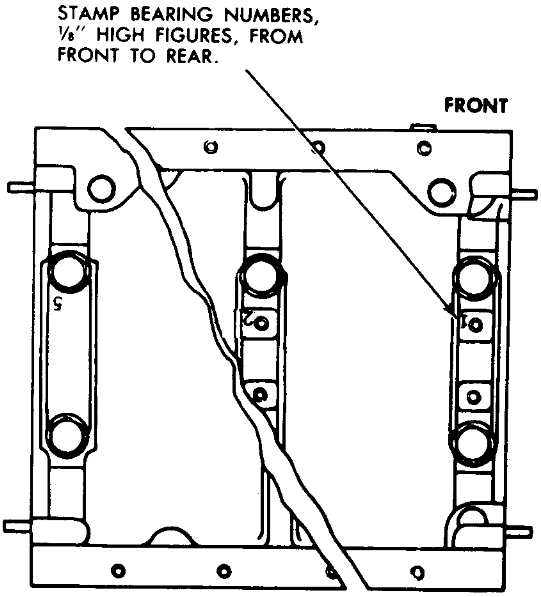
1. INSTALL PLUGS FLUSH TO BELOW TOP OF FINISHED SURFACES OF BLOCK.

- **APPLY LOCTITE J 26558-92 PIPE SEALER WITH TEFLON OR EQUIVALENT TO BE APPLIED PRIOR TO INSTALLATION.**

• TOP SURFACE PLUGGING INSTRUCTIONS ⁷⁄₁₆" SPECIAL CUP PLUG

	HOLES PLUGGED 1	2	3	4
2-53				
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	





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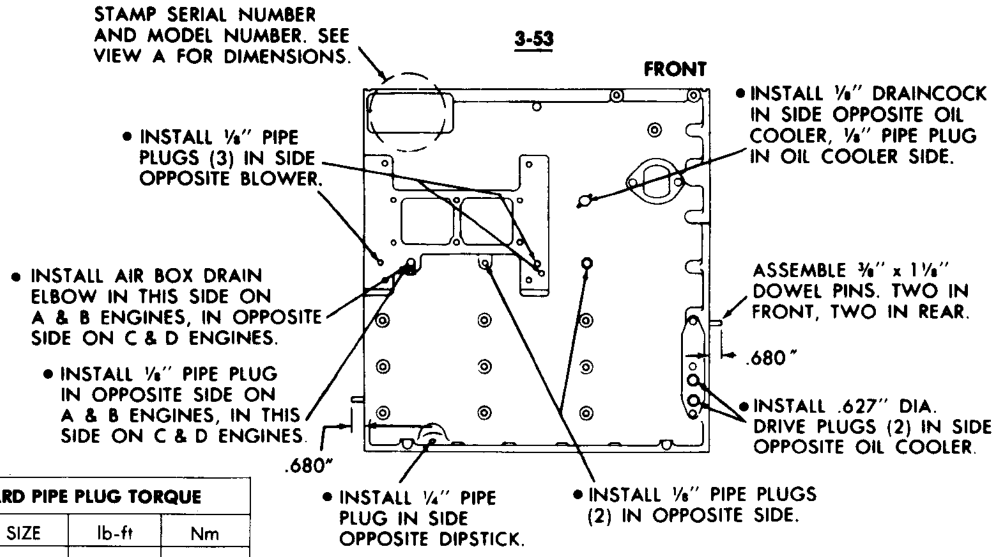
CYLINDER BLOCK PLUGGING INSTRUCTIONS (IN-LINE ENGINES)

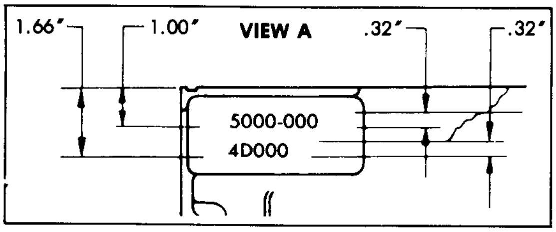


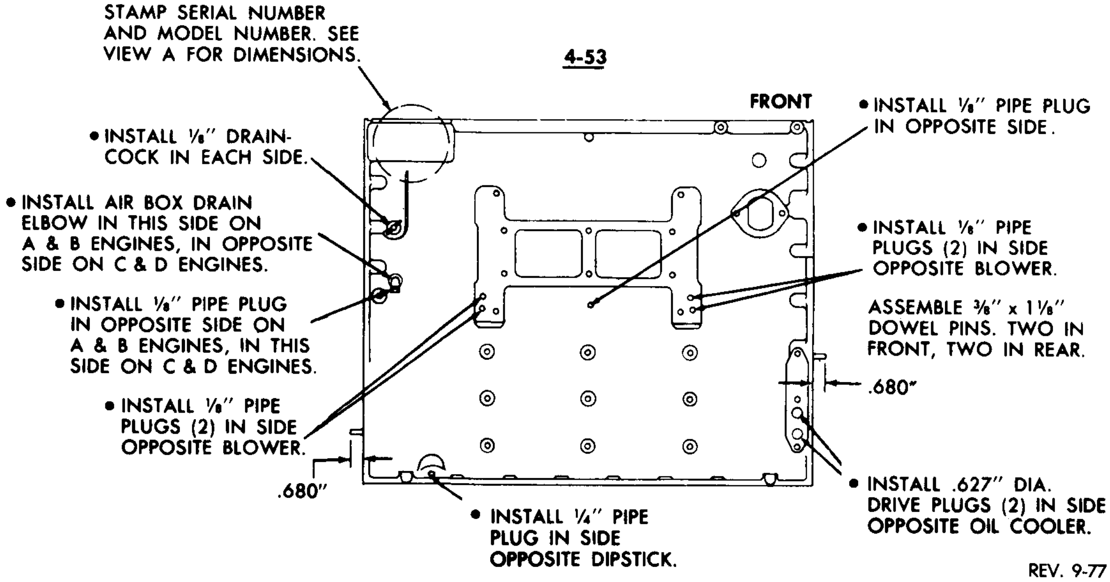
STANDARD PIPE PLUG TORQUE		
PIPE PLUG SIZE	lb-ft	Nm
1/8	10-12	14-16
1/4	14-16	19-22
3/8	18-22	24-30
1/2	23-27	31-37
3/4	33-37	45-50

NOTES

1. INSTALL PLUGS FLUSH TO BELOW TOP OF FINISHED SURFACES OF BLOCK.

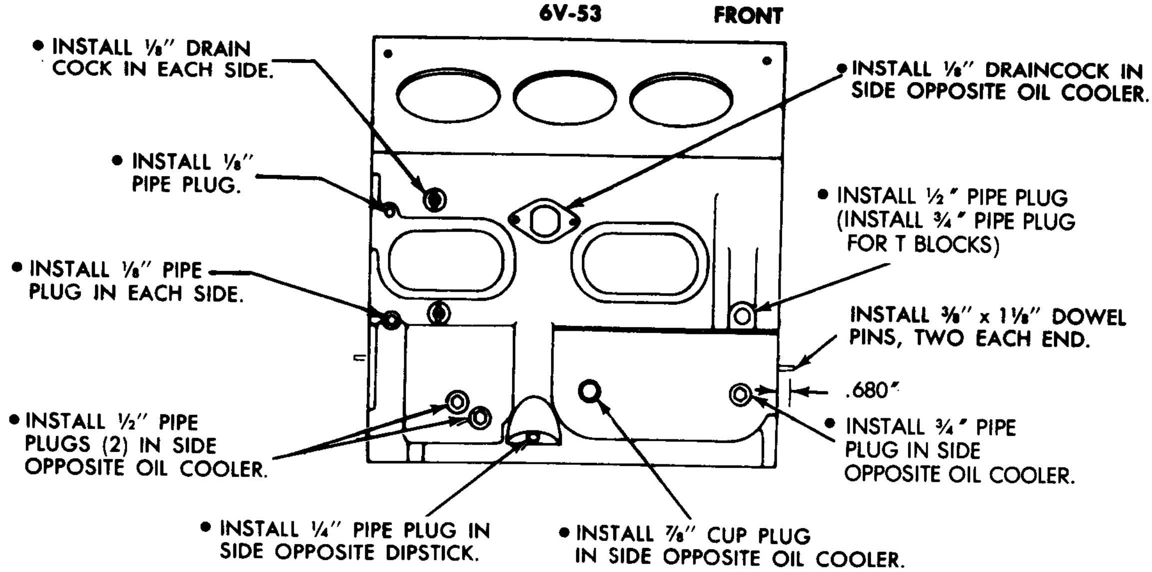
- **APPLY LOCTITE J 26558-92 PIPE SEALER WITH TEFLON OR EQUIVALENT TO BE APPLIED PRIOR TO INSTALLATION.**





REV. 9-77

CYLINDER BLOCK PLUGGING INSTRUCTIONS (6V AND 8V ENGINES)



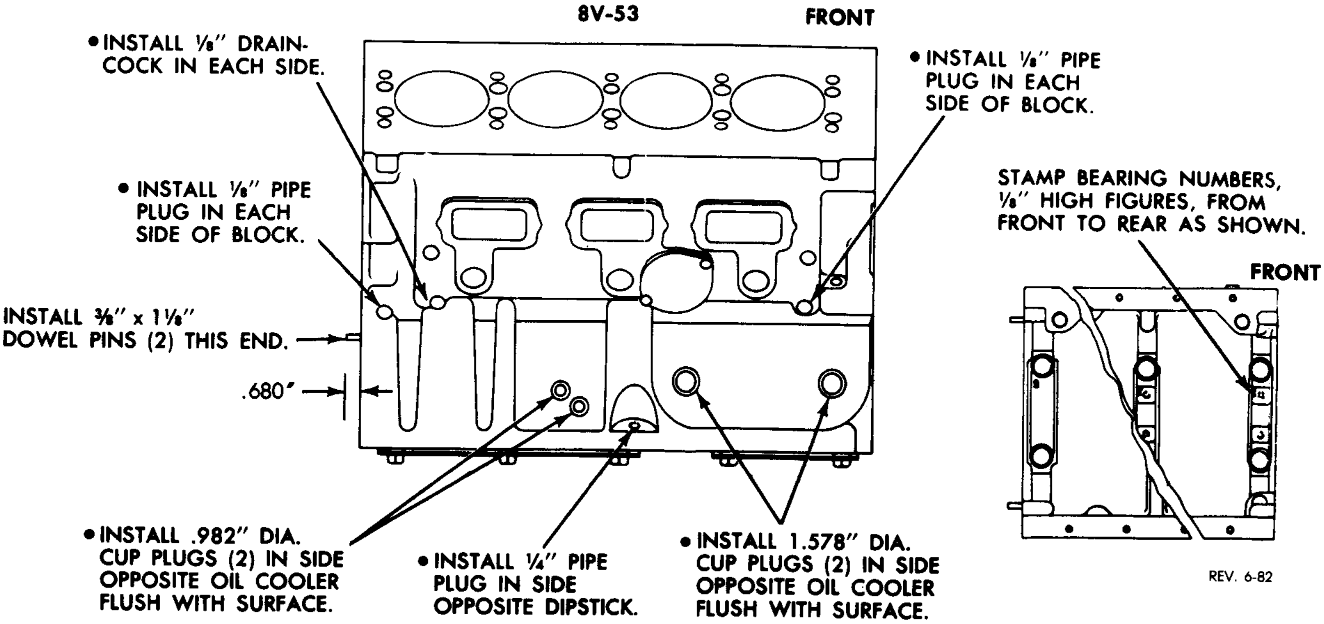
NOTES

1. INSTALL PLUGS FLUSH TO BELOW TOP OF FINISHED SURFACES OF BLOCK.

- **APPLY LOCTITE J 26558-92 PIPE SEALER WITH TEFLON OR EQUIVALENT TO BE APPLIED PRIOR TO INSTALLATION.**

STANDARD PIPE PLUG TORQUE

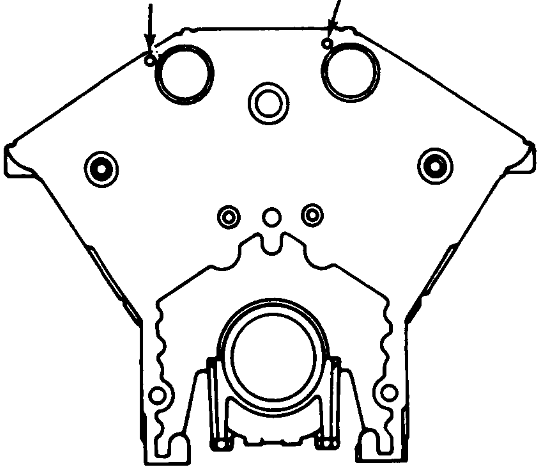
PIPE PLUG SIZE	lb-ft	Nm
1/8	10-12	14-16
1/4	14-16	19-22
3/8	18-22	24-30
1/2	23-27	31-37
3/4	33-37	45-50



CYLINDER BLOCK PLUGGING INSTRUCTIONS (6V AND 8V ENGINES)

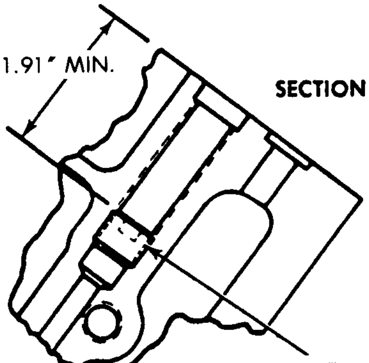
INSTALL $\frac{5}{16}$" x $\frac{5}{16}$" DOWEL PIN AT EACH END. (COPPER-FLASHED FOR 8V-53, PLAIN FOR 6V-53) FLUSH TO .020" BELOW SURFACE.

• INSTALL $\frac{5}{16}$" 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 $\frac{5}{8}$" SOCKET CUP SET SCREW RIGHT AND LEFT BANK AT REAR 8V-53 ONLY

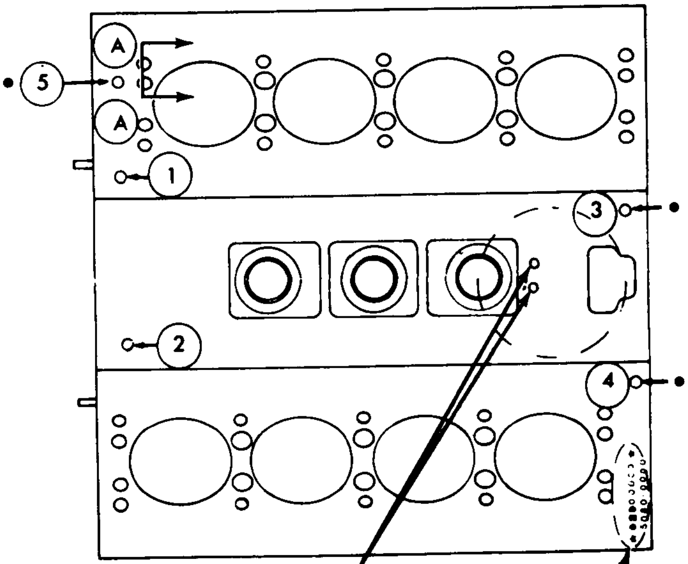
TOP SURFACE PLUGGING INSTRUCTIONS

USE $\frac{5}{16}$" 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	

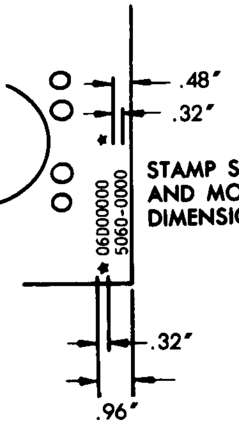
• *NO. 2 HOLE, PLUG WITH $\frac{5}{16}$" PLAIN DOWEL PIN. NO. 5 HOLE, PLUG WITH $\frac{1}{8}$" PIPE PLUG FLUSH TO .12" BELOW SURFACE.

FRONT

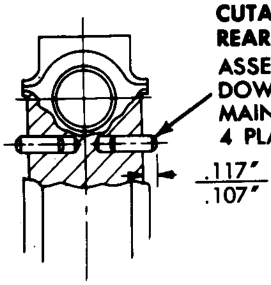


PLUG WITH .075" SPECIAL PLUG BLOCK 5149781 ONLY

NOTES
1. INSTALL PLUGS FLUSH TO BELOW TOP OF FINISHED SURFACES OF BLOCK.
•APPLY LOCTITE J 26558-92 PIPE SEALER WITH TEFLON OR EQUIVALENT TO BE APPLIED PRIOR TO INSTALLATION.



STAMP SERIAL NUMBER AND MODEL NUMBER TO DIMENSIONS SHOWN.



CUTAWAY SECTION OF REAR MAIN BEARING CAP

ASSEMBLE $\frac{5}{16}$" x $\frac{1}{2}$" DOWEL PINS IN REAR MAIN BEARING CAP. 4 PLACES

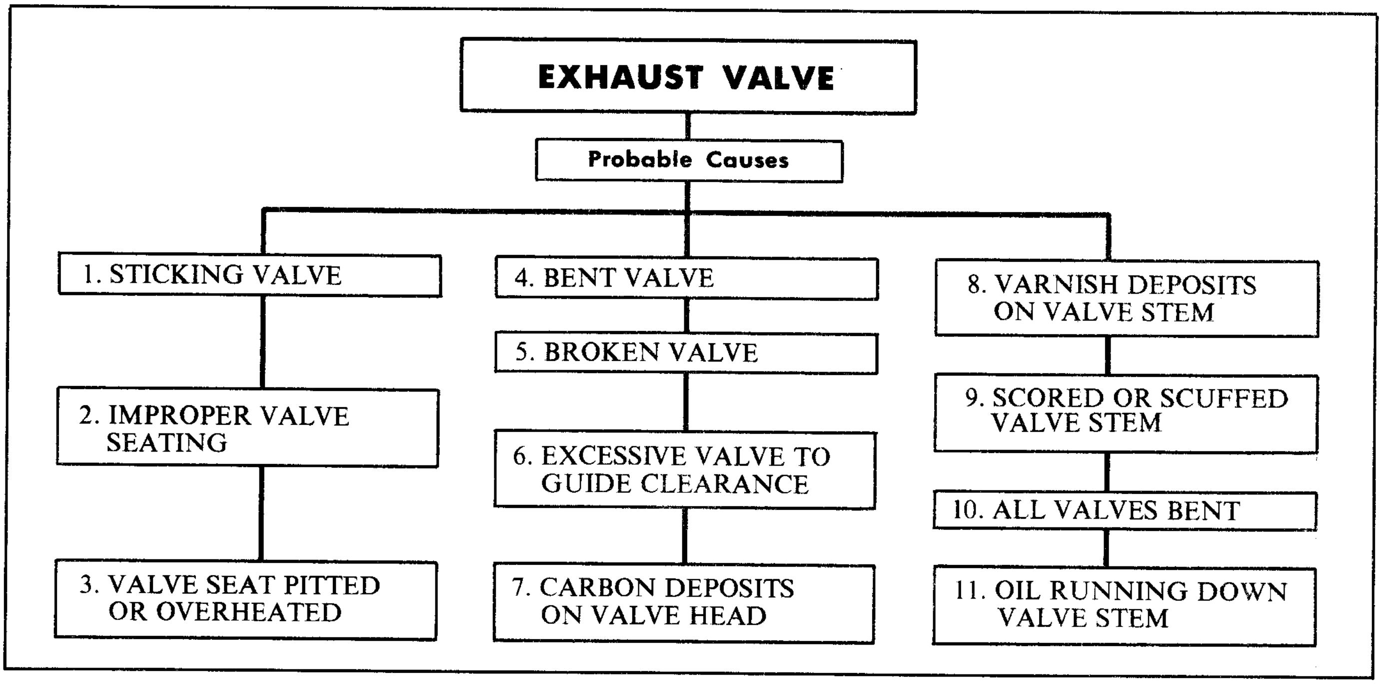
STANDARD PIPE PLUG TORQUE		
PIPE PLUG SIZE	lb-ft	Nm
1/8	10-12	14-16
1/4	14-16	19-22
3/8	18-22	24-30
1/2	23-27	31-37
3/4	33-37	45-50

REV. 6-82

SHOP NOTES

SHOP NOTES

TROUBLESHOOTING



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 jusgement 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 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 (CROSS-HEAD 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)	3.4990″	3.5000″	
Conn. rod bearing (In-line)	2.4990″	2.5000″	
Conn. rod bearing (V-Type)	2.7490″	2.7500″	
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″	
Runout at center bearing (mounted end brg.)		.0020″	
End thrust	.0030″	.0150″	.0190″
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)	Nm	NPTF SIZE THREAD	TORQUE (lb-ft)	Nm
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	280M OR BETTER TORQUE (lb-ft)	280M OR BETTER TORQUE Nm	THREAD SIZE	260M BOLTS TORQUE (lb-ft)	260M BOLTS TORQUE Nm
1/4 -20	7-9	10-12	1/4 -20	5- 7	7- 9
1/4 -28	8-10	11-14	1/4 -28	6- 8	8-11
5/16-18	13-17	18-23	5/16-18	10-13	14-18
5/16-24	15-19	20-26	5/16-24	11-14	15-19
3/8 -16	30-35	41-47	3/8 -16	23-26	31-35
3/8 -24	35-39	47-53	3/8 -24	26-29	35-40
7/16-14	46-50	62-68	7/16-14	35-38	47-51
7/16-20	57-61	77-83	7/16-20	43-46	58-62
1/2 -13	71-75	96-102	1/2 -13	53-56	72-76
1/2 -20	83-93	113-126	1/2 -20	62-70	84-95
9/16-12	90-100	122-136	9/16-12	68-75	92-102
9/16-18	107-117	146-159	9/16-18	80-88	109-119
5/8 -11	137-147	186-200	5/8 -11	103-110	140-149
5/8 -18	168-178	228-242	5/8 -18	126-134	171-181
3/4 -10	240-250	325-339	3/4 -10	180-188	244-254
3/4 -16	290-300	393-407	3/4 -16	218-225	295-305
7/8 - 9	410-420	556-569	7/8 - 9	308-315	417-427
7/8 -14	475-485	644-657	7/8 -14	356-364	483-494
1 - 8	580-590	786-800	1 - 8	435-443	590-600
1 -14	685-695	928-942	1 -14	514-521	697-705

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

12252

BOLT IDENTIFICATION CHART

EXCEPTIONS TO STANDARD BOLT AND NUT TORQUE SPECIFICATIONS

APPLICATION	THREAD	(lb-ft)	(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	3/8-24	20-28	27-38
Fuel line nuts	3/8-24	12-15	16-20
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
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
Flange mounted air compressor drive shaft nut	3/4-10	#	#
C/S end bolt pulley stamped "A"	1-14	200-220	271-298
Crankshaft end bolt (8V)	1-14	290-310	393-421
Camshaft 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
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
Pipe plug remover and installer (1/8″ dia.)	J 34650
Sled gage	J 22273-01
CYLINDER HEAD	
Cam follower service fixture	J 33421
Cylinder head guides (set of 2)	J 9665
Cylinder head lifter	J 22062-01
Injector body brush	J 8152
Piston ring gap feeler gage set	J 3172
Push rod remover (set of three)	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	J 7040
Dial gage	J 8165-2
Grinder	J 8165-1
Valve seat grinder adaptor kit (2-valve)	J 7924-02
Valve seat grinder adaptor kit (4-valve)	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)	J 23479-7
Valve seat insert remover collet (4-valve)	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
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

TOOL NAME	TOOL NO.
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
Remover 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 holder	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 conn. 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 retainer installer	J 23762-A
Piston pin retainer installer (cross-head)	J 35572
Piston pin retainer installer (turbo trunk)	J 24107-01
Piston pin retainer leak detector	J 23987-01
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

TOOL NAME	TOOL NO.
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

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.

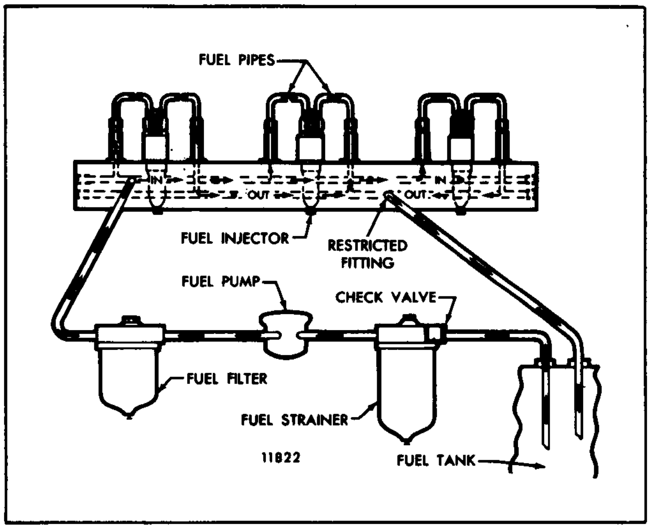


Fig. 1 - Typical Fuel System for In-Line Engines

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.

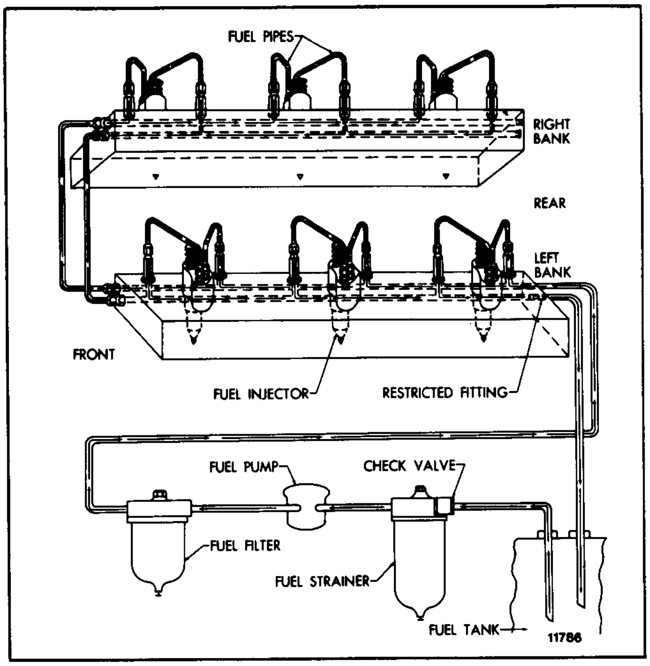


Fig. 2 - Fuel System for 6V-53 Engines

FUEL INJECTOR (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:

1. Creates the high fuel pressure required for efficient injection.

2. Meters and injects the exact amount of fuel required to handle the load.

3. Atomizes the fuel for mixing with the air in the combustion chamber.

4. Permits continuous fuel flow.

Combustion required for satisfactory engine operation is obtained by injecting, under pressure, a small

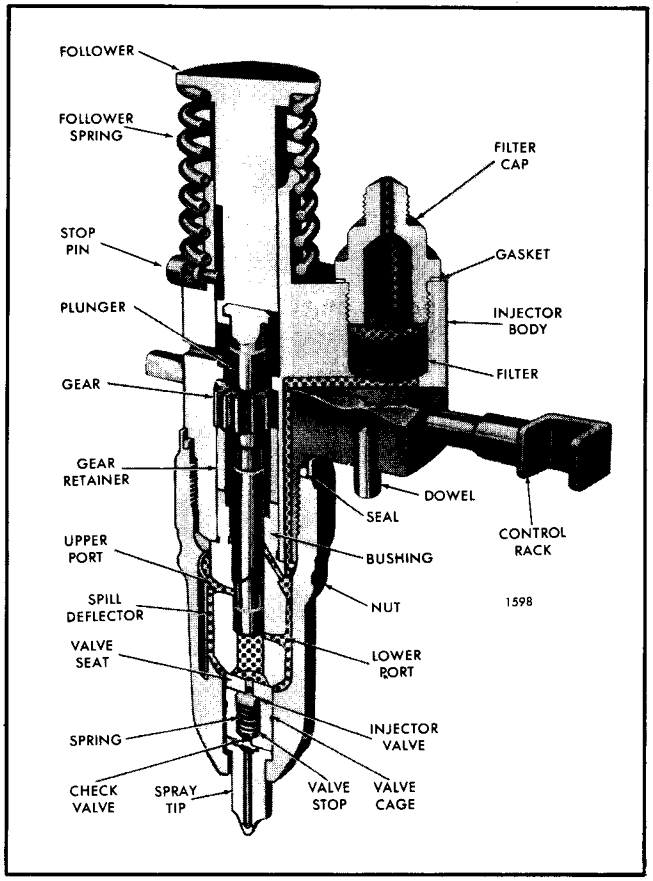


Fig. 1 - Fuel Injector Assembly

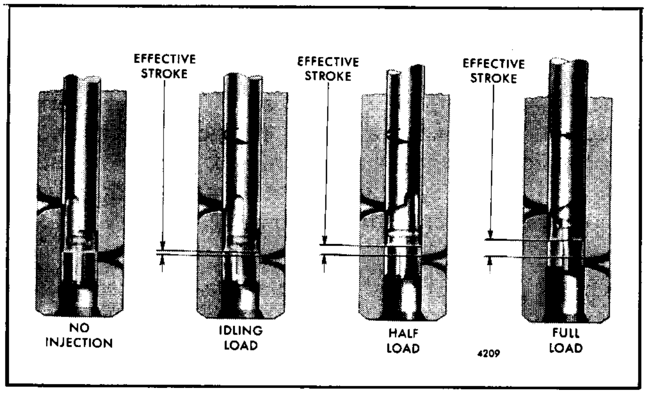


Fig. 2 - Fuel Metering from No-Load to Full-Load

quantity of accurately metered and finely atomized fuel oil into the cylinder.

Metering of the fuel is accomplished by an upper and lower helix machined in the lower end of the injector plunger. Figure 2 illustrates the fuel metering from no-load to full-load by rotation of the plunger in the bushing.

Figure 3 illustrates the phases of injector operation by the vertical travel of the injector plunger.

The continuous fuel flow through the injector serves, in addition to preventing air pockets in the fuel system, as a coolant for those injector parts subjected to high combustion temperatures.

To vary the power output of the engine, injectors having different fuel output capacities are used. The fuel output of the various injectors is governed by the

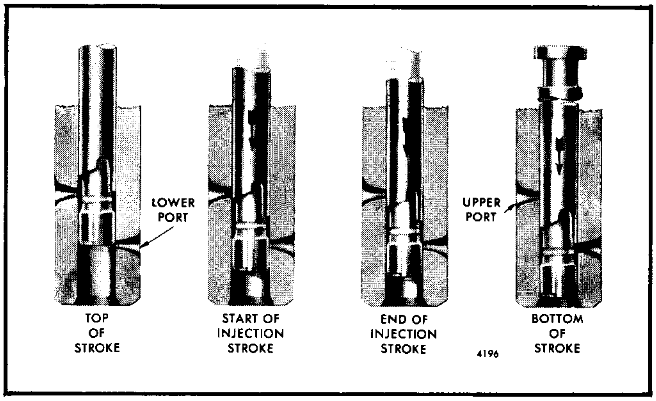


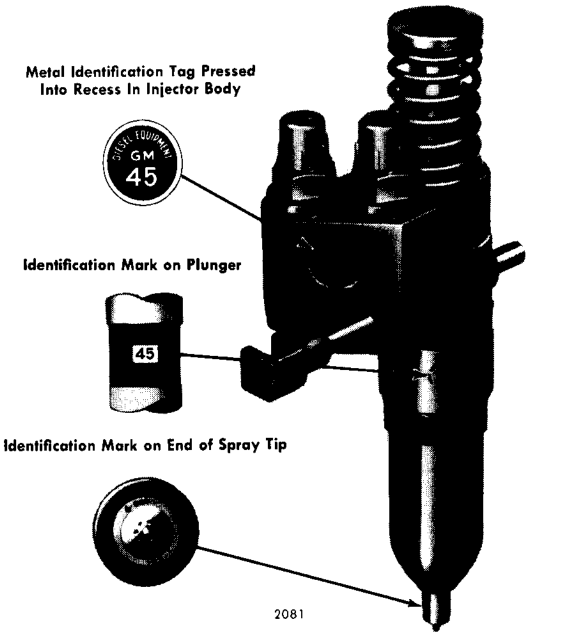
Fig. 3 - Phases of Injector Operation Through Vertical Travel of Plunger

helix angle of the plunger and the type of spray tip used. Refer to Fig. 4 for the identification of the injectors and their respective plungers and spray tips.

Since the helix angle on the plunger determines the output and operating characteristics of a particular type of injector, it is imperative that the correct injectors are used for each engine application. If injectors of different types are mixed, erratic operation will result and may cause serious damage to the engine or to the equipment which it powers.

Each fuel injector has a circular disc pressed into a recess at the front side of the injector body for identification purposes (Fig. 4). The identification tag indicates the nominal output of the injector in cubic millimeters.

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 of all of the injector racks.



INJECTOR	SPRAY TIP*	PLUNGER
35	8—.005—165	35
40	8—.005—165	40
45	8—.005—165	45
S40	8—.0055—165	40
S45	8—.0055—165	45
S50	8—.0055—165	55

*First numeral indicates number of spray holes, followed by size of holes and angle formed by spray from holes.

Fig. 4 - Injector Identification Chart

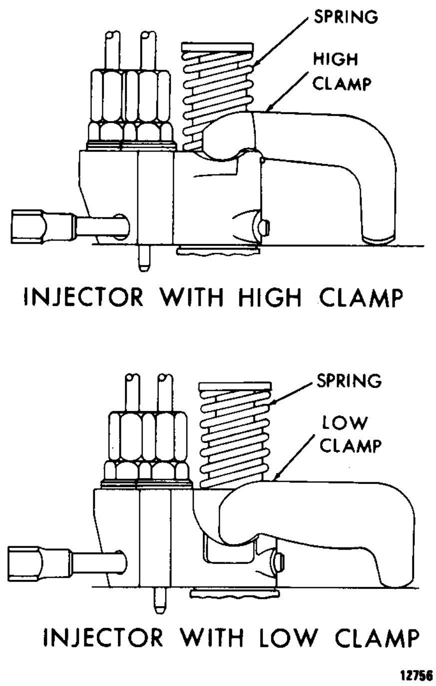


Fig. 5 - Comparison of High Clamp and Low Clamp Injectors

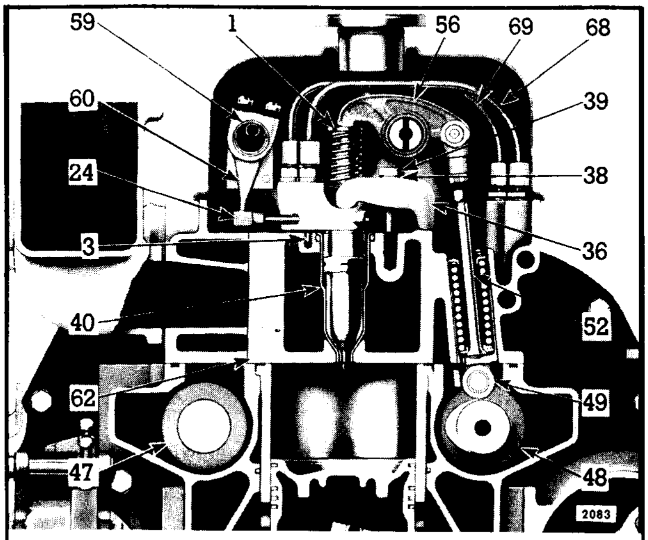
The injectors used in engines with a four valve cylinder head require an offset injector body due to the restricted area around the exhaust valve mechanism. A narrower injector clamp is required with the offset injector body and may be used with the standard injectors. Certain offset body injectors, designated as the "S" type, incorporate a clamp seat which is positioned lower on the injector body and require a different 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.

Operation

Fuel, under pressure, enters the injector at the inlet side through a filter cap and filter (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, the bore of which is open to the fuel supply in the annular chamber by two funnel-shaped ports in the plunger bushing.

The motion of the injector rocker arm is transmitted



1. Injector Assy.
3. Pin--Dowel
24. Rack--Injector Control
36. Clamp--Injector
38. Washer--Clamp
39. Bolt--Clamp
40. Tube--Injector Hole
47. Shaft--Balance
48. Camshaft
49. Cam Follower
52. Rod--Push
56. Arm--Injector Rocker
59. Tube--Injector Control
60. Lever--Rack Control
62. Head--Cylinder
68. Pipe--Fuel Inlet (Supply)
69. Pipe--Fuel Outlet (Return)

Fig. 6 - Fuel Injector Mounting

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, during operation, around its axis by the gear which meshes with the control rack. For metering the fuel, an upper helix and a lower helix are machined in the lower part of the plunger. The relation of the helices to the two ports changes with the rotation of the plunger.

As the plunger moves downward, under pressure of the injector rocker arm, a portion of that fuel trapped under the plunger is displaced into the supply chamber through the lower port until the port is closed off by the lower end of the plunger. A portion of the fuel trapped below the plunger is then forced up through a central passage in the plunger into the fuel metering recess and into the supply chamber through the upper port until that port is closed off by the upper helix of the plunger. With the upper and lower ports both closed off, the remaining fuel under the plunger is subjected to increased pressure by the continued downward movement of the plunger.

When sufficient pressure is built up, 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.

A check valve, mounted in the spray tip, prevents air leakage from the combustion chamber into the fuel injector if the valve is accidentally held open by a small particle of dirt. The injector plunger is then returned to its original position by the injector follower spring. Figure 3 shows the various phases of injector operation by the vertical travel of the injector plunger.

On the return upward movement of the plunger, the high pressure cylinder within the bushing is again filled with fuel oil through the ports. The constant circulation of fresh cool fuel through the injector renews the fuel supply in the chamber, helps cool the injector and also effectively removes all traces of air which might otherwise accumulate in the system and interfere with accurate metering of the fuel.

The fuel injector outlet opening, through which the excess fuel oil 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. Figure 2 shows the various plunger positions from no-load to full-load. With the control rack pulled out all the way (no injection), the upper port is not closed by the helix until after the lower port is uncovered. Consequently, with the rack in this position, all of the fuel is forced back into the supply chamber and no injection of fuel

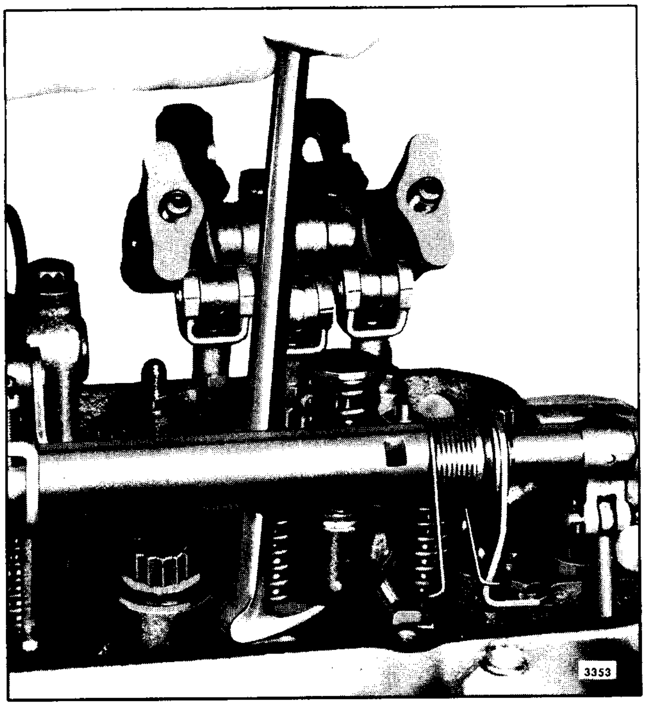


Fig. 7 - Removing Injector from Cylinder Head

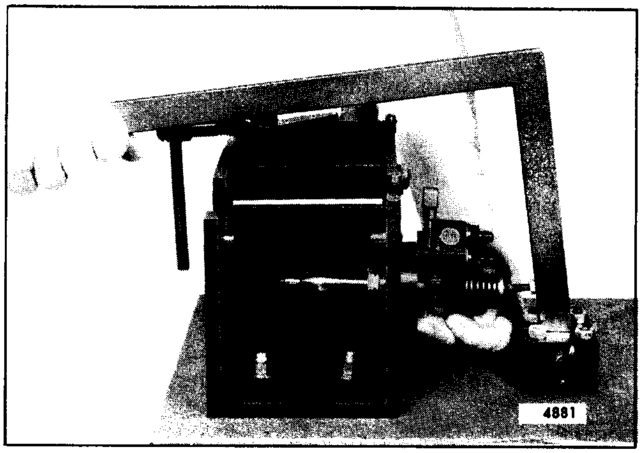


Fig. 8 - Checking Rack and Plunger For Free Movement using Tool J 22396

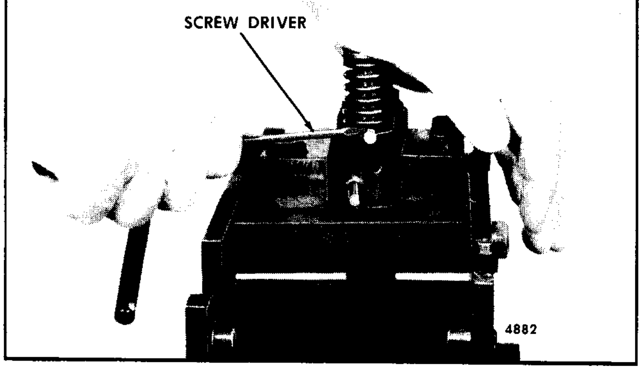


Fig. 9 - Removing Injector Follower Stop Pin

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 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. Also provide a source for 110 volt alternating current electric power.

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 agent, usually clean fuel oil, 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 cleaning tissue is a good, inexpensive 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. Also protect the fuel pipes and fuel connectors from 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 assembly 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).

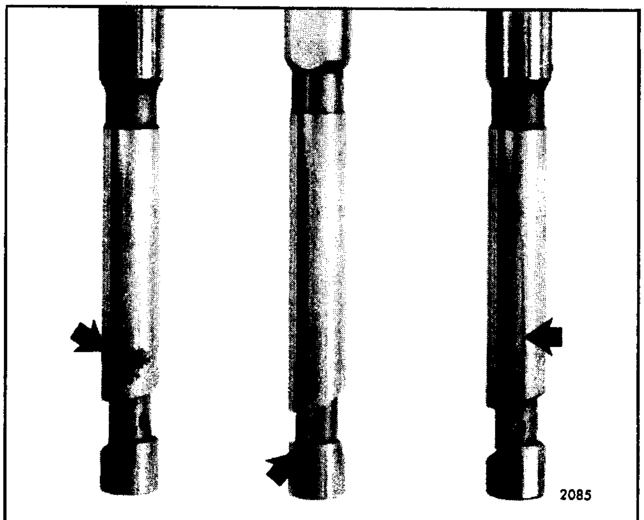


Fig. 10 - Unusable Injector Plungers

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.

> **NOTE:** 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.

2. Remove the fuel pipes from both the injector and the fuel connectors (Fig. 6).

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

3. Crank the engine to bring the outer ends of the push rods of the injector and valve rocker arms in line horizontally.

4. Remove the two rocker shaft bracket bolts and swing the rocker arms away from the injector and valves (Fig. 7).

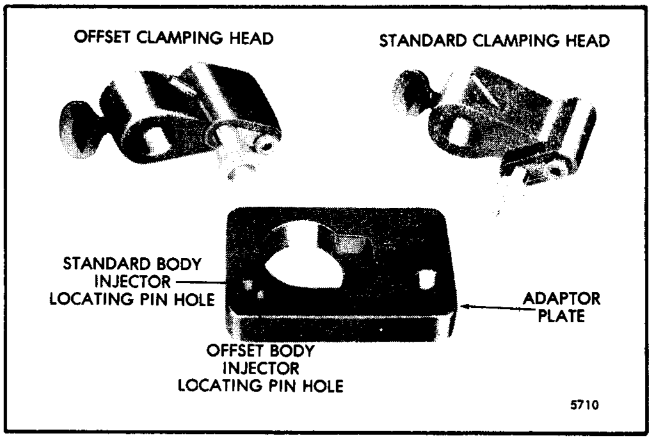


Fig. 11 - Injector Tester J 23010 Clamping Heads

5. Remove the injector clamp bolt, special washer and clamp.

6. Loosen the inner and outer adjusting screws 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).

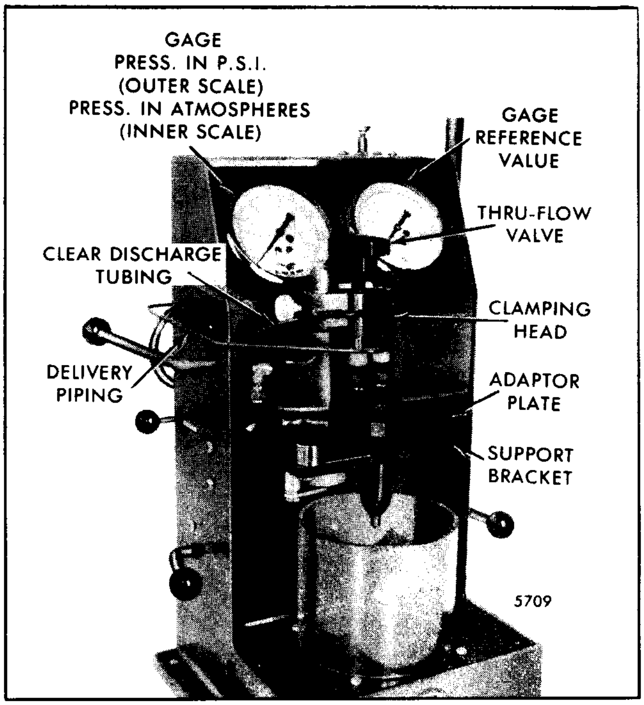


Fig. 12 - Injector Installed in Tester J 23010 with Clamping Head

8. Cover the injector hole in the cylinder head to keep foreign material out.

9. Clean the exterior of the injector with clean fuel oil and dry it with compressed air.

TEST INJECTOR

CAUTION: The fuel spray from an injector can penetrate the skin. Fuel oil which enters the blood stream can cause a serious infection. Therefore, follow instructions and use the proper equipment to test an injector.

If inspection does not reveal any external damage, then perform a series of tests to determine the condition of the injector to avoid unnecessary overhauling. Tests must be performed using injector test oil J 26400.

An injector that passes all of the tests outlined below may be considered to be satisfactory for service without disassembly, except for the visual check of the plunger.

However, an injector that fails to pass one or more of the tests is unsatisfactory. Perform all of the tests before disassembling an injector to correct any one condition.

Identify each injector and record the pressure drop and fuel output as indicated by the following tests:

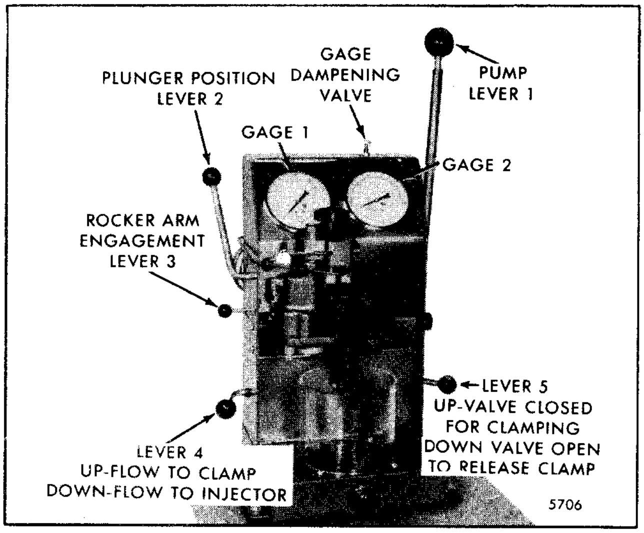


Fig. 13 - Injector in Position for Testing with Tester J 23010

Injector Control Rack and Plunger Movement Tests

Place the injector in the injector fixture and rack freeness tester J 22396. Refer to Fig. 8 and place the handle on top of the injector follower.

If necessary, adjust the contact screw in the handle to ensure the contact screw is at the center of the follower when the follower spring is compressed.

With the injector control rack held in the no-fuel position, push the handle down and depress the follower to the bottom of its stroke. Then very slowly release the pressure on the handle while moving the control rack up and down as shown in Fig. 8 until the follower reaches the top of its travel. If the rack does not fall freely, loosen the injector nut, turn the tip, then retighten the nut. Loosen and retighten the nut a couple of times if necessary. 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.

Visual Inspection of Plunger

An injector which passes all of the previous tests should have the plunger checked visually, under a magnifying glass, for excessive wear or a possible chip on the bottom helix. There is a small area on the bottom helix and lower portion of the upper helix, if chipped, that will not be indicated in any of the tests.

Remove the plunger from the injector as follows:

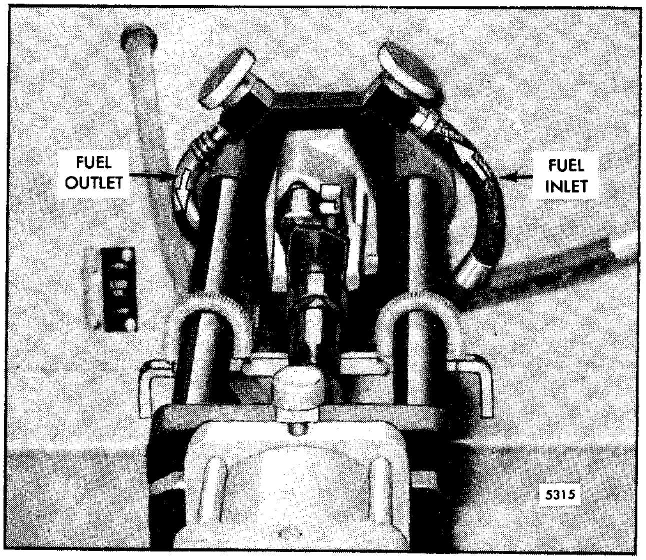


Fig. 14 - Position of Calibrator Fuel Flow Pipes

1. Support the injector, right side up, in holding fixture J 22396.

2. Compress the follower spring. Then raise the spring above the stop pin with a screw driver and withdraw the pin (Fig. 9). Allow the spring to rise gradually.

3. Remove the injector from the holding fixture. Turn the injector upside down, to prevent the entry of dirt, and catch the spring and plunger as they drop out.

4. Inspect the plunger. If the plunger is chipped (Fig. 10), replace the plunger and bushing assembly.

5. Reinstall the plunger, follower and spring.

Installing Fuel Injector in Tester J 23010

1. Select the proper clamping head (Fig. 11). Position it on the clamping post and tighten the thumb screw into the lower detent position (Fig. 12).

2. Connect the test oil delivery piping into the clamping head.

3. Connect the test oil clear discharge tubing onto the pipe on the clamping head.

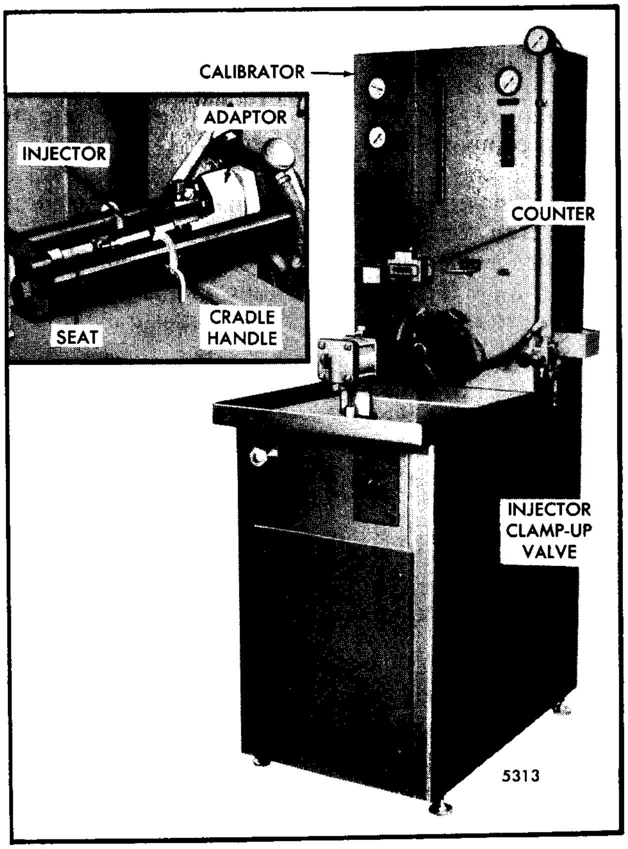


Fig. 15 - Injector in Calibrator J 22410

4. Locate the adaptor plate on top of the support bracket by positioning the 3/8" diameter hole at the far right of the adaptor plate onto the 3/8" diameter dowel pin. This allows the adaptor plate to swing out for mounting the injector.

5. Mount the injector through the large hole and insert the injector pin in the proper locating pin hole (Fig. 11).

6. Swing the mounted injector and adaptor plate inward until they contact the stop pin at the rear of the support bracket.

Clamping the Fuel Injector

1. Refer to Fig. 13 and position the tester levers as follows:

Lever 2 up and to the rear

Lever 3 in the rear detent position

Lever 4 up (horizontal)

Lever 5 up (horizontal)

2. Align the clamping head nylon seals over the injector filter caps (Fig. 12).

3. Back off the Thru-Flow valve about half-way to allow the self-aligning nylon seals to seat properly during the clamping operation.

4. Hold the clamping head in position over the filter caps and, with the left hand, operate pump lever 1 evenly to move the clamping head *down* to seal the filter caps. **The Thru-Flow valve should still turn freely. If it does not, turn the valve counterclockwise until it rotates freely and reapply clamping pressure.**

> **NOTE:** Excessive force on lever 1 during clamping can damage the seals in the valves operated by levers 4 and 5.

Purging Air from the System

Move lever 4 down and operate pump lever 1 to produce a test oil flow through the injector. When air bubbles no longer pass through the clear discharge tubing, the system is free of air and is now ready for testing.

Injector Valve Opening and Spray Pattern Test

This test determines spray pattern uniformity and the relative pressure at which the injector valve opens and fuel injection begins.

1. Clamp the injector properly and purge the air from the system.

2. Close the Thru-Flow valve to allow pressure to build in gage 1 (do not overtighten or the nylon seal will be damaged).

3. With the fuel rack in the full-fuel position, operate pump lever 1 rapidly until the valve opening pressure of 450 to 850 psi (3 100 to 5 857 kPa) is reached and the spray pattern occurs. Note if all spray tip holes are open by the pattern of the spray produced.

Injector High Pressure Test

This test checks for leaks at the filter cap gaskets, body plugs and nut seal ring.

1. Clamp the injector properly and purge the air from the system.

2. Close the Thru-Flow valve, but do not overtighten.

NOTE: Be sure lever 4 is in the *down* position before operating pump lever 1.

3. Move lever 2 to the forward, horizontal position.

4. Operate pump lever 1 to build up to 1600-2000 psi (11 024-13 780 kPa) on gage 1 and check for leakage at the filter cap gaskets, body plugs and nut seal ring.

Injector Pressure Holding Test

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 and purge the air from the system.

2. Close The Thru-Flow valve, but do not overtighten.

3. Move lever 2 to the rear, horizontal position.

4. Operate pump lever 1 until gage 1 reads approximately 500 psi (3 445 kPa).

5. Move lever 4 to the *up* position.

6. Time the pressure drop between 450 to 250 psi (3 100 to 1 723 kPa). If the pressure drop occurs in less than 15 seconds (fixture J 23010) or 40 seconds (fixture J 9787), leakage is excessive.

Refer to the *Trouble Shooting Charts* in Section 2.0 if the fuel injector does not pass any of the preceding tests.

Unclamping the Injector

1. Open the Thru-Flow valve to release pressure in the system.

2. Move lever 5 *down* to release the clamping pressure.

3. Swing out the adaptor plate and remove the injector after nylon seals in the clamping head are free and clear of the injector filter caps.

4. Carefully return lever 5 to the *up* (horizontal) position.

Fuel Output Test

Perform the injector fuel output test in calibrator J 22410.

When injectors are removed from an engine for fuel output testing and, if satisfactory, reinstalled without disassembly, extreme care should be taken to avoid reversing the fuel flow. When the fuel flow is reversed, dirt trapped by the filter is back-flushed into the injector components.

Before removing an injector from the engine, note the direction of the fuel flow. To avoid reversing the fuel flow when checking injector fuel output, use the appropriate adaptor. The position of the braided fuel inlet tube and the plastic fuel outlet tube on the

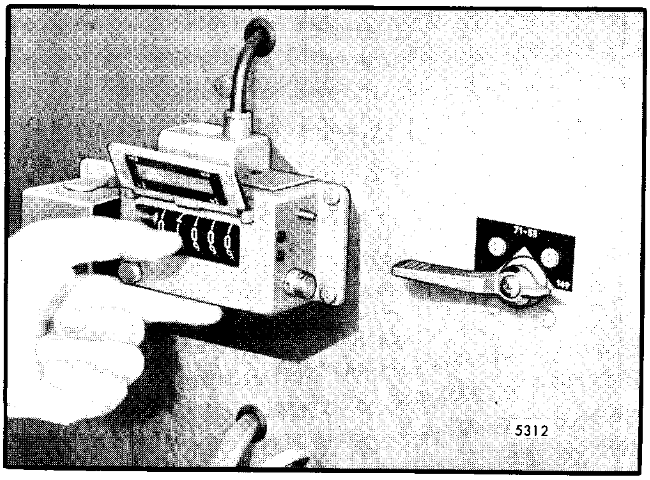


Fig. 16 - Setting Calibrator Stroke Counter

Injector	Calibrator J 22410	
	Min.	Max.
35	36	40
40	39	43
45	44	48
S40	43	47
S45	48	52
S50	52	56

Fig. 17 - Fuel Output Check Chart

calibrator (Fig. 14) depends on the adaptor being used and the direction of fuel flow through the injector.

Calibrator J 22410

To check the fuel output, operate the injector in calibrator J 22410 (Fig. 15) as follows:

> **NOTE:** Place the cam shift index wheel and fuel flow lever in their respective positions. Turn on the test fuel oil heater switch and preheat the test oil to 95-105° F (35-40° C).

1. Place the proper injector adaptor between the tie rods and engage it with the fuel block locating pin. Then slide the adaptor forward and up against the fuel block face.

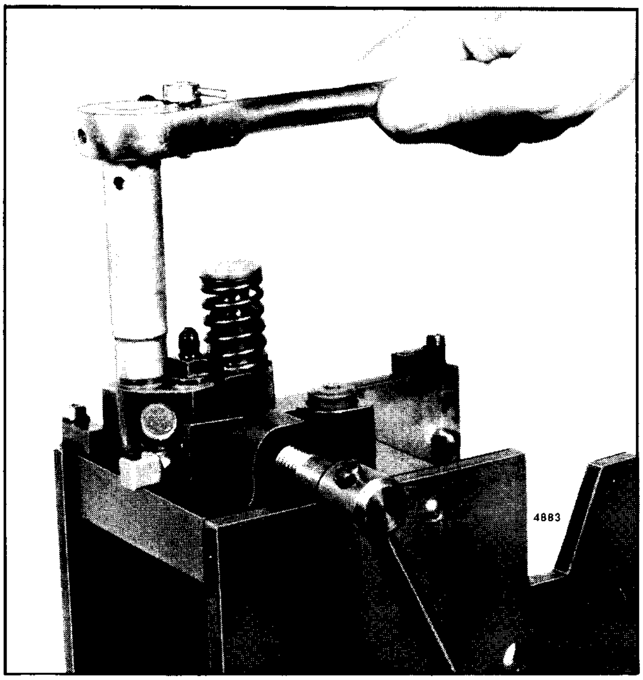


Fig. 18 - Removing or Installing Filter Cap

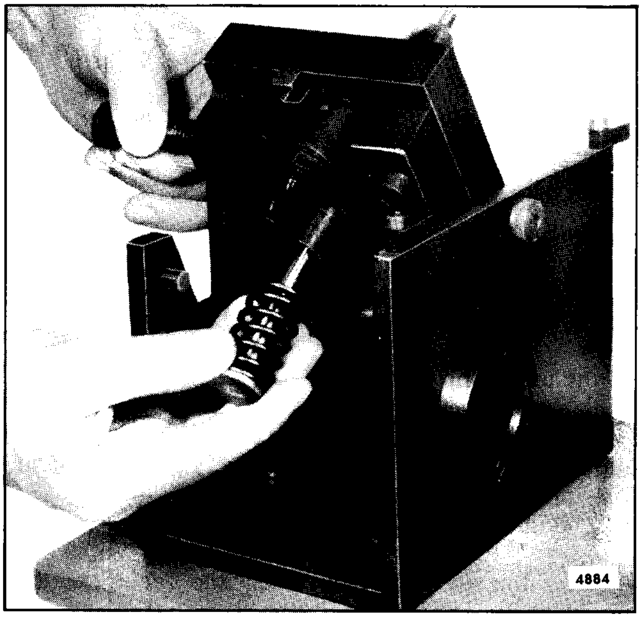


Fig. 19 - Removing or Installing Plunger Follower, Plunger and Spring

2. Place the injector seat J 22410-226 into the permanent seat (cradle handle in vertical position). Clamp the injector into position by operating the air valve.

> **NOTE:** Make sure the counter (Fig. 16) on the calibrator is preset at 1000 strokes. If for any reason this setting has been altered, reset the counter to 1000 strokes by twisting the cover release button to the left and hold the reset

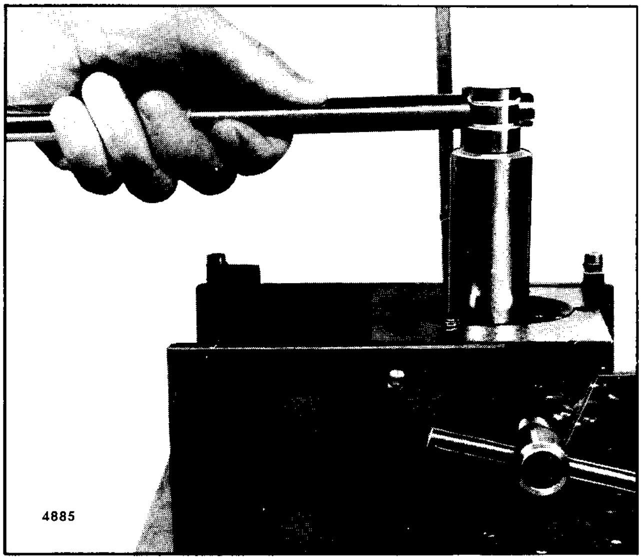


Fig. 20 - Removing Injector Nut using Tool J 4983-01

lever in the full up position while setting the numbered wheels. Close the cover. Refer to the calibrator instruction booklet for further information.

3. Pull the injector rack out to the no-fuel position.

4. Turn on the main power control circuit switch. Then start the calibrator by turning on the motor starter switch.

NOTE: The low oil pressure warning buzzer will sound briefly until the lubricating oil reaches the proper pressure.

5. After the calibrator has started, set the injector rack into the full-fuel position. Allow the injector to operate for approximately 30 seconds to purge the air that may be in the system.

6. After the air is purged, press the fuel flow start button (red). This will start the flow of fuel into the vial. The fuel flow to the vial will automatically stop after 1000 strokes.

7. Shut the calibrator off (the calibrator will stop in less time at full-fuel).

8. Observe the vial reading and refer to Fig. 17 to determine whether the injector fuel output falls within the specified limits. If the quantity of fuel in the vial does not fall within the specified limits, refer to *Trouble Shooting Chart* 3 and *Shop Notes* in Section 2.0 for the cause and remedy.

NOTE: Refer to Section 2.0 for different factors that may affect the injector calibrator output reading.

The calibrator may be used to check and select a set of injectors which will inject the same amount of fuel in each cylinder at a given throttle setting, thus resulting in a smooth running, well balanced engine.

An injector which passes all of the above tests may be put back into service. However, an injector which fails to pass one or more of the tests must be rebuilt and checked on the calibrator.

Any injector which is disassembled and rebuilt must be tested again before being placed in service.

Disassemble Injector

If required, disassemble an injector as follows:

1. Support the injector upright in injector holding fixture J 22396 (Fig. 18) and remove the filter caps, springs (early design filter cap), filters and gaskets.

NOTE: Whenever a fuel injector is disassembled, discard the filters and gaskets and replace with new filters and gaskets.

2. Compress the follower spring as shown in Fig. 9. Then raise the spring above the stop pin with a screw driver and withdraw the pin. Allow the spring to rise gradually.

3. Refer to Fig. 19 and remove the plunger follower, plunger and spring as an assembly.

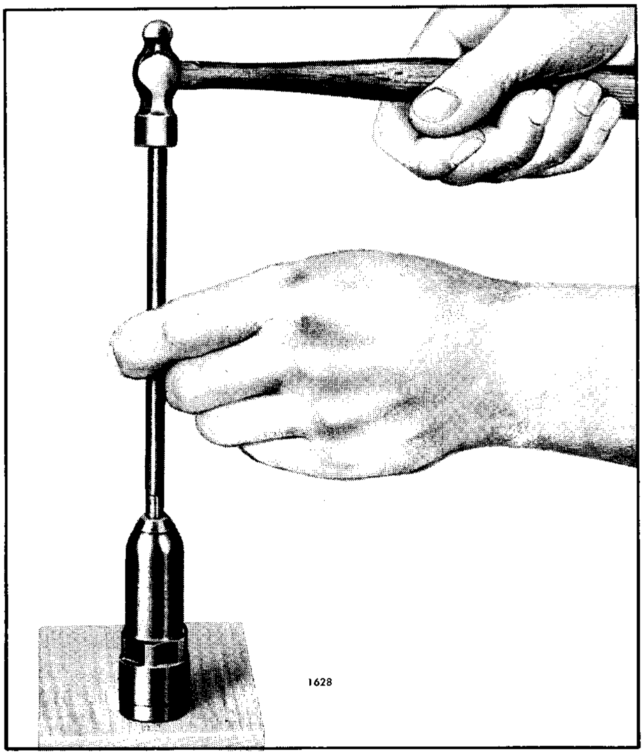


Fig. 21 - Removing Spray Tip from Injector Nut using Tool J 1291-02

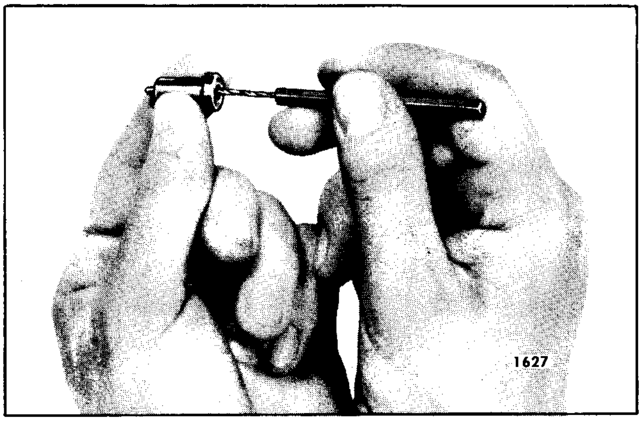


Fig. 22 - Cleaning Injector Spray Tip using Tool J 1243

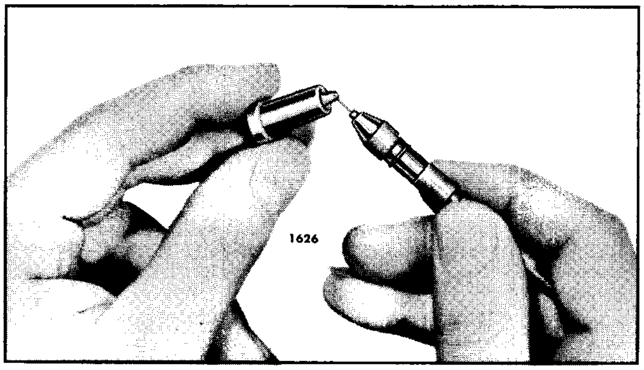


Fig. 23 - Cleaning Spray Tip Orifices using Tool J 4298-1

4. Invert the fixture and, using socket J 4983-01, loosen the nut on the injector body (Fig. 20).

5. Lift the injector nut straight up, being careful not to dislodge the spray tip and valve parts. Remove the spray tip and valve parts from the bushing and place them in a clean receptacle until ready for assembly.

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 as shown in Fig. 21.

6. Refer to Fig. 31 and remove the spill deflector and the seal ring from the injector nut.

7. Remove the plunger bushing, gear retainer and gear from the injector body.

8. Withdraw the injector control rack from the injector body.

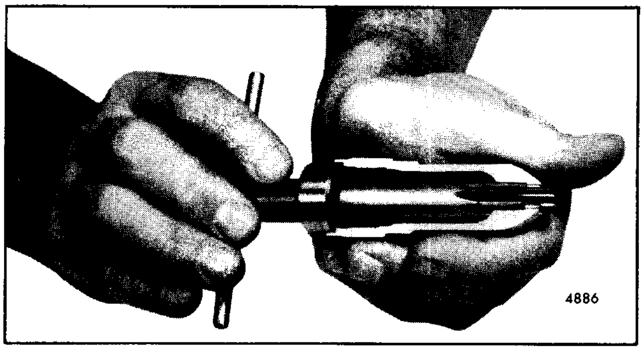


Fig. 24 - Cleaning Injector Nut Spray Tip Seat using Tool J 4986-01

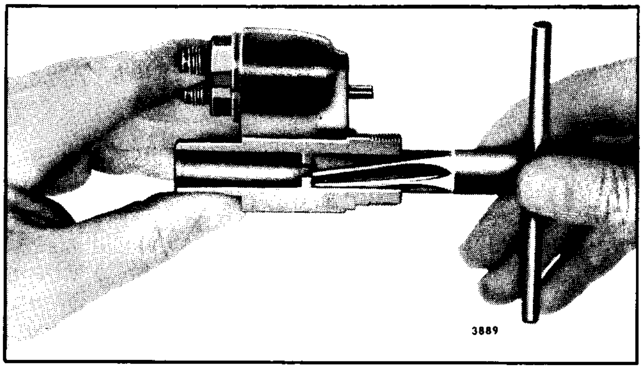


Fig. 25 - Cleaning Injector Body Ring using Tool J 21089

Clean Injector Parts

Since most injector difficulties are the result of dirt particles, it is essential that a clean area be provided on which to place the injector parts after cleaning and inspection.

Wash all of the parts with clean fuel oil or a suitable cleaning solvent and dry them with clean, filtered compressed air. *Do not use waste or rags for cleaning purposes.* Clean out all of 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. Methyl Ethyl Ketone J 8257 solution is recommended for this purpose.

Clean the spray tip with tool J 1243 (Fig. 22). Turn the reamer in a clockwise direction to remove the carbon deposits. Wash the spray tip in fuel oil and dry it with compressed air. Clean the spray tip orifices with pin vise J 4298-1, using the proper size spray tip cleaning wire (Fig. 23). Use wire J 21459 to clean .005" diameter holes, wire J 21460 to clean .0055" diameter holes and J-21461 wire to clean .006" diameter holes.

Before using the wire, hone the end until it is smooth

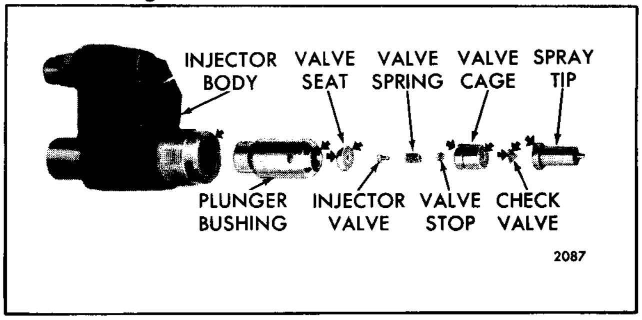


Fig. 26 - Sealing Surfaces Which May Require Lapping

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.

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.

NOTE: Do not buff 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. This cleans the spray tip orifice area and will not plug the orifices.

Wash the spray tip in clean fuel oil and dry it with compressed air.

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 4986-01 in the injector nut as shown in Fig. 24. Turn the reamer in a clockwise direction to remove the carbon deposits. Use care in reaming to prevent the removal of metal or setting up burrs on the spray tip seat. The purpose of the tool is to remove carbon build-up only, and is NOT meant to refinish the end area of the nut by removing metal. Wash the injector nut in clean fuel oil and dry it with compressed air. Carbon deposits on the spray tip seating surface of the injector nut will result in poor sealing and consequent fuel leakage around the spray tip.

Carefully insert reamer J 21089 in the injector body (Fig. 25). 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.

Carefully insert a .375" diameter straight fluted reamer inside the ring bore in the injector body. Turn the reamer in a clockwise direction and remove any burrs inside the ring bore. Then wash the injector body in clean fuel oil and dry it with compressed air.

When handling the injector plunger, do not touch the finished plunger surfaces with your fingers. Wash the plunger and bushing with clean fuel oil and dry 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 fuel oil. *Keep the parts of each injector assembly together.*

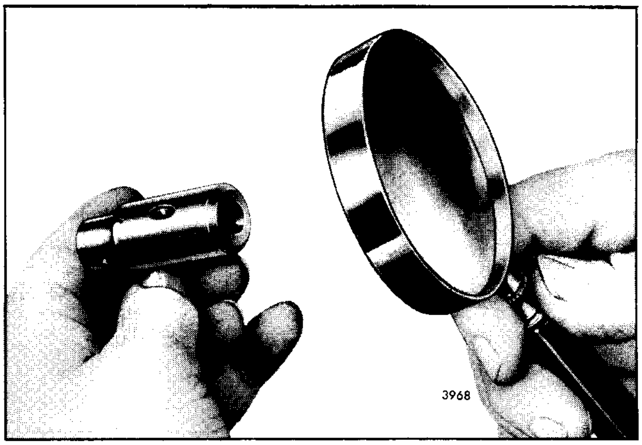


Fig. 27 - Examining Sealing Surface with a Magnifying Glass

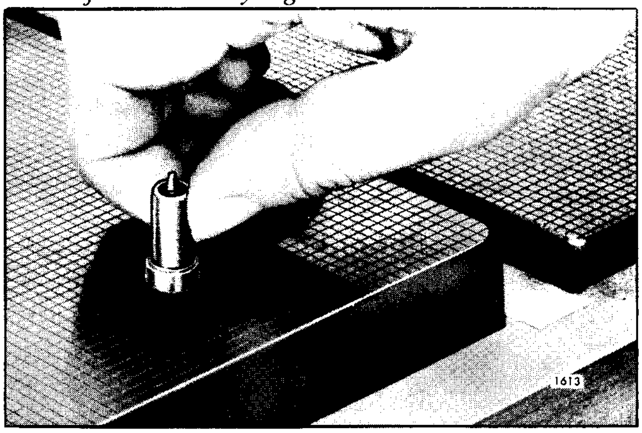


Fig. 28 - Lapping Spray Tip on Lapping Blocks J 22090

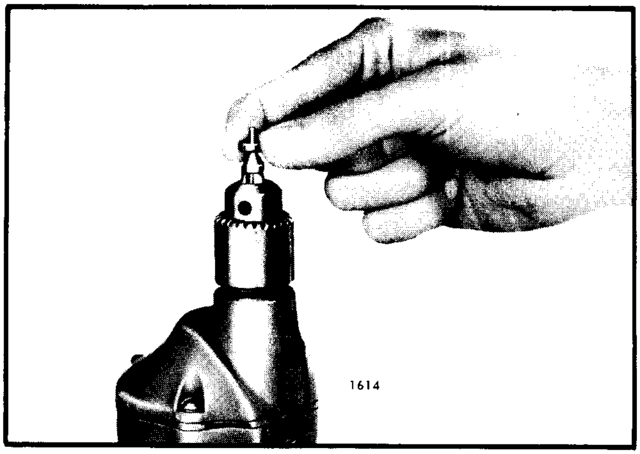


Fig. 29 - Lapping Edge of Hole in Valve Seat using Tool J 7174

Inspect Injector Parts

Inspect the teeth on the control rack and the control rack gear for excessive wear or damage. Also check for excessive wear in the bore of the gear and inspect the gear retainer. Replace damaged or worn parts.

Inspect the injector follower and pin for wear.

Inspect both ends of the spill deflector for sharp edges or burrs which could create burrs on the injector body or injector nut and cause particles of metal to be introduced into the spray tip and valve parts. Remove burrs with a 500 grit stone.

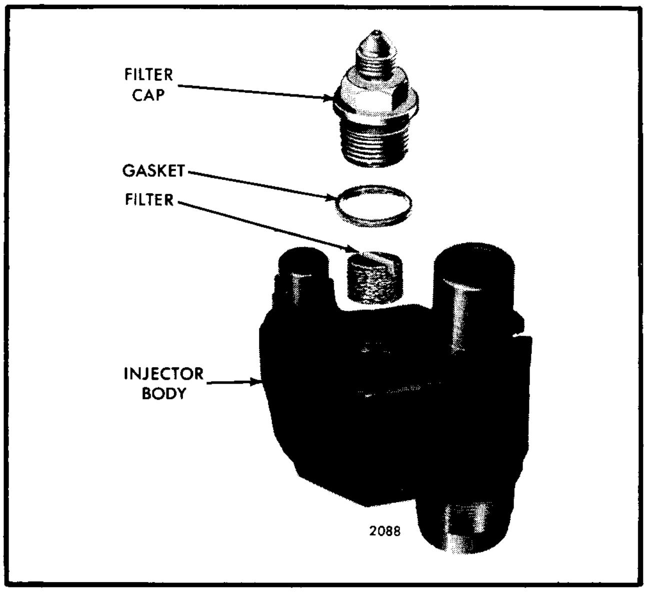


Fig. 30 - Details of Injector Filters and Caps and Their Relative Location

Inspect the follower spring for visual defects. Then check the spring with tester J 22738-02.

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". Formerly, a spring (.120" diameter wire) with a free length of approximately 1.668" was employed and it should be replaced when a load of less than 48 lbs. will compress it to 1.028".

It is recommended that at the time of overhaul, all injectors in an engine be converted to the current spring (.142" diameter wire) which will provide improved cam roller to shaft follow. However, in the event that one or two injectors are changed, the remaining injectors need not be reworked to incorporate the current spring.

Check the seal ring area on the injector body for burrs or scratches. Also check the surface which contacts the injector bushing for scratches, scuff marks or other damage. If necessary, lap this surface. A faulty sealing surface at this point will result in high fuel consumption and contamination of the lubricating oil. Replace any loose injector body plugs or a loose dowel pin. Install the proper number tag on a service replacement injector body.

Inspect the injector plunger and bushing for scoring, erosion, chipping or wear. Check for sharp edges on that portion of the plunger which rides in the gear. Remove any sharp edges with a 500 grit stone. Wash the plunger after stoning it. Injector Bushing Inspectalite J 21471 can be used to check the port holes in the inner diameter of the bushing for cracks or chipping. Slip the plunger into the bushing and check for free movement. *Replace the plunger and bushing as an assembly if any of the above damage is noted, since they are mated parts.* Use new mated factory parts to assure the best performance from the injector.

Injector plungers cannot be reworked to change the output. Grinding will destroy the hardened case at the helix and result in chipping and seizure or scoring of the plunger.

Examine the spray tip seating surface of the injector nut for nicks, burrs or brinelling. Reseat the surface or replace the nut if it is severely damaged.

The injector valve spring plays an important part in establishing the valve opening pressure of the injector assembly. Replace a worn or broken spring.

Inspect the sealing surfaces of the spray tip and valve parts indicated in Fig. 26. Examine the sealing

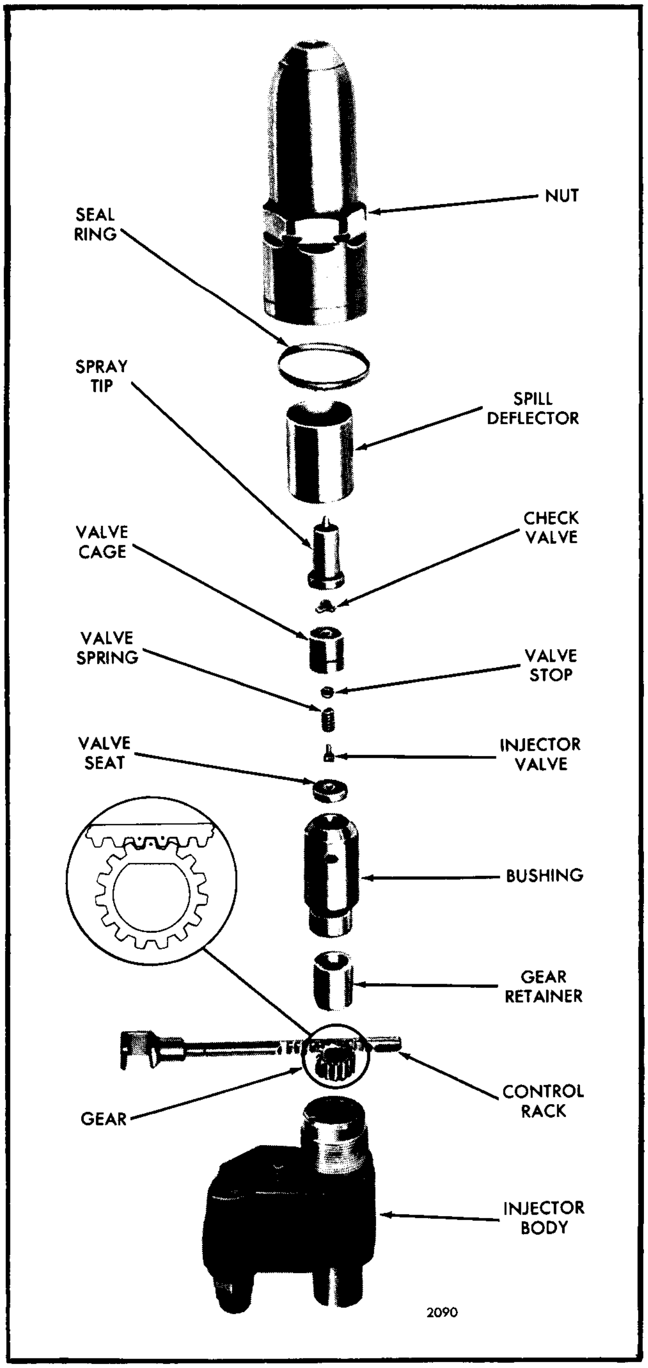


Fig. 31 - Injector Rack, Gear, Spray Tip and Valve Assembly Details and Relative Location of Parts

surfaces with a magnifying glass as shown in Fig. 27 for even the slightest imperfections will prevent the injector from operating properly. Check for burrs, nicks, erosion, cracks, chipping and excessive wear. Also check for enlarged orifices in the spray tip. Replace damaged or excessively worn parts. Check the

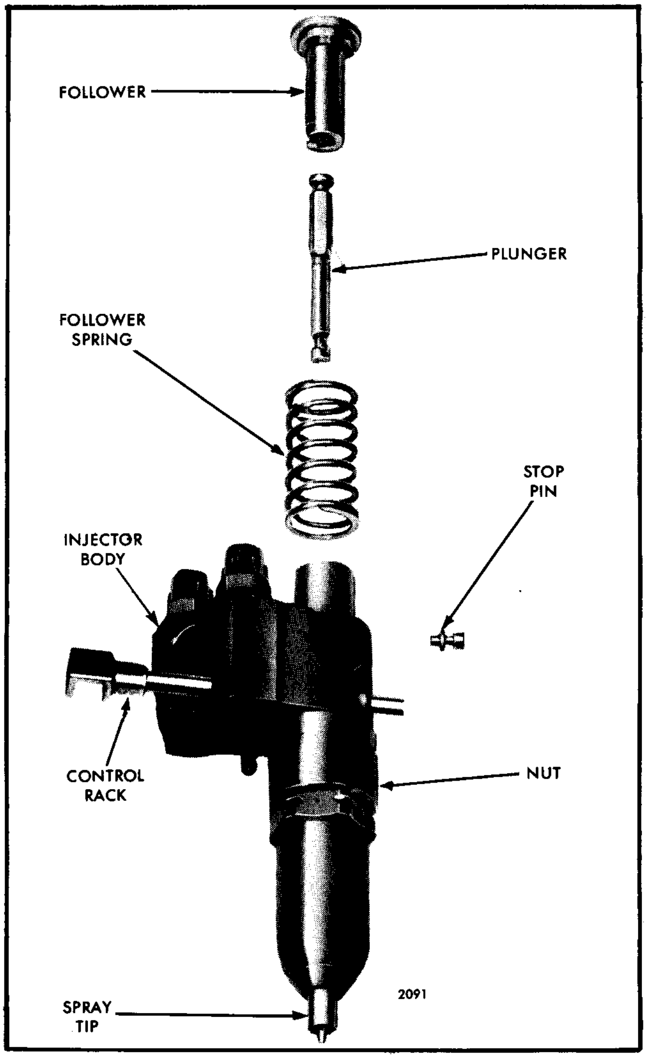


Fig. 32 - Injector Plunger, Follower and Relative Location of Parts

minimum thickness of the lapped parts as noted in the chart.

Part Name	Minimum Thickness
Spray Tip (shoulder)	.199"
Check Valve Cage	.163" – .165"
Check Valve	.022"
Valve Spring Cage	.602"

MINIMUM THICKNESS (Used Parts)

Before reinstalling used valve parts in an injector, lap all of the sealing surfaces indicated in Fig. 26, except the injector valve (crown valve). It is also good practice to lightly lap new valve parts, except the injector valve (crown valve), which may become burred or nicked during handling.

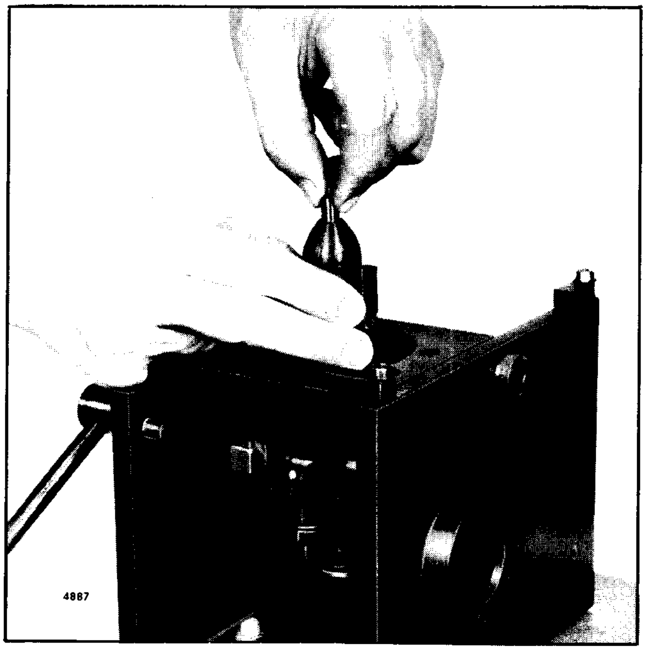


Fig. 33 - Tightening Injector Nut by Hand

Lapping Injector Parts

Lap the sealing surfaces indicated in Fig. 26 and the chart 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 as shown in Fig. 28 and, using a figure eight motion, move it back and forth across the block. Do not press on the part, but use just enough pressure to keep the part flat on the block. It is important that the part be kept flat on the block at all times.

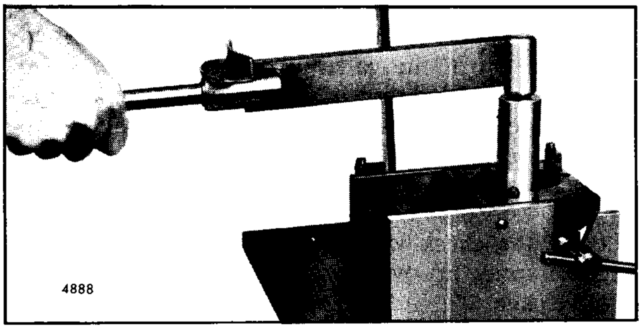


Fig. 34 - Tightening Injector Nut with Torque Wrench using Tool J 4983-01

4. After each four or five passes, clean the lapping powder from the part by drawing it across a clean piece of tissue placed on a flat surface and inspect the part. *Do not lap excessively* (refer to the chart on minimum thickness).

5. When the part is flat, wash it in cleaning solvent and dry it with compressed air.

6. Place the dry part on the second block. After applying lapping powder, move the part lightly across the block in a figure eight motion several times to give it a smooth finish. *Do not lap excessively.* Again wash the part in cleaning solvent and dry it with compressed air.

7. Place the dry part on the third block. Do not use lapping powder on this block. Keep the part flat and move it across the block several times, using the figure eight motion. Lapping the dry part in this manner gives it the "mirror" finish required for perfect sealing.

8. Examine the edge of the hole in the crown valve seat under a magnifying glass. If the edge of the hole shows small irregularities, lap the hole with tool J 7174. Since only the edge of this hole contacts the valve, it must be a true circle and present an unbroken surface.

Mount tool J 7174 in a drill motor (Fig. 29) and place a small amount of lapping powder and oil mixture on the tool. Place the valve seat over the pilot of the tool and start the drill motor. Touch the valve seat lightly against the rotating lapping tool to produce a uniform seat at the hole. After lapping the edge of the hole in this manner, flat lap the face of the seat lightly. Then clean and examine the width of the chamfer produced at the edge of the hole. The specified width is .002" to .005". A width in excess of these limits, due to

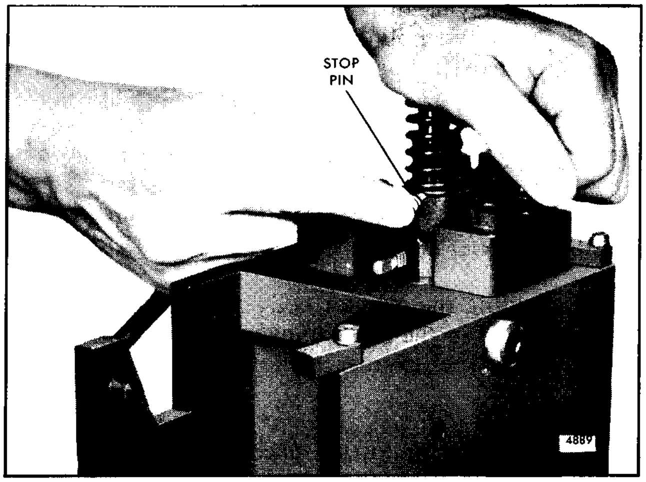


Fig. 35 - Installing Injector Follower Stop Pin

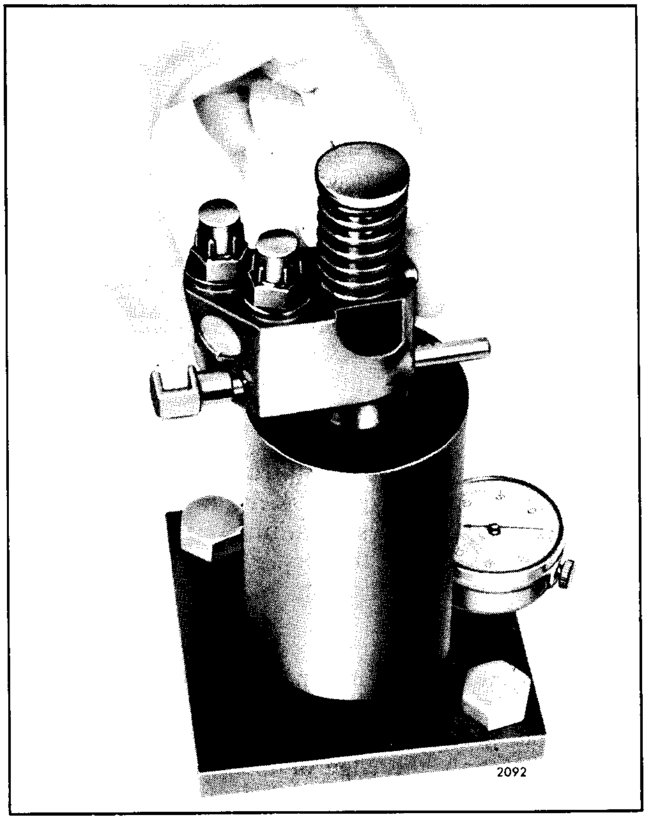


Fig. 36 - Checking Injector Spray Tip Concentricity with Tool J 5119

excessive lapping, will lower the valve opening pressure of the injector.

9. Wash all of the lapped parts in clean fuel oil and dry them with compressed air.

ASSEMBLE INJECTOR

Use an extremely clean bench to work on and to place the parts when assembling an injector. Also be sure all of the injector parts, both new and used, are clean.

Study Figs. 30 through 32 for the proper relative position of the injector parts, then proceed as follows:

Assemble Injector Filters

1. While holding the injector body right side up, place a new filter, slot in the filter up or toward the filter cap, in each of the fuel cavities in the top of the injector body (Fig. 30).

2. Place a spring on top of each filter (if an early design filter cap is used) and a new gasket on each filter cap. Lubricate the threads and install the filter caps. Use a 9/16" deep socket wrench as shown in Fig. 18 to tighten the filter caps to 65-75 lb-ft (88-102 Nm) torque.

3. Purge the filters after installation by directing compressed air or fuel through the filter caps.

4. Install clean shipping caps on the filter caps to prevent dirt from entering the injector.

Assemble Rack and Gears

Refer to Fig. 31 and note the drill spot marks on the control rack and gear. Then proceed as follows:

1. Hold the injector body, bottom end up, and slide the rack through the hole in the body. Look into the bore and move the rack until you can see the drill marks. Hold the rack in this position.

2. Place the gear in the injector body so that the marked tooth is engaged between the two marked teeth on the rack.

3. Place the gear retainer on top of the gear. Next align the locating pin in the bushing with the slot in the injector body, then slide the end of the bushing into place.

Assemble Injector Valve and Related Parts

After having lapped and cleaned the injector valve and its related parts, refer to Figs. 1 and 32 and assemble them as follows:

1. Support the injector body, bottom end up, in the injector holding fixture J 22396.

2. Place a new seal ring on the shoulder of the body. Wet the seal ring with test oil and install the ring all the way down past the threads and onto the injector body. This will prevent the seals from catching in the threads and becoming shredded. Then slide the spill deflector over the barrel of the bushing.

3. Place the valve seat on the end of the bushing. Then insert the stem of the valve in one end of the valve spring and the valve stop in the other end. Lower the valve cage over this assembly so that the valve stop seats in the cage. Place the valve cage assembly on the valve seat.

4. Locatc the check valve centrally on the cage and place the spray tip over the check valve and against the valve cage.

5. Lubricate the threads in the injector nut and carefully thread the nut on the injector body by hand. Rotate the spray tip between your thumb and first

finger while threading the nut on the injector body (Fig. 33). Tighten the nut as tight as possible by hand. At this point there should be sufficient force on the spray tip to make it impossible to turn with your fingers.

6. Use socket J 4983-01 and a torque wrench to tighten the injector nut to 55-65 lb-ft (75-88 Nm) torque (Fig. 34).

7. 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 which may allow assembly on the body without extruding the seal and forcing it out of the body-nut crevice.

> **NOTE:** 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.

Assemble Plunger and Follower

1. Refer to Fig. 32 and slide the head of the plunger into the follower.

2. Invert the injector in the assembly fixture (filter cap end up) and push the rack all the way in. Then place the follower spring on the injector body.

3. Refer to Fig. 35 and place the stop pin on the injector body so that the follower spring rests on the narrow flange of the stop pin. Then align the slot in the follower with the stop pin hole in the injector body. Next align the flat side of the plunger with the slot in the follower. Then insert the free end of the plunger in the injector body. Press down on the follower and at the same time press the stop pin into position. When in place, the spring will hold the stop pin in position.

Spray Tip Concentricity

To assure correct alignment, check the concentricity of the spray tip as follows:

1. Place the injector in the concentricity gage J 5119 as shown in Fig. 36 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. Then loosen the injector nut, center the spray tip and tighten the nut to 55-65 lb-ft (75-88 Nm) torque. Recheck the spray tip concentricity. If, after several attempts, the spray tip cannot be positioned satisfactorily, replace the injector nut.

Test Reconditioned Injector

Before placing a reconditioned injector in service, perform all of the tests (except the visual inspection of the plunger) previously outlined under *Test Injector*.

The injector is satisfactory if it passes these tests. Failure to pass any one of the tests indicates that defective or dirty parts have been assembled. In this case, disassemble, clean, inspect, assemble and test the injector again.

Install Injector

Before installing an injector in an engine, remove the carbon deposits from the beveled seat of the injector tube in the cylinder head. This will assure correct alignment of the injector and prevent any undue stresses from being exerted against the spray tip.

Use injector tube bevel reamer J 5286-9, Section 2.1.4, to clean the carbon from the injector tube. Exercise care to remove ONLY the carbon so that the proper clearance between the injector body and the cylinder head is maintained. Pack the flutes of the reamer with grease to retain the carbon removed from the tube.

Be sure the fuel injector is 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. 6 and 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 registers with the injector rack.

> **NOTE:** Intermixing "45" injectors with "S40" or "S45" injectors within an engine is not recommended because of the difference in spray tips and injector timing.

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 Nm) torque. Make sure that the clamp does not interfere with the injector follower spring or the exhaust valve springs.

> **NOTE:** Check the injector control rack for free movement. Excess torque can cause the control rack to stick or bind.

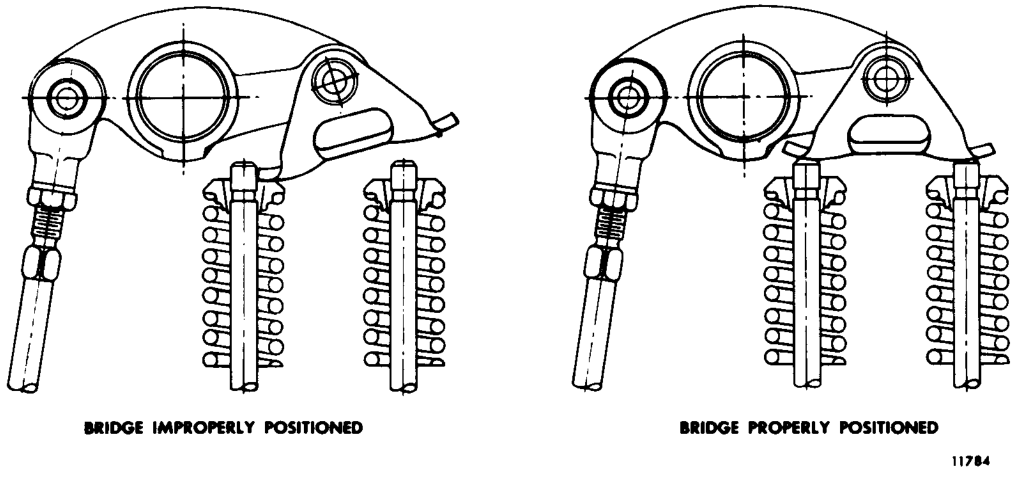


Fig. 37 - Relationship Between Exhaust Valve Bridge and Valve Stems

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.

NOTE: 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. Therefore, note the position of the exhaust valve bridges (Fig. 37) before, during and after tightening the rocker shaft bolts.

5. Remove the shipping caps. Then install the fuel pipes and connect them to the injector and the fuel connectors. Use socket J 8932-01 to tighten the connections to 12-15 lb-ft (16-20 Nm) torque. 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 *Pressurize Fuel System-Check for Leaks* in Section 2.0).

NOTE: 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. Reinstall the rocker cover. Then drain the lubricating oil and change the oil filter elements. Refer to Section 13.3 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.

FUEL INJECTOR (Needle Valve)

The fuel injector (Figs. 1 and 2) 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:

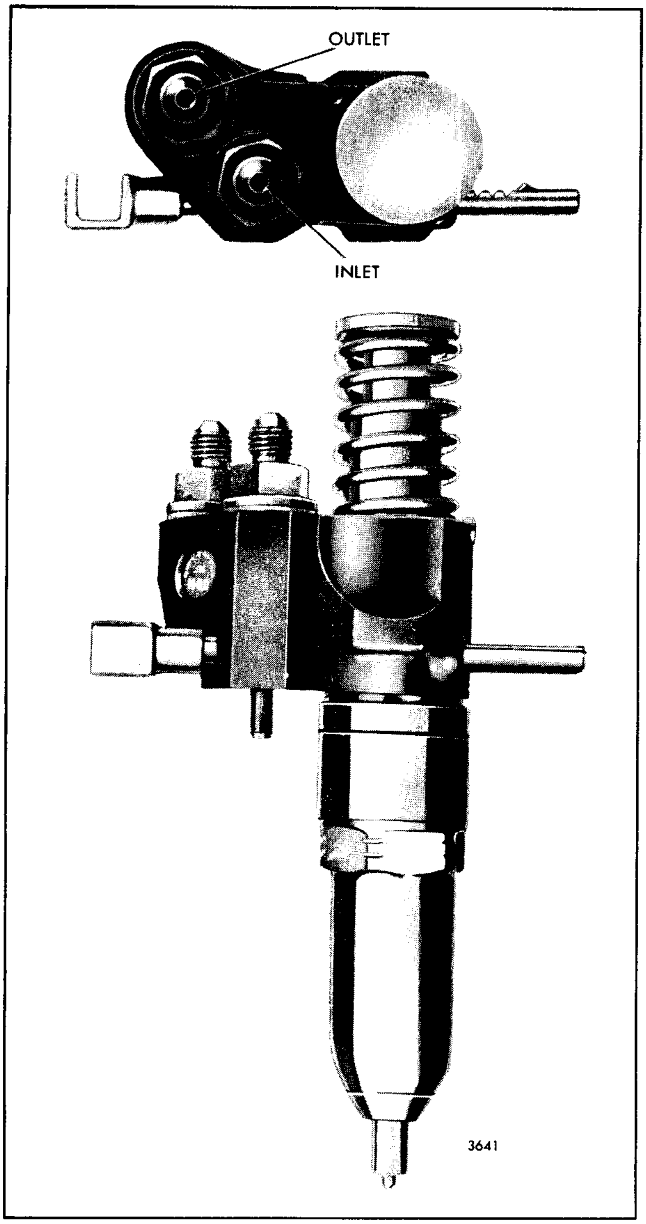


Fig. 1 - Fuel Injector Assembly

1. Creates the high fuel pressure required for efficient injection.

2. Meters and injects the exact amount of fuel required to handle the load.

3. Atomizes the fuel for mixing with the air in the combustion chamber.

4. Permits continuous fuel flow.

Combustion required for satisfactory engine operation is obtained by injecting, under pressure, a small quantity of accurately metered and finely atomized fuel oil into the cylinder.

Metering of the fuel is accomplished by an upper and lower helix machined in the lower end of the injector plunger. Figure 3 illustrates the fuel metering from no-load to full-load by rotation of the plunger in the bushing.

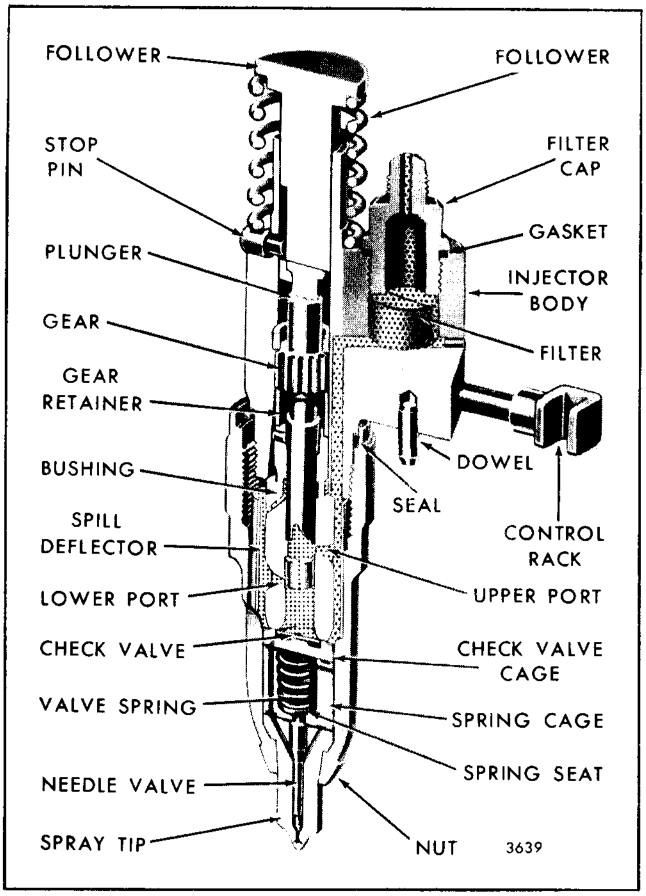


Fig. 2 - Cutaway View of Fuel Injector

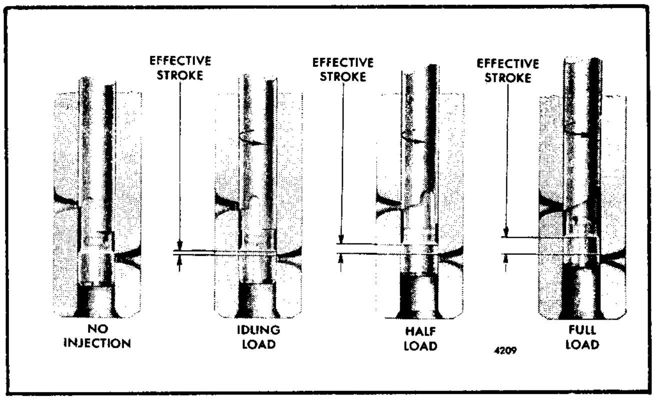


Fig. 3 - Fuel Metering from No-Load to Full-Load

Figure 4 illustrates the phases of injector operation by the vertical travel of the injector plunger.

The continuous fuel flow through the injector serves, in addition to preventing air pockets in the fuel system, as a coolant for those injector parts subjected to high combustion temperatures.

To vary the power output of the engine, injectors having different fuel output capacities are used. The fuel output of the various injectors is governed by the helix angle of the plunger and the type of spray tip used. Refer to Fig. 5 for the identification of the injectors and their respective plungers and spray tips.

Since the helix angle on the plunger determines the output and operating characteristics of a particular type of injector, it is imperative that the correct injectors are used for each engine application. If injectors of different types are mixed, erratic operation will result and may cause serious damage to the engine or to the equipment which it powers.

NOTE: Do not intermix the needle valve injectors with other types of injectors in an engine.

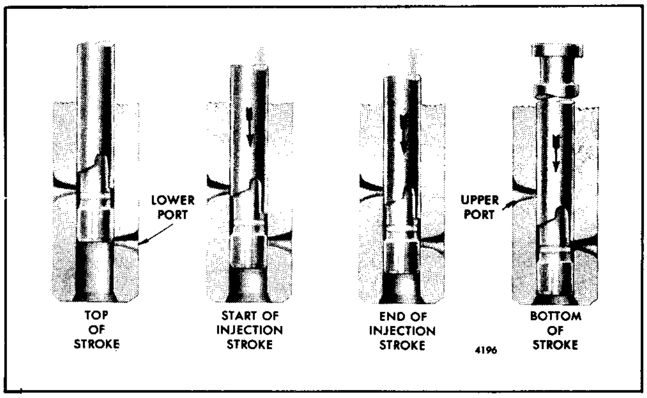


Fig. 4 - Phases of Injector Operation Through Vertical Travel of Plunger

Each fuel injector has a circular disc pressed into a recess at the front side of the injector body for identification purposes (Fig. 5). The identification tag indicates the nominal output of the injector in cubic millimeters.

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 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.

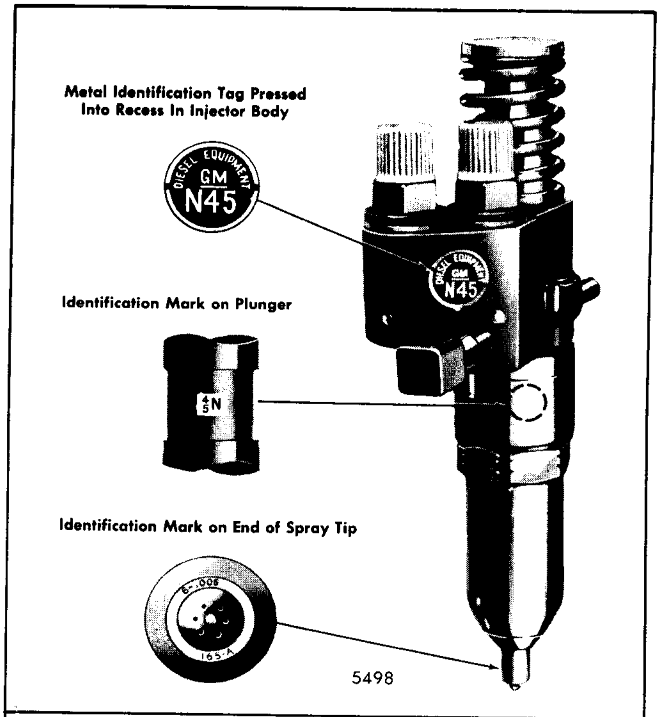
Operation

Fuel, under pressure, enters the injector at the inlet side through a filter cap and filter (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, the bore of which is open to the fuel supply in the annular chamber by two funnel-shaped ports in the plunger bushing.

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, during operation, around its axis by the gear which meshes with the control rack. For metering the fuel, an upper helix and a lower helix are machined in the lower part of the plunger. The relation of the helices to the two ports changes with the rotation of the plunger.

As the plunger moves downward, under pressure of the injector rocker arm, a portion of that fuel trapped under the plunger is displaced into the supply chamber through the lower port until the port is closed off by the lower end of the plunger. A portion of the fuel trapped below the plunger is then forced up through a central passage in the plunger into the fuel metering recess and into the supply chamber through the upper port until that port is closed off by the upper helix of the plunger. With the upper and lower ports both closed off, the remaining fuel under the plunger is subjected to increased pressure by the continued downward movement of the plunger.

When sufficient pressure is built up, it opens the flat, non-return check valve. The fuel in the check valve



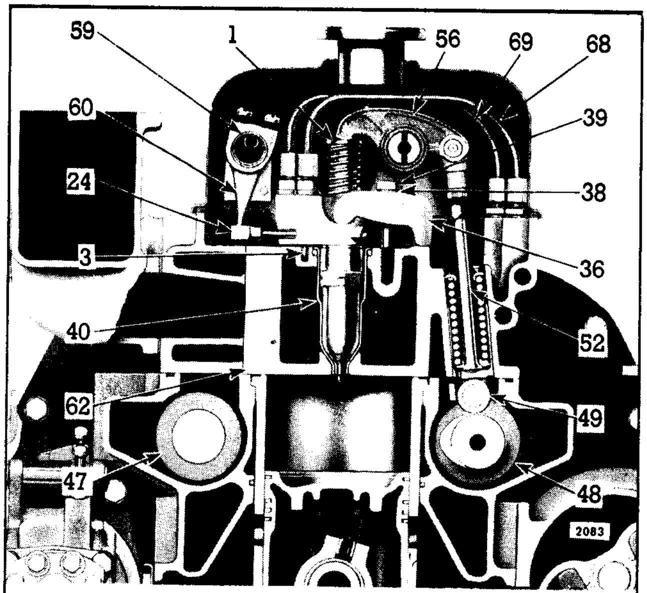
INJECTOR	SPRAY TIP*	PLUNGER
N35	6—.006 —165A	N35
L40	8—.0055—165A	4L
N40	6—.006 —165A	4N
N45	6—.006 —165A	45N
N50	6—.006 —165A	5N
C40	6—.006 —165A	4C
C45	6—.006 —165A	45C
C50	6—.006 —165A	5C
5A55	8—.0060—165A	5A55
5A60	8—.0060—165A	6N
N55	8—.0055—165A	55N
N60	8—.0055—165A	6N
N65	8—.006 —165A	65N
N70	7—.006 —165	7N
M60	7—.006 —165	5N
M70	7—.0060—165A	M70

*First numeral indicates number of spray holes, followed by size of holes and angle formed by spray from holes.

Fig. 5 - Injector Identification Chart

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



1. Injector Assy.
3. Pin--Dowel
24. Rack--Injector Control
36. Clamp--Injector
38. Washer--Clamp
39. Bolt--Clamp
40. Tube--Injector Hole
47. Shaft--Balance
48. Camshaft
49. Cam Follower
52. Rod--Push
56. Arm--Injector Rocker
59. Tube--Injector Control
60. Lever--Rack Control
62. Head--Cylinder
68. Pipe--Fuel Inlet (Supply)
69. Pipe--Fuel Outlet (Return)

Fig. 6 - Fuel Injector Mounting

plunger is relieved and the valve spring closes the needle valve, ending injection.

A pressure relief passage has been provided in the spring cage to permit bleed-off of fuel leaking past the needle pilot in the tip assembly.

A check valve, directly below the bushing, prevents leakage from the combustion chamber into the fuel injector in case the valve is accidentally held open by a small particle of dirt. The injector plunger is then returned to its original position by the injector follower spring. Figure 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

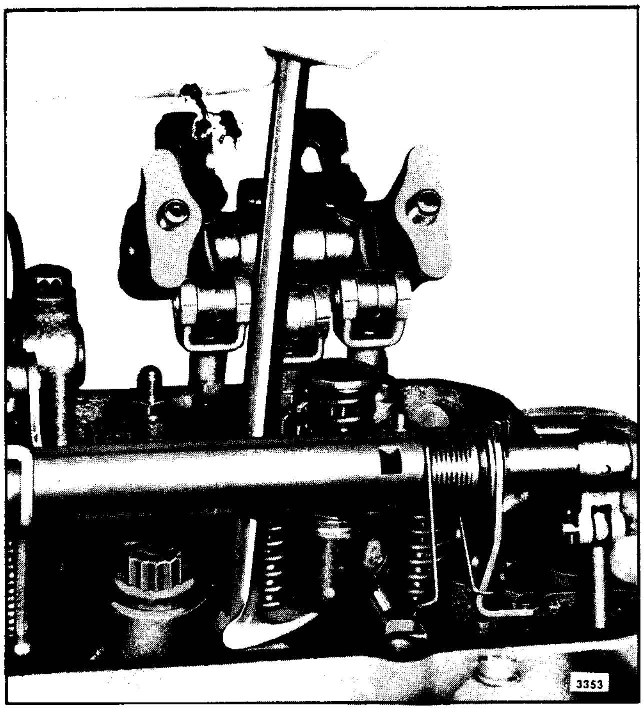


Fig. 7 - Removing Injector from Cylinder Head

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. Figure 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

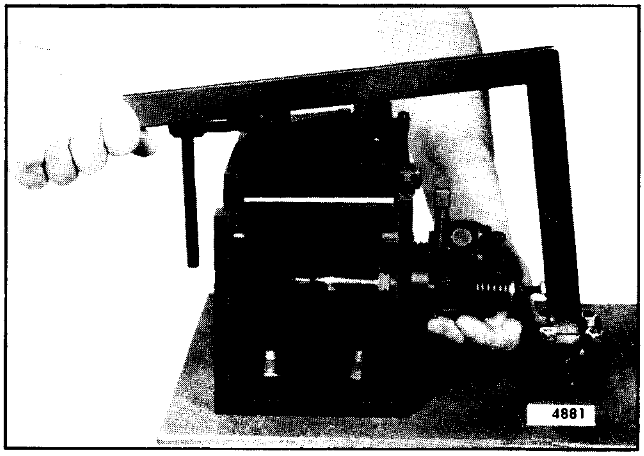


Fig. 8 - Checking Rack and Plunger for Free Movement with J 22396

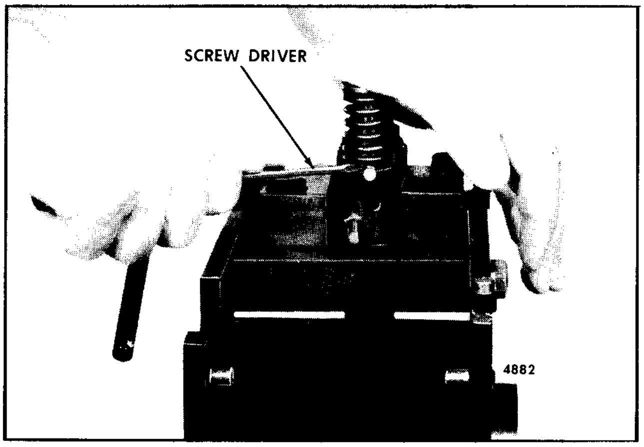


Fig. 9 - Removing Injector Follower Stop Pin

with the outgoing air. Also provide a source for 110 volt alternating current electric power.

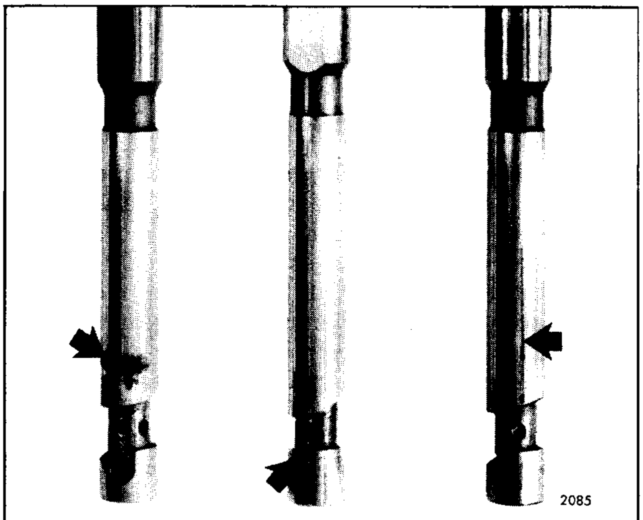
Provide the injector repair room with a supply of filtered, moisture-proof compressed air for drying the injector parts after they have been cleaned. Use wash pans of rust-proof material and deep enough to permit all of the injector parts to be completely covered by the cleaning agent, usually clean fuel oil, 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 cleaning tissue is a good, inexpensive 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. Also protect the fuel pipes and fuel connectors from 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 assembly of an injector.



Advanced stage of erosion caused by foreign matter in fuel due to improper filtration.

Chipped at lower helix.

The above condition can be caused by either lack of fuel at high speeds or water in fuel.

Fig. 10 - Unusable Injector Plungers

NOTE: In the offset injector, a filter is used in the inlet side only. No filter is required on the outlet side (Fig. 35).

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.

NOTE: 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.

2. Remove the fuel pipes from both the injector and the fuel connectors (Fig. 6).

NOTE: Immediately after removal of the fuel pipes from an injector, cover the filter caps with

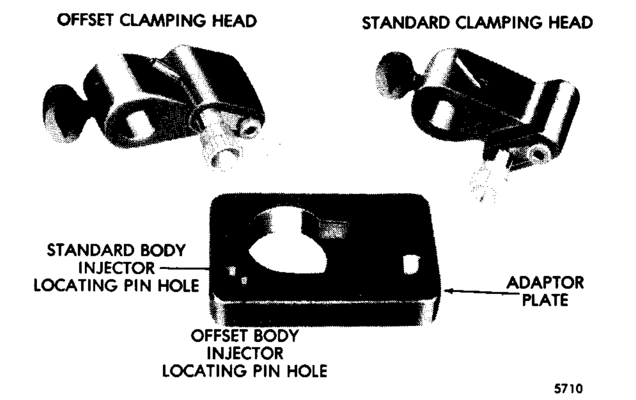


Fig. 11 - Injector Tester J 23010 Clamping Heads

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 outer ends of the push rods of the injector and valve rocker arms in line horizontally.

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 (certain engines have only one adjusting screw and lock nut) 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.

8. Cover the injector hole in the cylinder head to keep foreign material out.

9. Clean the exterior of the injector with clean fuel oil and dry it with compressed air.

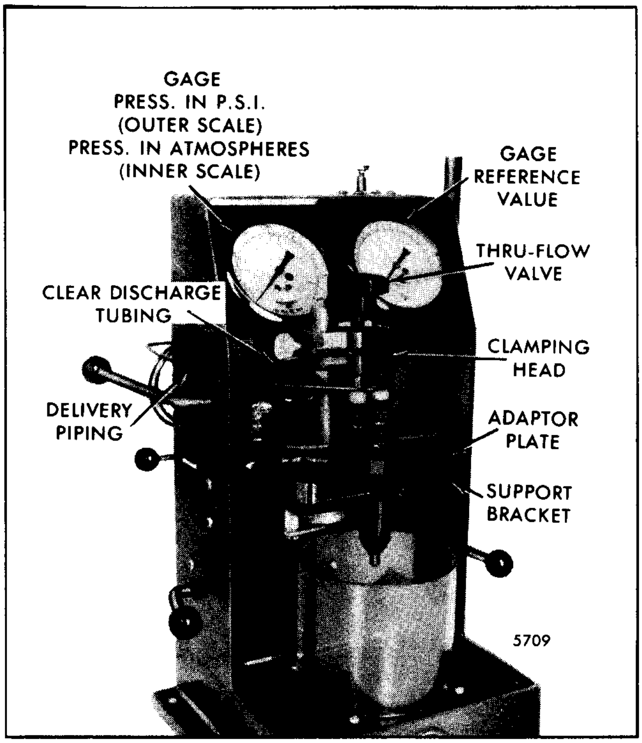


Fig. 12 - Injector Installed in Tester J 23010 with clamping Head

TEST INJECTOR

CAUTION: The fuel spray from an injector can penetrate the skin. Fuel oil which enters the blood stream can cause a serious infection. Therefore, follow instructions and use the proper equipment to test an injector.

If inspection does not reveal any external damage, then perform a series of tests to determine the condition of the injector to avoid unnecessary overhauling. Tests must be performed using injector test oil J 26400.

An injector that passes all of the tests outlined below may be considered to be satisfactory for service without disassembly, except for the visual check of the plunger.

However, an injector that fails to pass one or more of the tests is unsatisfactory. Perform all of the tests before disassembling an injector to correct any one condition.

Identify each injector and record the pressure drop and fuel output as indicated by the following tests:

Injector Control Rack and Plunger Movement Test

Place the injector in the injector fixture and rack freeness tester J 22396. Refer to Fig. 8 and place the handle on top of the injector follower.

If necessary, adjust the contact screw in the handle to ensure the contact screw is at the center of the follower when the follower spring is compressed.

With the injector control rack held in the no-fuel position, push the handle down and depress the follower to the bottom of its stroke. Then very slowly release the pressure on the handle while moving the control rack up and down as shown in Fig. 8 until the follower reaches the top of its travel. If the rack does not fall freely, loosen the injector nut, turn the tip, then retighten the nut. Loosen and retighten the nut a couple of times if necessary. 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.

Visual Inspection of Plunger

An injector which passes all of the previous tests should have the plunger checked visually, under a magnifying glass, for excessive wear or a possible chip

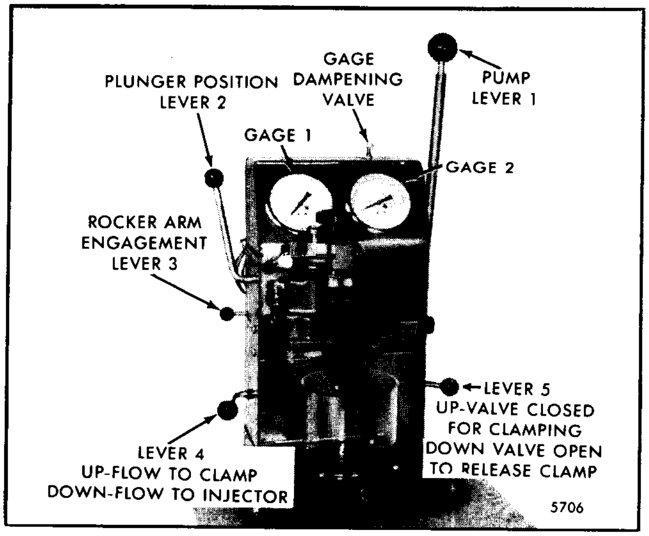


Fig. 13 - Injector in Position for Testing with Tester J 23010

on the bottom helix. There is a small area on the bottom helix and lower portion of the upper helix, if chipped, that will not be indicated in any of the tests.

Remove the plunger from the injector as follows:

1. Support the injector, right side up, in holding fixture J 22396.

2. Compress the follower spring. Then raise the spring above the stop pin with a screw driver and withdraw the pin (Fig. 9). Allow the spring to rise gradually.

3. Remove the injector from the holding fixture. Turn the injector upside down, to prevent the entry of dirt, and catch the spring and plunger as they drop out.

4. Inspect the plunger. If the plunger is chipped (Fig. 10), replace the plunger and bushing assembly.

5. Reinstall the plunger, follower and spring.

Installing Fuel Injector in Tester J 23010

1. Select the proper clamping head (Fig. 11). Position it on the clamping post and tighten the thumb screw into the lower detent position (Fig. 12).

2. Connect the test oil delivery piping into the clamping head.

3. Connect the test oil clear discharge tubing onto the pipe on the clamping head.

4. Locate the adaptor plate on top of the support bracket by positioning the 3/8" diameter hole at the far right of the adaptor plate onto the 3/8" diameter dowel pin. This allows the adaptor plate to swing out for mounting the fuel injector.

5. Mount the injector through the large hole and insert the injector pin in the proper locating pin hole (Fig. 11).

6. Swing the mounted injector and adaptor plate inward until they contact the stop pin at the rear of the support bracket.

Clamping the Fuel Injector

1. Refer to Fig. 13 and position the injector tester levers as follows:

Lever 2 up and to the rear

Lever 3 in the rear detent

Lever 4 up (horizontal)

Lever 5 up (horizontal)

2. Align the clamping head nylon seals over the injector filter caps (Fig. 12).

3. Back off the Thru-Flow valve about half-way to allow the self-aligning nylon seals to seat properly during the clamping operation.

4. Hold the clamping head in position over the filter caps and, with the left hand, operate pump lever 1 evenly to move the clamping head *down* to seal the **filter caps. The Thru-Flow valve should still turn freely. If it does not, turn the valve counterclockwise until it rotates freely and reapply clamping pressure.**

> **NOTE:** Excessive force on lever 1 during clamping can damage the seals in the valves operated by levers 4 and 5.

Purging Air from the System

Move lever 4 down and operate pump lever 1 to produce a test oil flow through the injector. When air bubbles no longer pass through the clear discharge tubing, the system is free of air and is now ready for testing.

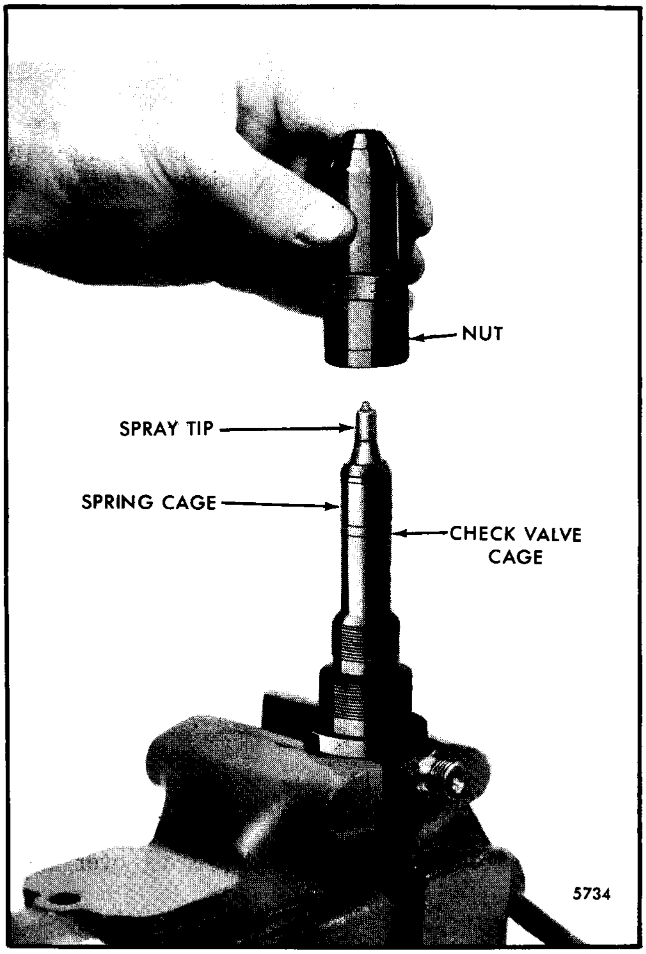


Fig. 14 - Assembling Injector Valve Parts on Tip Tester Adaptor J 23010-129

Injector Valve Opening and Spray Pattern Test

This test determines spray pattern uniformity and the relative pressure at which the injector valve opens and fuel injection begins.

1. Clamp the injector properly and purge the air from the system.

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 (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.

The highest pressure reference number shown on gage 2 will be reached just before injection ends. Use the following reference values to determine the relative acceptability of the injector. Reference values for Series 53 injectors are from 127 minimum to 146 maximum, except the L-40 injector which is from 116 minimum to 127 maximum.

> **NOTE:** The reference value obtained when pop testing the needle valve injectors is to be used as a trouble shooting and diagnosis aid. This allows comparative testing of injectors without disassembly. Exact valve opening pressure values can only be determined by the *Needle Valve Tip Test* using tester J 23010 and tip test adaptor J 23010-129 or auxiliary tester J 22640.

Injector High Pressure Test

This test checks for leaks at the filter cap gaskets, body plugs and nut seal ring.

1. Clamp the injector properly and purge the air from the system.

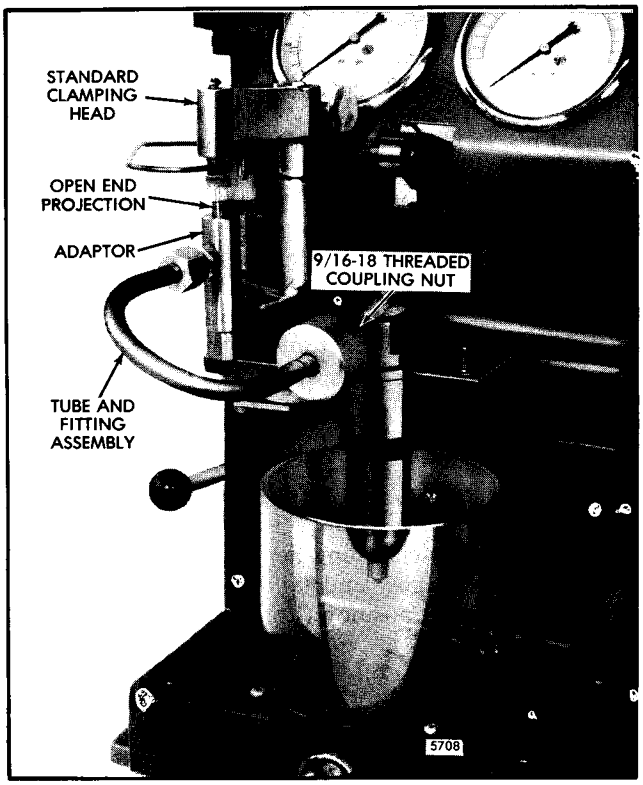


Fig. 15 - Adaptor and Tube Assembly on Injector Tester J 23010

2. Close the Thru-Flow valve, but do not overtighten.

NOTE: Make sure lever 4 is in the *down* position before operating pump lever 1.

3. Operate pump lever 1 to build up to 1600 to 2000 psi (11 024 to 13 780 kPa) on gage 1. Check for leakage at the injector filter cap gaskets, body plugs and injector nut seal ring.

Injector Pressure Holding Test

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 and purge the air from the system.

2. Close the Thru-Flow valve, but do not overtighten.

3. Move lever 2 to the rear, horizontal position.

4. Operate pump lever 1 until gage 1 reads approximately 700 psi (4 823 kPa).

5. Move lever 4 to the *up* position.

6. Time the pressure drop between 450 to 250 psi (3 100 to 1 723 kPa). If the pressure drop occurs in **less than 15 seconds (fixture J 23010) or 40 seconds (fixture J 9787), leakage is excessive.**

Refer to the *Trouble Shooting Charts* in Section 2.0 if the fuel injector does not pass any of the preceding tests.

If the fuel injector passes all of the above tests, proceed with the *Fuel Output Test*.

Unclamping the Injector

1. Open the Thru-Flow valve to release pressure in the system.

2. Move lever 5 *down* to release the clamping pressure.

3. Swing out the adaptor plate and remove the injector after the nylon seals in the clamping head are free and clear of the injector filter caps.

4. Carefully return lever 5 to the *up* (horizontal) position.

Needle Valve Tip Test (Using J 23010 Tester and Tip-Test Adaptor)

Assemble injector parts on tip test adaptor as follows:

1. Clamp the flat sides of the tip test adaptor J 23010-129 firmly in a vise and assemble the cleaned injector parts including the check valve cage, spring, spring seat, spring cage and spray tip assembly.

2. Carefully pilot the injector nut over the spray tip and valve parts and thread it onto the adaptor (Fig. 14).

3. Tighten the injector nut.

4. Mount the adaptor and assembled injector parts in the support bracket (adaptor plate not needed). Refer to Fig. 15.

5. Install the offset clamping head on the clamping post (on J 23010 testers without serial numbers, use the upper detent position and on J 23010 testers numbered 1051 and higher, use the lower detent position).

6. Select the (larger) 9/16"-18 threaded coupling nut J 23010-20 and thread it on tubing J 23010-75.

Install the tubing and fitting to adaptor J 23010-167.

7. Connect the tubing to tip test adaptor J 23010-129 by threading the coupling nut on the tip test adaptor.

Installing Adaptor and Tube Assembly on Tester J 23010

1. Position the adaptor and tubing assembly with the solid projecting end located in the hole on the left side of the support bracket.

2. Swing the clamping head over the adaptor and clamp it with the oil supply outlet aligned over the open projecting end of the adaptor (Fig. 15).

NOTE: Use the fuel injector clamping procedure to clamp adaptor J 23010-167 in the injector tester.

Spray Tip Test

1. Move lever 4 *down* and operate pump lever 1 rapidly with smooth even strokes (40 strokes per minute) simulating the action of the tip functioning in the engine (Fig. 13).

2. Note the pressure at which the needle valve opens on gage 1. The valve should open between 2200 and

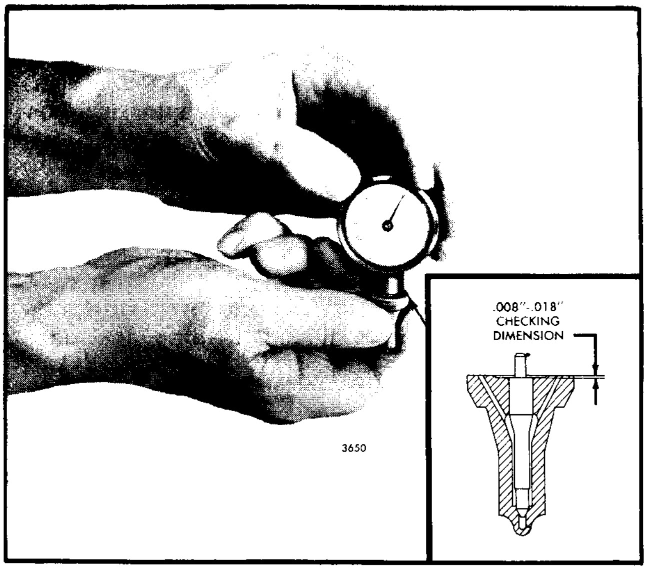


Fig. 16 - Checking Needle Valve Lift with Tool J 9462-02

3300 psi (15 158 and 22 737 kPa). The opening and closing action should be sharp and produce a normal, finely atomized spray pattern.

If the valve opening pressure is below 2200 psi (15 158 kPa) and/or atomization is poor, the cause is usually a weak valve spring or a poor needle valve seat.

If the valve opening pressure is within 2200-3300 psi (15 158-22 **737** kPa) or 1700-2300 psi (11 713-15 847 kPa) for the L-40 injector, proceed to check for spray tip leakage as follows:

> **NOTE:** When testing for spray tip leakage using the auxiliary tester, be sure to use the proper spring for the valve tip being tested.

a. Actuate pump lever 1 several times and hold the pressure at 1500 psi (10 335 kPa) for 15 seconds.

b. Inspect the spray tip for leakage. There should be no fuel droplets, although a slight wetting at the spray tip is permissable.

Needle Valve Lift Test

To measure the needle valve lift, use tool J 9462-01 (Fig. 16) as follows:

1. Zero the indicator by placing the bottom surface of the plunger assembly on a flat surface and zero the indicator dial.

2. Place the spray tip and needle valve assembly tight against the bottom of the gage with the quill of the needle valve in the hole in the plunger.

3. While holding the spray tip and needle valve assembly tight against the gage, read the needle valve lift on the indicator. 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.

4. 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.

5. Reassemble the injector as outlined under *Assemble Injector* and check the injector output with calibrator J 22410.

Needle Valve Tip Test (Using Auxiliary Tester J 22640)

1. Connect the pipe from auxiliary tester J 22640 to the rear of the J 23010 tester at the connection located near the bottom of the tester (Fig.17).

2. Assemble cleaned injector parts, including the check valve cage, spring, spring seat, spring cage and spray tip assembly, on the auxiliary tester J 22640 (Fig. 18).

3. Carefully pilot the injector nut over the spray tip and valve parts and thread it on the auxiliary tester.

4. Tighten the injector nut.

5. Open the valve on the auxiliary tester and place lever 4 in the *up* (horizontal) position.

6. Install the shield on the auxiliary tester and operate pump lever 1 until the needle valve has opened several times to purge the air from the system.

7. Operate pump lever 1 rapidly with smooth even strokes (40 strokes per minute) simulating the action of the tip functioning in the engine. Note the pressure at which the test oil delivery occurs. Test oil delivery should occur between 2200 and 3300 psi (15 158 and 22 **737** kPa) except for the L-40 injector which should open between 1700 and 2300 psi (11 713 and 15 847 kPa). The beginning and ending of delivery should be sharp and the test oil should be a finely atomized spray.

If the valve opening pressure is below 2200 psi (15 158 kPa) or 1700 psi (11 713 kPa) for the L-40 injector and/or atomization is poor, the cause is usually a weak valve spring or poor needle valve seat.

If the valve opening pressure is within 2200-3300 psi (15 158-22 **737** kPa) or 1700-2300 psi (11 713-15 847

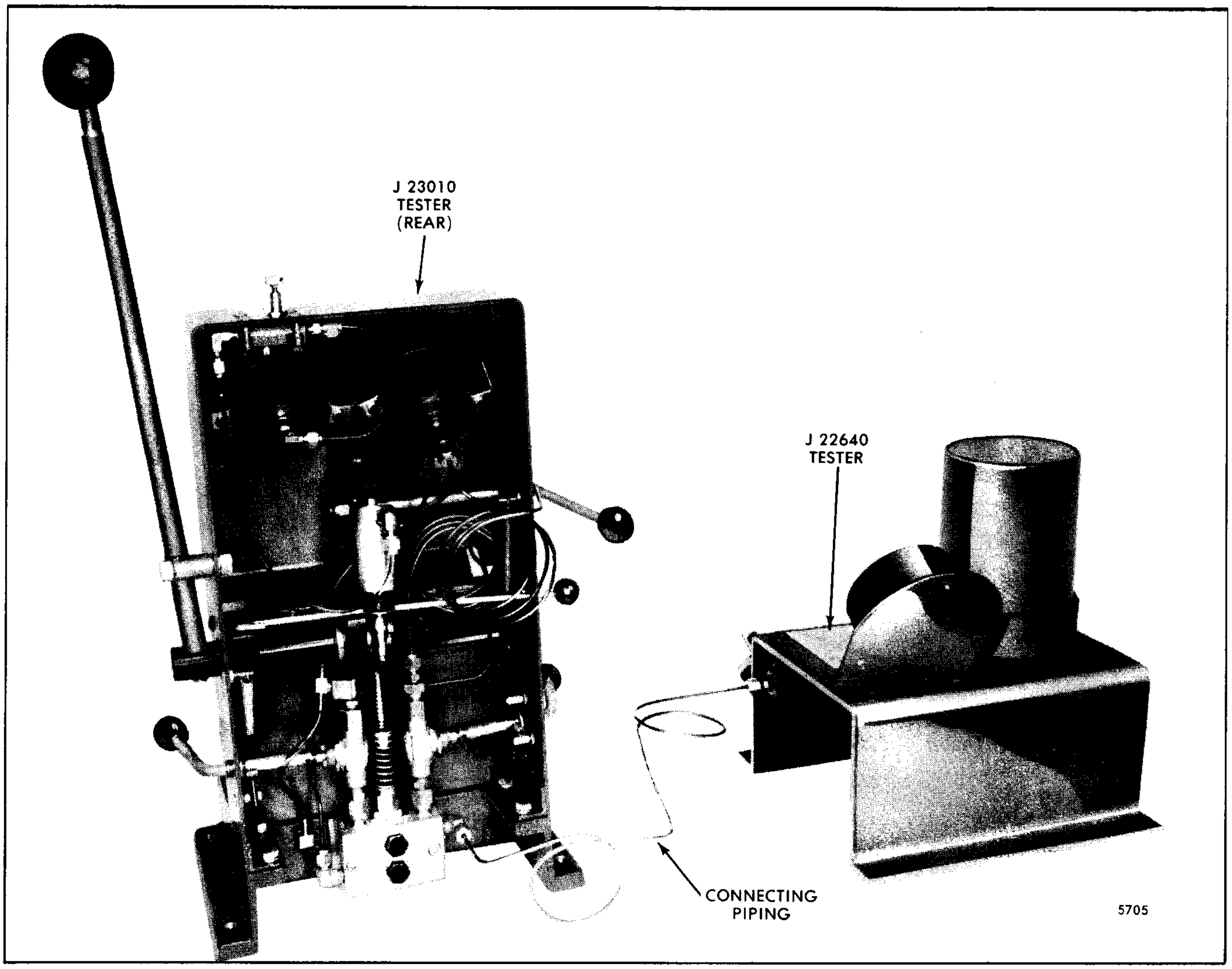


Fig. 17 - Injector Needle Valve Tester J 23010 with Auxiliary Tester J 22640

kPa) for the L-40 injector, proceed to check for spray tip leakage as follows:

NOTE: When testing for spray tip leakage using the auxiliary tester, be sure to use the proper spring for the valve tip being tested.

a. Actuate the pump lever several times and hold the pressure at 1500 psi (10 335 kPa) for 15 seconds.

b. Inspect the spray tip for leakage. There should be no fuel droplets although a slight wetting at the spray tip is permissable.

Perform the needle valve lift test.

Fuel Output Test

Perform the injector fuel output test in calibrator J 22410.

When injectors are removed from an engine for fuel output testing and, if satisfactory, reinstalled without disassembly, extreme care should be taken to avoid reversing the fuel flow. When the fuel flow is reversed, dirt trapped by the filter is back-flushed into the injector components.

Before removing an injector from the engine, note the direction of the fuel flow. To avoid reversing the fuel flow when checking injector fuel output, use the appropriate adaptor. The position of the braided fuel inlet tube and the plastic fuel outlet tube on the calibrator (Fig. 20) depends on the adaptor being used and the direction of fuel flow through the injector.

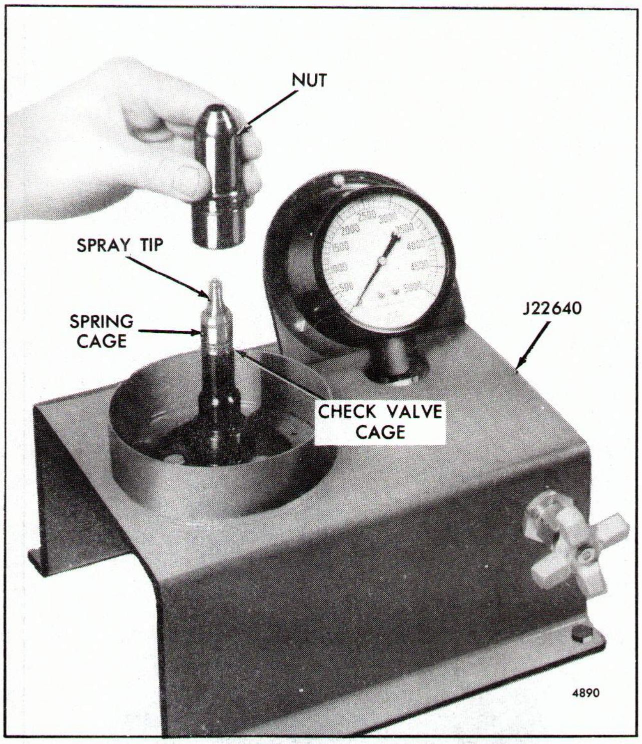


Fig. 18 - Installing Injector Valve Parts on Auxiliary Tester J 22640

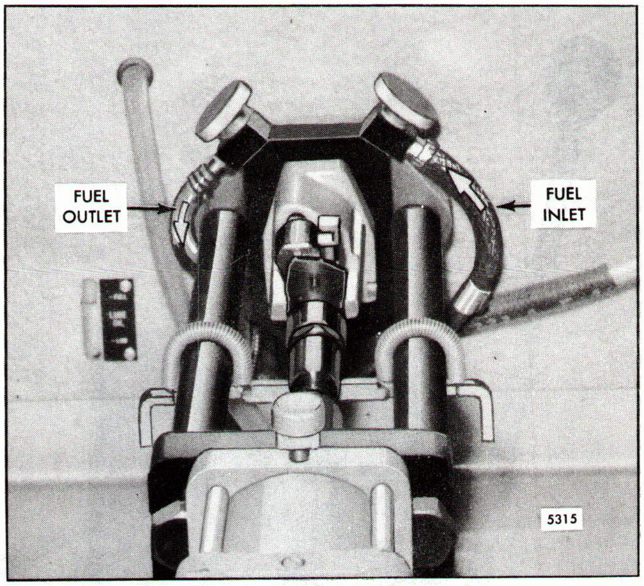


Fig. 20 - Position of Calibrator Fuel Flow Pipes

1. Place the proper injector adaptor between the tie rods and engage it with the fuel block locating pin. Then slide the adaptor forward and up against the fuel block face.

Calibrator J 22410

To check the fuel output, operate the injector in calibrator J 22410 (Fig. 21) as follows:

NOTE: Place the cam shift index wheel and fuel flow lever in their respective positions. Turn on the test fuel oil heater switch and preheat the test oil to 95-105 °F (35-40 °C).

Injector	Calibrator J 22410	
	Min.	Max
N35	36	41
L40	41	46
N40	42	47
N45	47	52
N50	50	55
C40	42	47
C45	47	52
C50	50	55
5A50	53	58
5A55	56	61
5A60	63	68
N55	53	58
N60	57	62
N65	64	69
5N65	64	69
N70	71	76
M60	60	65
M70	73	77

Fig. 19 - Fuel Output Chart

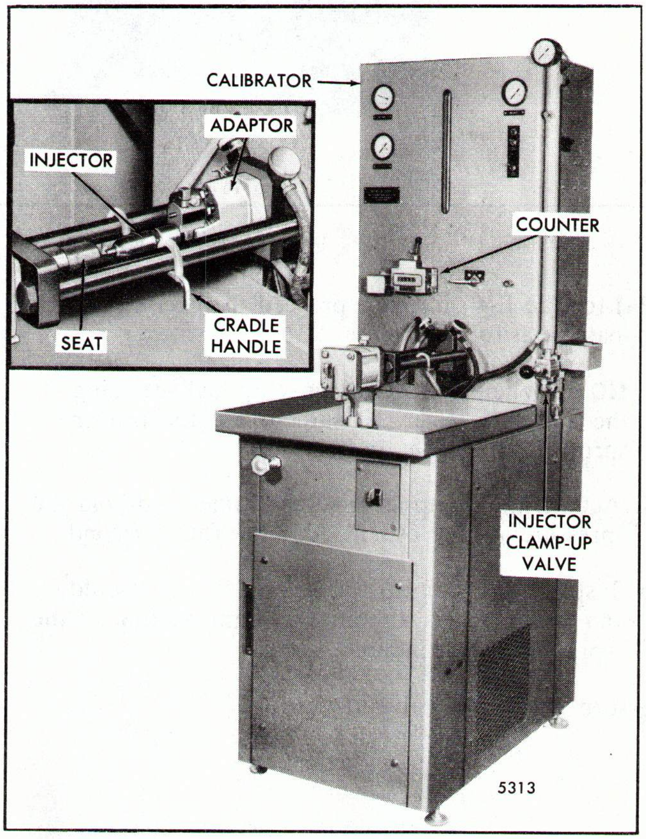


Fig. 21 - Injector in Calibrator J 22410

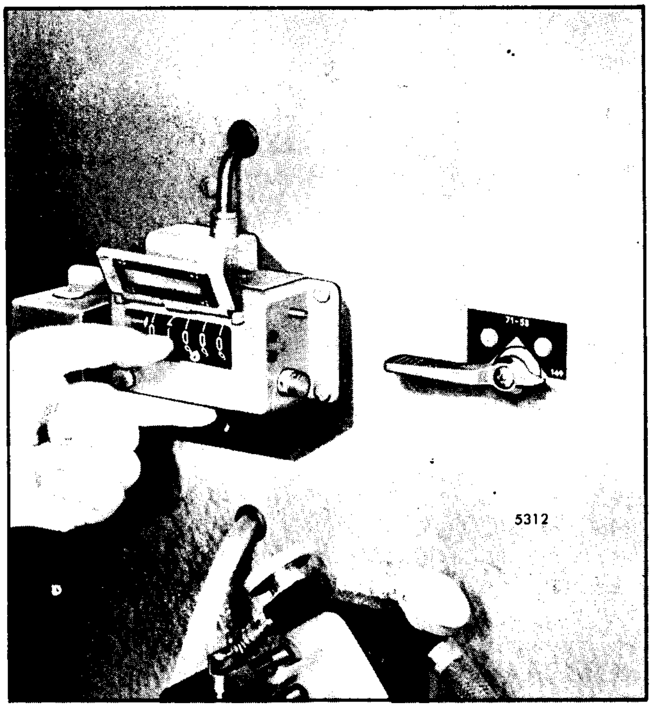


Fig. 22 - Setting Calibrator Stroke Counter

2. Place the injector seat J 22410-226 into the permanent seat (cradle handle in vertical position). Clamp the injector into position by operating the air valve.

> **NOTE:** Make sure the counter (Fig. 22) on the calibrator is preset at 1000 strokes. If for any reason this setting has been altered, reset the counter to 1000 strokes by twisting the cover release button to the left and hold the reset lever in the full up position while setting the numbered wheels. Close the cover. Refer to the calibrator instruction booklet for further information.

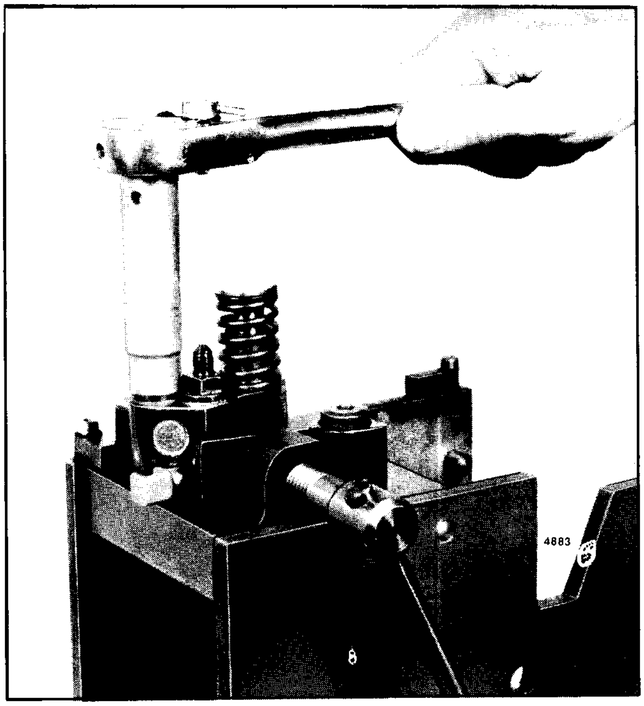


Fig. 23 - Removing or Installing Filter Cap

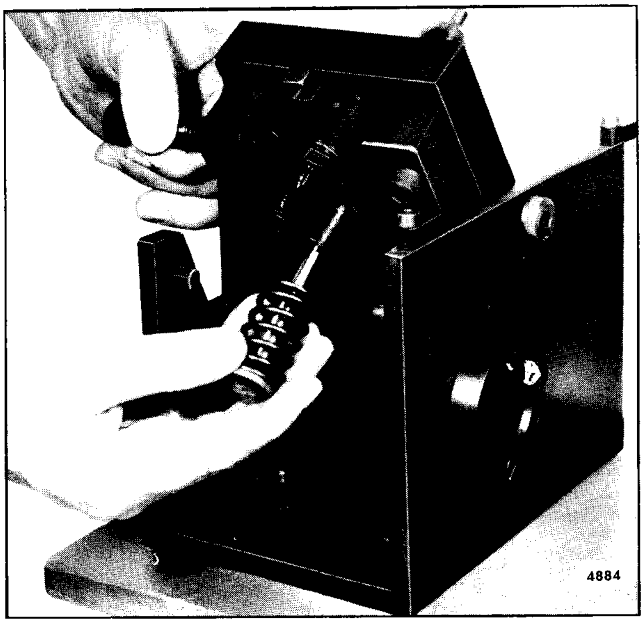


Fig. 24 - Removing or Installing Plunger Follower, Plunger and Spring

3. Pull the injector rack out to the no-fuel position.

4. Turn on the main power control circuit switch. Then start the calibrator by turning on the motor starter switch.

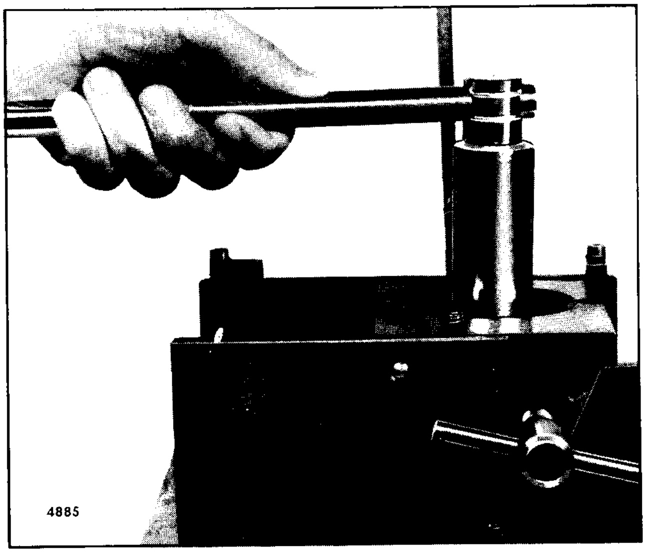


Fig. 25 - Removing Injector Nut using Tool J 4983-01

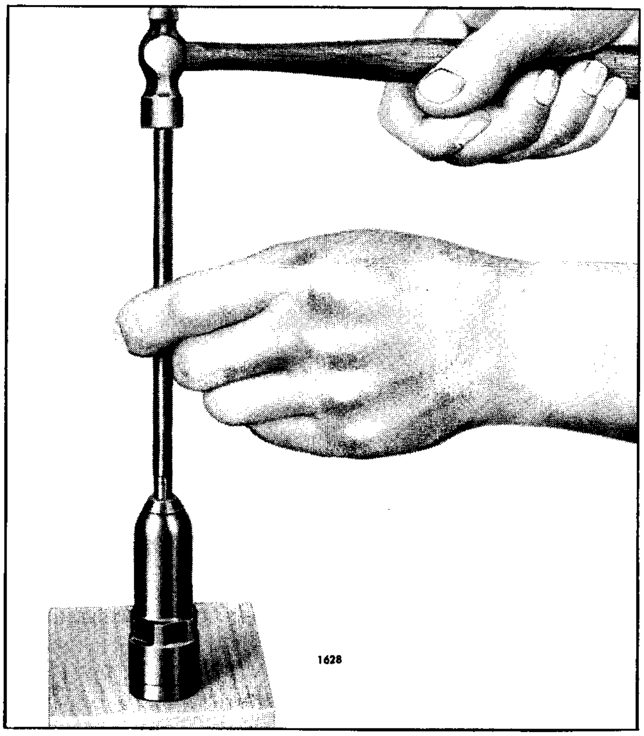


Fig. 26 - Removing Spray Tip from Injector Nut using Tool J 1291-02

NOTE: The low oil pressure warning buzzer will sound briefly until the lubricating oil reaches the proper pressure.

5. After the calibrator has started, set the injector rack into the full-fuel position. Allow the injector to operate for approximately 30 seconds to purge the air that may be in the system.

6. After the air is purged, press the fuel flow start button (red). This will start the flow of fuel into the vial. The fuel flow to the vial will automatically stop after 1000 strokes.

7. Shut the calibrator off (the calibrator will stop in less time at full-fuel).

8. Observe the vial reading and refer to Fig. 19 to determine whether the injector fuel output falls within the specified limits. If the quantity of fuel in the vial does not fall within the specified limits, refer to *Trouble Shooting Chart* 6 and *Shop Notes* in section 2.0 for the cause and remedy.

NOTE: Refer to Section 2.0 for different factors that may affect the injector calibrator output reading.

The calibrator may be used to check and select a set of injectors which will inject the same amount of fuel in

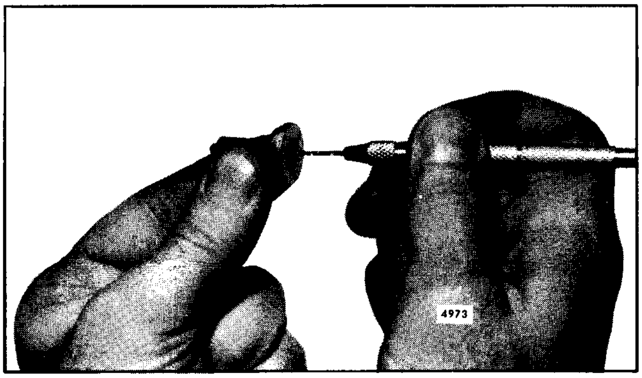


Fig. 27 - Cleaning Injector Spray Tip with Tool J 24838

each cylinder at a given throttle setting, thus resulting in a smooth running, well balanced engine.

An injector which passes all of the above tests may be put back into service. However, an injector which fails to pass one or more of the tests must be rebuilt and checked on the calibrator.

Any injector which is disassembled and rebuilt must be tested again before being placed in service.

Disassemble Injector

If required, disassemble an injector as follows:

1. Support the injector upright in injector holding fixture J 22396 (Fig. 23) and remove the filter caps, gaskets and filters.

NOTE: Whenever a fuel injector is disassembled, discard the filters and gaskets and replace with new filters and gaskets. *In the offset*

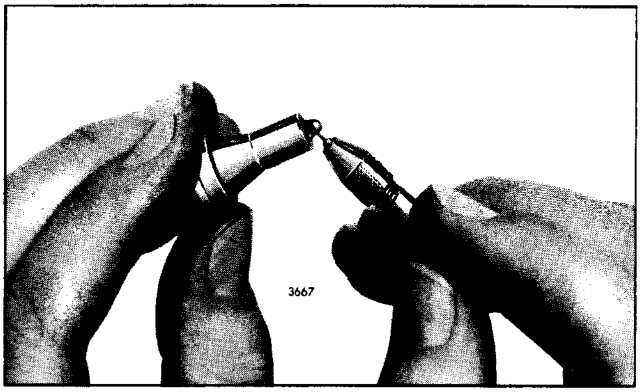


Fig. 28 - Cleaning Spray Tip Orifices with Tool J 4298-1

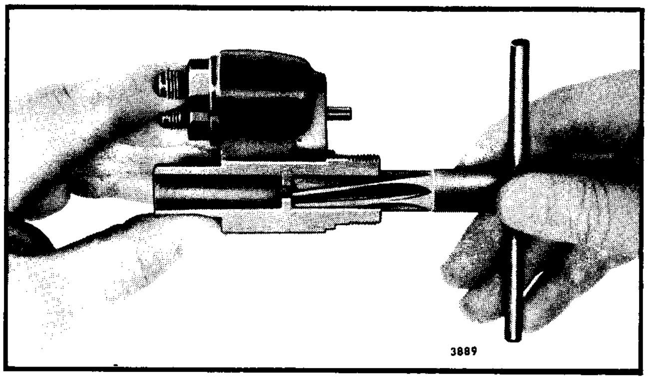


Fig. 29 - Cleaning Injector Body Ring with Tool J 21089

injector, a filter is used in the inlet side only. No filter is required in the outlet side (Fig. 35).

2. Compress the follower spring as shown in Fig. 11. Then raise the spring above the stop pin with a screw driver and withdraw the pin. Allow the spring to rise gradually.

3. Refer to Fig. 24 and remove the plunger follower, plunger and spring as an assembly.

4. Invert the fixture and, using socket J 4983-01, loosen the nut on the injector body (Fig. 25).

5. Lift the injector nut straight up, being careful not to dislodge the spray tip and valve parts. Remove the spray tip and valve parts from the bushing and place them in a clean receptacle until ready for assembly.

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 as shown in Fig. 26.

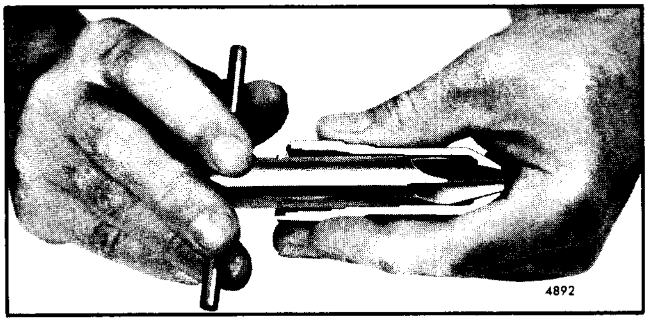


Fig. 30 - Cleaning Injector Nut Spray Tip Seat with Tool J 9418-5

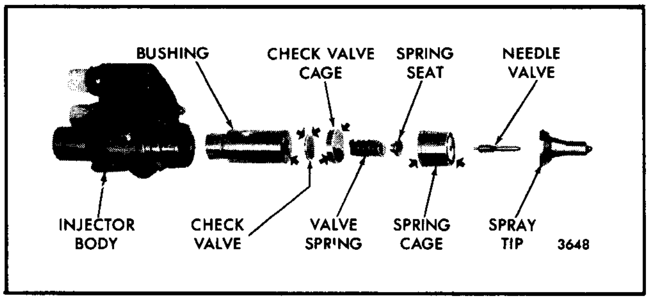


Fig. 31 - Sealing Surfaces which may Require Lapping

6. Refer to Fig. 37 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 difficulties are the result of dirt particles, it is essential that a clean area be provided on which to place the injector parts after cleaning and inspection.

Wash all of the parts with clean fuel oil or a suitable cleaning solvent and dry them with clean, filtered compressed air. *Do not use waste or rags for cleaning purposes.* Clean out all of the passages, drilled holes and slots in all of the injector parts.

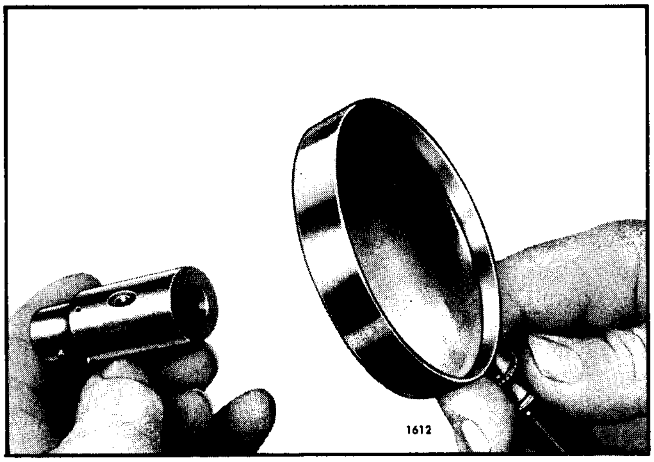


Fig. 32 - Examining Sealing Surface with a Magnifying Glass

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 9464-01 (Fig. 27).

NOTE: Care must be exercised when inserting the carbon remover J 9464-01 in the spray tip to avoid contacting the needle valve seat in the tip.

Wash the tip in fuel oil 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. 28).

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.

The exterior surface of an injector spray tip may be cleaned by using a brass wire buffing wheel, tool J 7944. To obtain a good polishing effect and longer brush life, the buffing wheel should be installed on a motor that turns the wheel at approximately 3000 rpm. A convenient method of holding the spray tip while cleaning and polishing is to place the tip over the drill end of the spray tip cleaner tool J 1243-01 and hold the body of the tip against the buffing wheel. In this way, the spray tip is rotated while being buffed.

NOTE: Do not buff 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. This cleans the spray tip orifice area and will not plug the orifices.

Wash the spray tip in clean fuel oil and dry it with compressed air.

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. 29). 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.

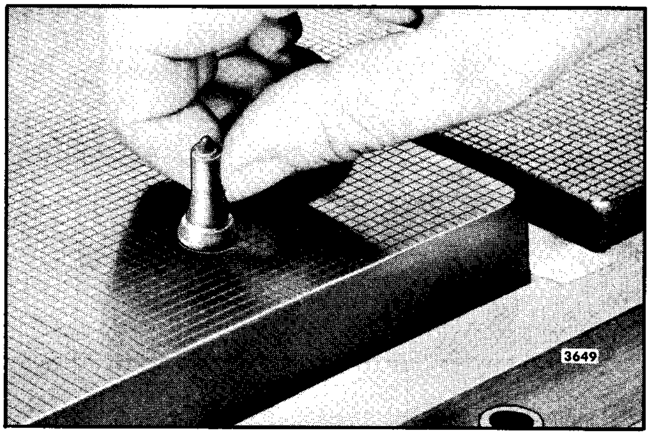


Fig. 33 - Lapping Spray Tip on Lapping Blocks J 22090

Carefully insert a .375" diameter straight fluted reamer inside the ring bore in the injector body. Turn the reamer in a clockwise direction and remove any burrs inside the ring bore. Then wash the injector body in clean fuel oil and dry it with compressed air.

Remove the carbon deposits from the lower inside diameter taper of the injector nut with carbon remover J 9418-5 (Fig. 30). 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. Carefully insert carbon remover J 9418-1 in the injector nut. Turn it clockwise to remove the carbon deposits on the flat spray tip seat.

Wash the injector nut in clean fuel oil and dry it with compressed air. Carbon deposits on the spray tip seating surfaces of the injector nut will result in poor sealing and consequent fuel leakage around the spray tip.

When handling the injector plunger, do not touch the

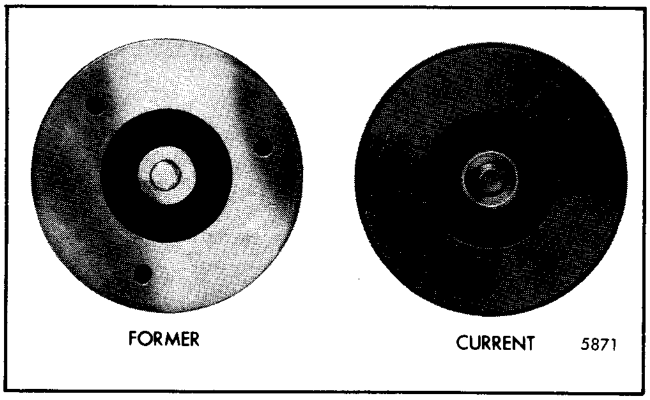


Fig. 34 - Spray Tip Sealing Surface Identification

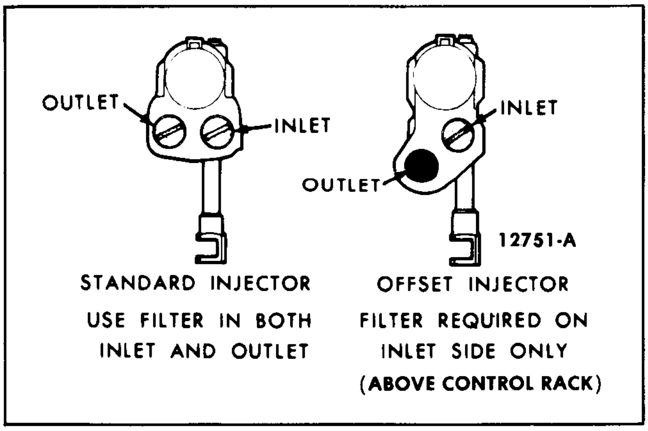


Fig. 35 - Location of Filter in Injector Body

finished plunger surfaces with your fingers. Wash the plunger and bushing with clean fuel oil 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.*

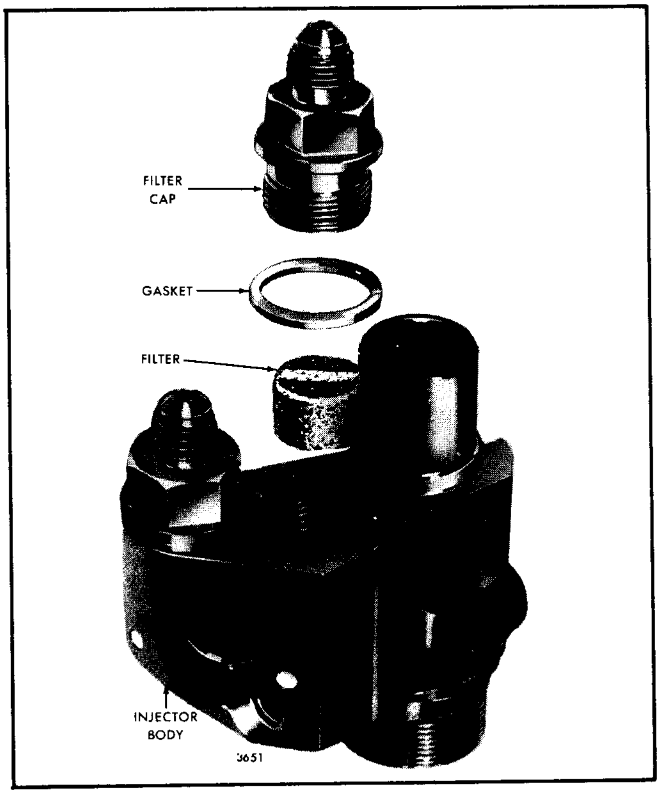


Fig. 36 - Details of Injector Filters and Caps and Their Relative Location

After washing, submerge the parts in a clean receptable containing clean fuel oil. *Keep the parts of each injector assembly together.*

Inspect Injector Parts

Inspect the teeth on the control rack and the control rack gear for excessive wear or damage. Also check for excessive wear in the bore of the gear and inspect the gear retainer. Replace damaged or worn parts.

Inspect the injector follower and pin for wear.

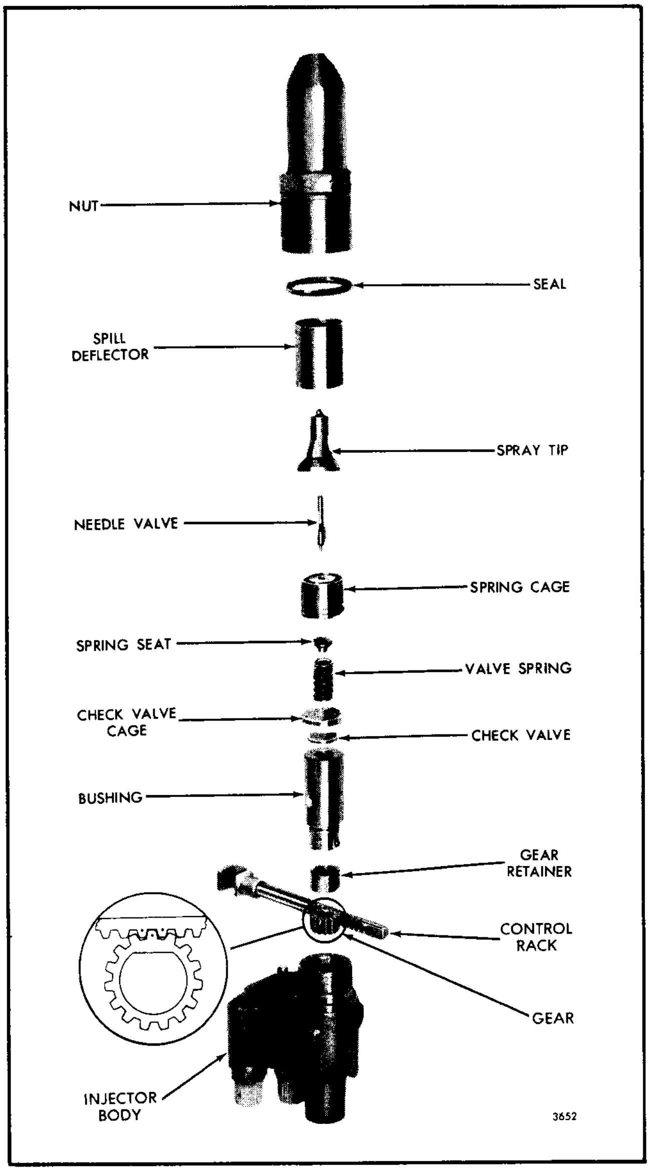


Fig. 37 - Injector Rack, Gear, Spray Tip and Valve Assembly Details and Relative Location of Parts

Inspect both ends of the spill deflector for sharp edges or burrs which could create burrs on the injector body or injector nut and cause particles of metal to be introduced into the spray tip and valve parts. Remove burrs with a 500 grit stone.

Inspect the follower spring for visual defects. Then check the spring with spring tester J 22738-02.

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".

It is recommended that at the time of overhaul, all injectors in an engine be converted to the current spring (.142" diameter wire) which will provide improved cam roller to shaft follow. However, in the event that one or two injectors are changed, the remaining injectors need not be reworked to incorporate the current spring.

Check the seal ring area on the injector body for burrs or scratches. Also check the surface which contacts the injector bushing for scratches, scuff marks or other damage. If necessary, lap this surface. A faulty sealing surface at this point will result in high fuel consumption and contamination of the lubricating oil. Replace any loose injector body plugs or a loose dowel pin. Install the proper number tag on a service replacement injector body.

Inspect the injector plunger and bushing for scoring, erosion, chipping or wear. Check for sharp edges on that portion of the plunger which rides in the gear. Remove any sharp edges with a 500 grit stone. Wash the plunger after stoning it. Check the port holes in the inner diameter of the bushing for cracks or chipping. Slip the plunger into the bushing and check for free movement. *Replace the plunger and bushing as an assembly if any of the above damage is noted, since they are mated parts.* Use new mated factory parts to assure the best performance from the injector.

Injector plungers cannot be reworked to change the output. Grinding will destroy the hardened case at the helix and result in chipping and seizure or scoring of the plunger.

Examine the spray tip seating surface of the injector nut and spray tip for nicks, burrs, erosion or brinelling. Reseat the surface or replace the nut or tip if it is severely damaged.

The injector valve spring plays an important part in establishing the valve opening pressure of the injector assembly. Replace a worn or broken spring.

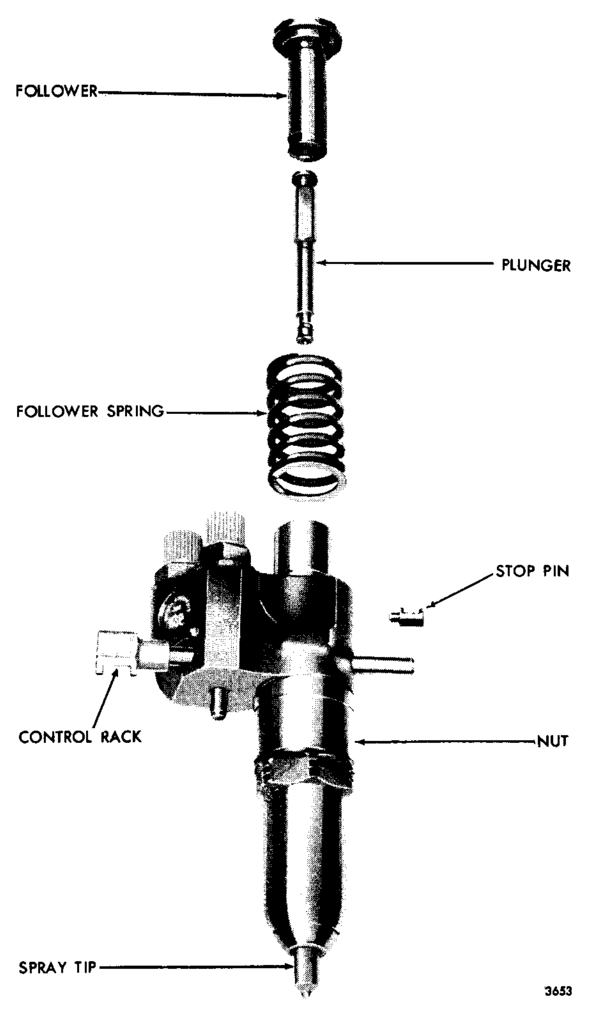


Fig. 38 - Injector Plunger, Follower and Relative Location of Parts

Inspect the sealing surfaces of the injector parts indicated by arrows in Fig. 31. Examine the sealing surfaces with a magnifying glass as shown in Fig. 32 for even the slightest imperfections will prevent the injector from operating properly. Check for burrs, nicks, erosion, cracks, chipping and excessive wear. Also check for enlarged orifices in the spray tip. Replace damaged or excessively worn parts. Check the minimum thickness of the lapped parts as noted in the chart.

Examine the seating area of the needle valve for wear or damage. Also examine the needle quill and its contact point with the valve spring seat. Replace damaged or excessively worn parts.

Examine the needle valve seat area in the spray tip for foreign material. The smallest particle of such

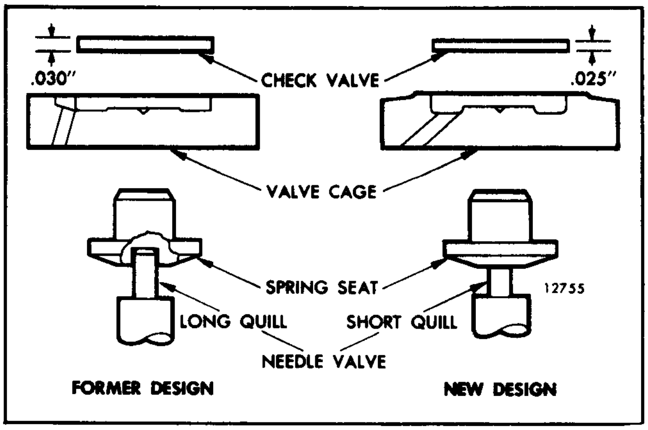


Fig. 39 - Comparison of Former and New Design Injector Parts

material can prevent the needle valve from seating properly. Polish the seat area with polishing stick J 22964. Coat only the tapered end of the stick with polishing compound J 23038 and insert it directly into the center of the spray tip until it bottoms. Rotate the stick 6 to 12 times, applying a light pressure with the thumb and forefinger.

NOTE: Be sure that no compound is accidentally placed on the lapped surfaces located higher up in the spray tip. The slightest lapping action on these surfaces can alter the near-perfect fit between the needle valve and tip.

Before reinstalling used injector parts, lap all of the sealing surfaces indicated by the arrows in Fig. 31. It is also good practice to lightly lap the sealing surfaces of new injector parts which may become burred or nicked during handling.

NOTE: 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. 34). It is not recommended or necessary to lap the surface of a *new* current spray tip.

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)

Lapping Injector Parts

Lap the sealing surfaces indicated in Fig. 31 and Table 1 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 as shown in Fig. 33 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* (refer to Table 1).

5. When the part is flat, wash it in cleaning solvent and dry it with compressed air.

6. Place the dry part on the second block. After applying lapping powder, move the part lightly across the block in a figure eight motion several times to give it a smooth finish. *Do not lap excessively.* Again wash the part in cleaning solvent and dry it with compressed air.

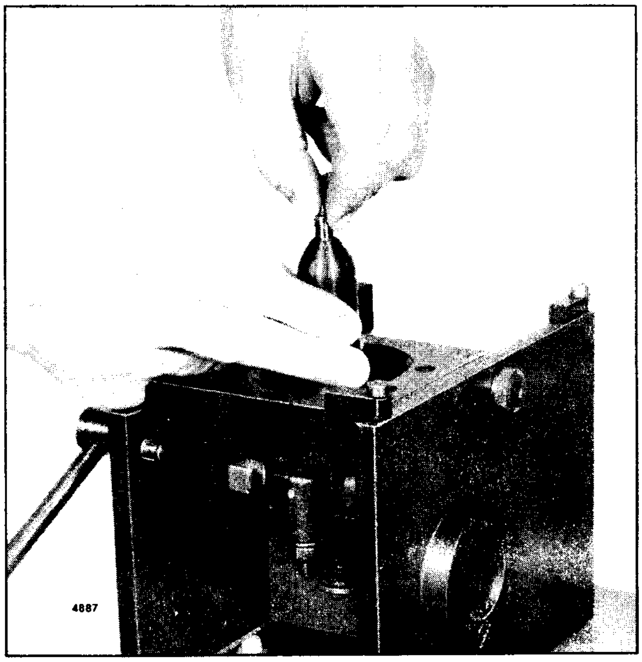


Fig. 40 - Tightening Injector Nut by Hand

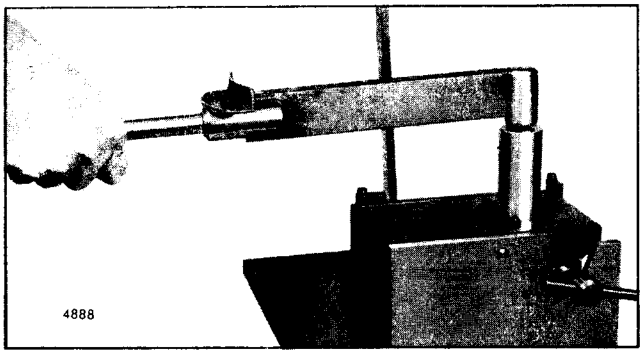


Fig. 41 - Tightening Injector Nut With Torque Wrench and Tool J 4983-01

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 fuel oil and dry them with compressed air.

ASSEMBLE INJECTOR

Use an extremely clean bench to work on and to place the parts when assembling an injector. Also be sure all of the injector parts, both new and used, are clean.

Study Figs. 35 through 38 for the proper relative position of the injector parts, then proceed as follows:

Assemble Injector Filters

Always use new filters and gaskets when re-assembling an injector.

1. Insert a new filter, dimple end down, slotted end up, in each of the fuel cavities in the top of the injector body (Fig. 36).

   NOTE: Install a new filter in the inlet side (located over the injector rack) in a fuel injector with an offset body. No filter is required in the outlet side of the offset body injector (Fig. 35).

2. Place a new gasket on each filter cap. Lubricate the threads and install the filter caps. Tighten the filter caps to 65-75 lb-ft (88-102 Nm) torque with a 9/16" deep socket (Fig. 23).

3. Purge the filters after installation by directing compressed air or fuel through the filter caps.

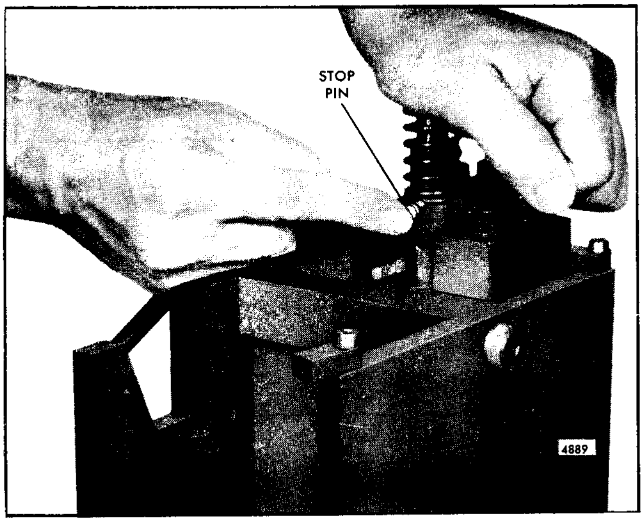


Fig. 42 - Installing Injector Follower Stop Pin

4. Install clean shipping caps on the filter caps to prevent dirt from entering the injector.

Assemble Rack and Gears

Refer to Fig. 37 and note the drill spot marks on the control rack and gear. Then proceed as follows:

1. Hold the injector body, bottom end up, and slide the rack through the hole in the body. Look into the body bore and move the rack until you can see the drill marks. Hold the rack in this position.

2. Place the gear in the injector body so that the marked tooth is engaged between the two marked teeth on the rack (Fig. 37).

3. Place the gear retainer on top of the gear.

4. Align the locating pin in the bushing with the slot in the injector body, then slide the end of the bushing into place.

Assemble Spray Tip, Spring Cage and Check Valve Assemblies

Refer to Fig. 37 and assemble the parts as follows:

1. Support the injector body, bottom end up, in injector holding fixture J 22396.

2. Place a new seal ring on the shoulder of the body.

   NOTE: Wet the seal ring with test oil and install the ring all the way down past the threads and onto the shoulder of the injector body. This will

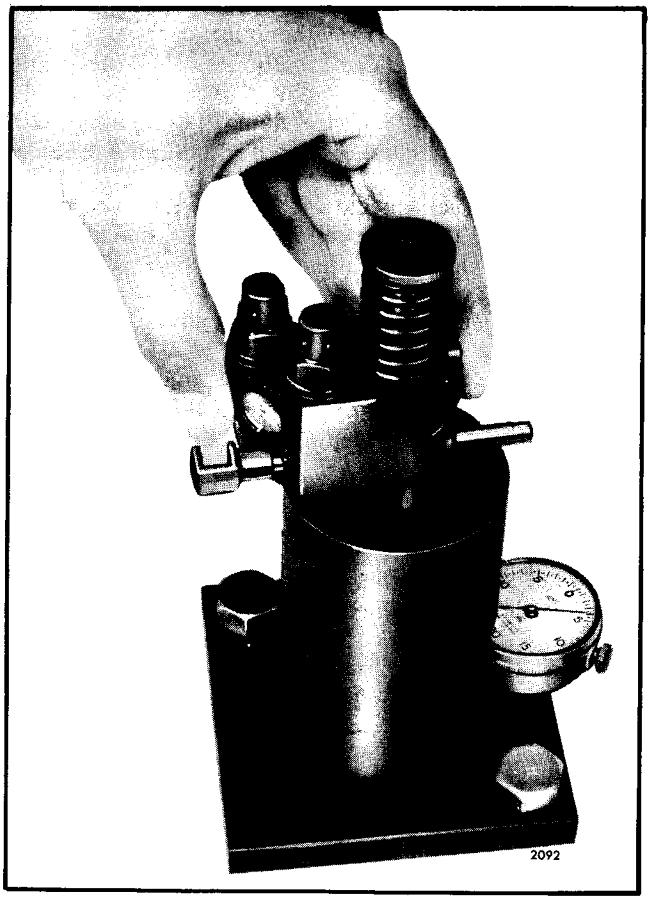


Fig. 43 · Checking Injector Spray Tip Concentricity with Tool J 5119

prevent the seal from catching in the threads and becoming shredded.

A new injector nut seal ring protector (J 29197) is now available to install the seal ring. Use the following procedure when installing the seal ring with the new protector:

a. PLace the new seal ring and protector in a container with a small amount of injector test oil.

NOTE: Lubrication of the seal ring and protector is important to assure proper installation of the seal ring.

b. Support the injector body, bottom end up, in injector holding fixture J 22396.

c. Place the lubricated protector over the threads of the injector body. 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.

d. Removė the protector.

3. Install the spill deflector over the barrel of the bushing.

4. 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.

NOTE: The former and new check valve and check valve cage are not separately interchangeable in a former injector (Fig. 39).

5. Insert the spring seat in the valve spring, then insert the assembly into the spring cage, spring seat first.

NOTE: Install a new spring seat (Fig. 39) in a former injector if a new design spray tip assembly is used.

6. Place the spring cage, spring seat and valve spring assembly (valve spring down) on top of the check valve cage.

NOTE: When installing a new spray tip assembly in a former injector, a new valve spring seat must also be installed. The current needle valve has a shorter quill.

7. Insert the needle valve, tapered end down, inside of the spray tip (Fig. 2). Then place the spray tip and needle valve on top of the spring cage with the quill end of the needle valve in the hole in the spring cage.

8. 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. 40). 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.

9. Use socket J 4983-01 and a torque wrench to tighten the injector nut to 75-85 lb-ft (102-115 Nm) torque (Fig. 41).

10. 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 which may allow assembly on the body without extruding the seal and forcing it out of the body-nut crevice.

NOTE: 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.

Assemble Plunger and Follower

1. Refer to Fig. 38 and slide the head of the plunger into the follower.

2. Invert the injector in the assembly fixture (filter cap end up) and push the rack all the way in. Then place the follower spring on the injector body.

3. Refer to Fig. 42 and place the stop pin on the injector body so that the follower spring rests on the narrow flange of the stop pin. Then align the slot in the follower with the stop pin hole in the injector body. Next align the flat side of the plunger with the slot in the follower. Then insert the free end of the plunger in the injector body. Press down on the follower and at the same time press the stop pin into position. When in place, the spring will hold the stop pin in position.

Check Spray Tip Concentricity

To assure correct alignment, check the concentricity of the spray tip as follows:

1. Place the injector in the concentricity gage J 5119 as shown in Fig. 43 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 75-85 lb-ft (102-115 Nm) torque. Recheck the spray tip concentricity. If, after several attempts, the spray tip cannot be positioned satisfactorily, replace the injector nut.

Test Reconditioned Injector

Before placing a reconditioned injector in service, perform all of the tests (except the visual inspection of the plunger) previously outlined under *Test Injector.*

The injector is satisfactory if it passes these tests. Failure to pass any one of the tests indicates that defective or dirty parts have been assembled. In this case, disassemble, clean, inspect, reassemble and test the injector again.

Install Injector

Before installing an injector in an engine, remove the carbon deposits from the beveled seat of the injector tube in the cylinder head. This will assure correct alignment of the injector and prevent any undue stresses from being exerted against the spray tip.

Use injector tube bevel reamer J 5286-9, Section 2.1.4, to clean the carbon from the injector tube. Exercise care to remove ONLY the carbon so that the proper clearance between the injector body and the cylinder head is maintained. Pack the flutes of the reamer with grease to retain the carbon removed from the tube.

Be sure the fuel injector is 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. 6 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 Nm) torque. Make sure that the clamp does not interfere with the injector follower spring or the exhaust valve springs.

> **NOTE:** 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.

> **NOTE:** 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. Therefore, note the position of the exhaust valve bridge (Fig. 44) before, during and after tightening the rocker shaft bolts.

5. Remove the shipping caps. Then install the fuel pipes and connect them to the injector and the fuel connectors. Use socket J 8932-01 to tighten the connections to 12-15 lb-ft (16-20 Nm) torque. 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 *Pressurize Fuel System-Check for Leaks* in Section 2.0).

> **NOTE:** An indication of fuel leakage at the fittings of the fuel injector supply lines and connector nut seals could be either low

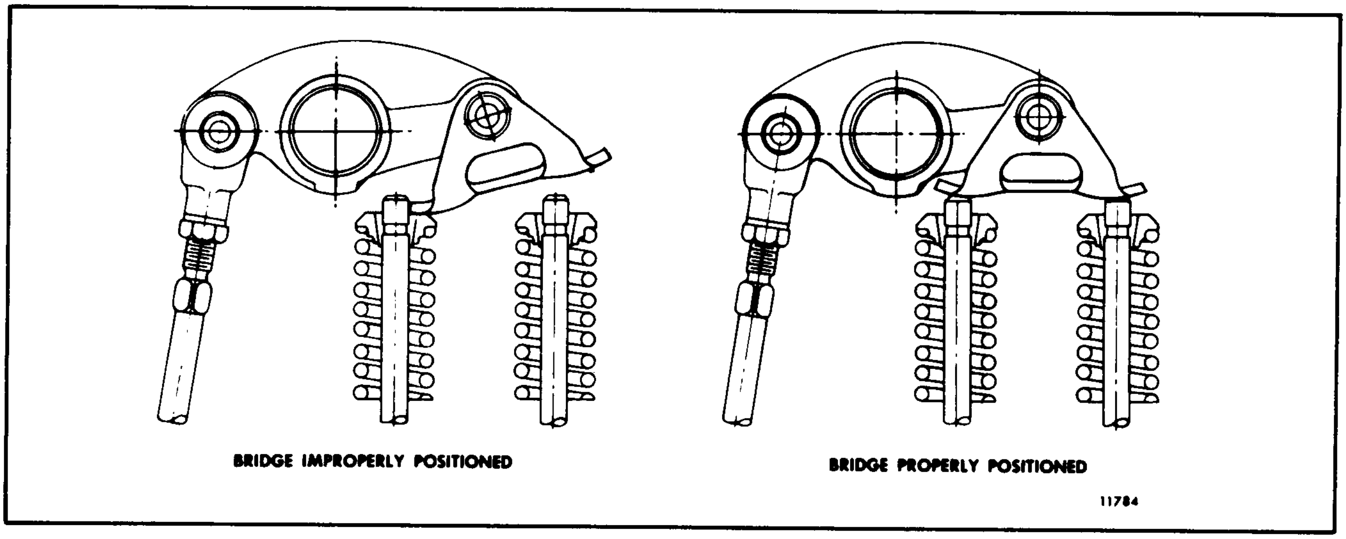


Fig. 44 - Relationship Between Exhaust Valve Bridge and Valve Stems

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. Reinstall the rocker cover. Then drain the lubricating oil and change the oil filter elements. Refer to Section 13.3 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 lever.

FUEL INJECTOR TUBE

The bore in the cylinder head for the fuel injector is directly through the cylinder head water jacket as shown in Fig. 1. To prevent coolant from contacting the injector and still maintain maximum cooling of the injector, a tube is pressed into the injector bore. This tube is sealed at the top with a neoprene ring (former) or fluorelastomer (current) and upset into a flare on the lower side of the cylinder head to create water-tight and gas-tight joints at the top and bottom.

NOTE: Ethylene glycol base antifreeze is recommended for use in all Detroit Diesel engines. Methyl alcohol base antifreeze is not recommended because of its effect on the fluoroelastomer seal rings in the cylinder head.

Remove Injector Tube

When removal of an injector tube is required, use injector tube service tool set J 22525 as follows:

1. Remove, disassemble and clean the cylinder head, as outlined in Section 1.2.

2. Place the injector tube installer J 5286-4A in the injector tube. Insert the pilot J 5286-5 through the small opening of the injector tube and thread the pilot into the tapped hole in the end of the installer (Fig. 1).

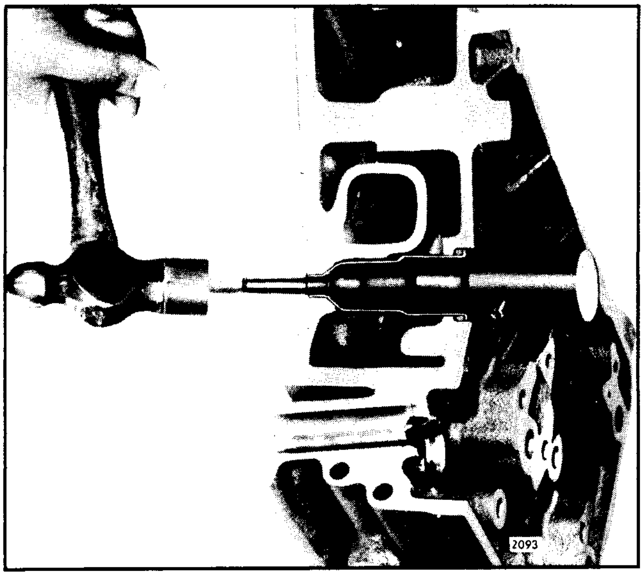


Fig. 1 - Removing Injector Tube using Tools J 5286-4A and J 5286-5

3. Tap on the end of the pilot to loosen the injector tube. Then, lift the injector tube, installer and pilot from the cylinder head.

Install Injector Tube

Thoroughly clean the injector tube hole in the cylinder head to remove dirt, burrs or foreign material that may prevent the tube from seating at the lower end or sealing at the upper end. Then, install the tube as follows:

1. Lubricate the new injector tube seal ring with engine oil and place it in the counterbore in the cylinder head.

NOTE: DO NOT lubricate the outside of the injector tube or inside the cylinder head injector tube bore to facilitate installation of the tube. Lubricant will cause the tube to turn during reaming or rolling operations possibly damaging the injector tube or reamers.

2. Place the installer J 5286-4A 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).

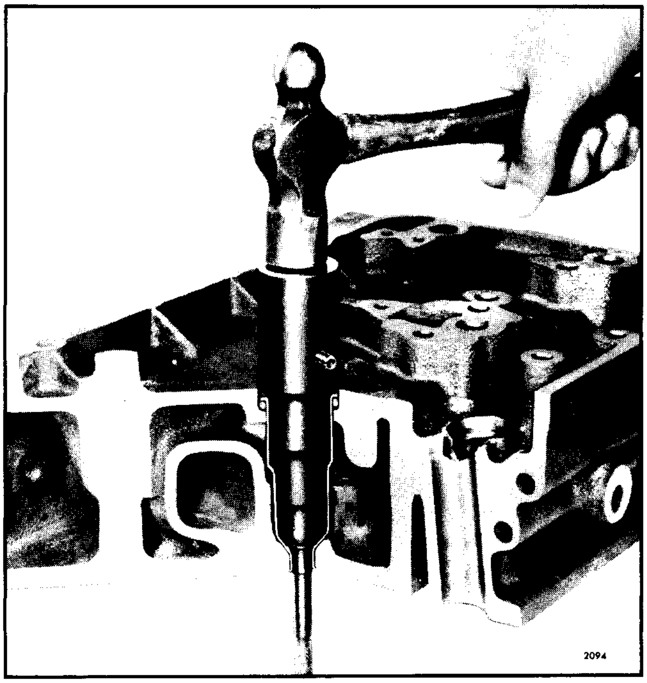


Fig. 2 - Installing Injector Tube using Tools J 5286-4A and J 5286-5

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.

NOTE: 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 5286-4A (Fig. 3).

b. Then, using a socket and torque wrench, apply approximately 30 lb-ft (41 Nm) torque on the upsetting die.

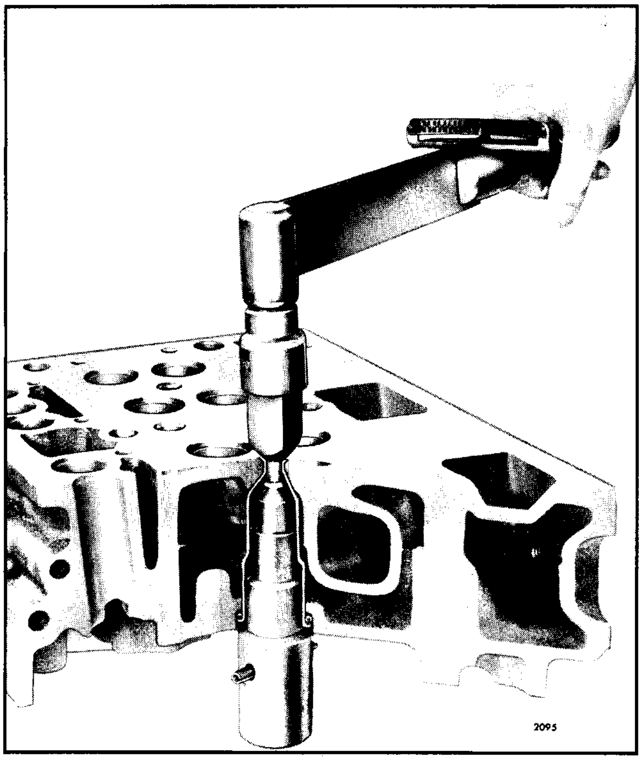


Fig. 3 - Upsetting Injector Tube using Tools J 5286-4A and J 5286-6

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. 4, to receive the injector body nut and spray tip; second, *spot-faced* to remove excess stock at the lower end of the injector tube; and third, *hand reamed,* as shown in Fig. 5, to provide a good seating surface for the bevel or the lower end of the injector nut. Reaming must be done carefully and without undue force or speed so as to avoid cutting through the thin wall of the injector tube.

NOTE: 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

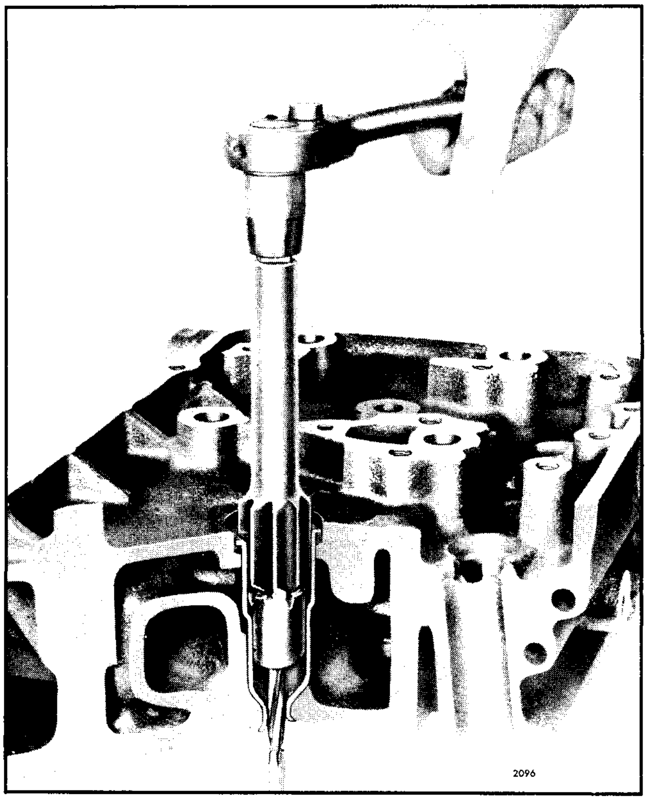


Fig. 4 - Reaming Injector Tube for Injector Body Nut and Spray Tip using Tool J 22525-1

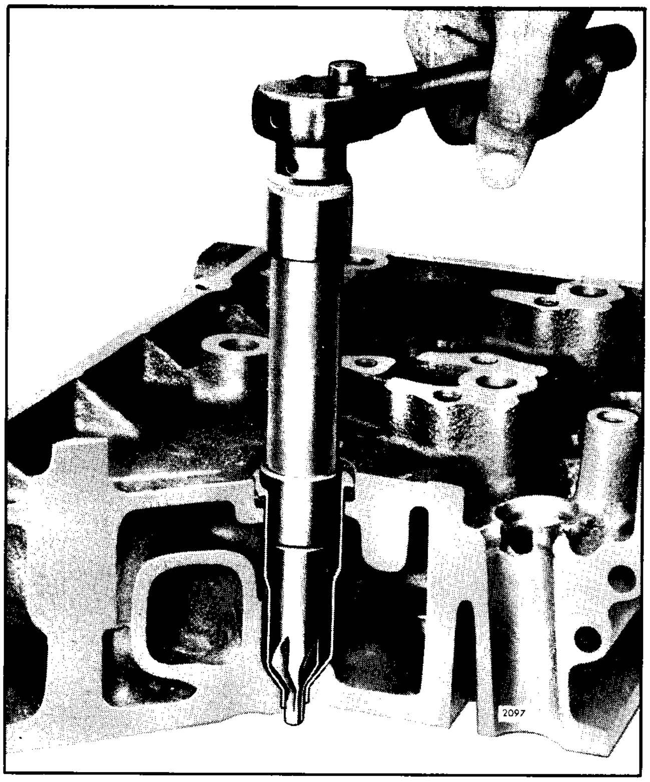


Fig. 5 - Reaming Injector Tube for Injector Nut using Tool J 5286-9

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. 4). 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.

3. Ream the bevel seat in the injector tube:

The tapered lower end of the injector tube must provide a smooth and true seat for the lower end of the injector nut to effectively seal the cylinder pressures and properly position the injector tip in the combustion chamber. Therefore, to determine the

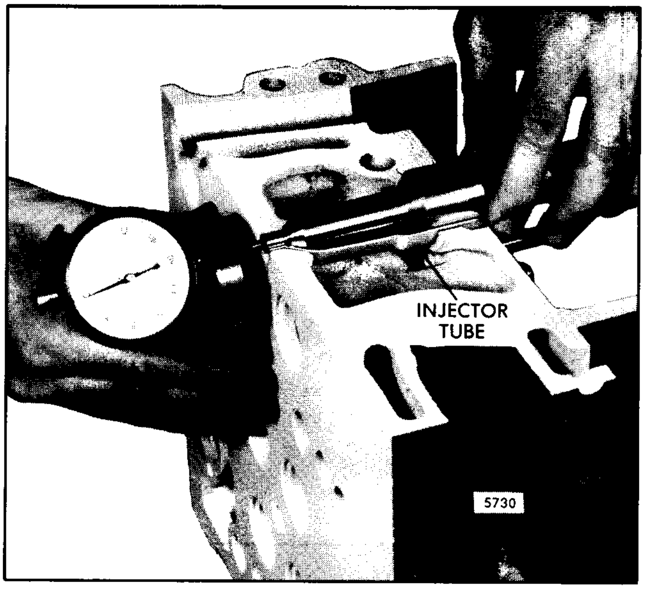


Fig. 6 - Measuring Relationship of Bevel Seat in Injector Tube to Cylinder Head Fire Deck using Tools J 22273 and J 25521

amount of stock that must be reamed from the bevel seat of the tube, refer to Fig. 6.

Install gage J 25521 in the injector tube. Zero the sled gage dial indicator J 22273 to the fire deck. Gage J 25521 should be flush to $\pm$.014" with the fire deck of the cylinder head (Fig. 7).

NOTE: Any fire deck resurfacing work must be done prior to final injector tube seat gaging. Refer to Section 1.2 for resurfacing instructions.

With the first reaming operation completed and the injector tube spot-faced, wash the interior of the injector tube with clean solvent and dry it with compressed air. Then perform the second reaming operation as follows:

a. Place a few drops of cutting oil on the bevel seat of the tube. Carefully lower the reamer J 5286-9 into the injector tube until it contacts the bevel seat.

b. Make a trial cut by turning the reamer steadily without applying any downward force on the reamer. Remove the reamer, blow out the chips and look at the bevel seat to see what portion of the seat has been cut.

c. Proceed carefully with the reaming operation, withdrawing the reamer occasionally to observe the reaming progress.

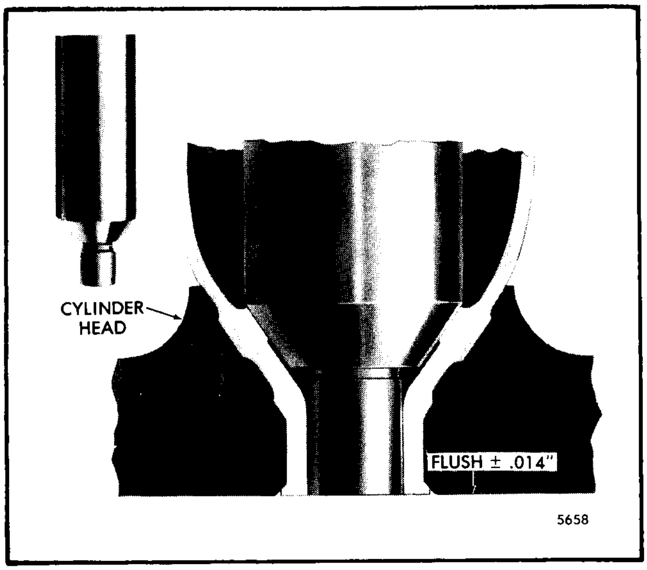


Fig. 7 - Measuring Relationship of Gage to Cylinder Head Fire Deck using Tool J 25521

d. Remove the chips from the injector tube and, using gage J 25521, continue the reaming operation until the shoulder of the spray tip is flush to ±.014" with the fire deck of the cylinder head as shown in Fig. 7. Then wash the interior of the injector tube with clean solvent and dry it with compressed air.

FUEL PUMP

The positive displacement gear-type fuel pump transfers fuel from the supply tank to the fuel injectors (Fig. 1). The pump circulates an excess supply of fuel through the injectors which purges the air from the system and cools the injectors. The unused portion of fuel returns to the fuel tank by means of a fuel return manifold and fuel return line.

On the In-line engine, the fuel pump is mounted on the governor weight housing and is driven through a drive coupling by the governor weight shaft. On the V-type engine, the fuel pump is mounted on the flywheel housing and is driven by the accessory drive gear.

Certain engine applications use a high-capacity fuel pump with 3/8" wide gears to increase fuel flow and reduce fuel spill temperature. The high-capacity fuel pump and the standard fuel pump with 1/4" wide gears may not be completely interchangeable; therefore, when replacing a standard pump with a high-capacity pump, the appropriate fuel lines and connections must be used.

The fuel pump cover and body are positioned by two dowels. The dowels aid in maintaining gear shaft alignment. The mating surfaces of the pump body and cover are perfectly flat ground surfaces. No gasket is used between the cover and body since the pump clearances are set up on the basis of metal-to-metal contact. A very thin coat of sealant provides a seal against any minute irregularities in the mating surfaces. Cavities in the pump cover accommodate the ends of the drive and driven shafts.

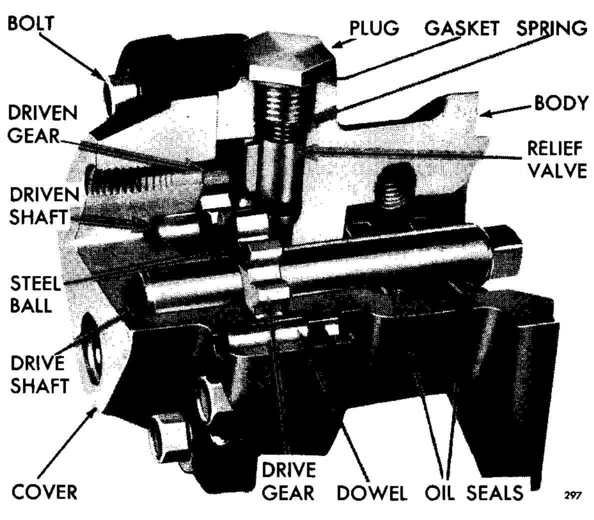


Fig. 1 - Typical Fuel Pump Assembly

The fuel pump body is recessed to provide running space for the pump gears (Fig. 2). Recesses are also provided at the inlet and outlet positions of the gears. The small hole "A" permits the fuel oil in the inlet side of the pump to lubricate the relief valve at its outer end and to eliminate the possibility of a hydrostatic lock which would render the relief valve inoperative. Pressurized fuel contacts the relief valve through hole "B" and provides for relief of excess discharge pressures. Fuel reenters the inlet side of the pump through hole "C" when the discharge pressure is great enough to move the relief valve back from its seat. Part of the relief valve may be seen through hole "C". The cavity "D" provides escape for the fuel oil which is squeezed out of the gear teeth as they mesh together on the discharge side of the pump. Otherwise, fuel trapped at the root of the teeth would tend to force the gears apart, resulting in undue wear on the gears, shafts, body and cover.

Two oil seals are pressed into the bore in the flanged side of the pump body to retain the fuel oil in the pump and the lubricating oil in the blower timing gear compartment (Fig. 3). A small hole "E" (Fig. 2) serves as a vent passageway in the body, between the inner oil seal and the suction side of the pump, which prevents building up any fuel oil pressure around the shaft ahead of the inner seal.

A higher temperature material lip type seal is now being used in the fuel pumps. The new fuel pump seal is made of a polyacrylate material, whereas the former seal is made of nitrile. The new fuel pumps (with the polyacrylate seals) will have the seals installed with the lips of the seals facing in the opposite direction of each other (Fig. 3). The former fuel pumps have the seals installed with both seal lips facing the mounting flange end of the pump. Both the polyacrylate and former nitrile seals are interchangeable in a fuel pump. Only the polyacrylate seals and fuel pumps with polyacrylate seals will be serviced.

Some fuel oil seepage by the fuel pump seals can be expected, both with a running engine and immediately after an engine has been shut down. This is especially true with a new fuel pump and/or new pump seals, as the seals have not yet conformed to the pump drive shaft. Fuel pump seals will always allow some seepage. Tapped holes in the pump body are provided to prevent fuel oil from being retained between the seals. Excessive fuel retention between the seals could provide enough pressure to cause engine oil dilution by fuel, therefore, drainage of the excess fuel oil is mandatory. However, if leakage exceeds one drop per minute, replace the seals.

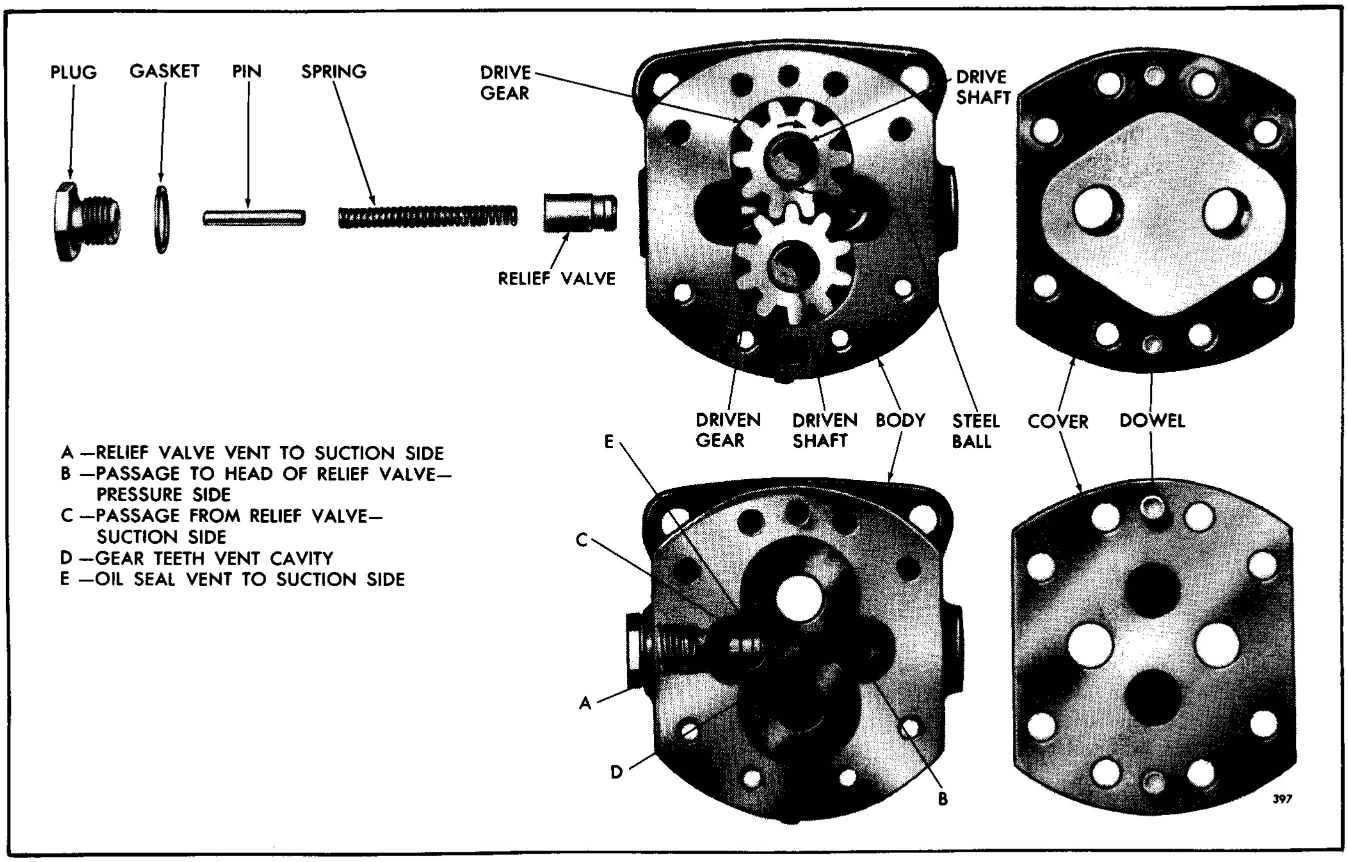


Fig. 2 - Fuel Pump Valving and Rotation (Right Hand Pump Shown)

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 bypassing 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.

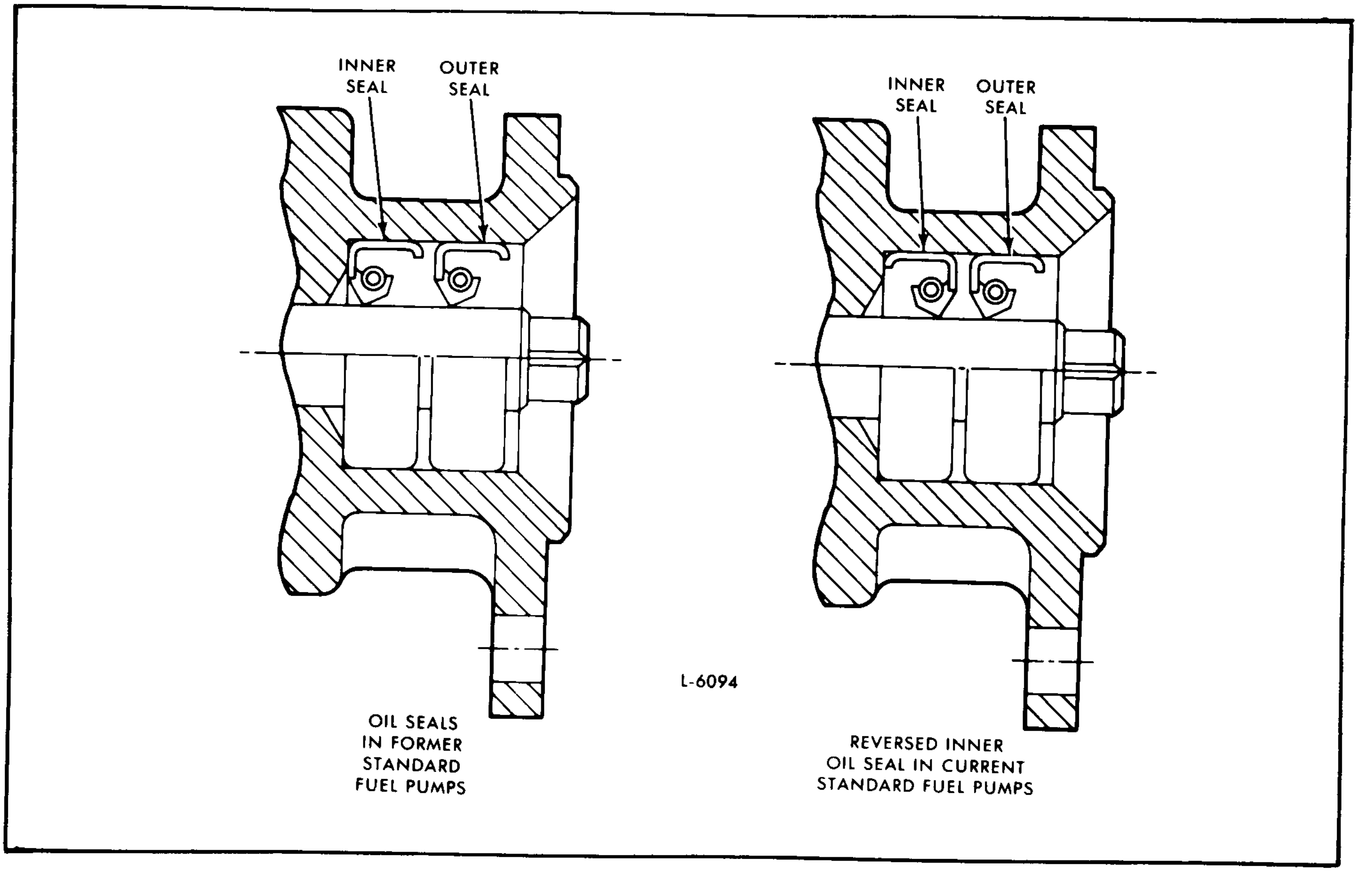


Fig. 3 - Fuel Pump Oil Seal Arrangements

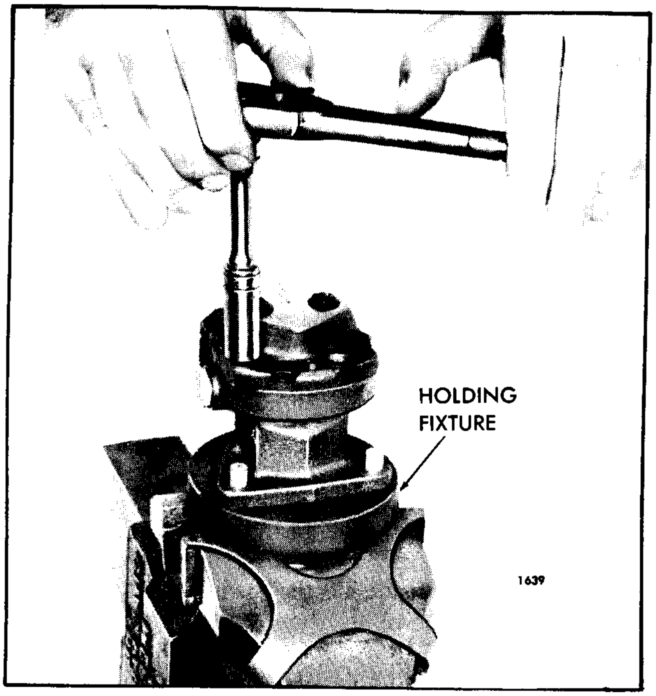


Fig. 4 - Removing Fuel Pump Cover

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.

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.

> **NOTE:** Observe the position of the oil seal lips before removing the old seals to permit installation of the new seals in the same position.

Inspection

Clean all of the parts in clean fuel oil and dry them with compressed air.

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.

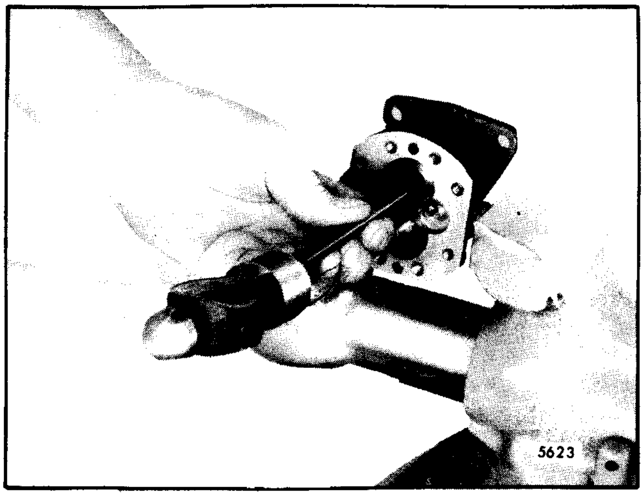


Fig. 5 - Removing Oil Seals using Tool J 1508-13

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 seals 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.

   > **NOTE:** When replacing the former nitrile fuel pump seals with the current polyacrylate seals, install them with the seal lips facing each other (Fig. 4).

   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 Nm) torque.

3. Install the pump drive gear over the end of the

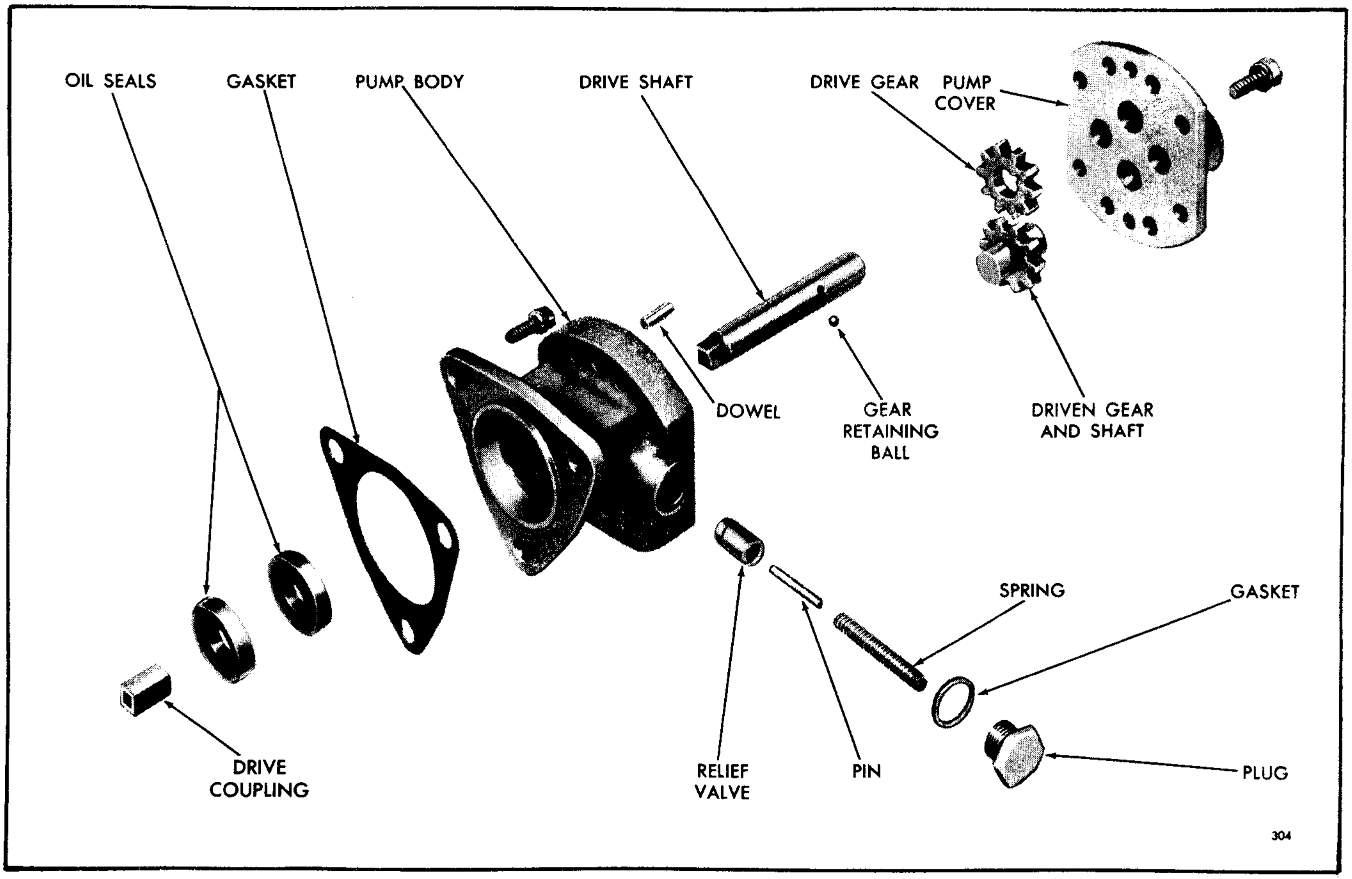


Fig. 6 - Fuel Pump Details and Relative Location of Parts (Right Hand Pump Shown)

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.

5. Place the driven shaft and gear assembly in the pump body.

> **NOTE:** 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.

> **NOTE:** 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.

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,

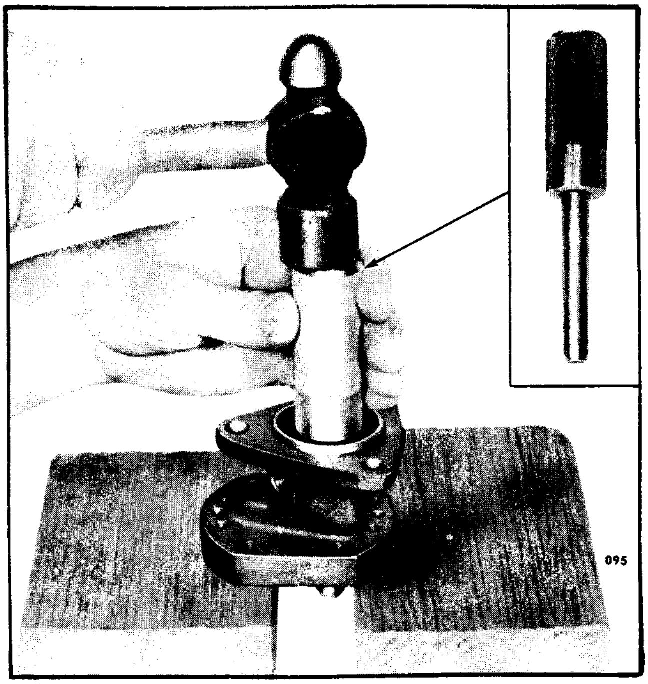


Fig. 7 - Installing Inner Oil Seal using Tool J 1508-8

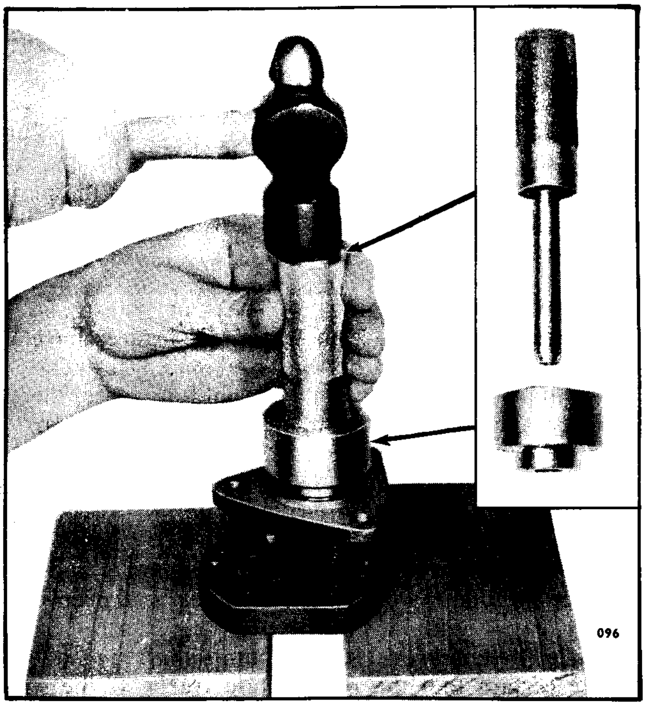


Fig. 8 - Installing Outer Oil Seal using Tools J 1508-8 and J 1508-9

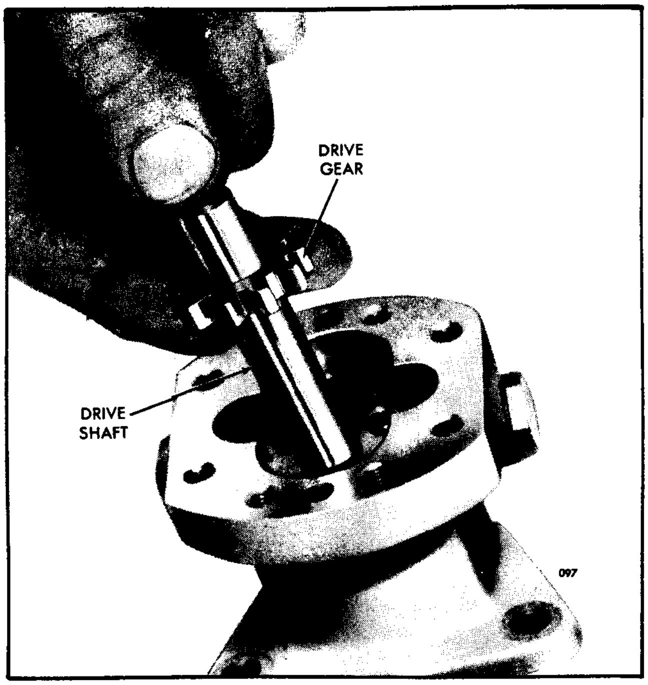


Fig. 9 - Installing Fuel Pump Drive Shaft and Gear Assembly

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.

> **NOTE:** To provide improved sealing against leakage, nylon patch bolts are used in place of the former bolt and seal assemblies.

3. Connect the inlet and outlet fuel lines to the fuel pump.

4. Connect the fuel pump drain tube, if used, to the pump body.

5. 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

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.

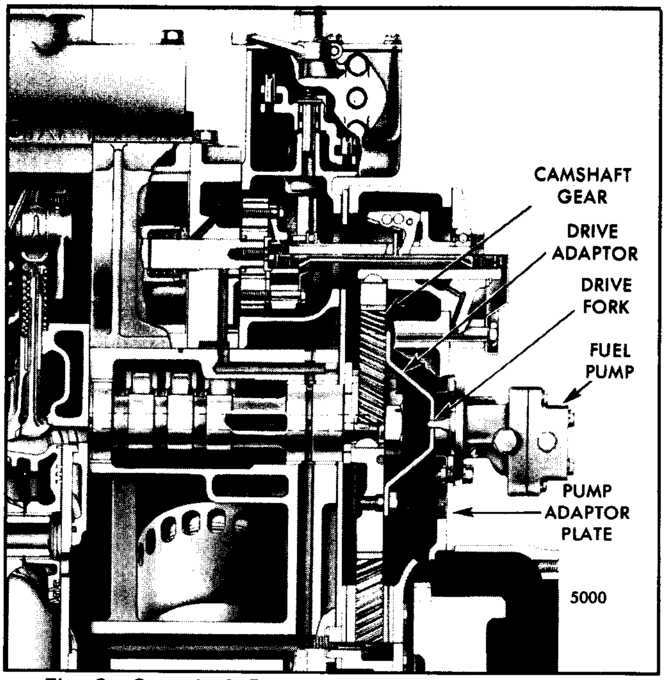


Fig. 2 - Camshaft Drive for Fuel Pump (6V Engine Shown)

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.

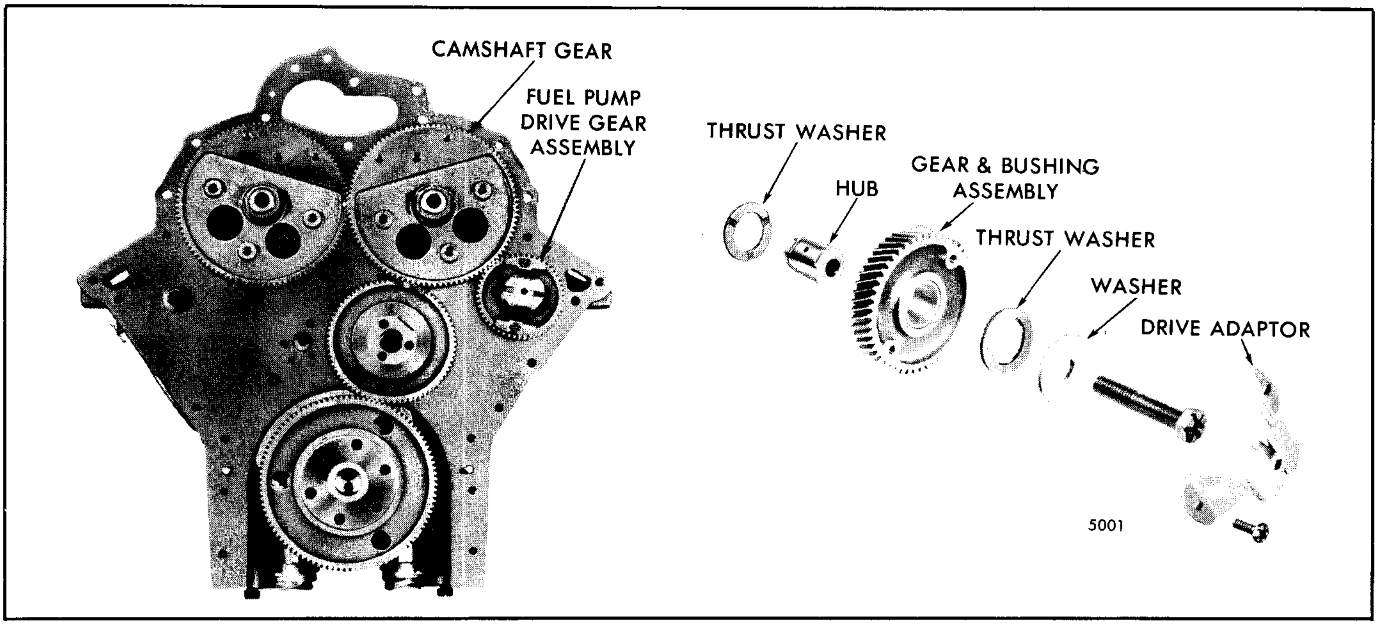


Fig. 1 - Typical Fuel Pump Drive Gear Mounting and Details (V-Type Engine)

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. 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. 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)

A fuel strainer (primary) and fuel filter (secondary), Fig. 1, are used to remove impurities from the fuel. The fuel strainer is located between the fuel tank and the fuel pump. The replaceable density-type element is capable of filtering out particles of 30 microns (a micron is approximately .00004 "). The fuel filter is installed between the fuel pump and the fuel inlet manifold. The replaceable paper-type element (Fig. 2) can remove particles as small as 10 microns.

> **NOTE:** 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.

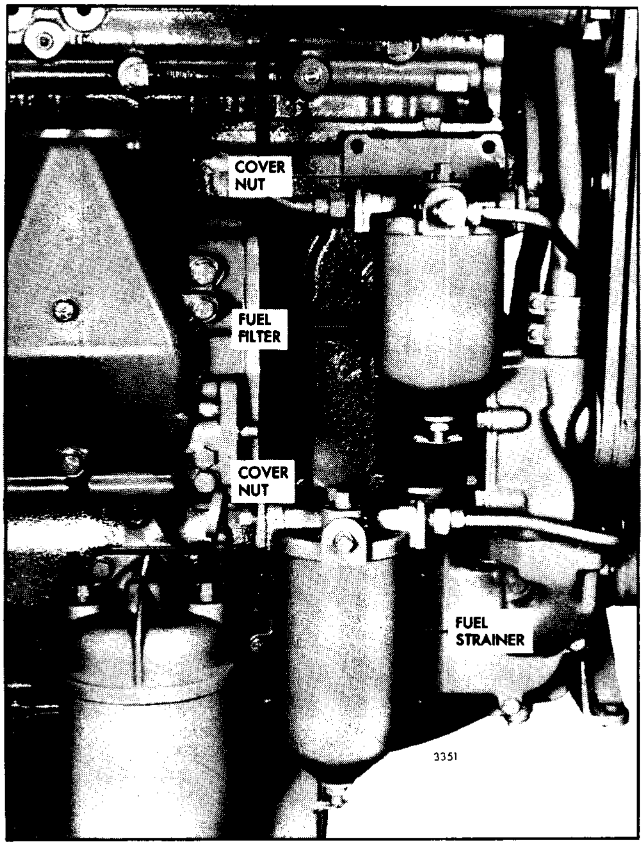


Fig. 1 - Typical Fuel Strainer and Fuel Filter Mounting

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 bolt and a cover 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 cover 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 by a cast letter "P" (primary) that has been added to the top of the strainer cover and the letter "S" (secondary) that 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 filter, placed between the fuel pump and the fuel inlet manifold in the cylinder head, operates under

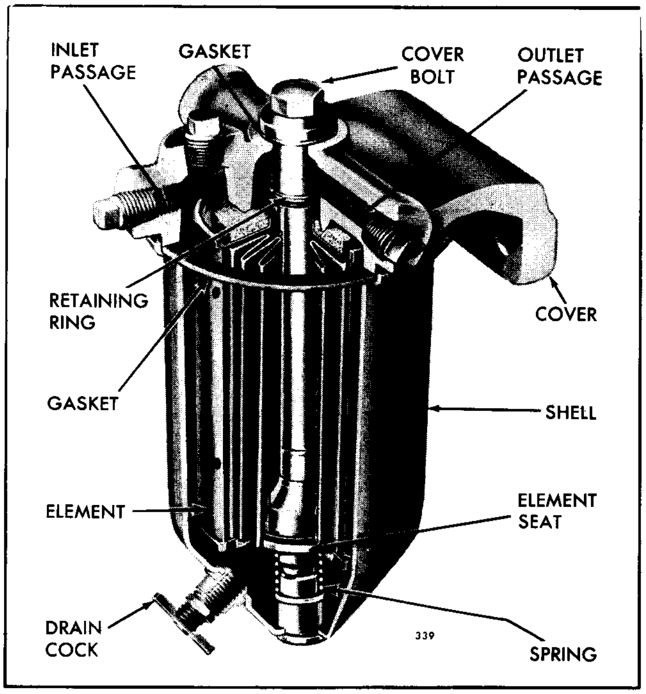


Fig. 2 - Fuel Filter Assembly

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 *Trouble Shooting* in Section 15.2 for corrective measures.

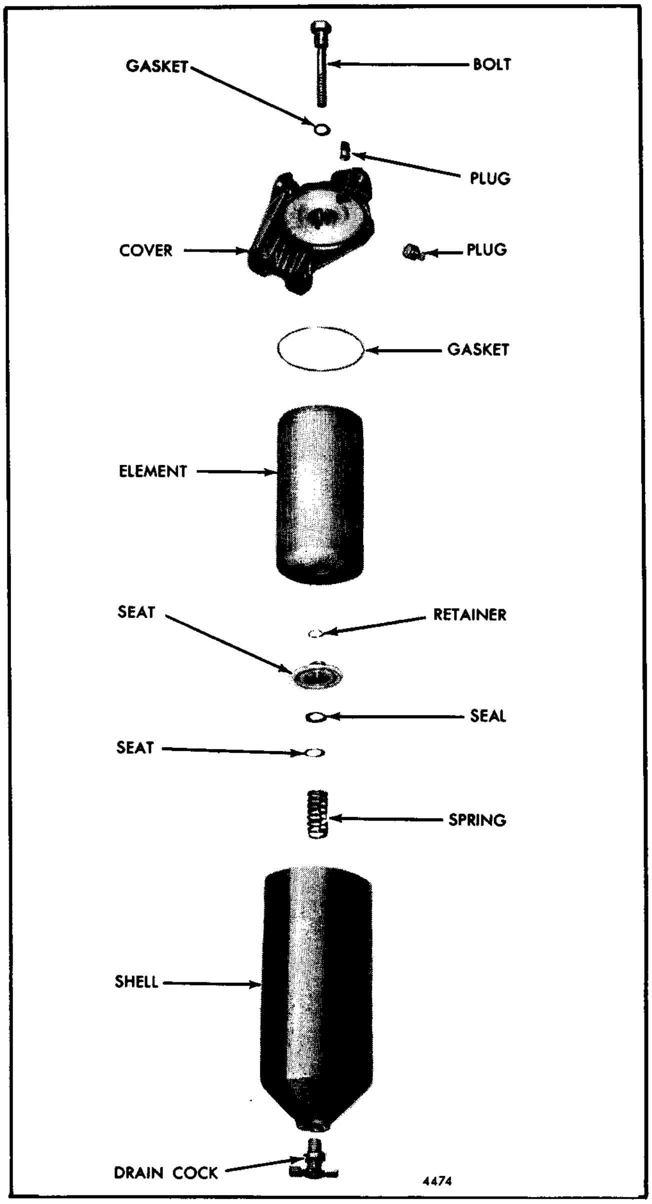


Fig. 3 - Fuel Strainer Details and Relative Location of Parts

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:

> **NOTE:** Only filter elements designed for fuel oil filtration should be used to filter the fuel.

1. With the engine stopped, place a container under the strainer or filter and open the drain cock. Loosen the cover bolt just enough to allow the fuel oil to drain out freely. Then close the drain cock.

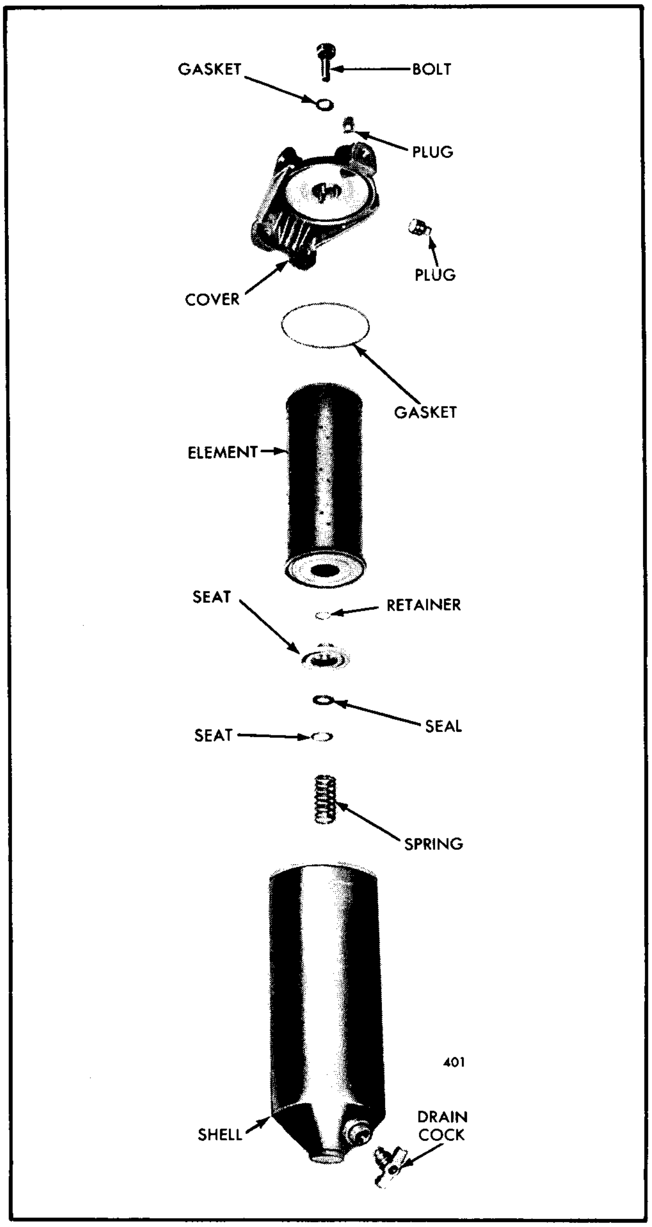


Fig. 4 - Fuel Filter Details and Relative Location of Parts

NOTE: 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 bolt and remove the shell and element.

3. Remove and discard the filter element and shell gasket and the cover bolt gasket. Wash the shell thoroughly with clean fuel oil and dry it with compressed air.

4. Examine the element seat and the retaining ring to make sure they have not slipped out of place. Check the spring by pressing on the element seat. When released, the seat must return against the retaining ring.

NOTE: The element seat, spring, washer and seal cannot be removed from the strainer shell. If necessary, the shell assembly must be replaced. However, the components of the filter shell are serviced. Examine the filter retainer seal for cracks or hardening. If necessary, replace the seal.

5. 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.

NOTE: Thoroughly soak the density-type *strainer* element in clean fuel oil before installing it. This will expel any air entrapped in the element and is conducive to a faster initial start.

6. Place a new shell gasket in the recess of the shell; also place a new gasket on the cover bolt.

7. Place the shell and element in position under the cover. Then thread the cover bolt into the center stud.

8. With the shell and the gasket properly positioned, tighten the cover bolt just enough to prevent fuel leakage.

9. 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.

10. Start the engine and check the fuel system for leaks.

FUEL STRAINER AND FUEL FILTER

(Spin-On Type)

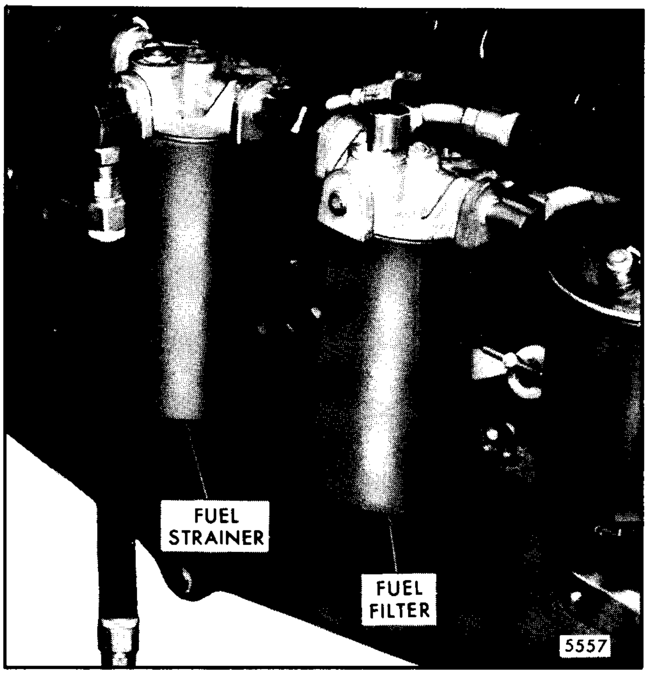


Fig. 5 - Typical Spin-On Type Fuel Strainer and Fuel Filter Mounting

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.

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.

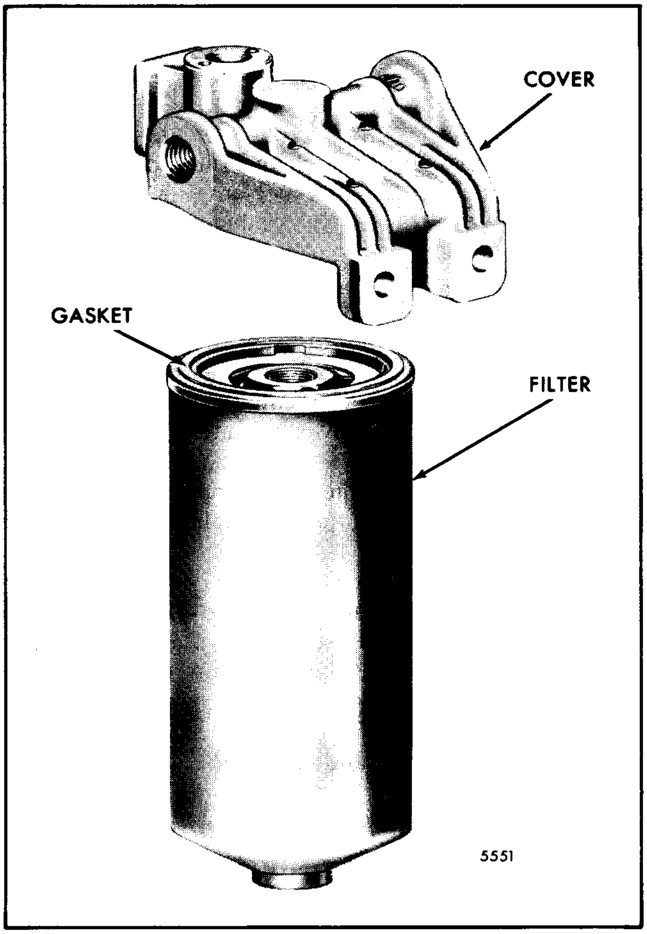


Fig. 6 - Spin-On Filter Details and Relative Location of Parts

Replace the filter as follows:

1. Unscrew the filter (or strainer) and discard it.

2. Fill a new filter replacement cartridge 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.

4. Start the engine and check for leaks.

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 (32.2 °C) will result in a brake horsepower loss of approximately 2% per 20 °F (6.67 °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 (.227 kg) of oxalic acid to each 2-1/2 gallons (1.893 litres) 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 and, 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.

WARNING: 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.

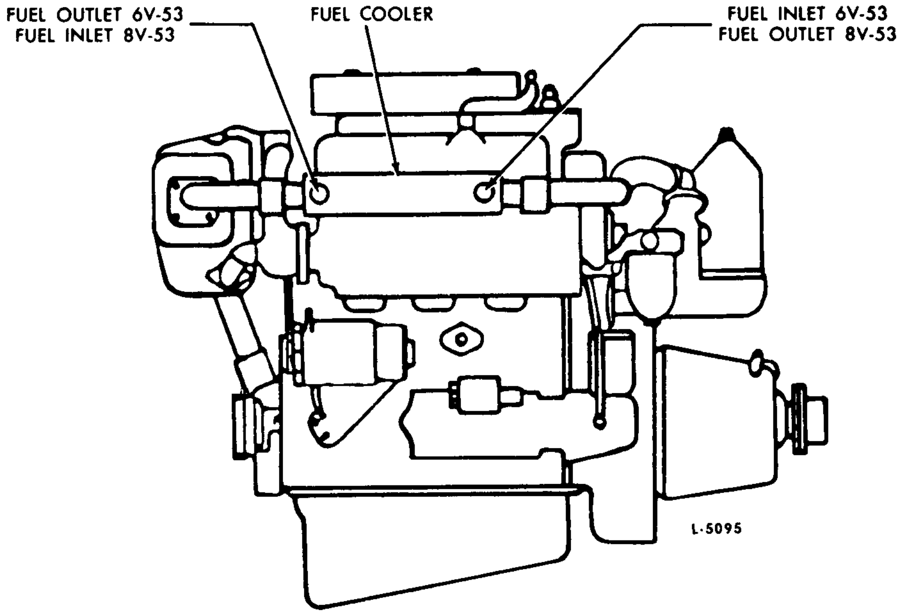


Fig. 1 - Fuel Cooler Mounting (V Engines)

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 Nm) 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 re-aligning the control tube supporting brackets. If the control tube support brackets were loosened, re-aligned 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

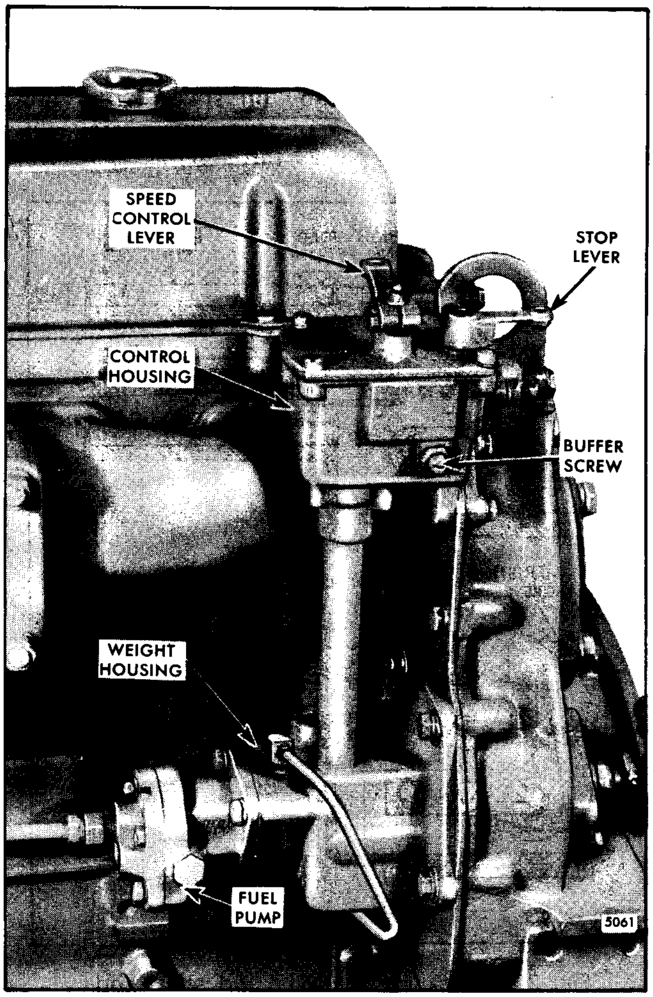


Fig. 1 - Governor Mounting

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.

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.

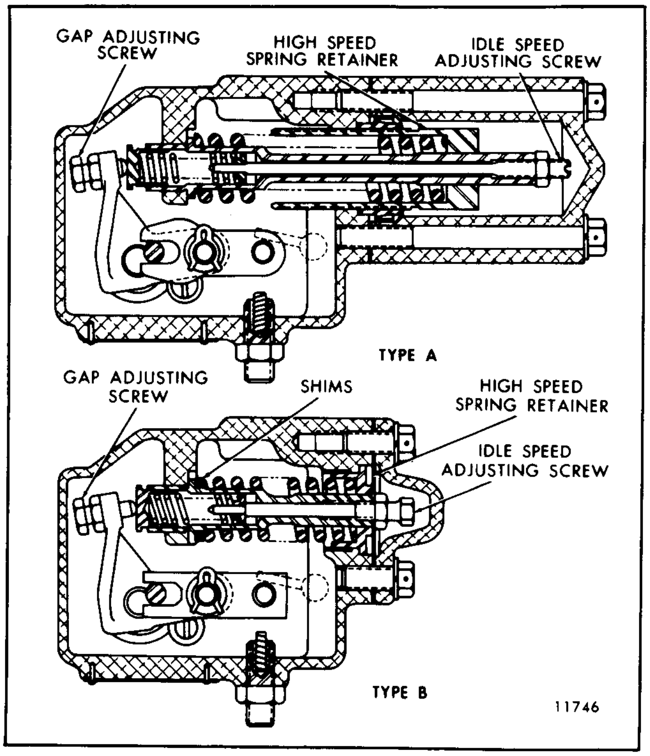


Fig. 2 - Differences Between Industrial and Vehicle Type Governor Assemblies

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.

NOTE: The single lever cover has the seal ring at the top of the cover. The double lever cover has the seal ring at the bottom of the cover.

4. Loosen the governor stop lever retaining bolt and lift the lever from the stop lever shaft.

5. Remove the retaining ring and washers and withdraw the stop lever shaft from the cover.

6. Remove the seal ring from the top of the cover.

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.

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.

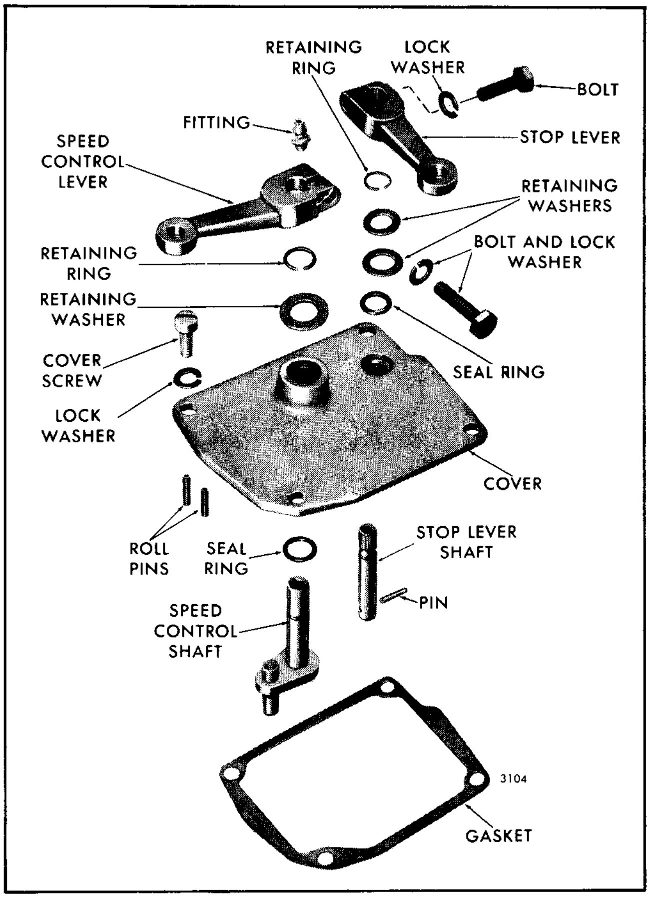


Fig. 3 - Governor Cover Details and Relative Location of Parts

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

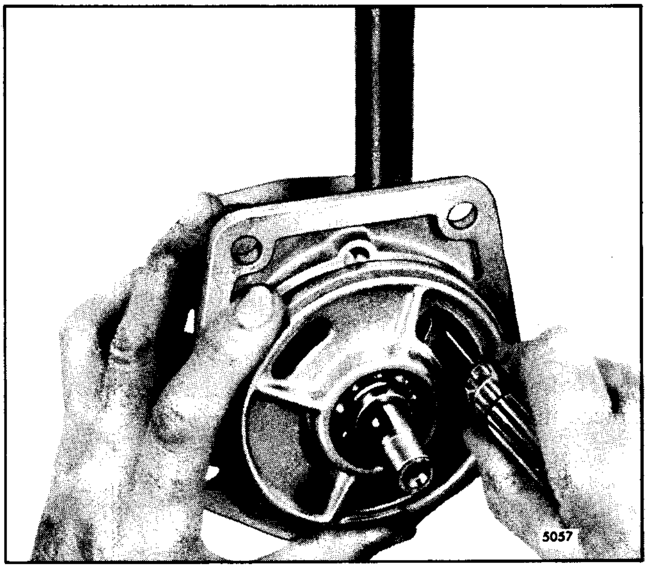


Fig. 4 - Removing Fork from Operating Shaft

weight pins, then drive the pins out of the carrier and weights. 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.

NOTE: Drive the pins out of the carrier from the weight pin retainer end.

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.

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).

NOTE: The single lever cover has the seal ring at the top of the cover. The double lever cover has the seal ring at the bottom of the cover.

2. Lubricate the speed control shaft with engine oil, then slide the shaft through the cover. Install the washer and 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).

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.

NOTE: To prevent any damage, press only on the inner race of the bearing.

5. Place the riser on the weight shaft.

6. Position the low speed weights, identified by the short cam arm and three center laminations, each approximately 9/64" thick, on the weight carrier.

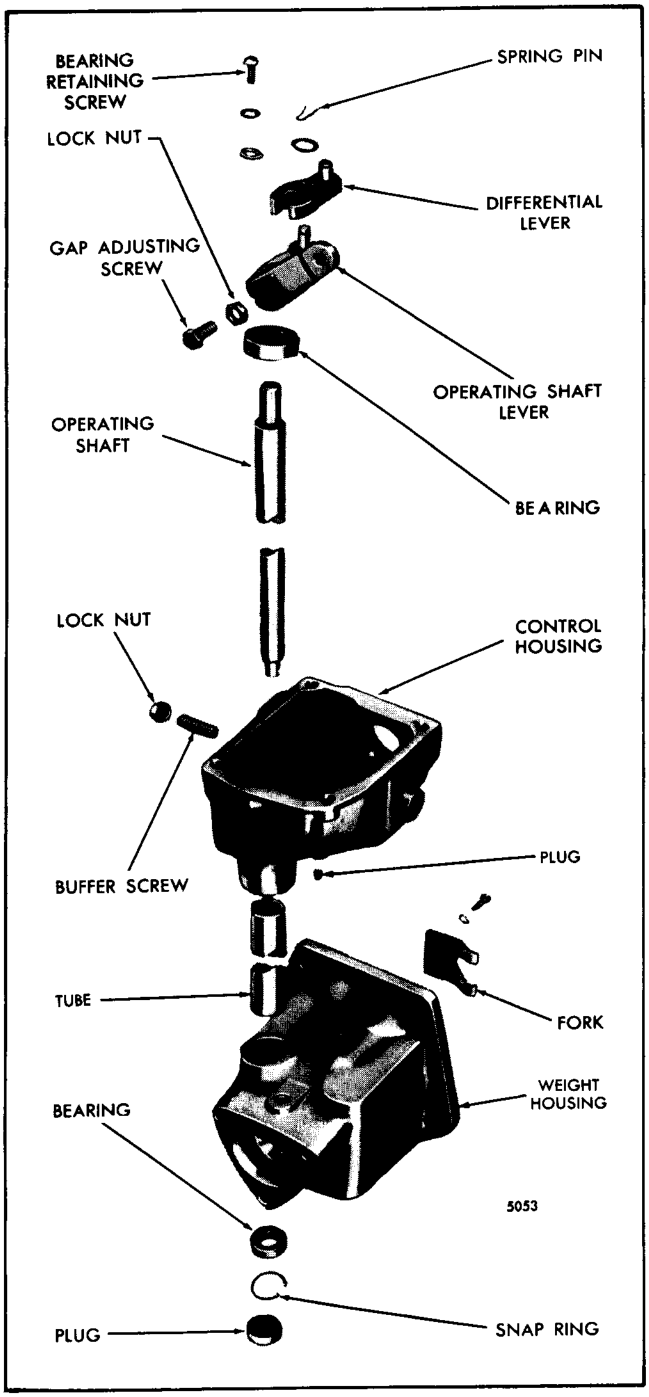


Fig. 5 - Governor Housings and Relative Location of Parts

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.

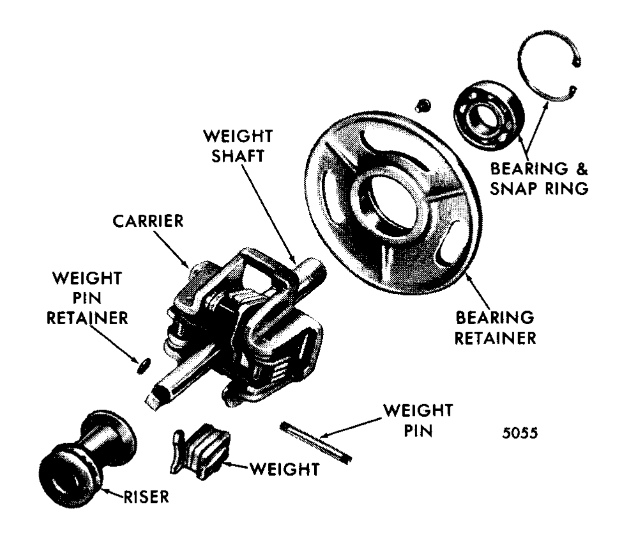


Fig. 6 - Governor Weight Details and Relative Location of Parts

NOTE: 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 Nm) 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 Nm) torque.

5. Install the two governor control housing attaching bolts and lock washers. Tighten the bolts to 10-12 lb-ft (14-16 Nm) 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.

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.

> **NOTE:** 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.

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 subassemblies: 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.

Current governor covers include a longer serrated shutdown shaft and lever to provide positive clamping between the serrated levers and shafts. The longer shaft also has provisions for a yieldable speed control lever.

To limit fuel input during engine start-up, when the speed control lever is in its idle position, the turbocharged engines use a starting aid screw (Fig. 7).

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.

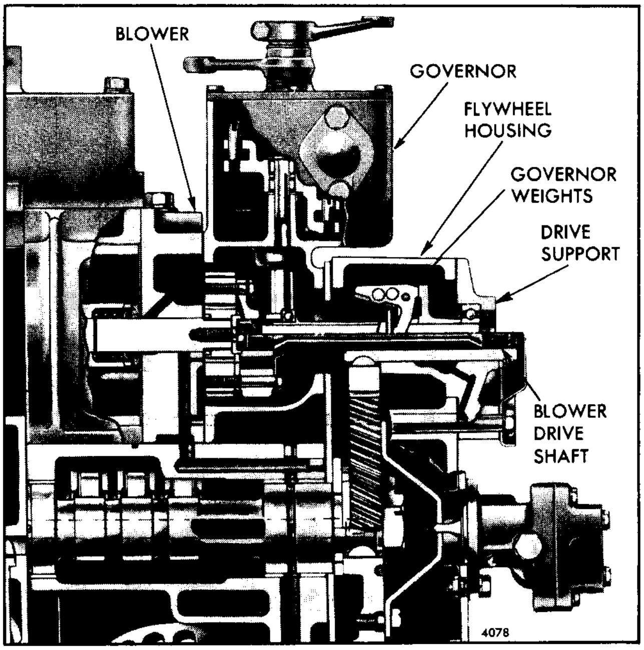


Fig. 1 - Limiting Speed Governor and Drive on 6V-53 Engine

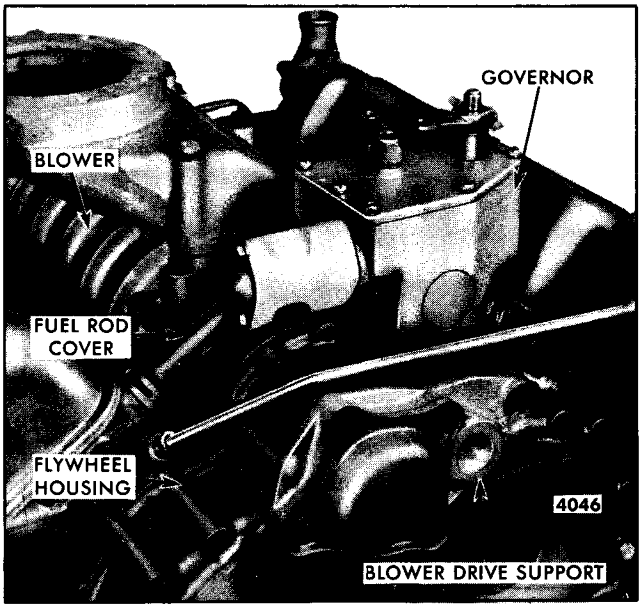


Fig. 2 - Governor Mounting on 6V-53 Engine

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 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.

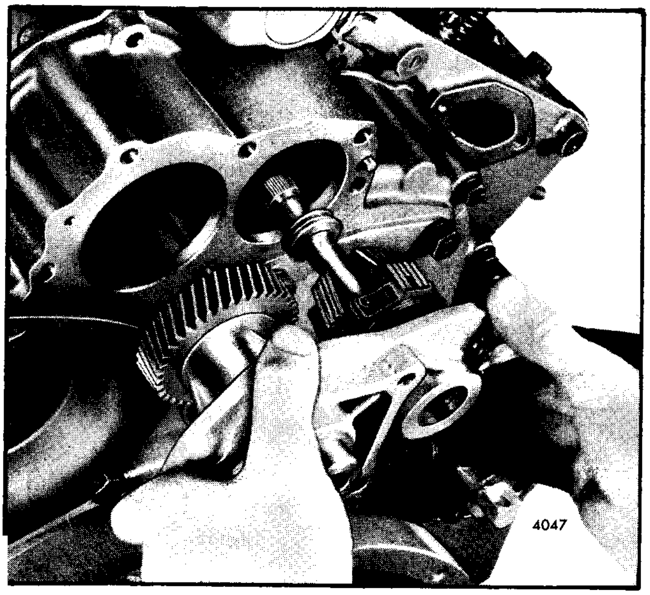


Fig. 3 - Removing or Installing Blower Drive Support

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.

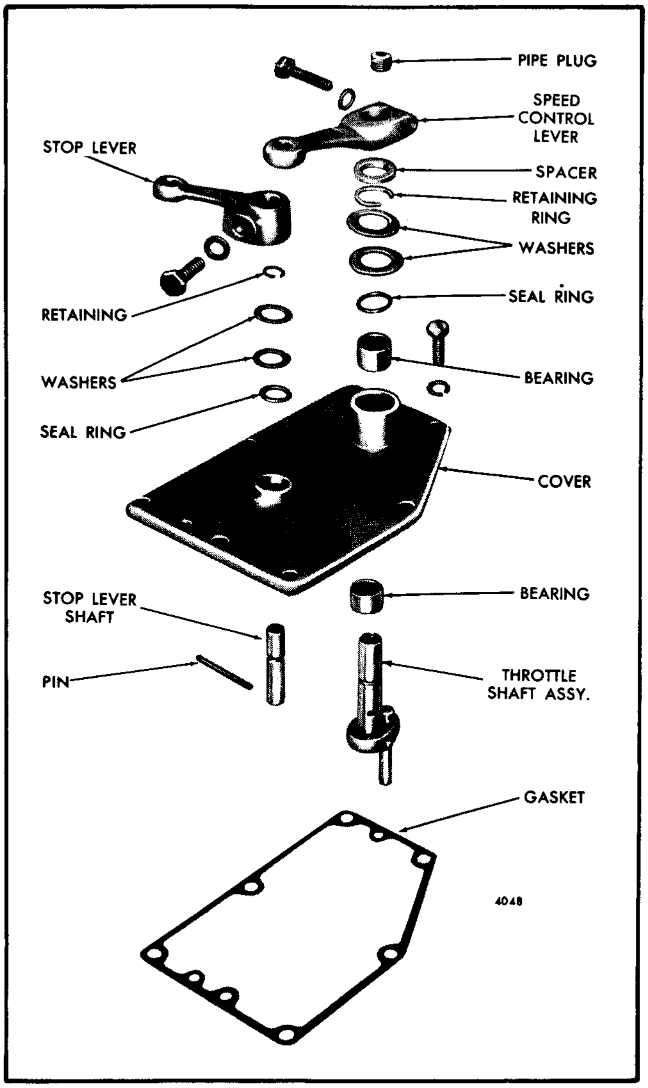


Fig. 4 - Governor Cover Details and Relative Location of Parts

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.

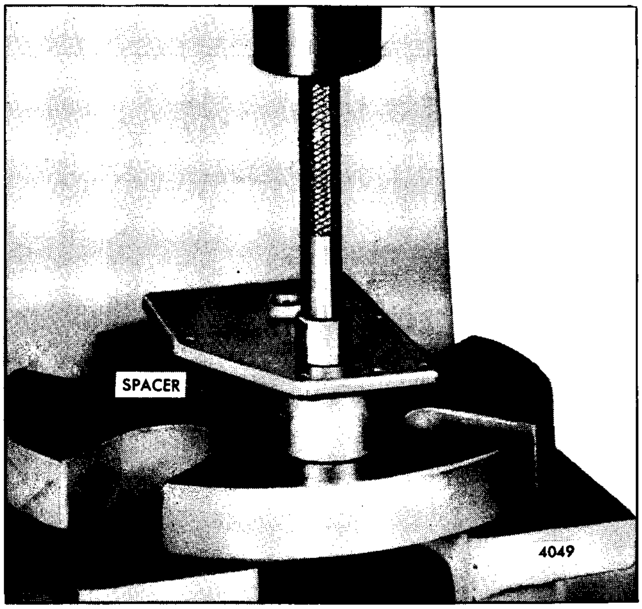


Fig. 5 - Removing Governor Cover Bearing using Tool J 21967-01

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.

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. 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.

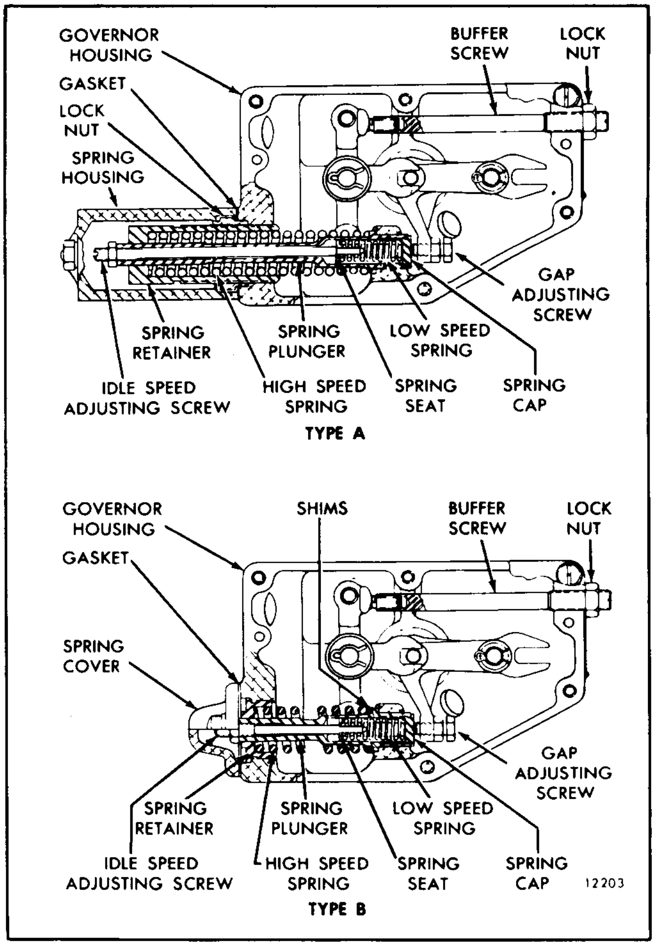


Fig. 6 - Governor Spring Assemblies

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 21967-01 (Fig. 5).

Disassemble Governor Springs

Refer to Fig. 6 and disassemble the governor spring assembly as follows:

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 bearings.

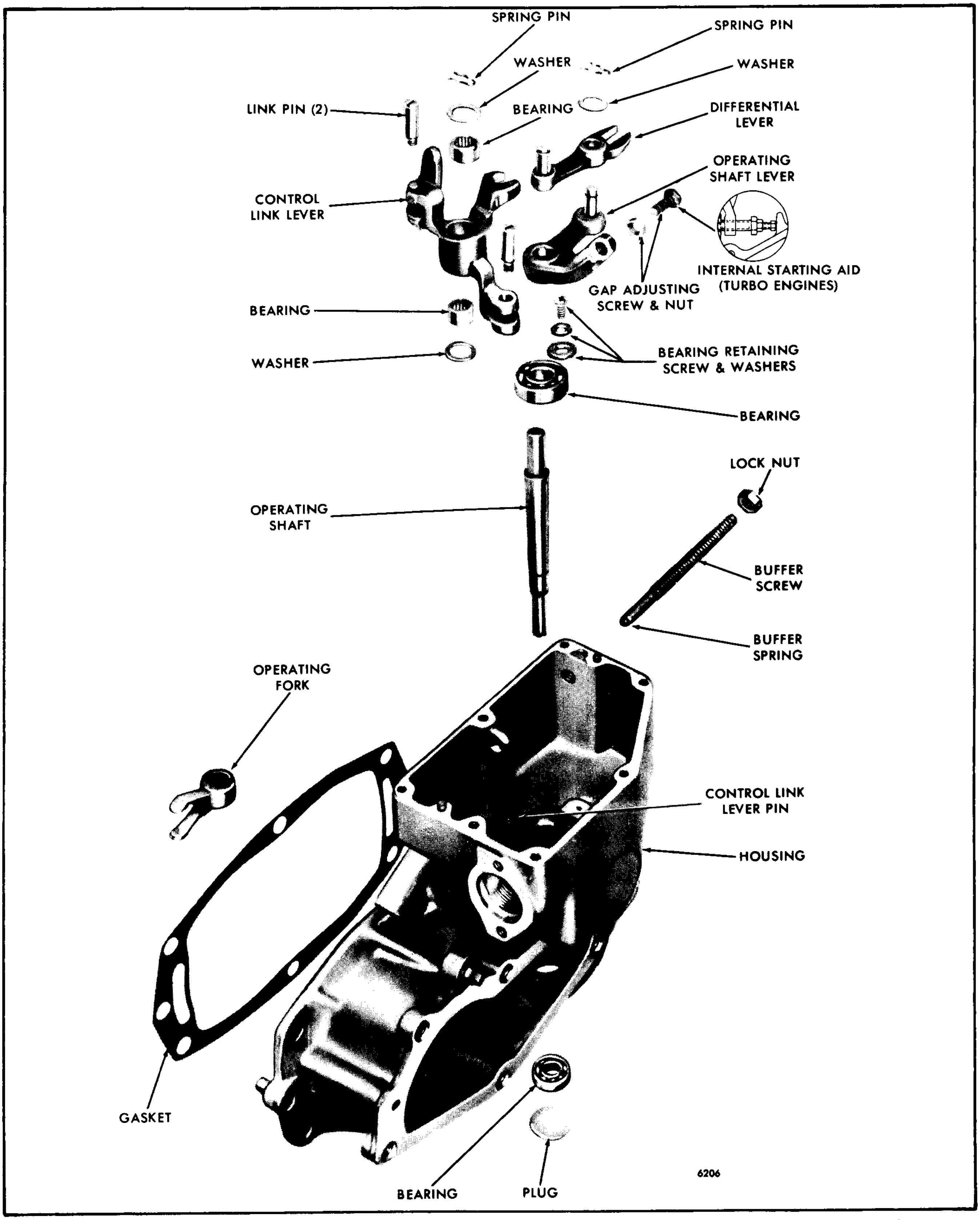


Fig. 7 - Governor Housing Details and Relative Location of Parts

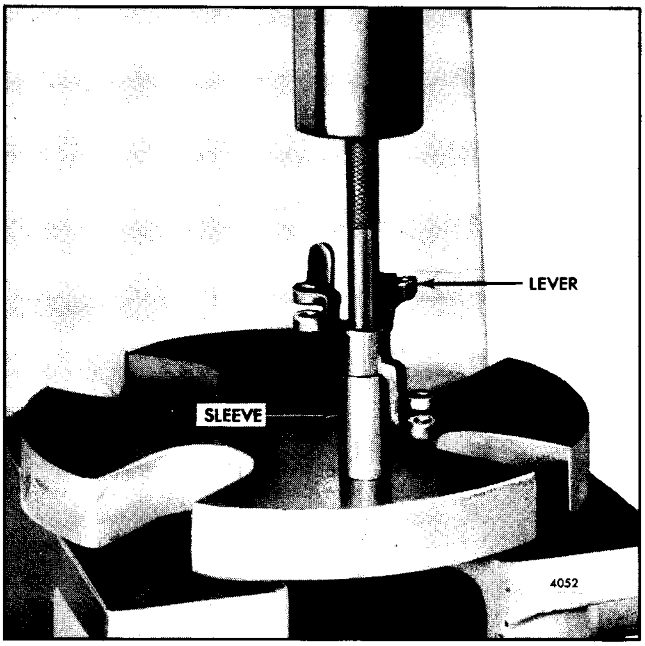


Fig. 8 - Removing Bearings from Control Link Lever using Tool J 8985

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.

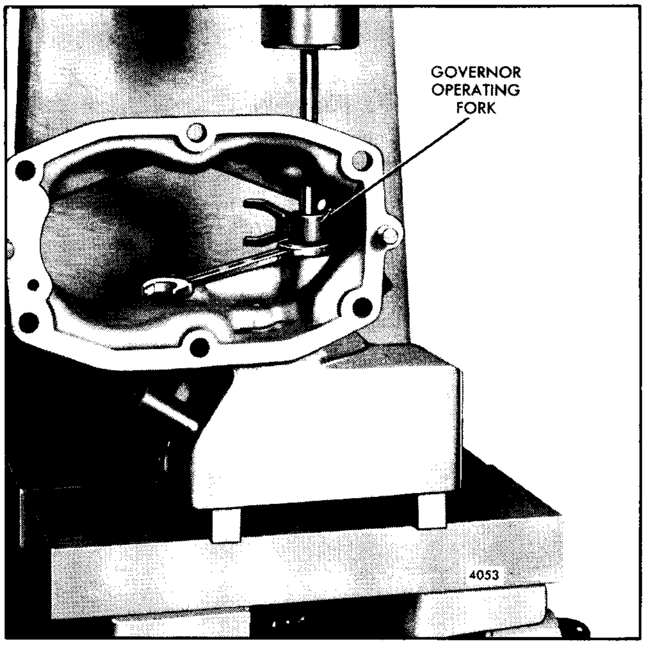


Fig. 9 - Removing Governor Operating Fork

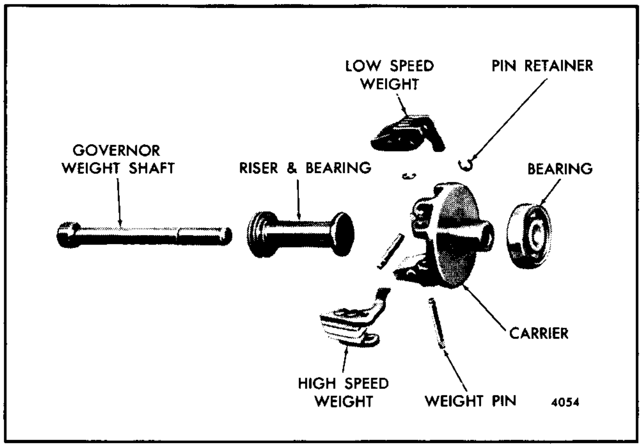


Fig. 10 - Governor Weight Details and Relative Location of Parts

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.

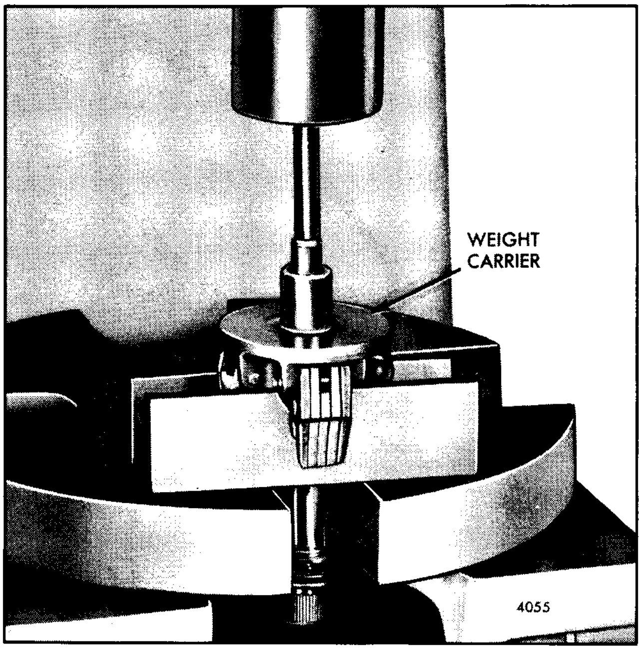


Fig. 11 - Removing Shaft from Weight Carrier

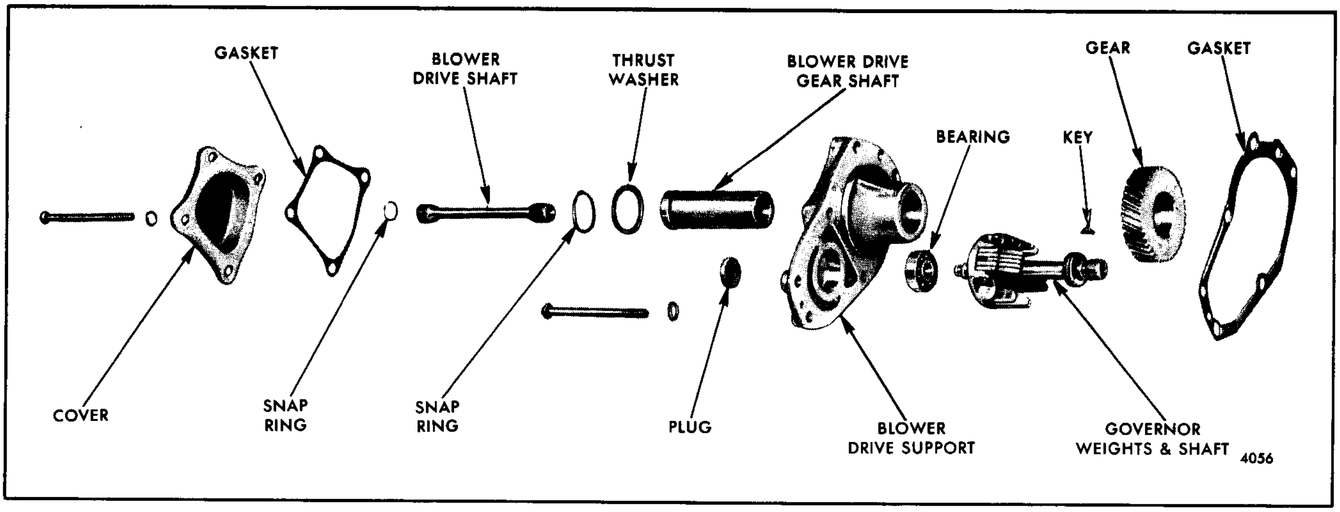


Fig. 12 - Blower Drive Support Assembly Details and Relative Location of Parts

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.

Inspect all of the 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

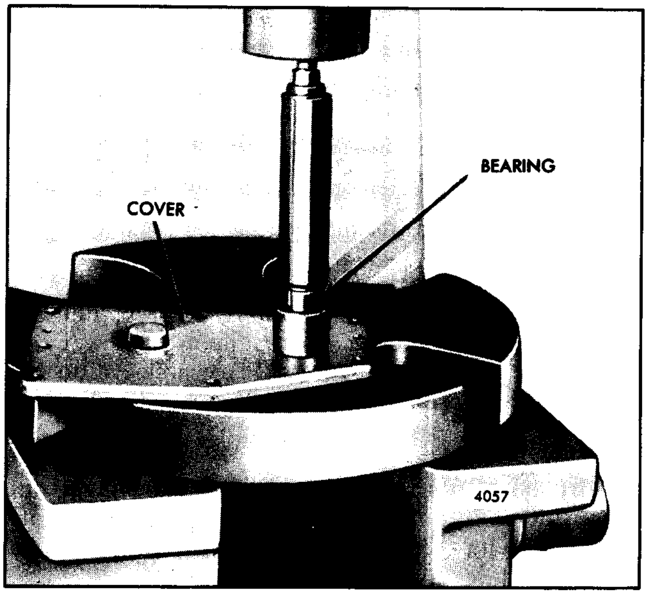


Fig. 13 - Installing Governor Cover Bearings using Tool J 21068

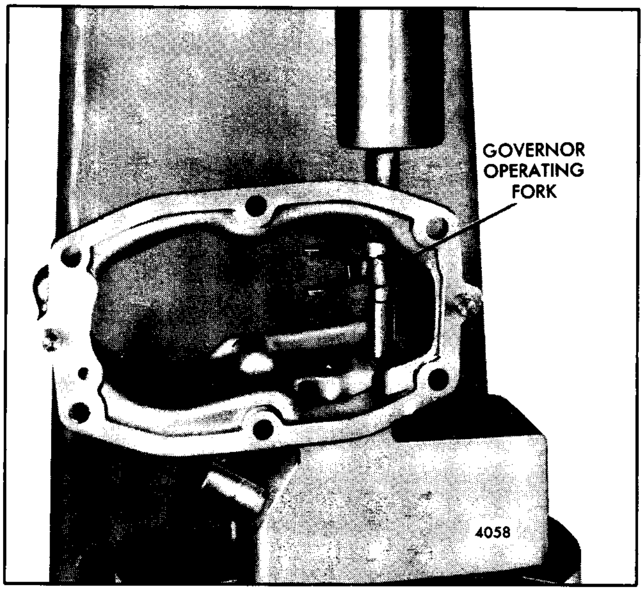


Fig. 14 - Installing Governor Operating Fork on Shaft

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).

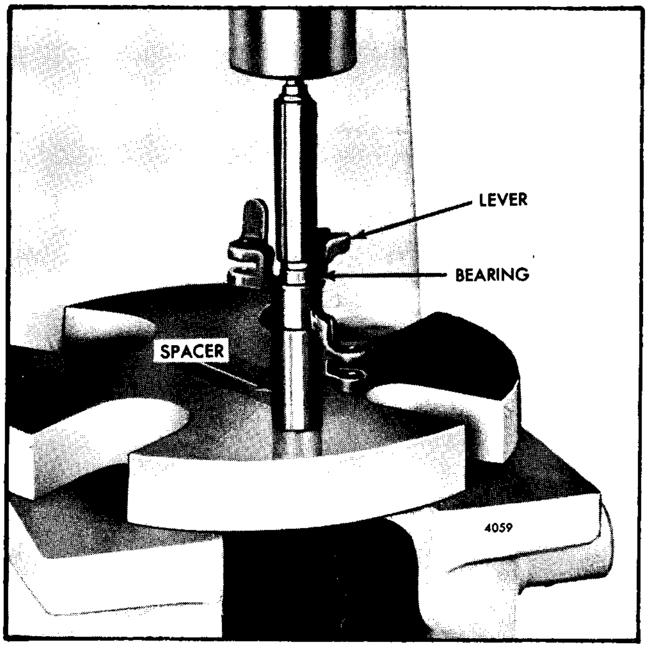


Fig. 15 - Installing Bearings in Control Link Lever using Tool J 21068

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 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.

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.

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.

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

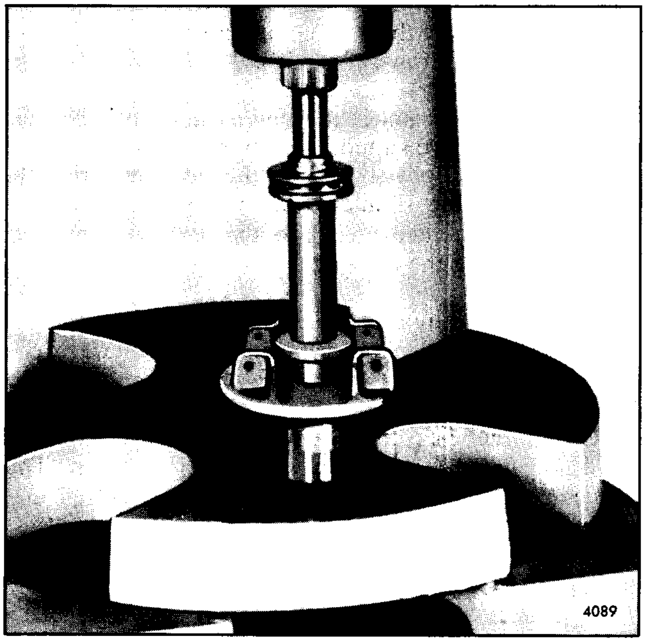


Fig. 16 - Installing Weight Carrier on Shaft using Tool J 8984

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.

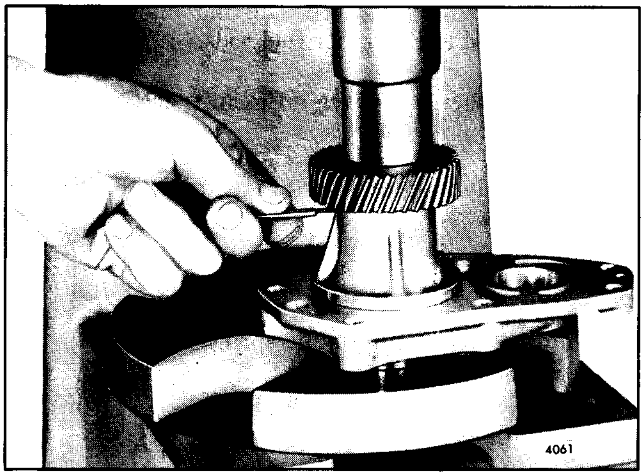


Fig. 17 - Installing Blower Drive Gear on Shaft

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.

9. Place the differential lever over the pivot pin in the operating shaft lever (Fig. 7). 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.

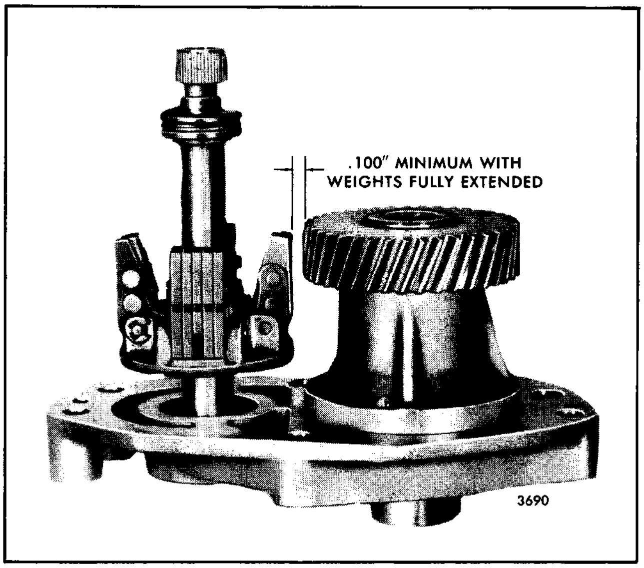


Fig. 18 - Minimum Clearance Between Blower Drive Gear and Governor Weights

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 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 larger 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 long cam arm.

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).

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.

The turbocharged engines use a starting aid screw threaded into the gap adjusting screw. The starting aid screw is threaded in the low-speed gap adjusting screw so that its head contacts the governor housing wall (Fig. 1). Both the gap adjusting screw and the starting aid screw have a nylon locking patch on the threads in place of lock nuts.

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.

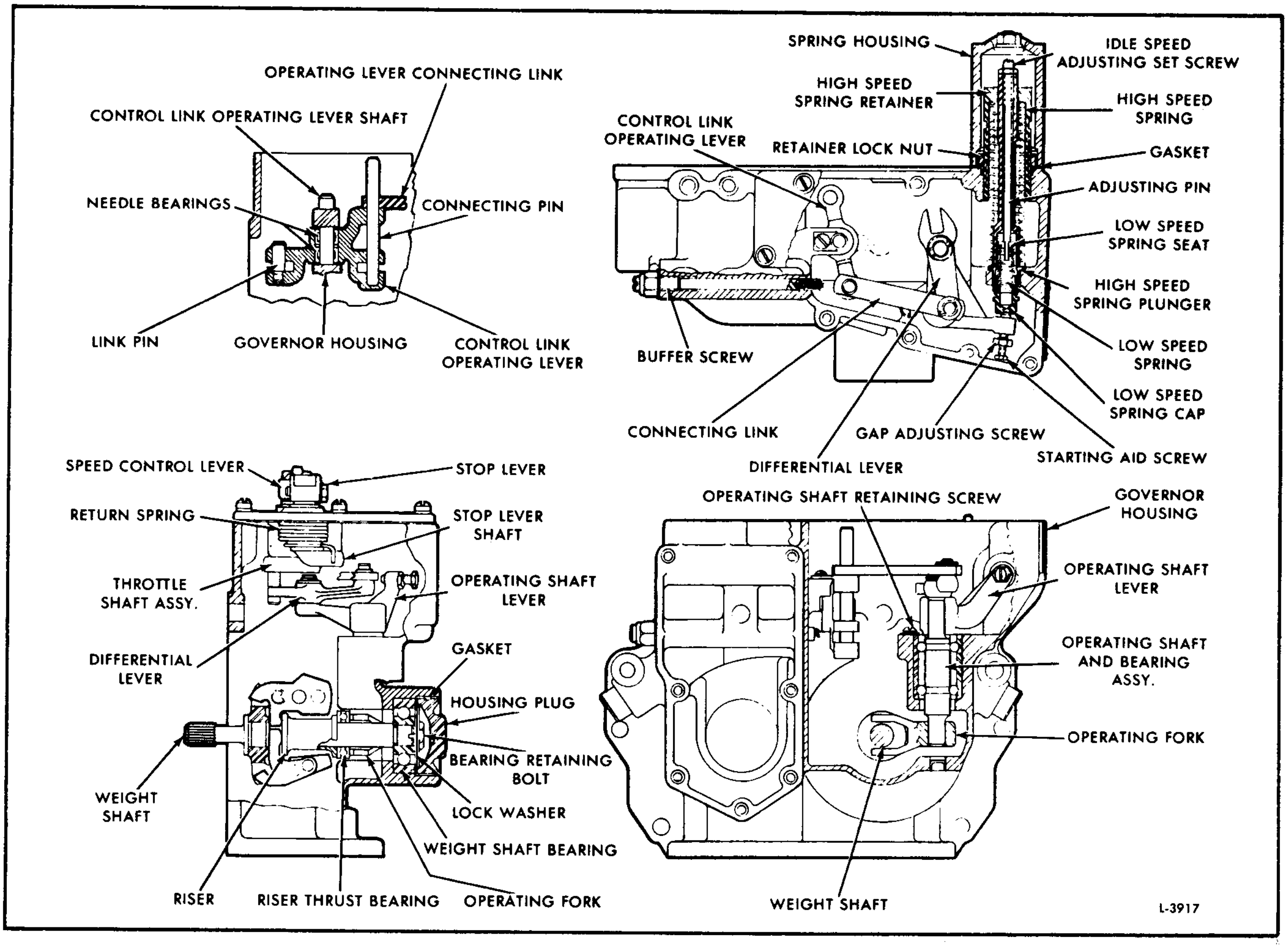


Fig. 1 - Limiting Speed Governor for 8V-53 Engine

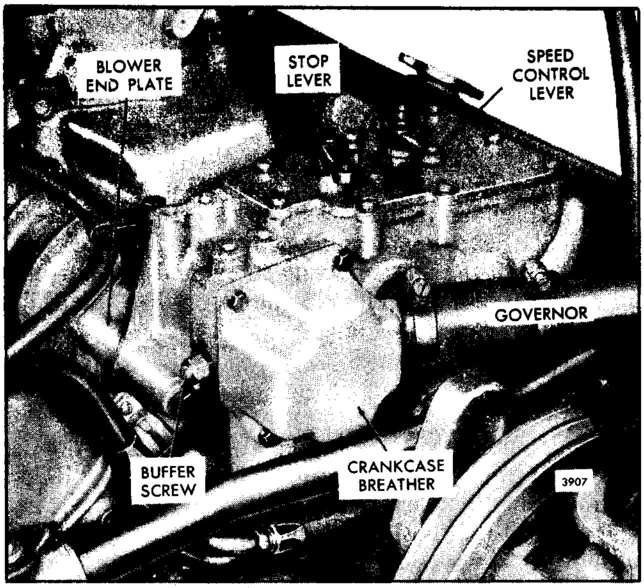


Fig. 2 - Governor Mounting

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

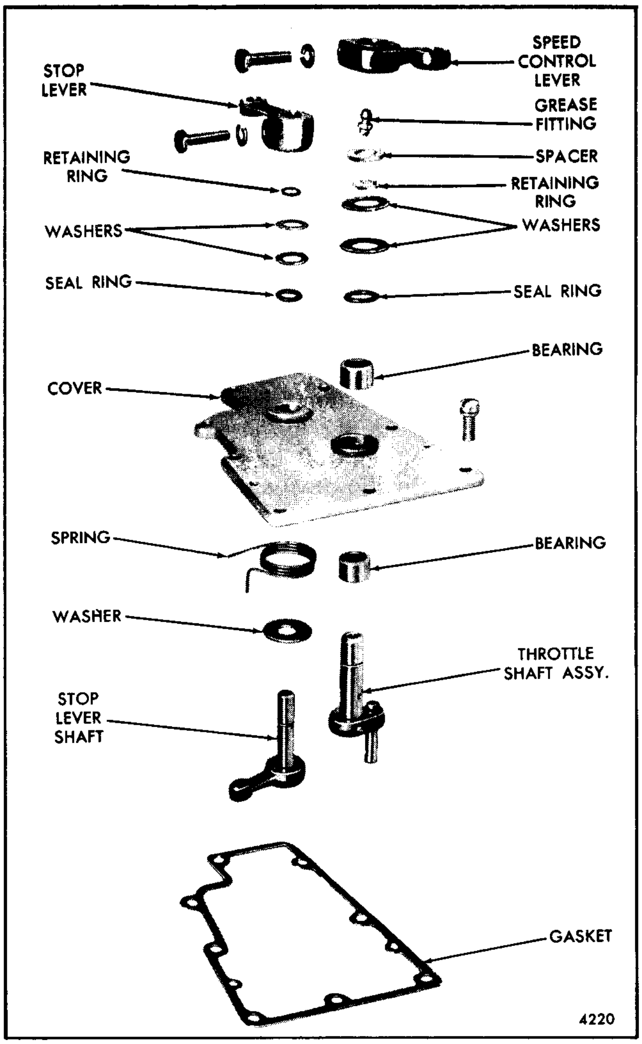


Fig. 3 - Governor Cover Details and Relative Location of Parts

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.

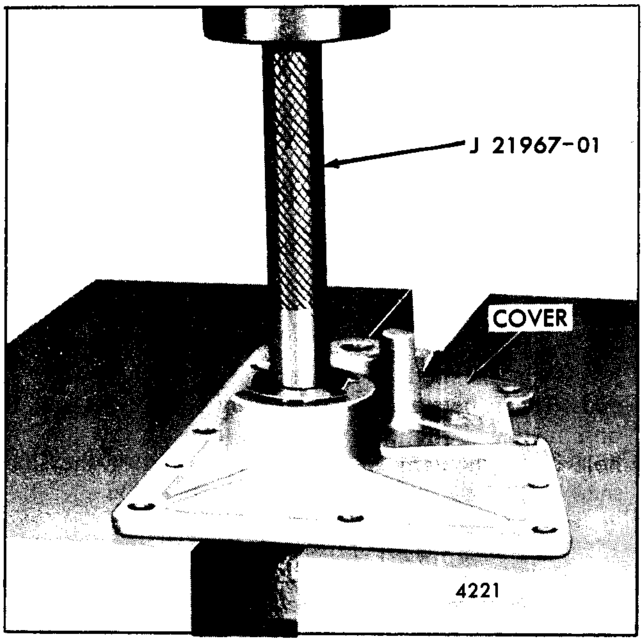


Fig. 4 - Removing Governor Cover Bearings

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 21967-01 (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.

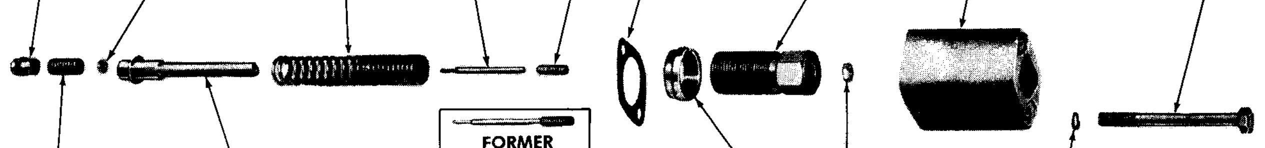


Fig. 5 - Governor Spring Assembly Details and Relative Location of Parts

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.

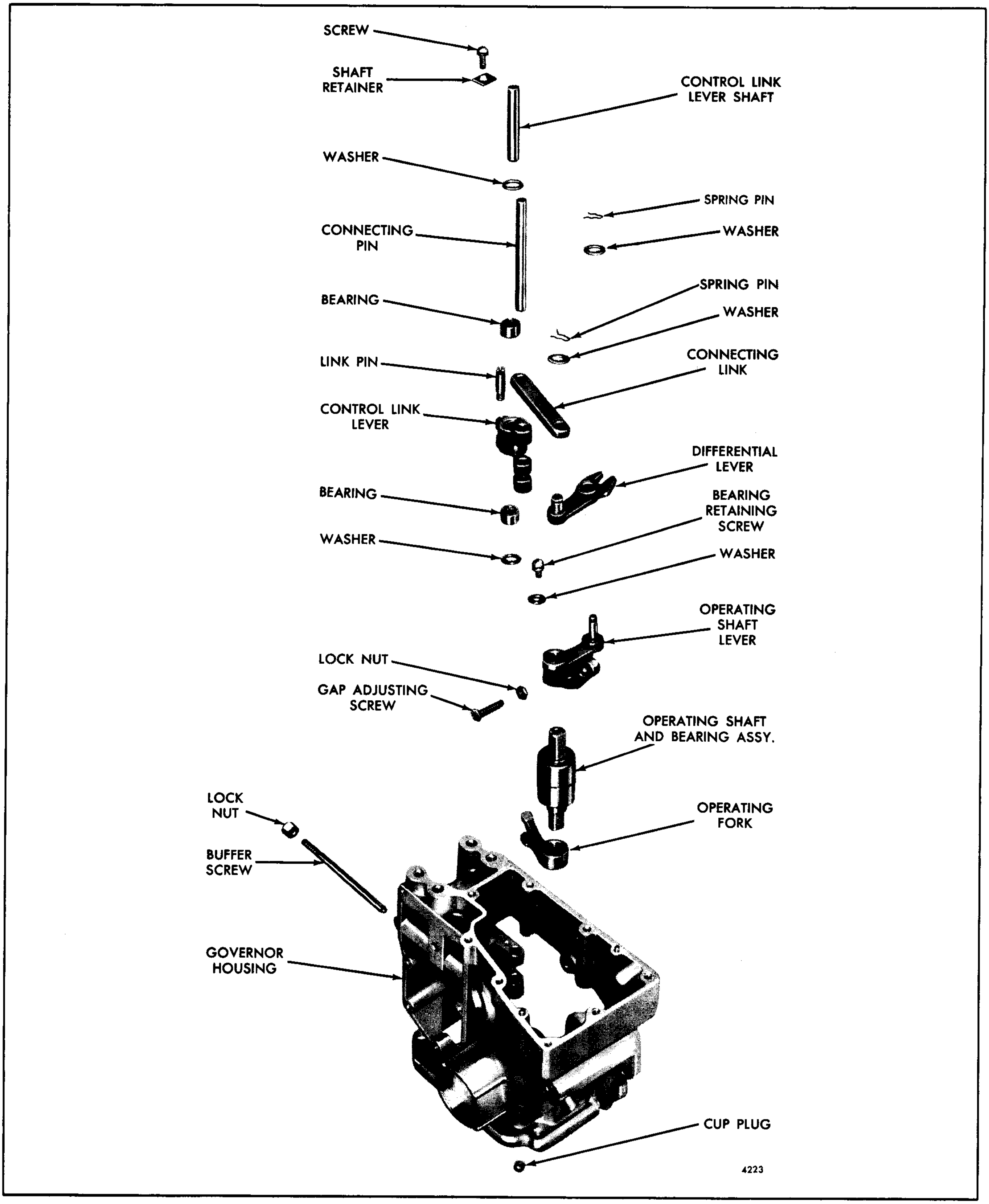


Fig. 6 - Governor Housing Details and Relative Location of Parts

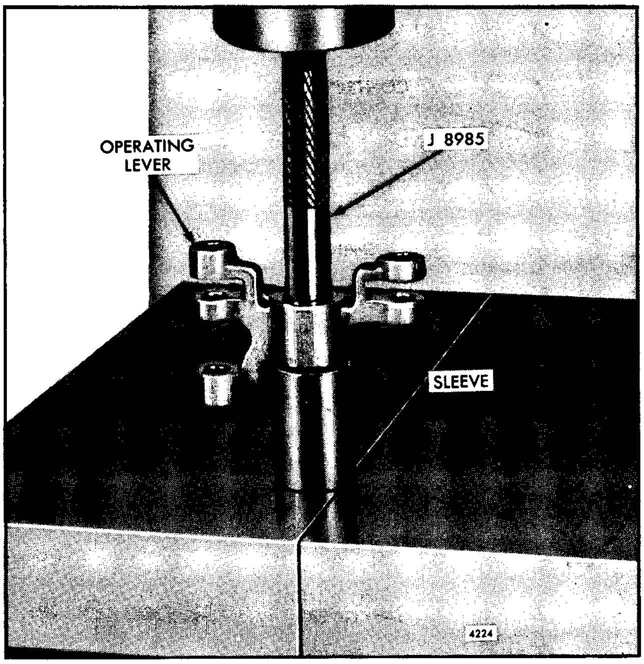


Fig. 7 - Removing Control Link Lever Bearings

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.

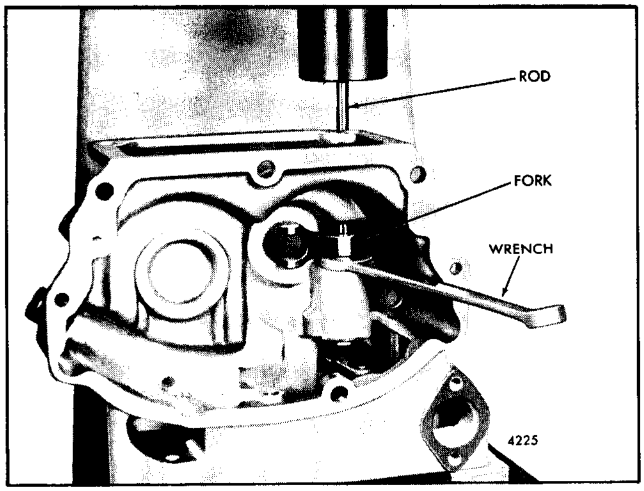


Fig. 8 - Removing Governor Operating Fork

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

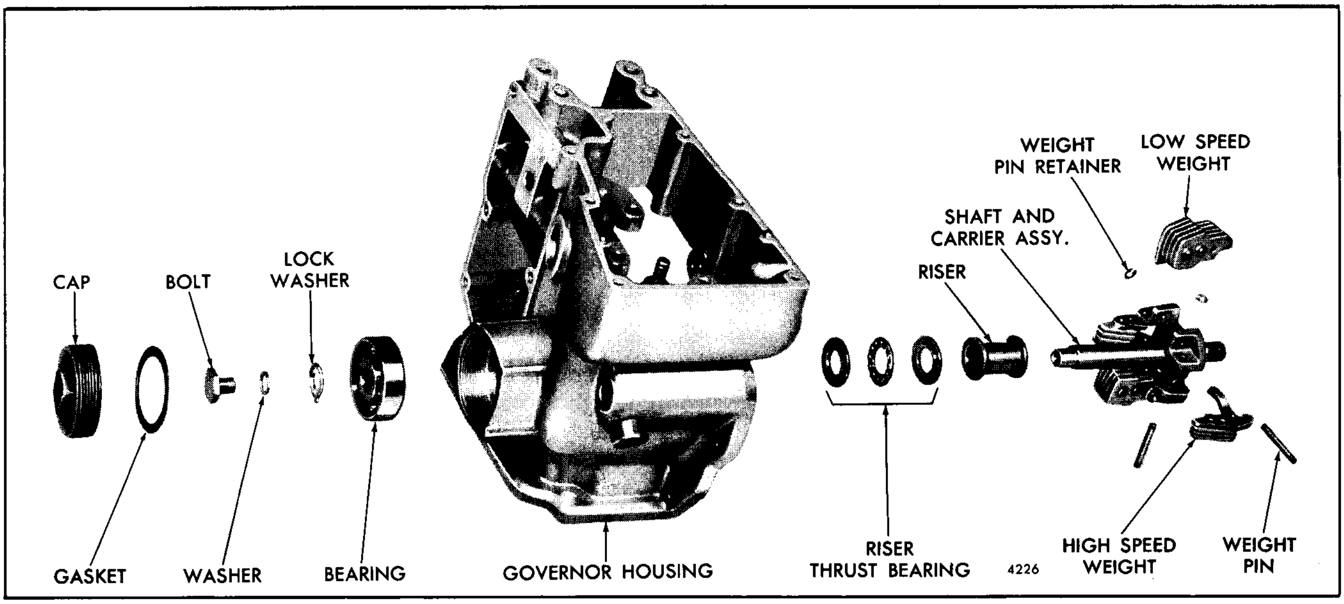


Fig. 9 - Governor Weight Details and Relative Location of Parts

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.

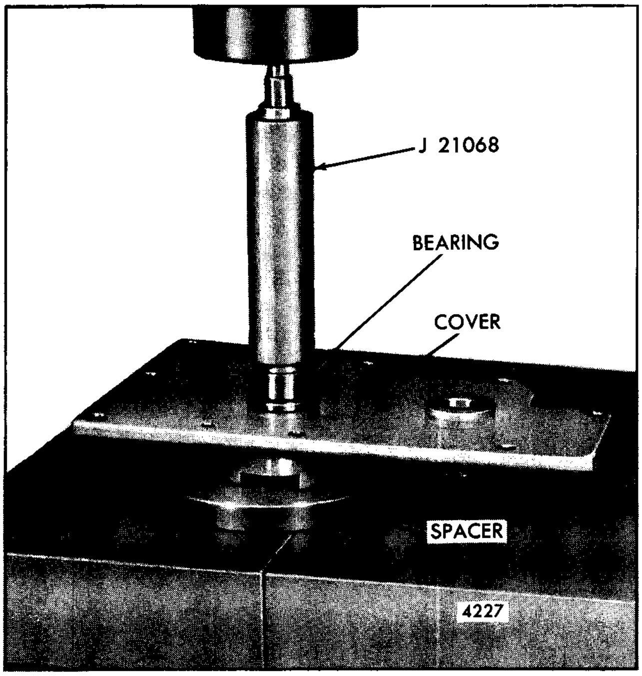


Fig. 10 - Installing Governor Cover Bearings

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

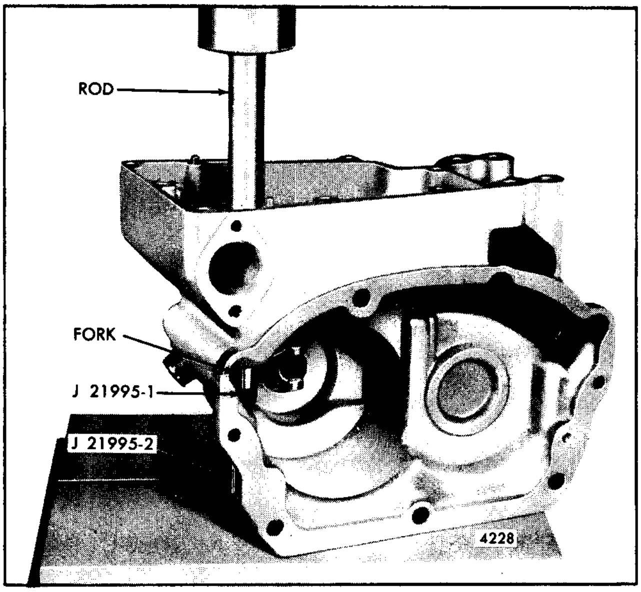


Fig. 11 - Installing Governor Operating Fork

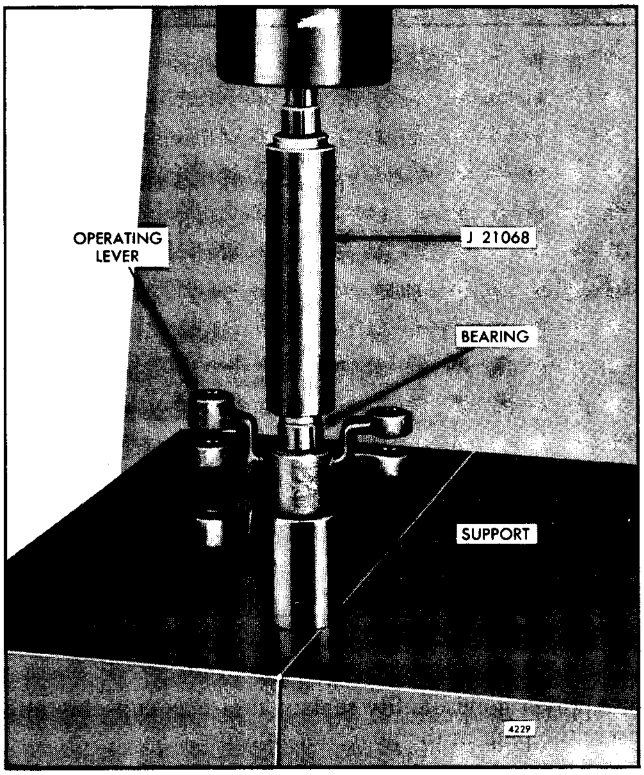


Fig. 12 - Installing Control Link Lever Bearings

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. Clean the plug with solvent to remove any oil or grease before applying the sealant. Apply a sealant such as Loctite grade H, HV, HVW or equivalent onto the threads of the governor housing and the plug. Thread the plug into the housing and tighten the plug to 45 lb-ft (61 Nm) 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)

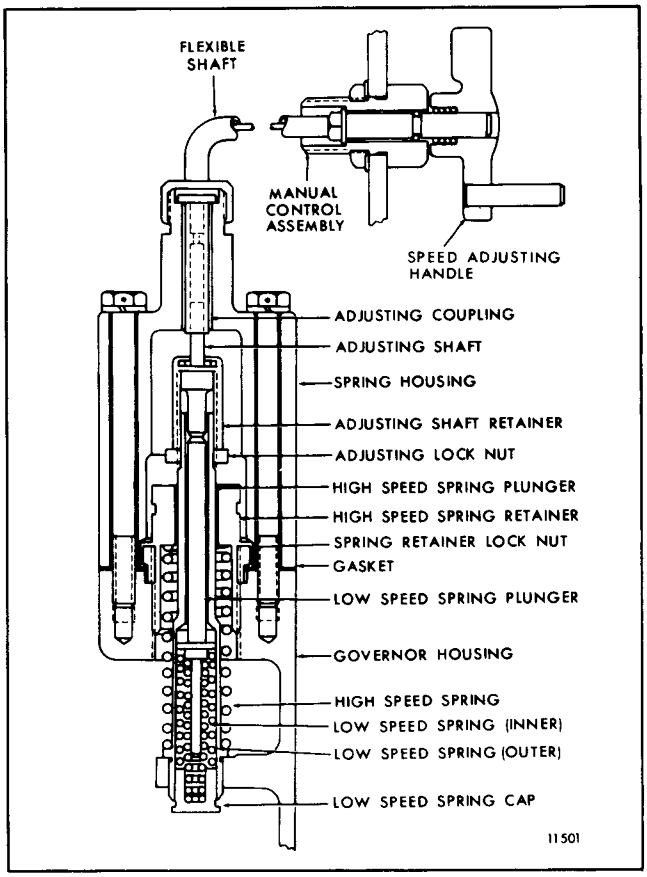


Fig. 1 - Cable Operated Governor Spring Housing and Components

The variable low-speed limiting speed mechanical governor used on In-Line and 6V-53 highway vehicle engines is of the double-weight type. It is used where the same engine powers both the vehicle and the auxiliary equipment for unloading bulk products (such as cement, grain or liquids) and a 500 to 1200 rpm idle speed range is desired during the auxiliary operation. A service kit is available to convert the short spring pack 6V-53 double weight limiting speed governor assembly to a cable operated variable low-speed limiting speed governor for 500-1600 rpm idle speed range for auxiliary aoperations.

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.

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 speed adjusting handle, on the cable operated governor (Fig. 1), is turned to the speed required within the above range to operate the auxiliary equipment. For the air operated governor (Fig. 3), the engine speed is changed to the speed required by increasing or decreasing the air supply pressure to the governor. The governor then functions as a variable speed governor, maintaining a constant speed when the load is constantly changing, during the unloading operation. Before resuming highway operations, the speed adjusting handle on the cable operated governor must be turned back to the stop, then turned ahead about one-quarter of a turn. The air operated governor's air supply pressure must be vented before resuming highway operations.

Lubrication

The governor is lubricated in the same manner as the limiting speed mechanical governor (Section 2.7.1 or 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.

CABLE OPERATED GOVERNOR

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 or 2.7.1.1.

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 or 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.

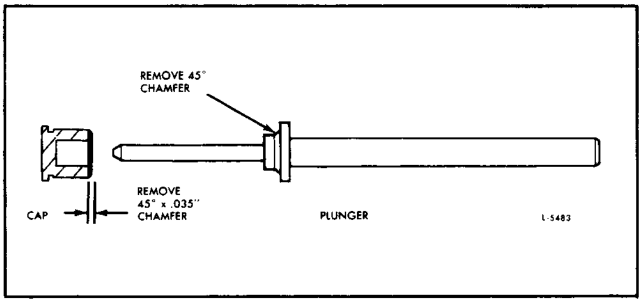


Fig. 2 - Rework Former Plunger and Cap

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 or 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 or 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-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).

NOTE: 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.

NOTE: 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 or 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.

AIR OPERATED GOVERNOR

Remove Governor from Engine

1. Disconnect the air controls from the governor spring housing.

2. Remove the governor following the same procedures outlined in Section 2.7.1 or 2.7.1.1.

Disassemble Governor

The air operated 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 or 2.7.1.1, then disassemble the spring housing and its components (Fig. 3) 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. Discard the gasket.

3. Loosen the 5/16 ″-24 idle speed jam nut and remove the idle speed adjusting screw, seal ring and nut as an assembly. Discard the seal ring.

4. Hold the 1/2 ″-20 jam nut on the high-speed spring plunger with a wrench and unscrew the air cylinder cap, retainer ring, pin, piston, air cylinder and seal ring as an assembly from the end of the high-speed spring plunger.

a. Disengage the retainer ring from the air cylinder and remove the air cap and piston from the air cylinder.

b. Remove the seal ring from the piston. Discard the seal ring.

5. 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.

6. 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.

Inspect Govenor 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 or 2.7.1.1.

Assemble Governor

NOTE: During assembly, lubricate all spring housing components 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 or

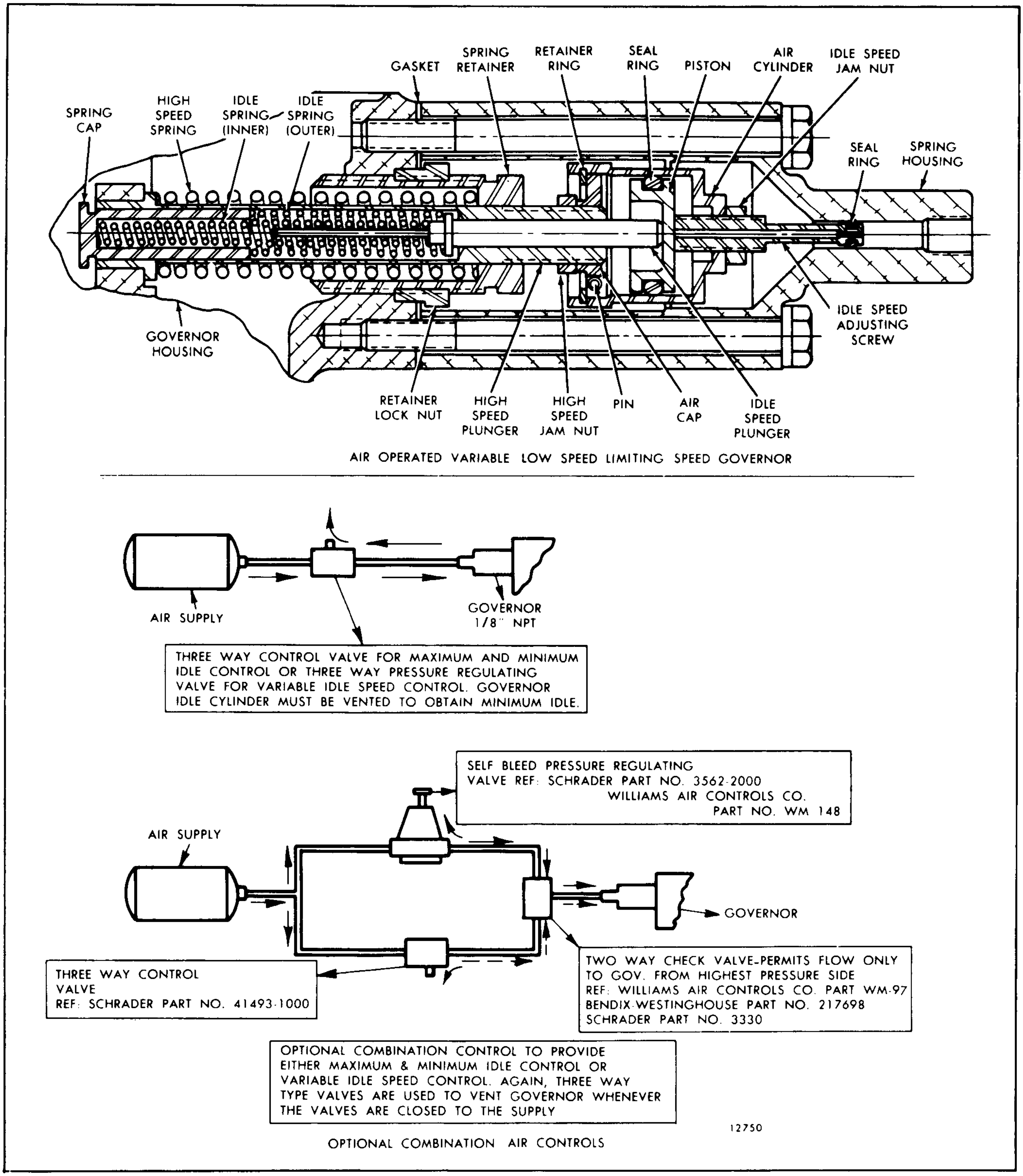


Fig. 3 - Air Operated Variable Low Speed Limiting Speed Governor and Air Controls

2.7.1.1, then assemble the spring housing and components (Fig. 3) as follows:

1. Thread the spring retainer lock nut approximately 1-1/2 " onto the high-speed spring retainer.

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.

NOTE: Place the new spring housing gasket in position before installing the assembly.

7. If removed, thread the 1/2 ″-20 high-speed spring jam nut approximately 1/2 ″ onto the threaded end of the plunger.

8. Place a new seal ring on the piston and assemble the piston and air cap in the air cylinder. Secure them in the air cylinder with the retainer ring.

9. Screw the air cylinder assembly onto the high-speed spring plunger and against the high-speed spring plunger and jam nut.

10. Place a new seal ring on the idle adjusting screw and install the adjusting screw and jam nut in the air cylinder.

11. Install the spring housing after the governor adjustments (Section 14.3.3) have been performed.

NOTE: Be sure and lubricate the bore of the spring housing with grease as stated in the above note.

Install Govenor

Install the governor as outlined in Section 2.7.1 or 2.7.1.1, then connect the air controls to the governor spring housing (Fig. 3).

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

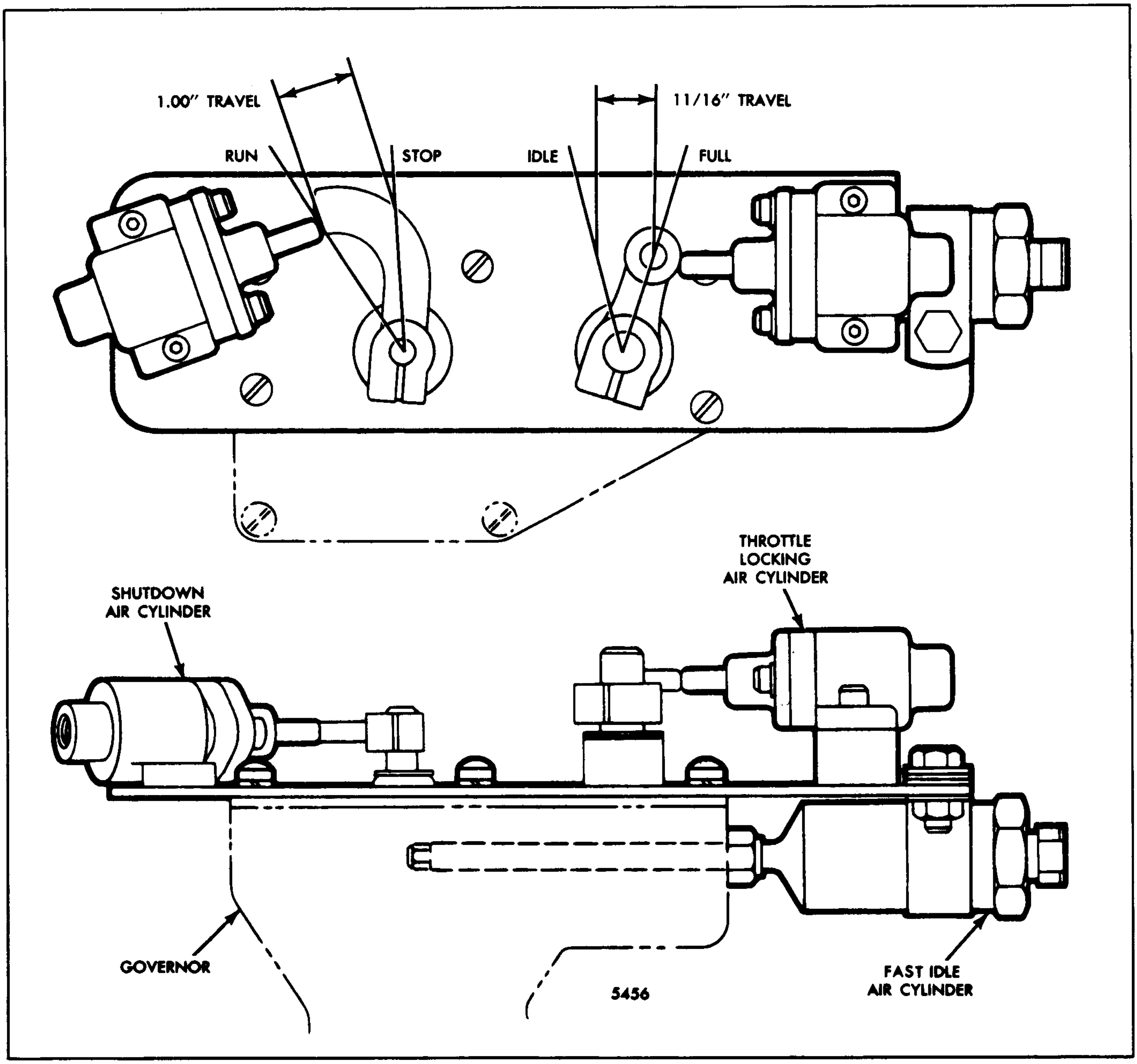


Fig. 1 - Governor with Fast Idle Cylinder

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.

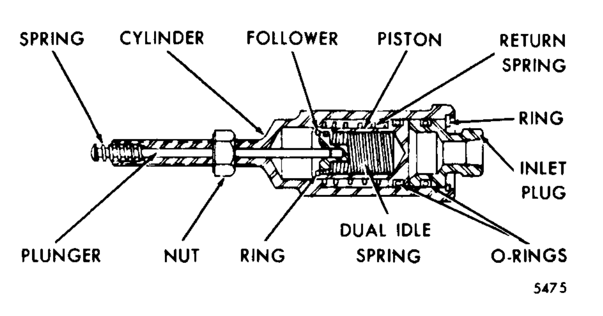


Fig. 2 - Fast Idle Air Cylinder

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.

LIMITING SPEED MECHANICAL GOVERNOR

(Variable High-Speed)

The air operated variable high speed limiting speed mechanical governor is provided for highway vehicle applications where the same engine powers both the vehicle and auxiliary equipment, for unloading bulk products (such as cement, grain or liquids) and where a variable speed range is desired during auxiliary constant speed operation.

Operation

The idle speed range for these governors is the same as for the standard limiting speed governors. The normal no-load speed range is the same as for the standard limiting speed governor. A variable high speed limiting governor will control engine RPM from any normal no-load speed down to near idle speed. Also, in addition to the high speed control kit, a regulated air supply and an air cylinder to move the throttle to the wide open throttle position is required.

Install Control Housing

Without disturbing the engine tune-up, install a high speed control housing assembly on a standard limiting speed governor having a long spring pack, as follows (Fig. 1):

1. Loosen the two bolts and copper washers and remove the spring retainer housing.

2. Remove the idle speed adjustment screw and replace it with the longer high speed control idle speed screw and reset the idle speed RPM to the previous setting.

NOTE: If the governor has the former one piece idle speed screw, replace it with the current idle speed pin and long screw.

The engine tune-up procedure for the high speed control governor is the same as stated in Section 14.3 except the idle speed adjustment is made, using the longer idle speed screw.

3. Assemble the high speed control housing as follows:

   a. Install the small ring in the spring housing and the large seal ring on the piston.

   b. Lubricate the piston and inside of housing with engine oil and install the piston in the housing.

4. Slide the housing and piston assembly over the spring retainer and idle speed screw.

5. Install the idle screw self-locking nut and make the following adjustments:

   a. Place a .010" feeler gage between the VHS housing gasket and the main governor housing.

   b. Adjust the elastic stop nut, while holding the idle screw stationary, until a slight drag is felt on the shim (Fig. 2). This adjustment is made easily with Tool J 28598-A.

   c. Remove the shim.

6. Install the gasket and either flat or tamper-resistant cover with two copper washers and two 5/16"-18 x 4 1/2" bolts (flat cover). Tighten bolts.

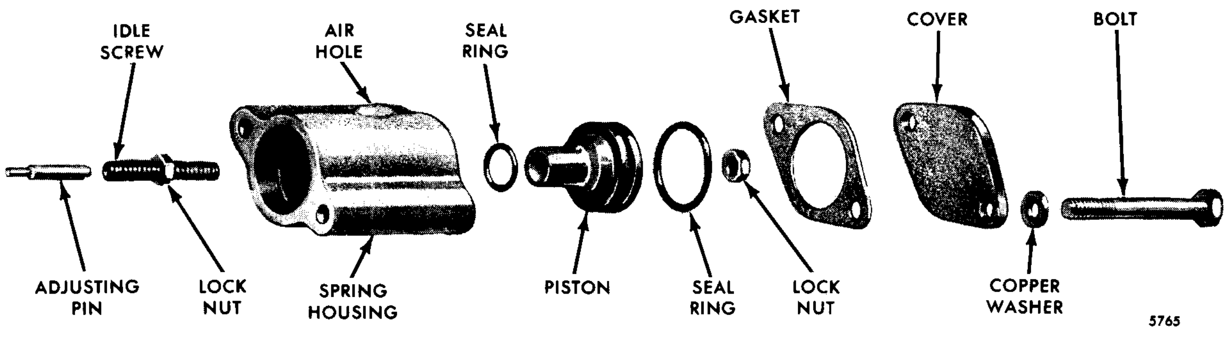


Fig. 1 - Air Operated Variable High Speed Limiting Speed Mechanical Governor Components

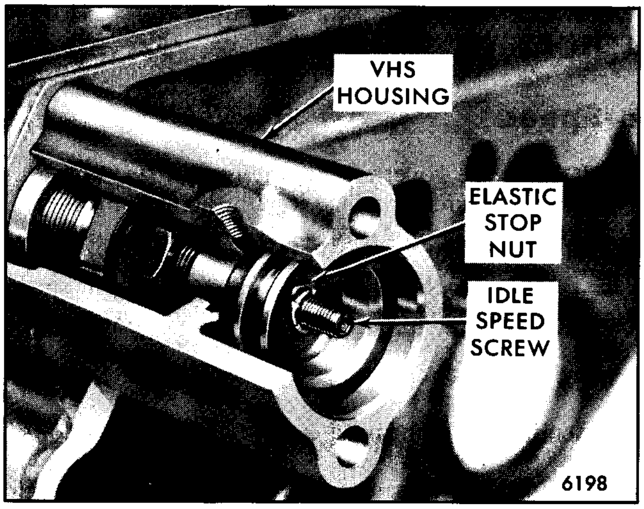


Fig. 2 - Adjust Elastic Stop Nut using Tool J 28598-A

Install the air cylinder on the governor cover so that it does not interfere with the throttle linkage when no air pressure applied and moves the speed control lever to the wide open throttle position with full air pressure applied (Fig. 3).

Supply air should only be taken from the accessory air supply. At no time should supply air be taken from the service brake system. However all air supply components should be plumbed and mounted in compliance with the recommendations for the air brake system. Both air cylinders must be vented to insure rapid disengagement.

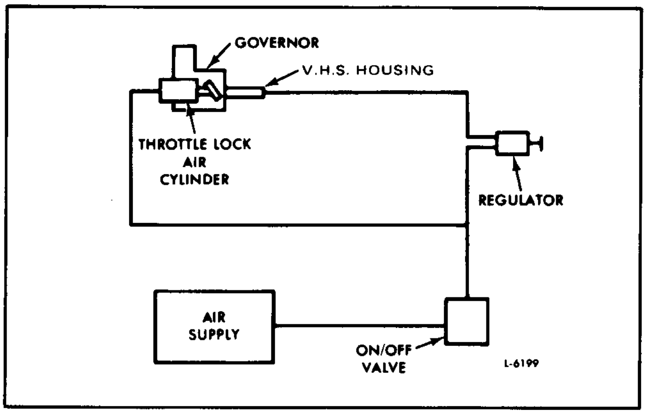


Fig. 3 - Schematic Drawing of Limiting Speed Mechanical Governor (Variable High Speed)

Before starting an engine after an engine speed control adjustment or after removal of the engine governor cover and lever assembly, the serviceman must determine that the injector racks move to the no fuel postion when the governor stop lever is placed in the stop position. Engine over-speed will result if the injector racks cannot be positioned at no fuel with the governor stop lever.

CAUTION: An over-speeding engine can result in engine damage which could cause personal injury.

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.

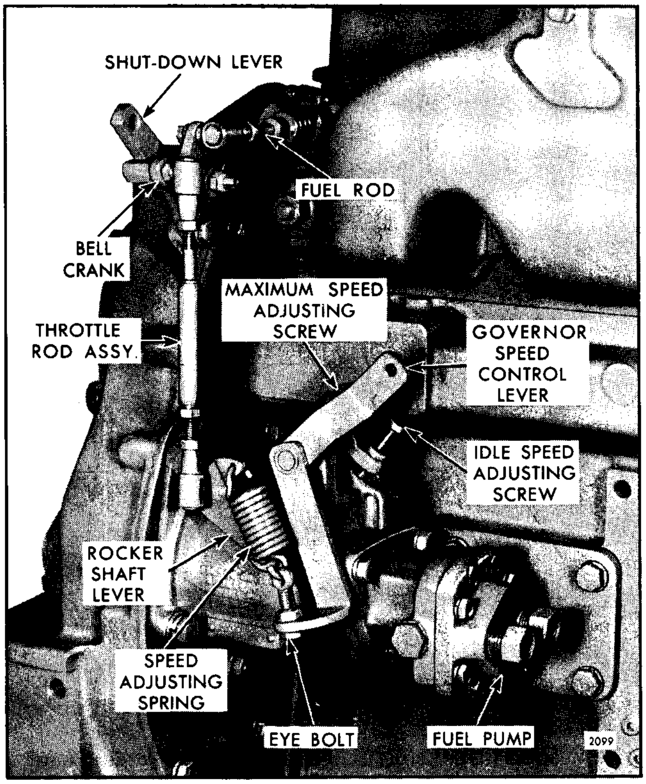


Fig. 1 - Governor Mounting

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.

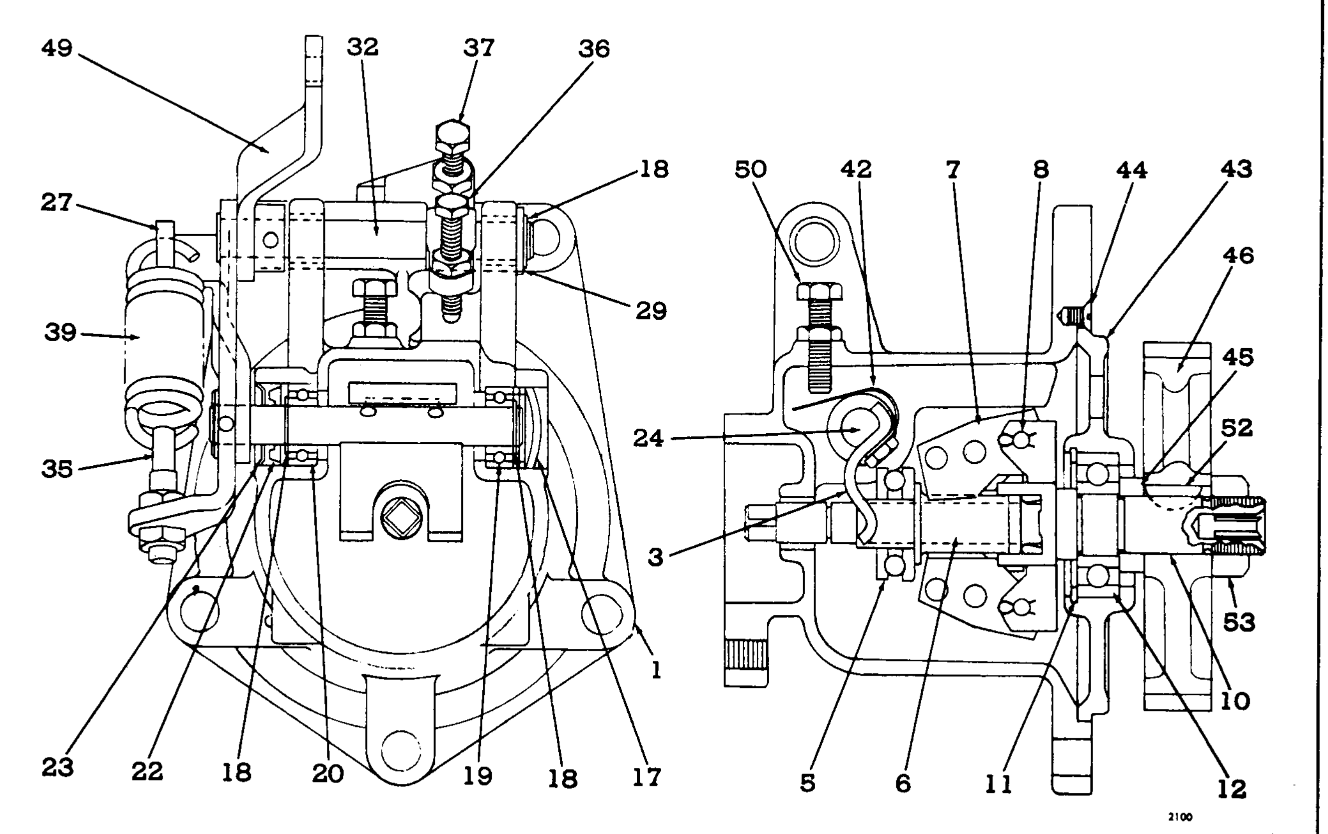
Surplus oil drains from the governor through holes in the governor bearing housing back to the engine crankcase.

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
3. Fork--Operating
5. Bearing--Riser Thrust
6. Riser
7. Flyweights
8. Pins--Weight Supporting
10. Spider and Shaft Assembly--Operating
11. Ring--Snap (Internal)
12. Bearing--Shaft
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
27. Lever--Rocker Shaft
29. Washer
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
49. Lever--Governor Speed Control
50. Screw--Buffer
52. Key--Drive
53. Nut--Drive Gear Retaining

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.

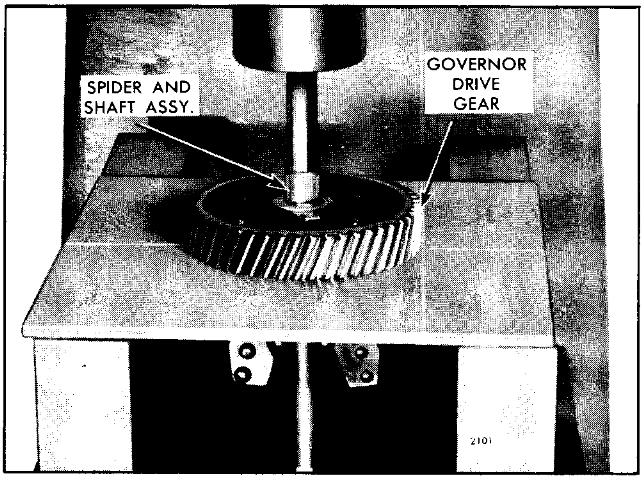


Fig. 3 - Removing Drive Gear from Spider and Shaft Assembly

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.

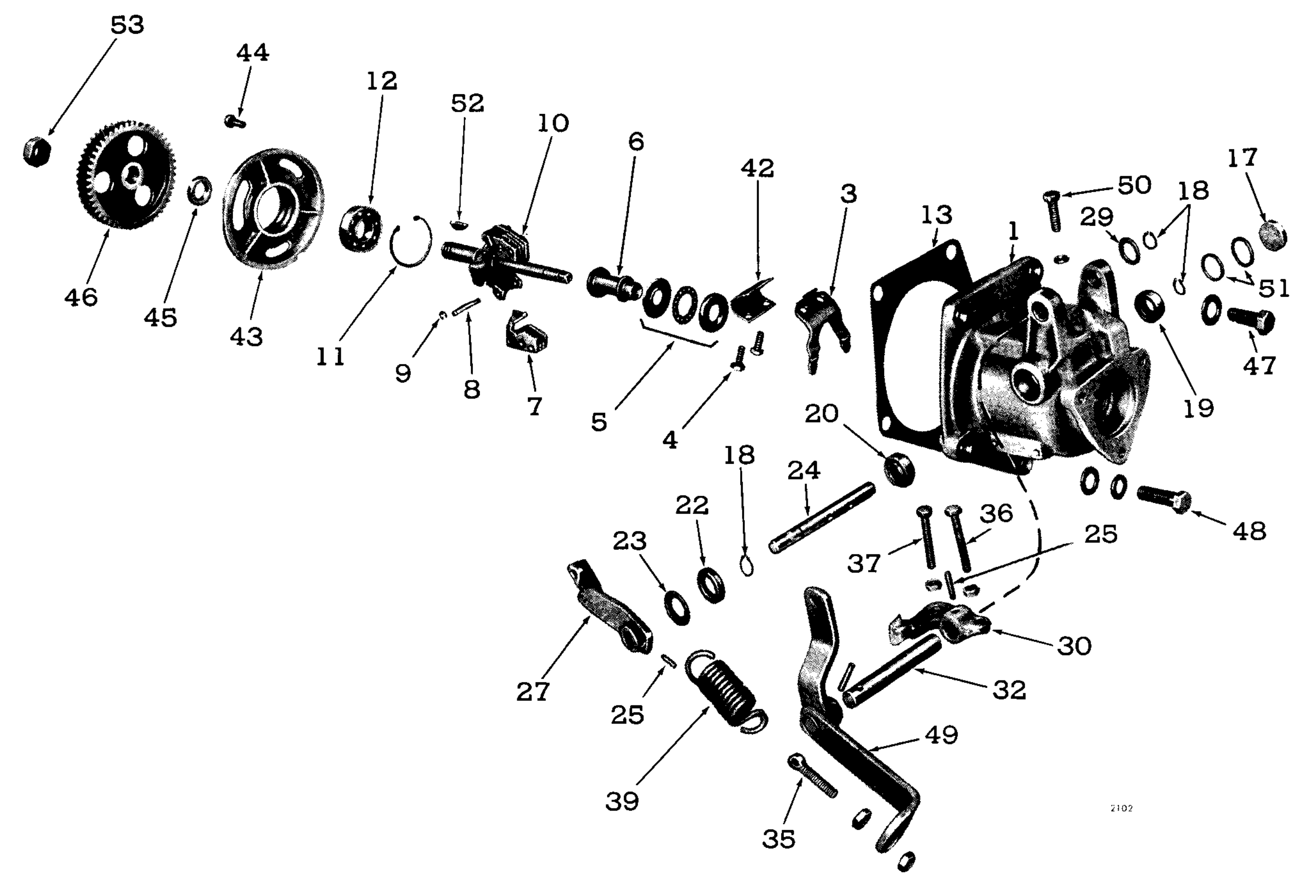
17. Remove the oil seal plug (17) by driving lightly with a small punch at the lower edge of the plug, thus forcing the upper edge outward. Then place a screw driver behind the plug and remove it from the governor body. Remove the gaskets (51).

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).

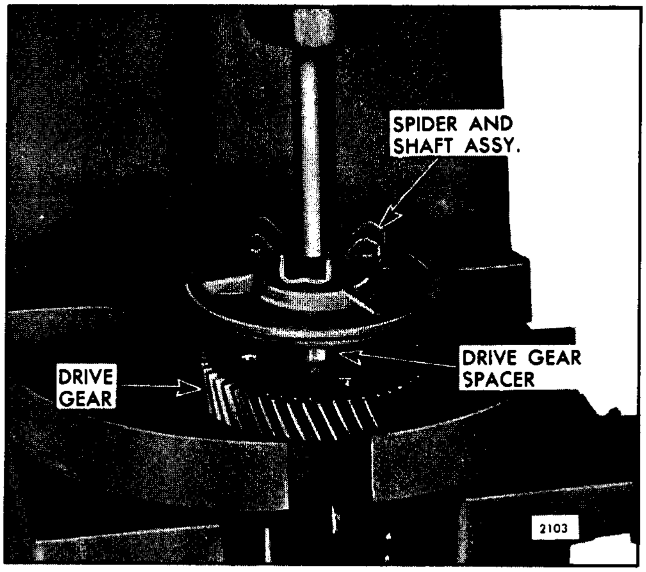


Fig. 5 - Installing Drive Gear on Spider and Shaft Assembly

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)

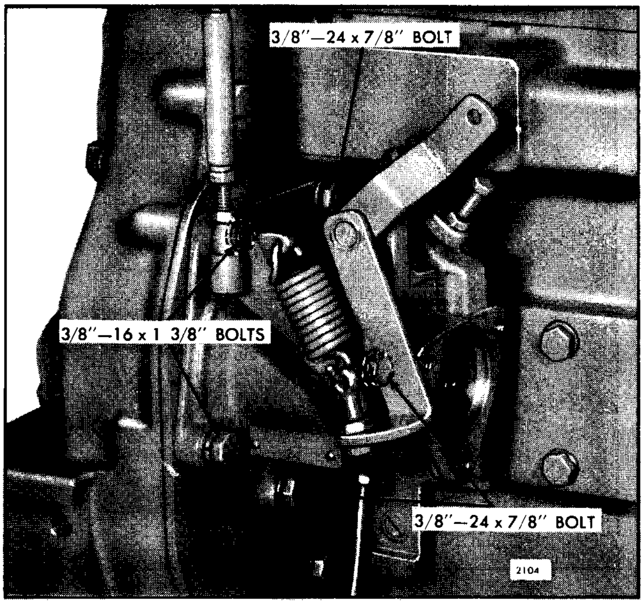


Fig. 6 - Location of Governor Retaining Bolts

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.

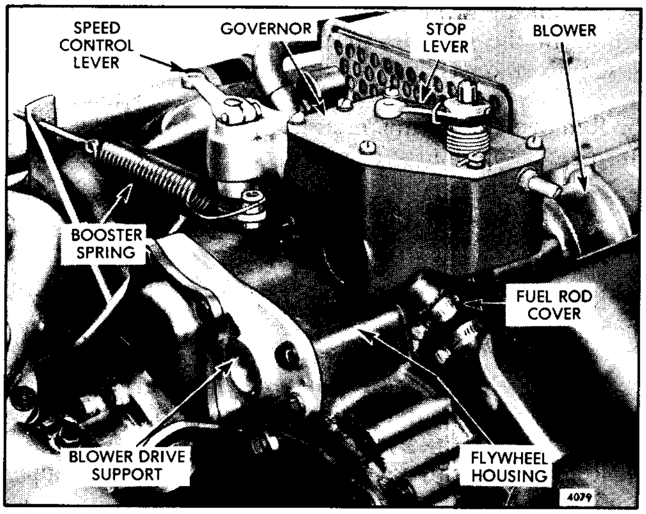


Fig. 1 - Governor Mounting

A new riser thrust bearing is being used in V-53 variable speed governors. The new thrust bearing has a molded nylon retainer, whereas the former bearing had a plain steel retainer. The new nylon retainer bearing is completely interchangeable with the current steel retainer bearing. However, only the new bearing will be serviced.

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.

Current governor covers include a longer serrated shutdown shaft and lever to provide positive clamping between the serrated levers and shafts. The longer shaft also has provisions for a yieldable speed control lever.

The centrifugal force of the revolving governor weights is converted into linear motion which is

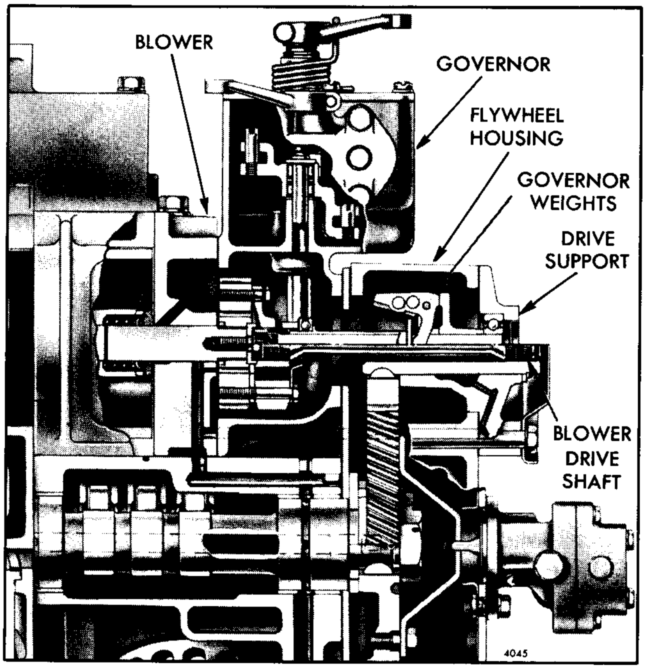


Fig. 2 - Governor and Drive

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.

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 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.

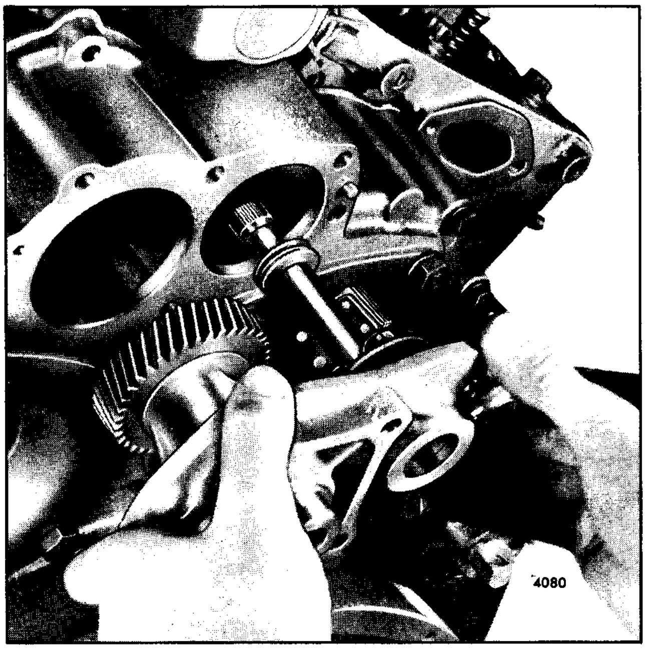


Fig. 3 - Removing or Installing Blower Drive Support

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 from the speed control lever (Fig. 1).

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 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 21967-01 on top of the upper bearing (or bushing) and press both bearings (or bushing) out of the cover.

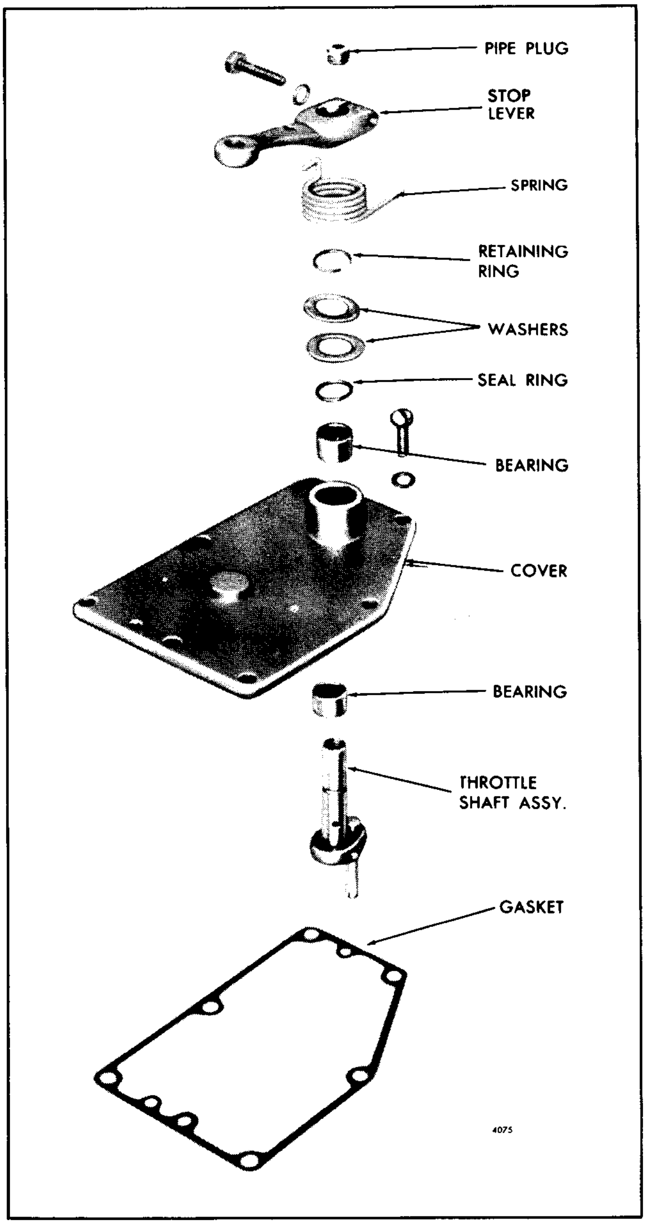


Fig. 4 - Governor Cover Details and Relative Location of Parts

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.

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.

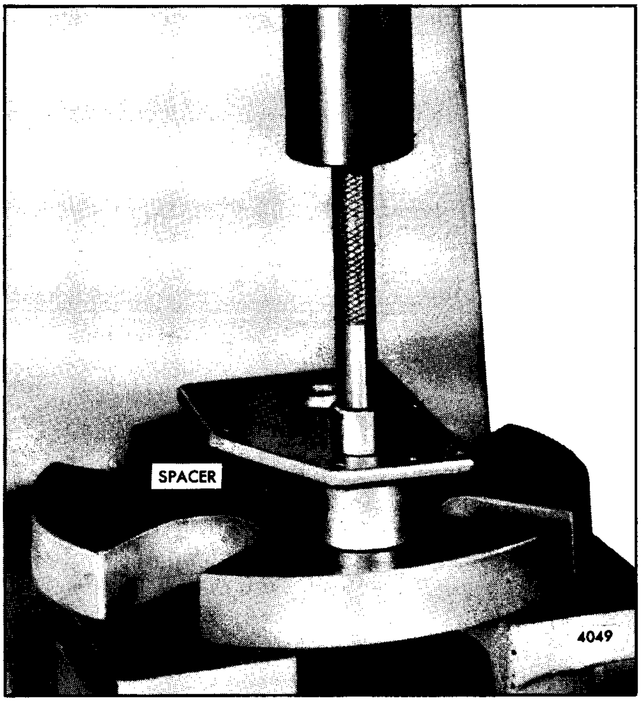


Fig. 5 - Removing Governor Cover Bearings using Tool J 21967-01

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.

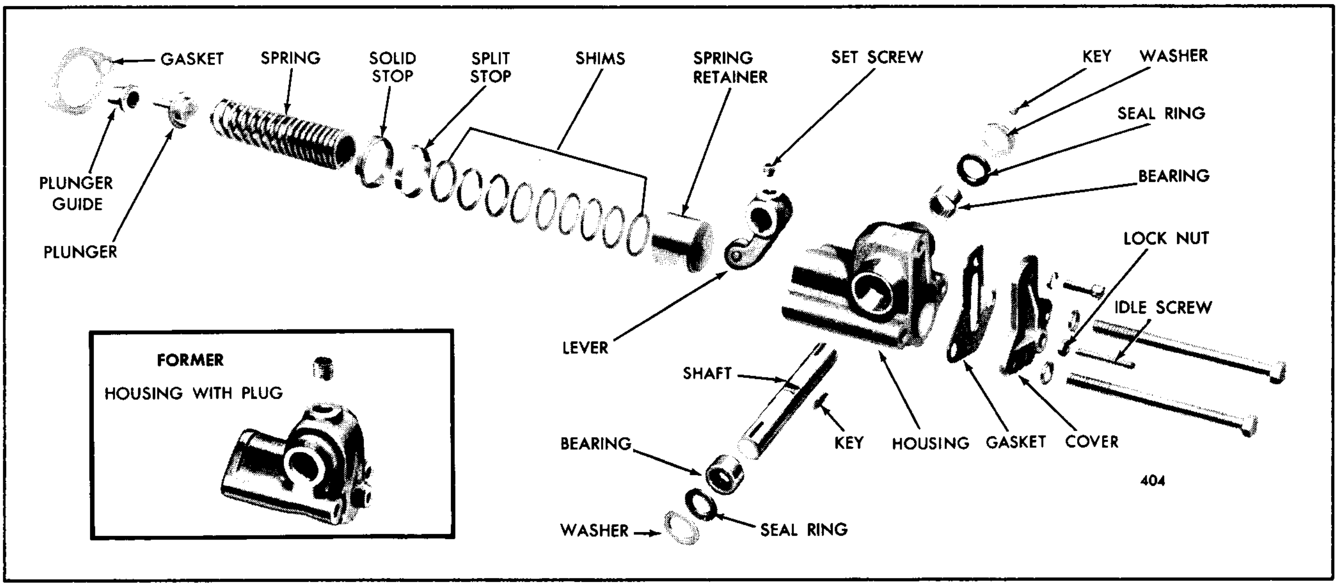


Fig. 6 - Variable Speed Spring Housing Assembly

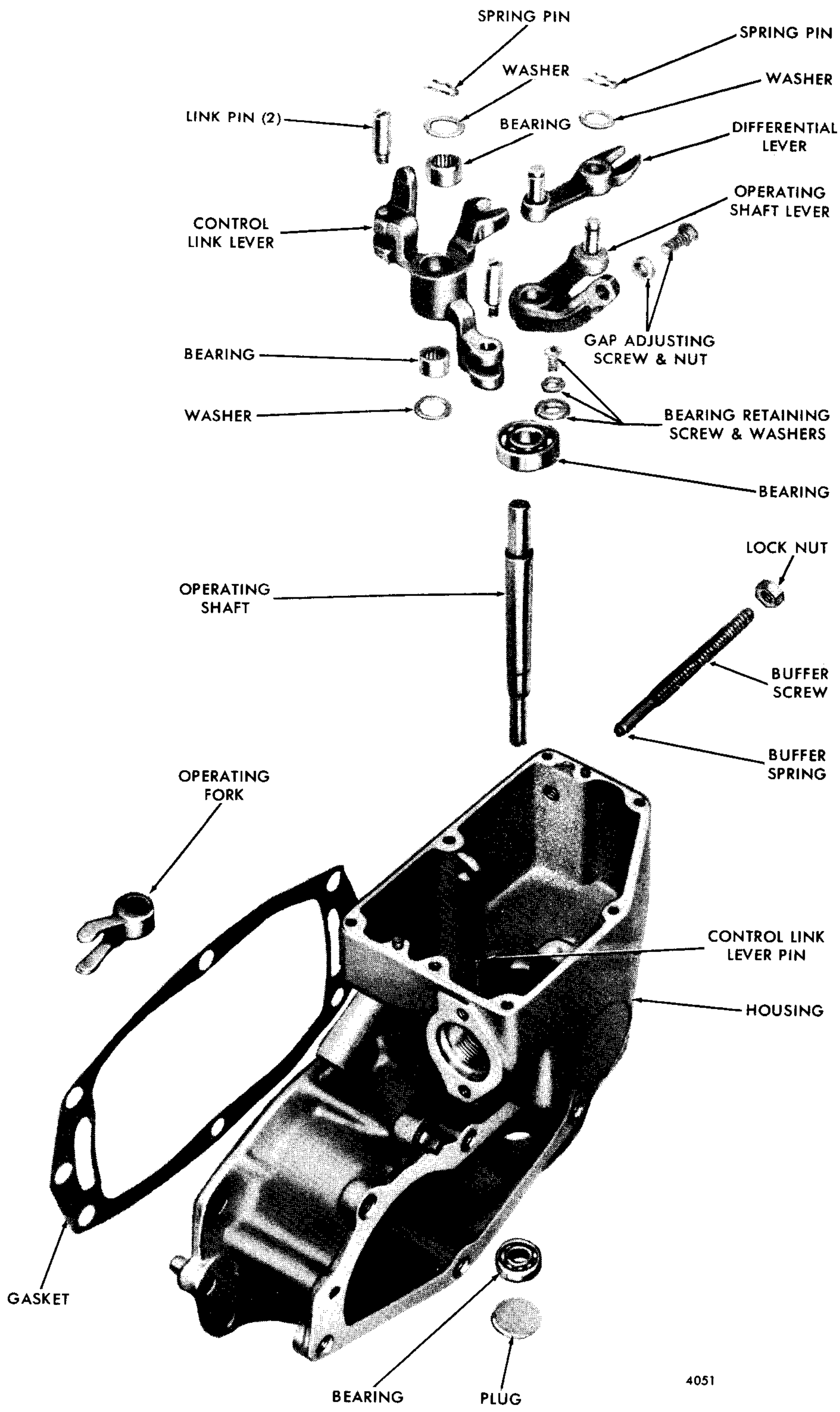


Fig. 7 - Governor Housing Details and Relative Location of Parts

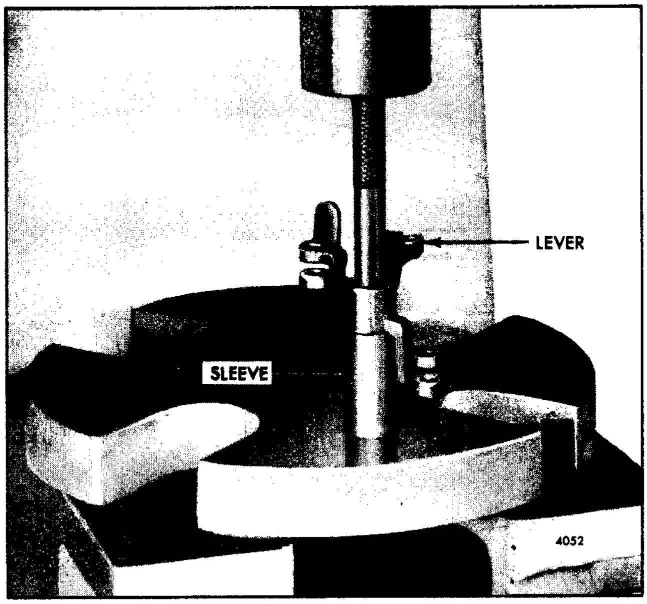


Fig. 8 - Removing or Installing Control Link Lever Bearings using Tool J 8985

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.

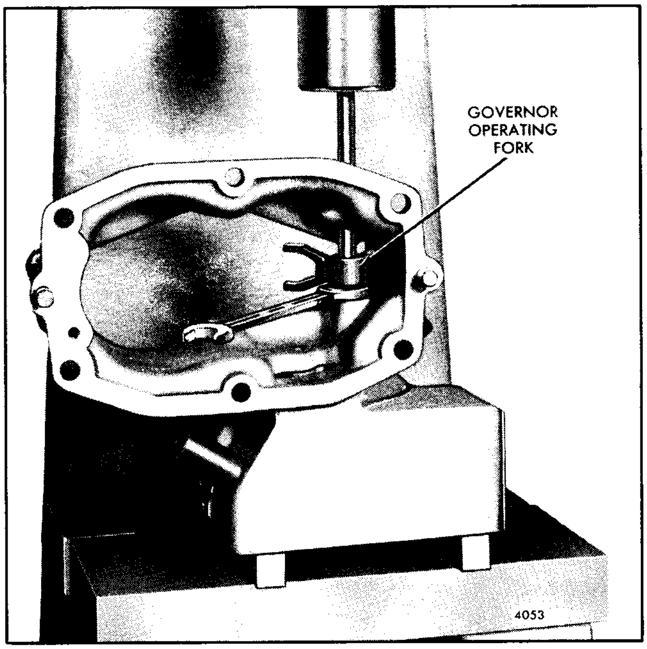


Fig. 9 - Removing Governor Operating Fork

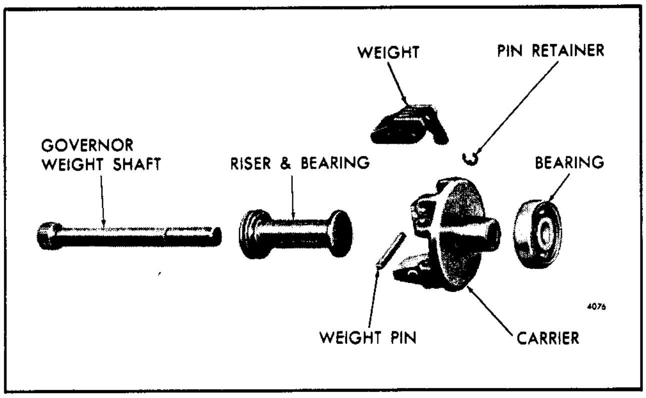


Fig. 10 - Governor Weight Details and Relative Location of Parts

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.

> **NOTE:** Do not use a solvent-base paint stripper or carbon remover when cleaning a nylon race bearing. The nylon can be seriously damaged by these compounds.

Inspect all bearings. Replace corroded or pitted

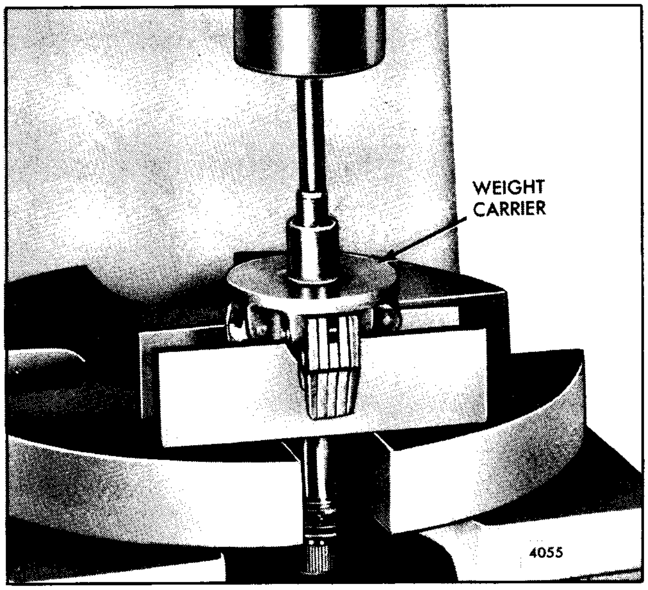


Fig. 11 - Removing Shaft from Weight Carrier

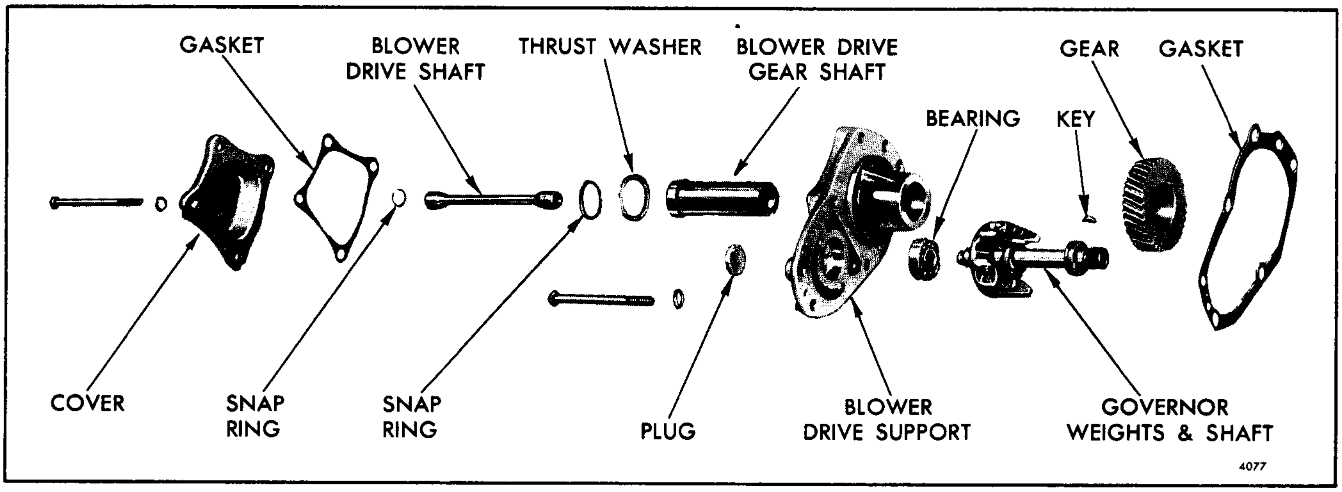


Fig. 12 - Blower Drive Support Details and Relative Location of Parts

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 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 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.

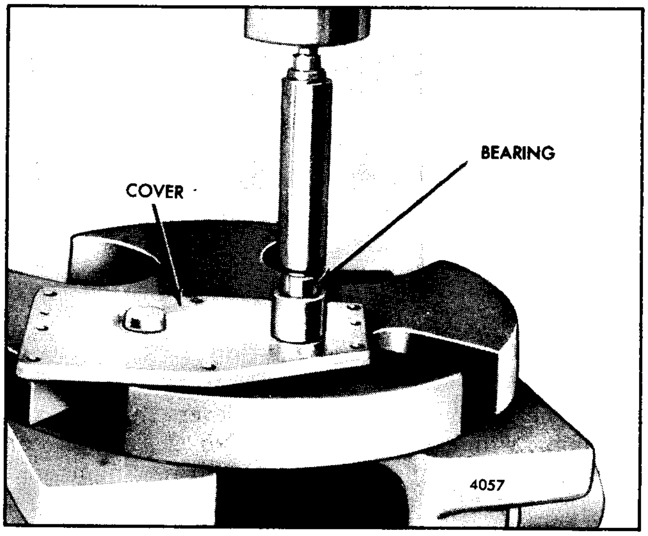


Fig. 13 - Installing Governor Cover Bearings using Tool J 21068

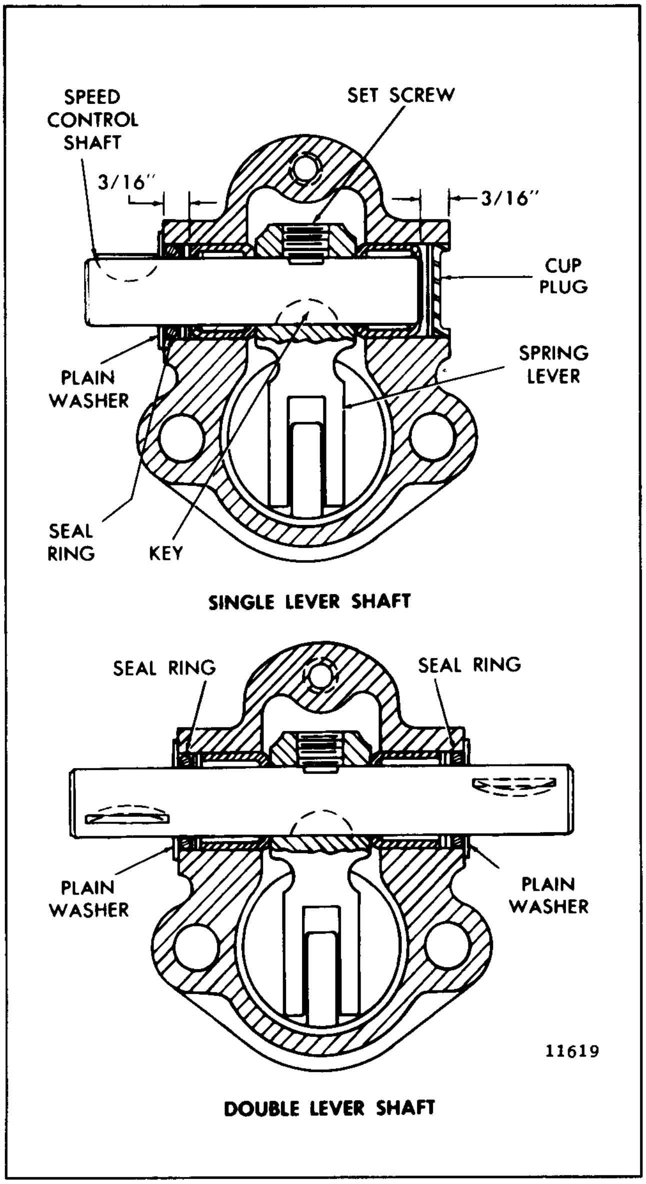


Fig. 14 - Governor Variable Speed Spring Housing

5. If a torsion-type stop lever retracting spring is used, place it over the cover hub with the hooked end up (Fig. 4). 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.

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

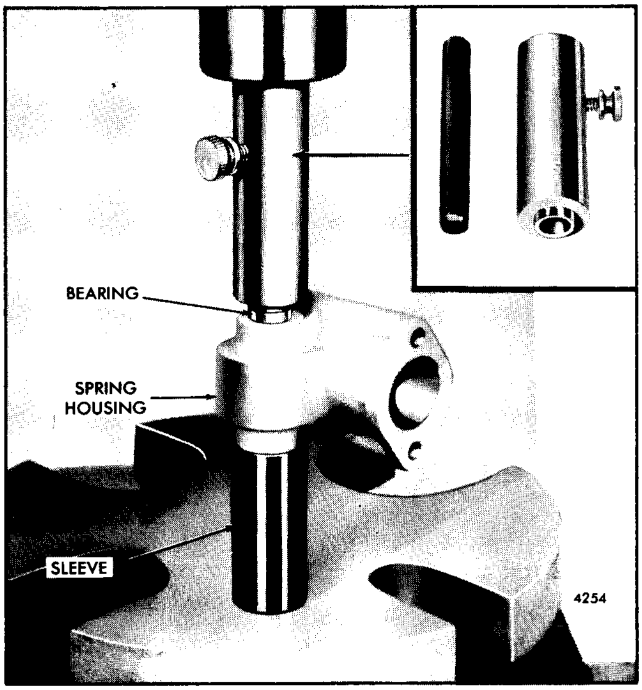


Fig. 15 - Installing Speed Control Shaft Bearings In Spring Housing using Tool J 9196

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.

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 5-7 lb-ft (7-10 Nm) 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.

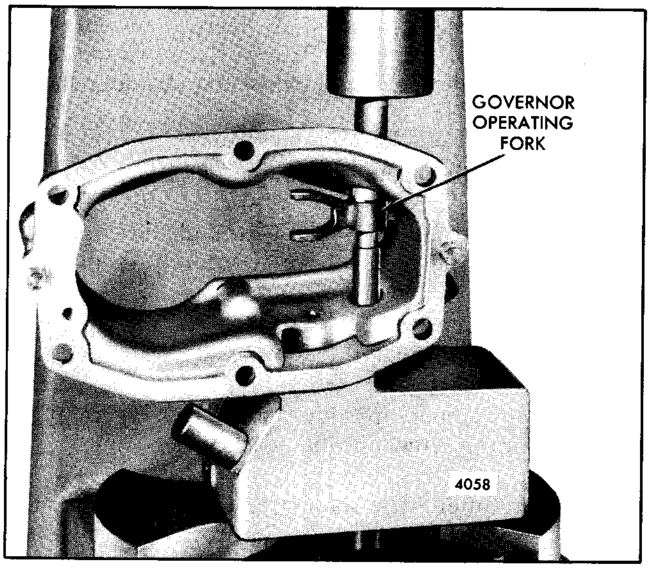


Fig. 16 - Installing Governor Operating Fork on Shaft

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.

NOTE: Do not break the housing.

8. Secure the upper operating shaft bearing in place with a retaining screw and flat washer.

9. Place the differential lever over the pivot pin in the operating shaft lever (Fig. 7). 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.

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

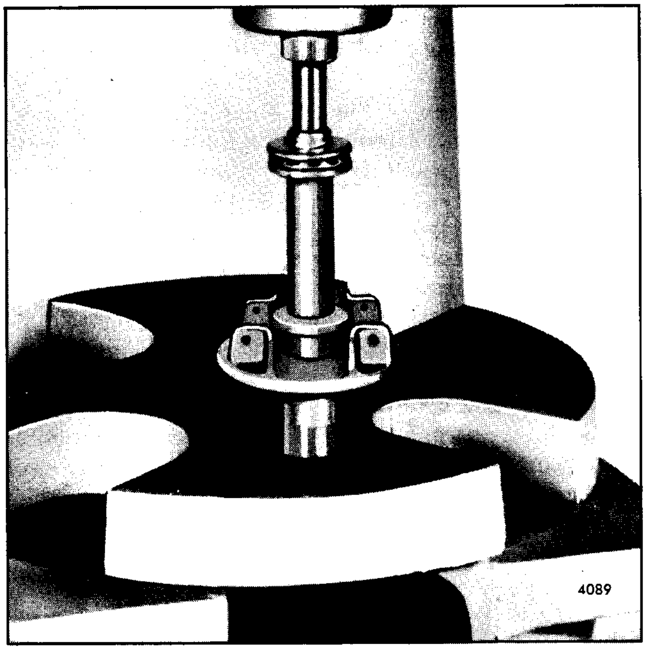


Fig. 17 - Installing Weight Carrier on Shaft using Tool J 8984

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 washer.

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:

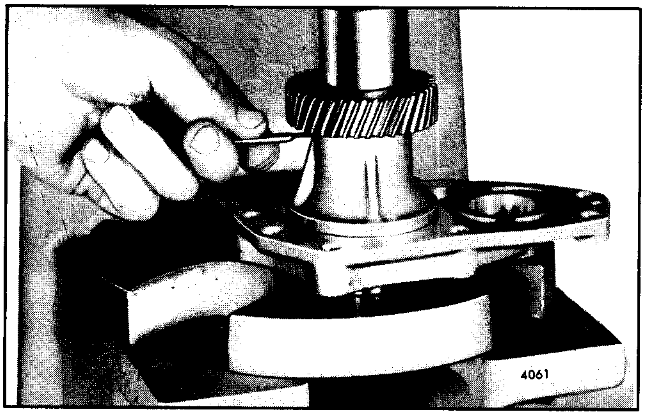


Fig. 18 - Installing Blower Drive Gear on Shaft

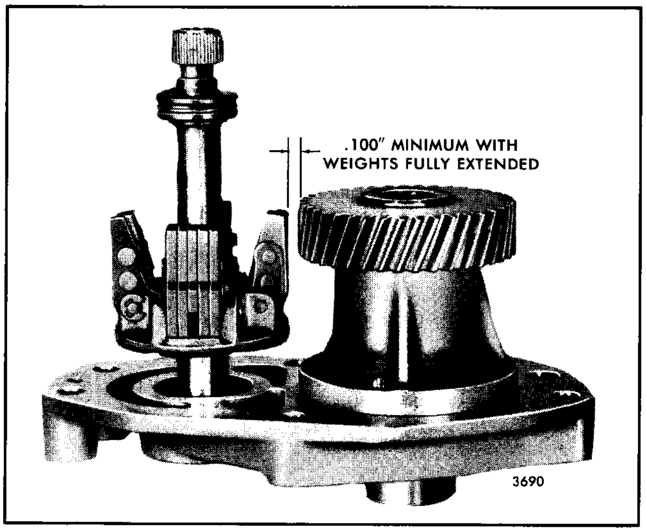


Fig. 19 - Minimum Clearance Between Blower Drive Gear and Governor Weights

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 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 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:

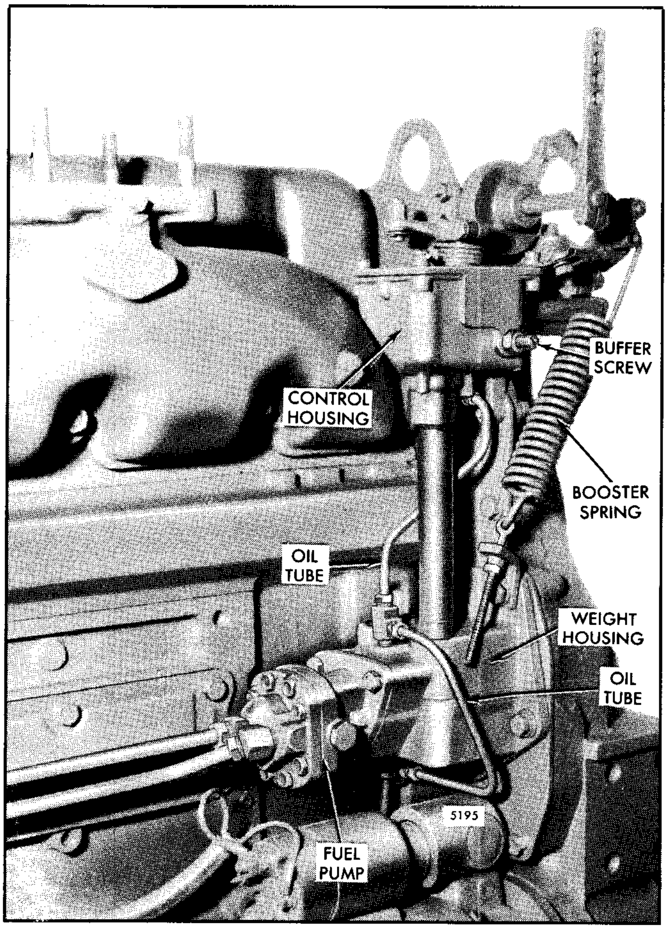


Fig. 1 - Governor Mounting

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 with a .400" restricted fitting has been added between the control housing and the weight housing on current engines. 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. 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 from the cover (Fig. 2).
4. Remove the seal ring from 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. 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.

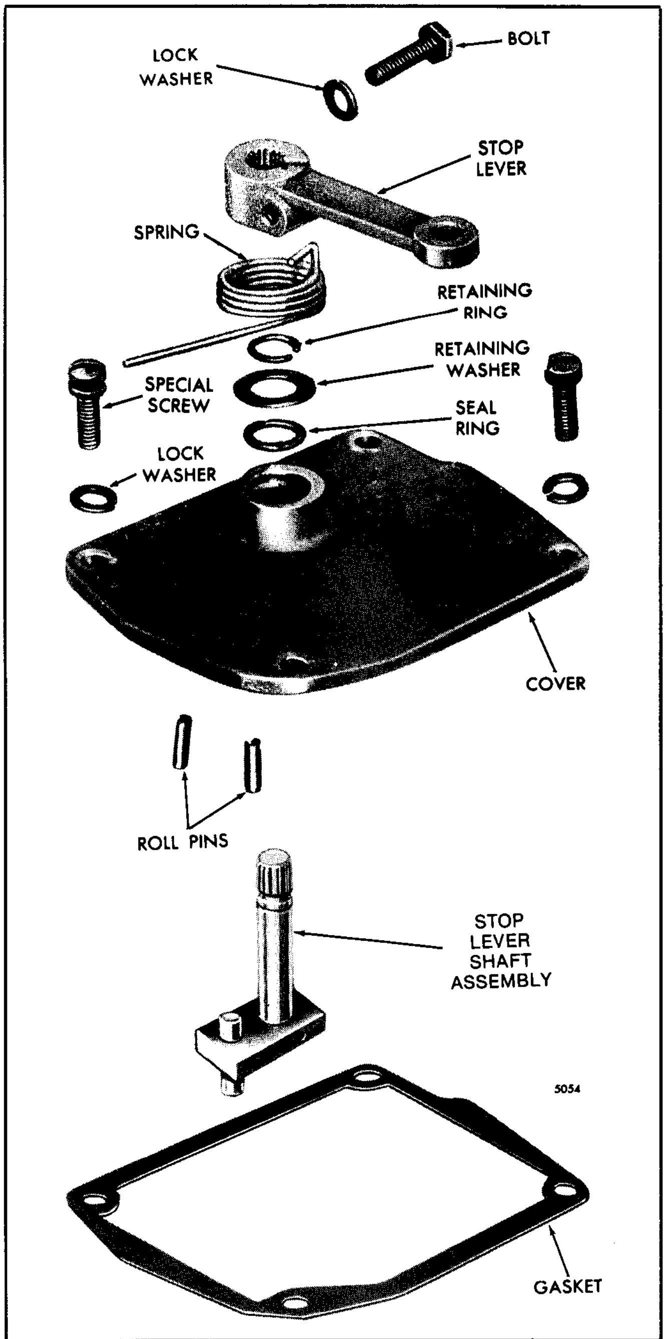


Fig. 2 - Governor Cover Details and Relative Location of Parts

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 which holds the bearing retainer in place (Fig. 5).

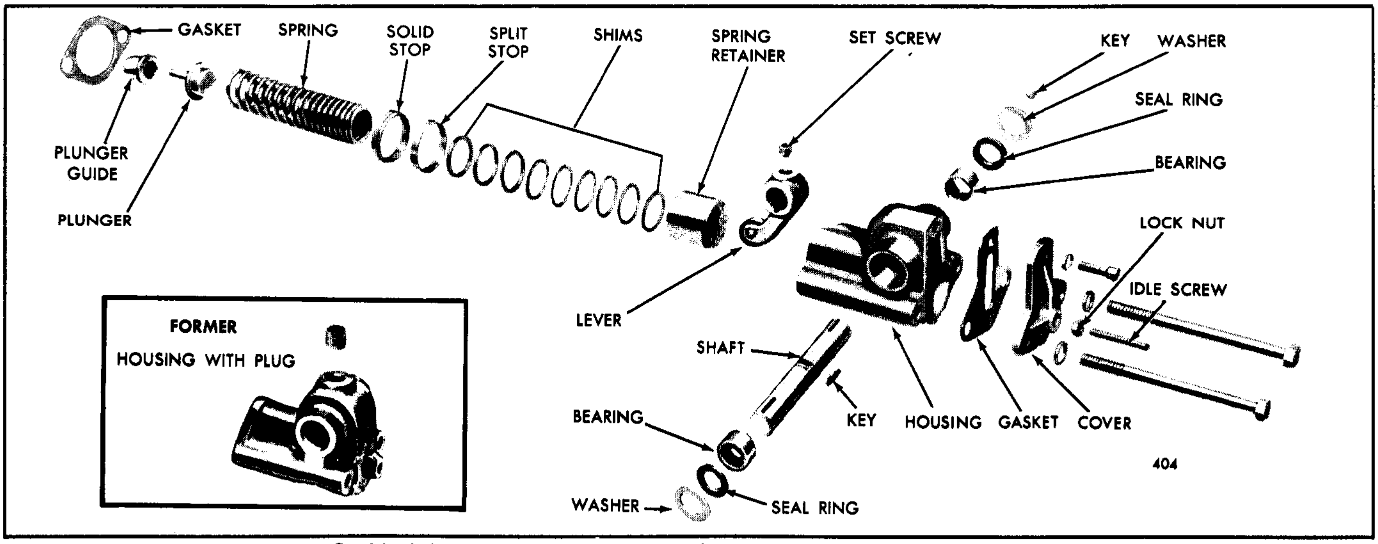


Fig. 3 - Variable Speed Spring Housing and Relative Location of Parts

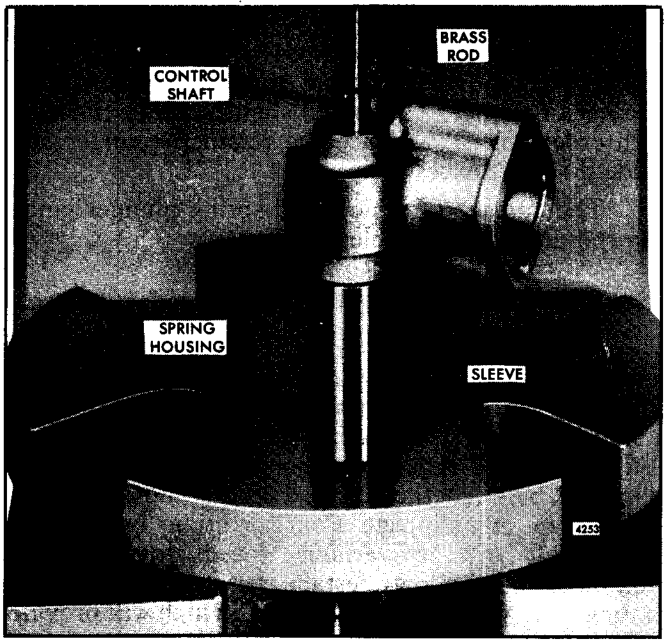


Fig. 4 - Removing Shaft and Bearing from Spring Housing

3. Turn the bearing retainer until the large opening is centered over the fork on the governor operating shaft (Fig. 6).

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 locknut.

7. Remove the upper bearing retaining screw and washer and withdraw the operating shaft and lever assembly from the governor control housing.

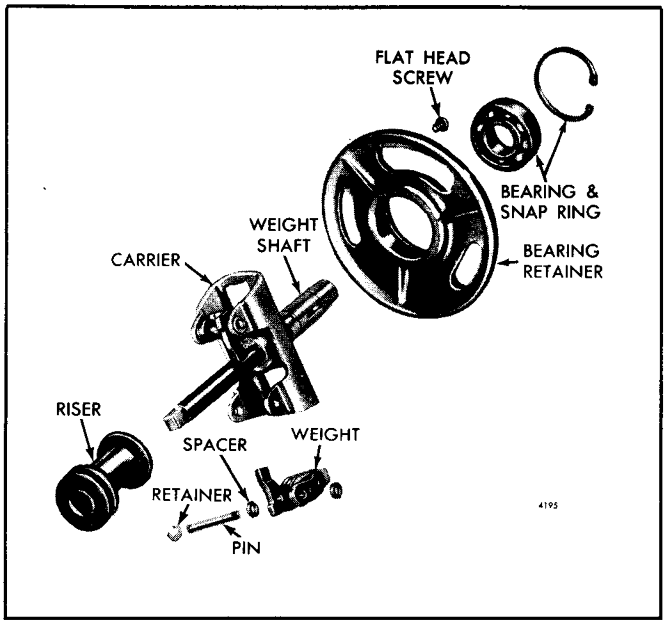


Fig. 5 - Governor Weight Details and Relative Location of Parts

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.

12. If necessary, disassemble the control housing from the weight housing.

Disassemble Weight Shaft Assembly

1. Press the bearing retainer from the weight shaft (Fig. 5).

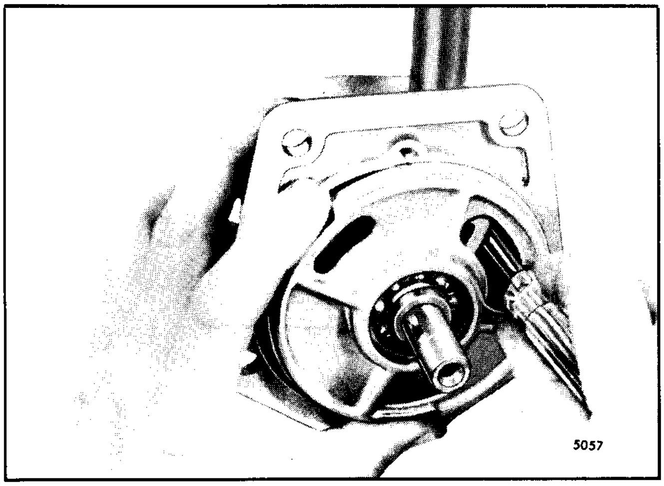


Fig. 6 - Removing or Installing Operating Shaft Fork

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. The weight pin hole in the carrier is larger at the side where the pin retainers are located. Remove the weights.
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" locknut 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

New mechanical governor cover assemblies with serrated shafts are being used on In-line 53 engines. The new variable speed governor cover assemblies include a new 7/16" diameter serrated stop lever shaft (Fig. 2). 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 variable 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. 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 over the shaft and lock the shaft in place with the retaining ring (Fig. 2).
3. If a torsion-type stop lever retracting spring is used, place it over the cover hub with the hooked end up (Fig. 2). Then, place the stop lever on the shaft and tighten the clamping bolt.

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. 7.

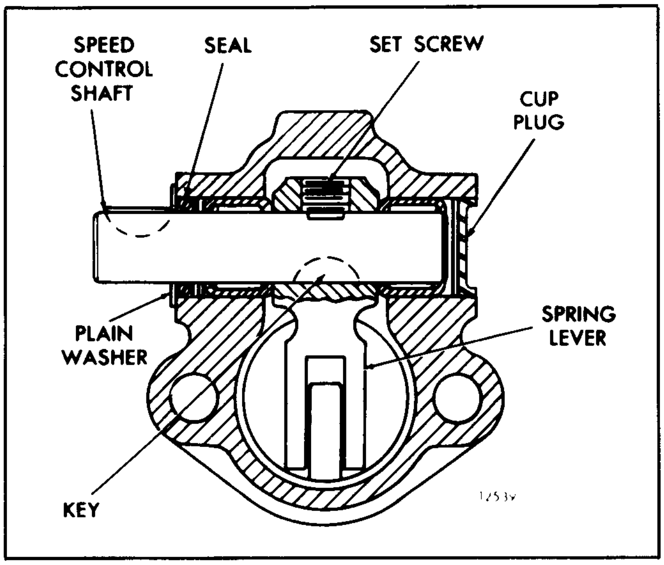


Fig. 7 - Governor Variable Speed Spring Housing

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. 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 and press the bearing in the housing until the shoulder on the installer contacts the housing (Fig. 8). 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.

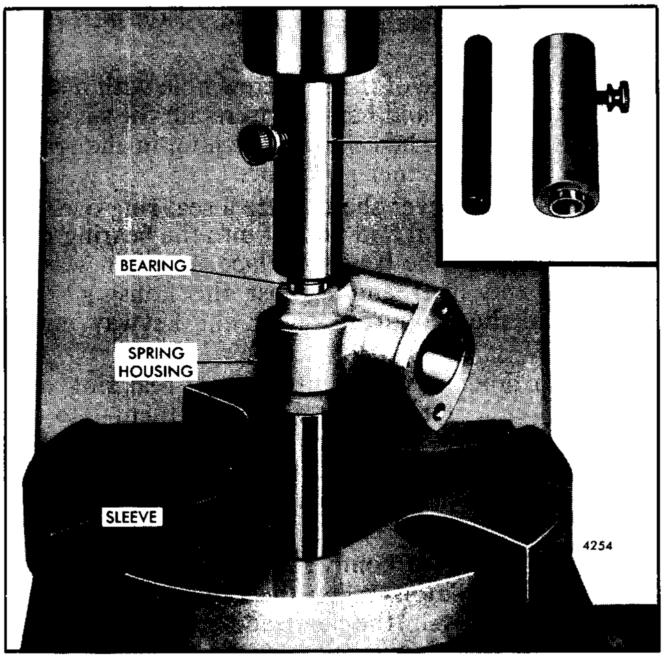


Fig. 8 - Installing Speed Control Shaft Bearings in Spring Housing using Tool J 9196

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 and press the bearing in the housing until the shoulder on the installer contacts the housing (Fig. 8).
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 5-7 lb-ft (7-10 N·m) 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

!x1. 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.
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 over the pin in the governor operating shaft lever (Fig. 9). Secure the lever in place with a washer and spring pin.

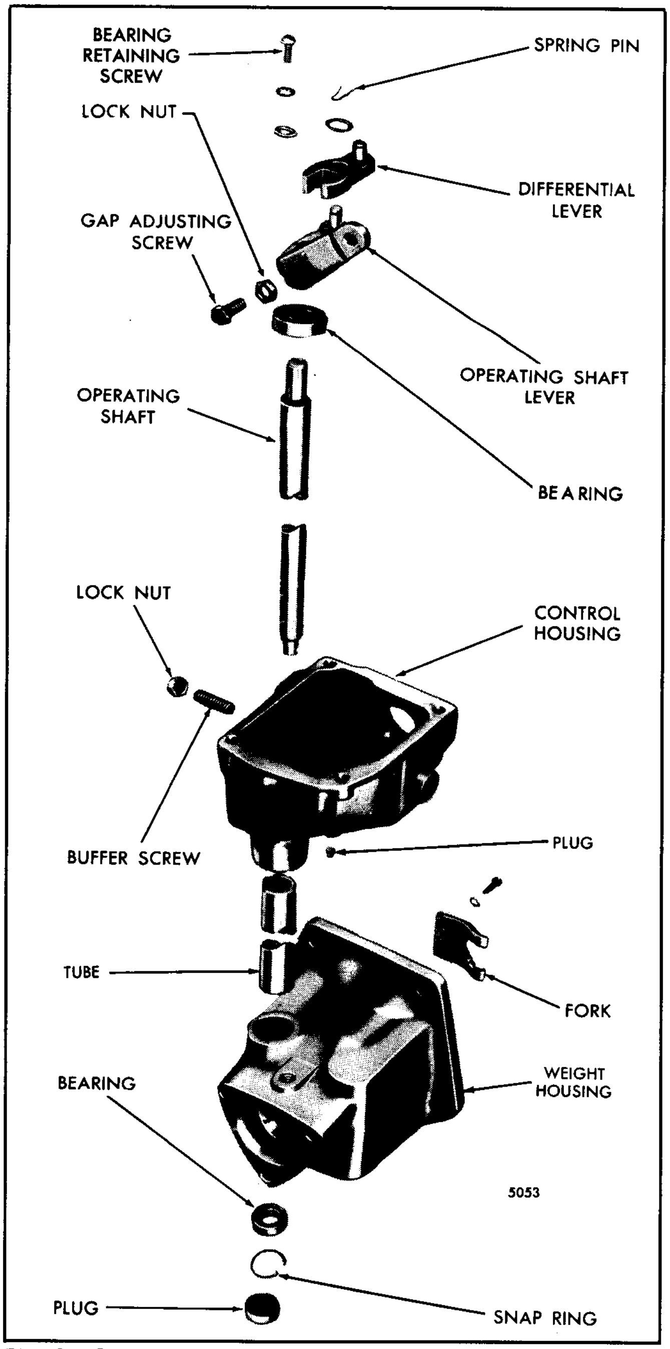


Fig. 9 - Governor Housing and Relative Location of Parts

10. Install the buffer screw and locknut, leaving approximately .750" of the screw extending from the governor housing.
11. If previously removed, install the gap adjusting screw and locknut 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 in the retainer (press on the outer race) - (Fig. 5). 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. 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. 6).
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.

Do not mix the former and the current hardened gears on the same engine. Mixing the gears will result in excessive gear wear and may lead to serious engine damage. The hardened gears are used on 3-53 turbocharged industrial engines. This change became effective with engine serial number 3D-193516.

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 (170-183 N·m) 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 (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 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.
   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.

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 (18-23 N·m) torque.

k. Install the idle speed adjusting screw and locknut 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. If a torsion-type stop lever spring is used, a special cover screw is used to hold the spring in place (Fig. 2). If a long coil spring is used, the spring retaining bracket is held in place by one of the standard cover retaining screws

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 overnor stop lever. An overspeeding engine can result in engine damage which could cause personal injury.

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.

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.

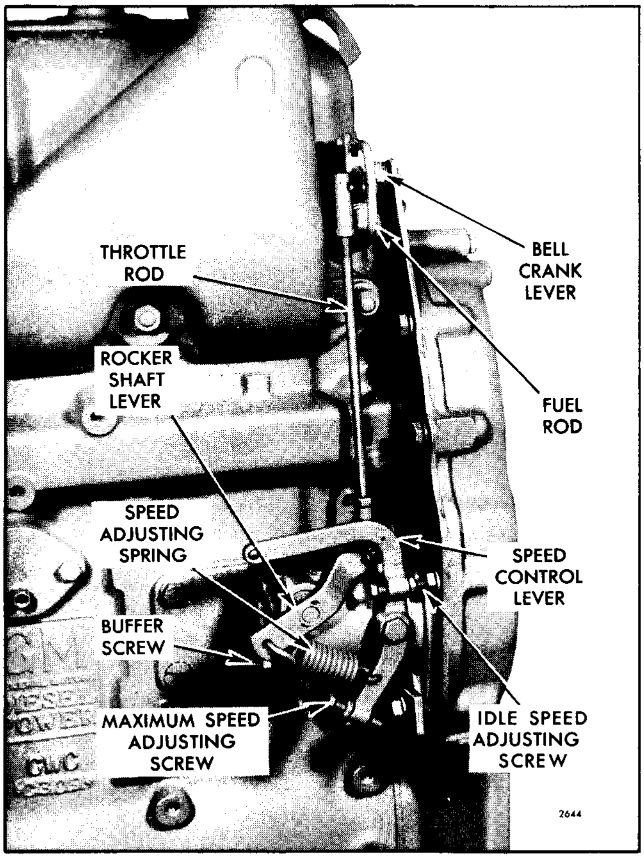


Fig. 1 - Governor Mounted on Engine

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.

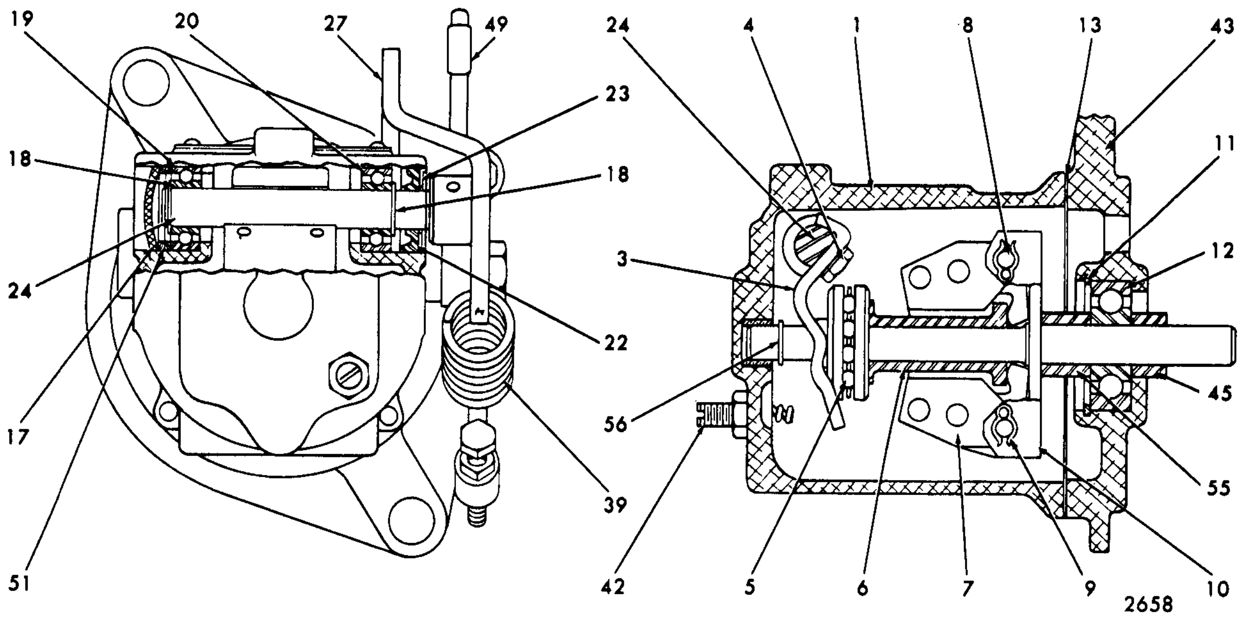
Surplus oil drains from the governor assembly through holes in the governor bearing housing back to the engine crankcase.

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
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
27. Lever--Rocker Shaft
39. Spring--Speed Adjusting
42. Screw and Spring Assembly--Buffer
43. Housing--Bearing
45. Spacer--Gear
49. Lever--Governor Speed Control
51. Gaskets--Oil Seal Plug
55. Spacer--Spider and Shaft Assembly
56. Snap Ring--External

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

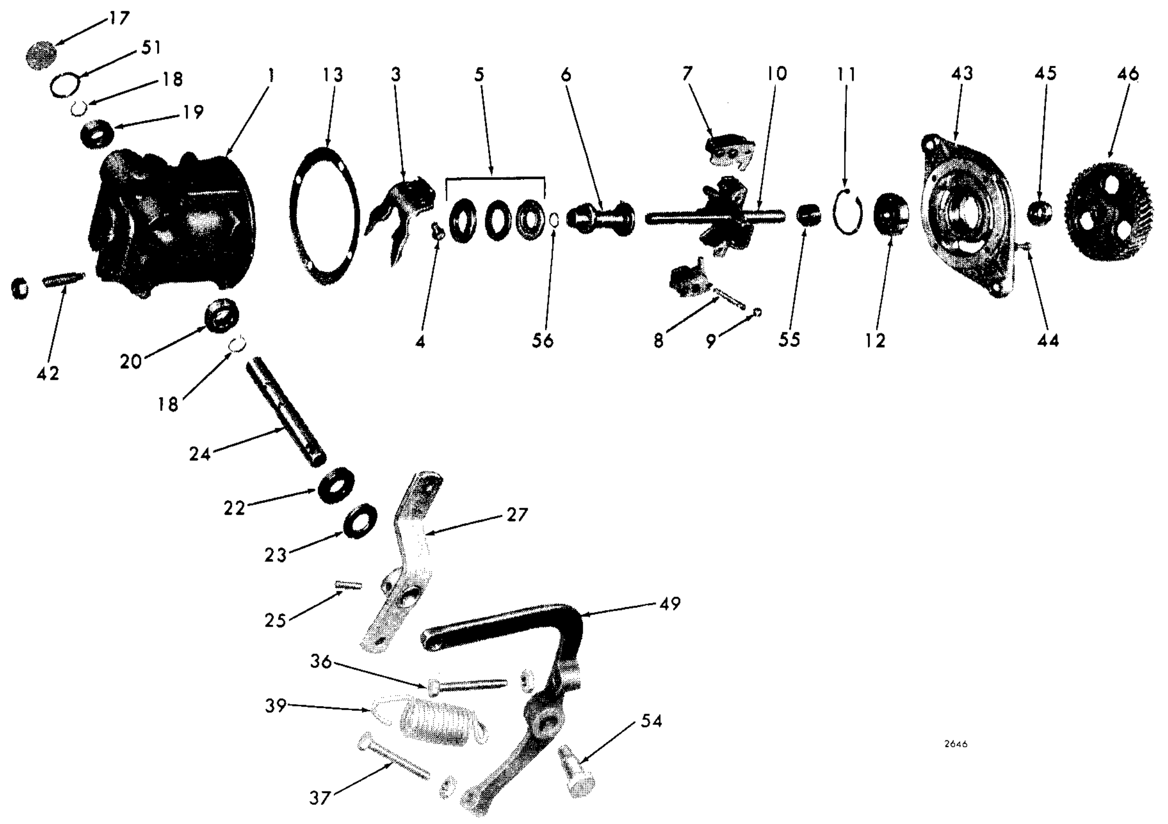
Before removing any parts from the governor, wash the entire unit in clean fuel oil and dry it with compressed air.

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	11. Snap Ring--Internal	25. Pin--Roll	45. Spacer--Gear
3. Fork--Operating	12. Bearing	27. Lever--Rocker Shaft	46. Gear--Governor Drive
4. Bolt--Special	13. Gasket--Body-to-Bearing Housing	36. Screw--Idle Speed Adjusting	49. Lever--Governor Speed Control
5. Bearing--Riser Thrust	17. Plug--Oil Seal	37. Screw--Maximum Speed Adjusting	51. Gasket--Oil Seal Plug
6. Riser	18. Snap Ring	39. Spring--Speed Adjusting	54. Bolt--Governor Speed Control Lever
7. Flyweights	19. Bearing--Ball (Inner)	42. Screw and Spring Assembly--Buffer	55. Spacer--Spider and Shaft Assembly
8. Pin--Weight Supporting	20. Bearing--Ball (Outer)	43. Housing--Bearing	56. Snap Ring--External
9. Retainer Ring	22. Seal--Rocker Shaft	44. Screws--Bearing Housing	
10. Spider and Shaft Assembly--Operating	23. Retainer--Oil Seal		
	24. Shaft--Rocker		

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.

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.

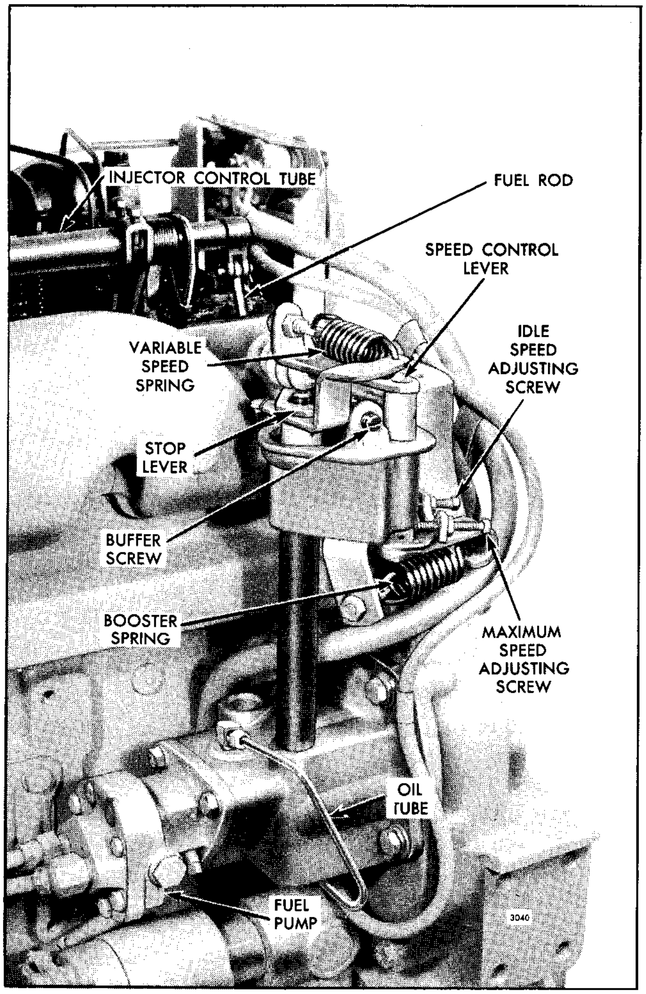


Fig. 1 - Variable Speed Open Linkage Governor Mounted on Engine

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.

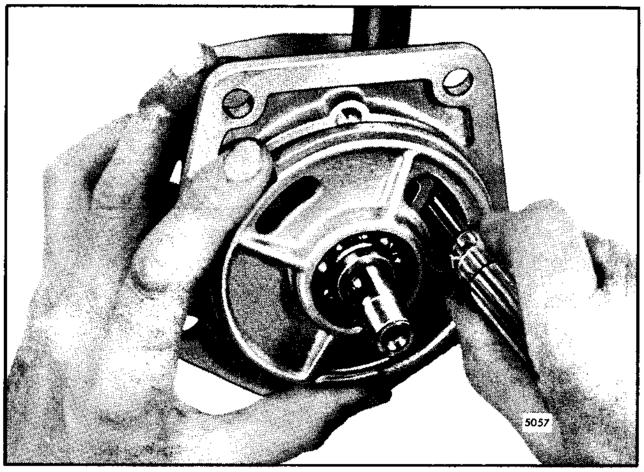


Fig. 2 - Removing or Installing Operating Shaft Fork

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.

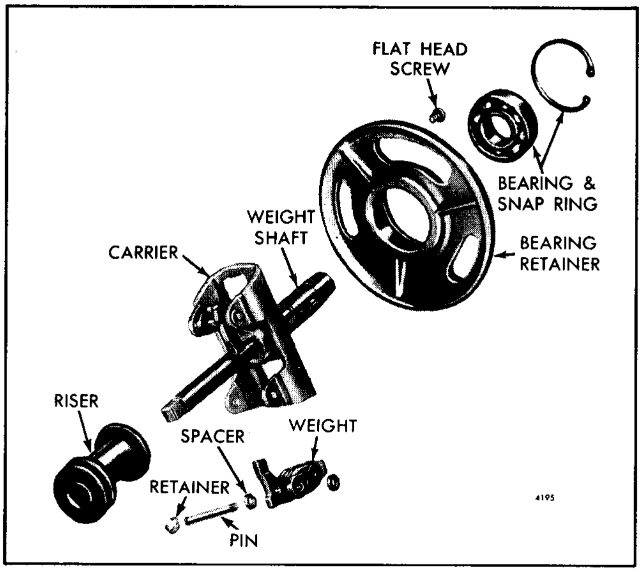


Fig. 3 - Governor Weight Details and Relative Location of Parts

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.

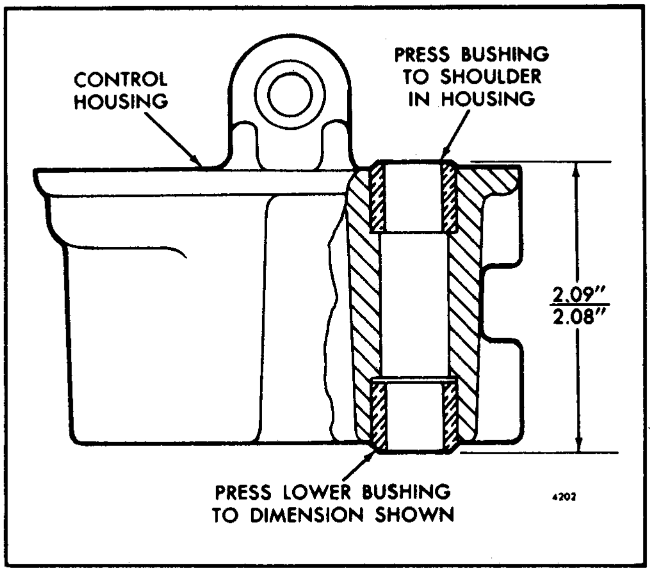


Fig. 4 - Bushings in Control Housing

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.

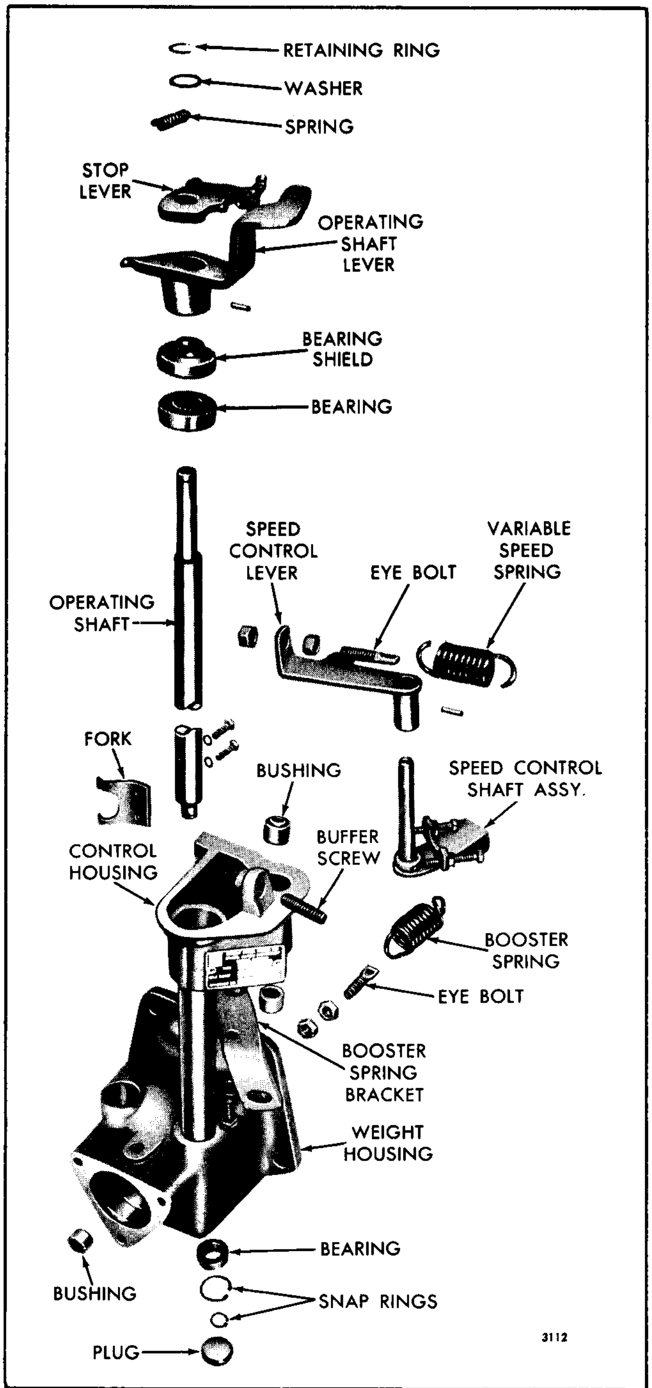


Fig. 5 - Governor Housing Details and Relative Location of Parts

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.

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 (Fig. 1). 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

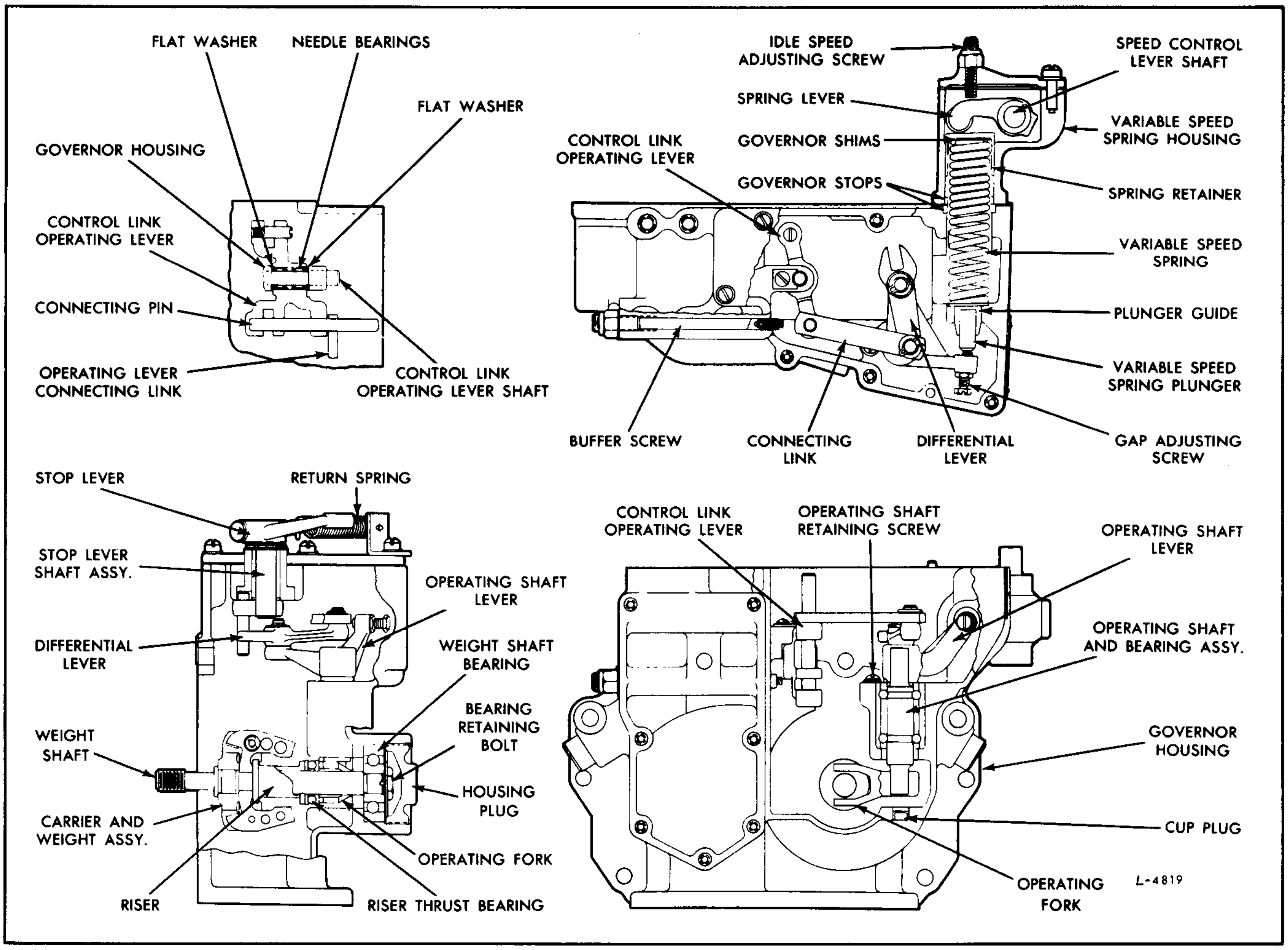


Fig. 1 - Cross Sections of Variable Speed Mechanical Governor

housing, refer to Fig. 1 and disassemble the cover as follows:

1. Disassemble the governor cover:

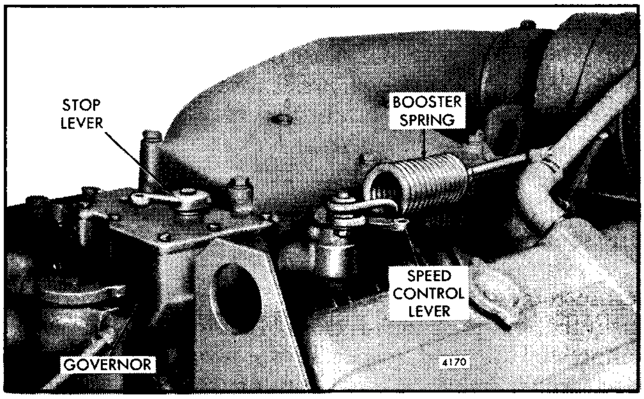


Fig. 2 - Variable Speed Governor Mounting

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 21967-01 on top of the stop shaft bushing and 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.

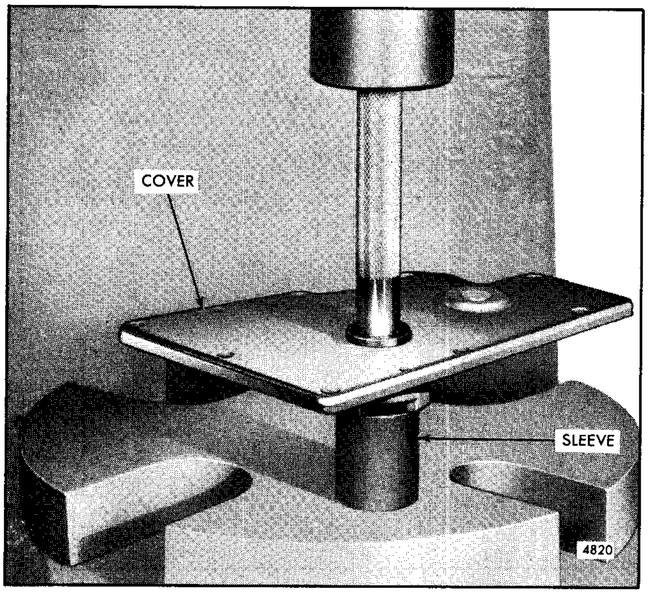


Fig. 3 - Removing Stop Lever Shaft Bushing from Governor Cover using Tool J 21967-01

b. Remove the Woodruff key and flat washer from the speed control shaft.

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

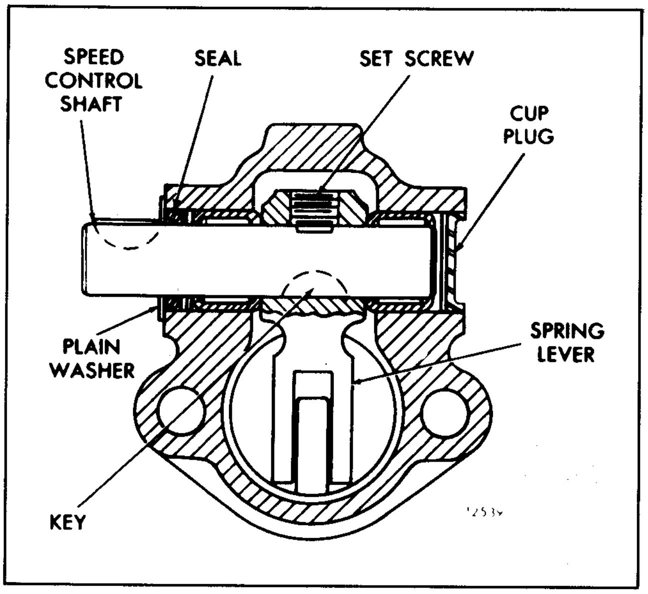


Fig. 4 - Cross Section of Governor Spring Housing and Lever Assembly

bearing for wear and damage. If the bearing is satisfactory for further use, removal is unnecessary.

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 21967-01 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.

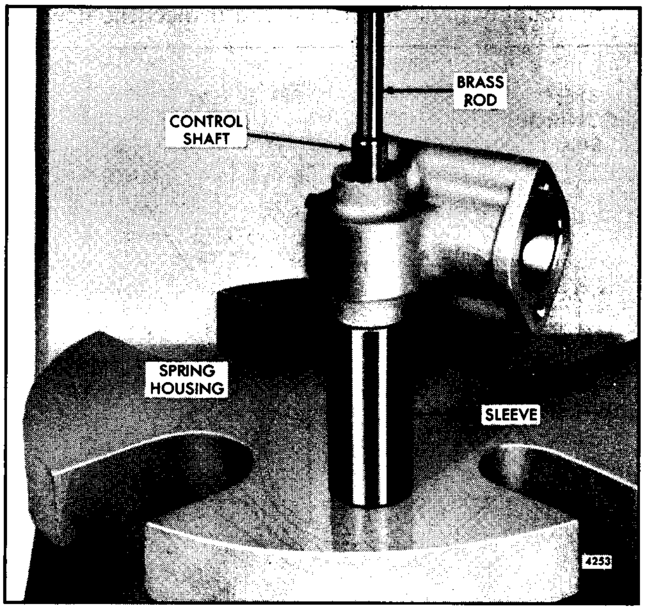


Fig. 5 - Removing Speed Control Shaft, Bearing and Cup plug from Governor Spring Housing

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

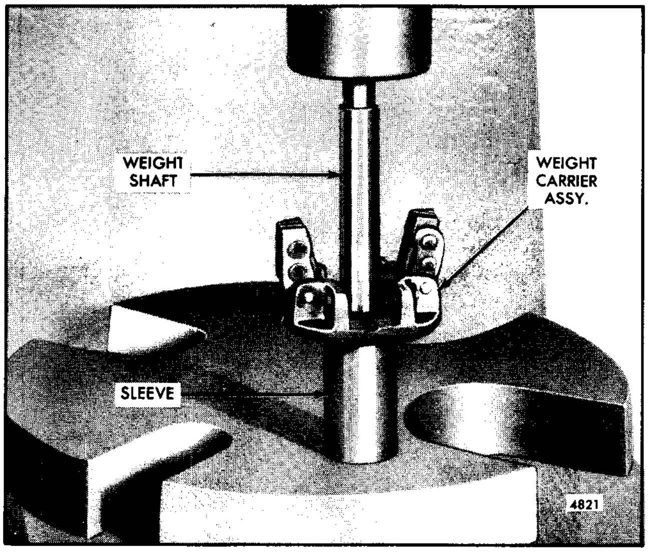


Fig. 6 - Removing Governor Weight Shaft from Weight Carrier Assembly

securing the differential lever to the operating shaft lever and remove the differential lever.

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.

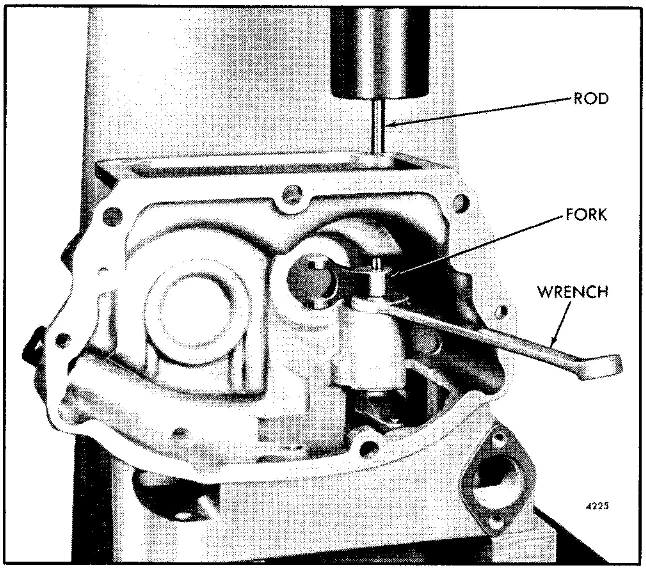


Fig. 7 - Removing Governor Operating Fork from Operating Shaft and Bearing Assembly

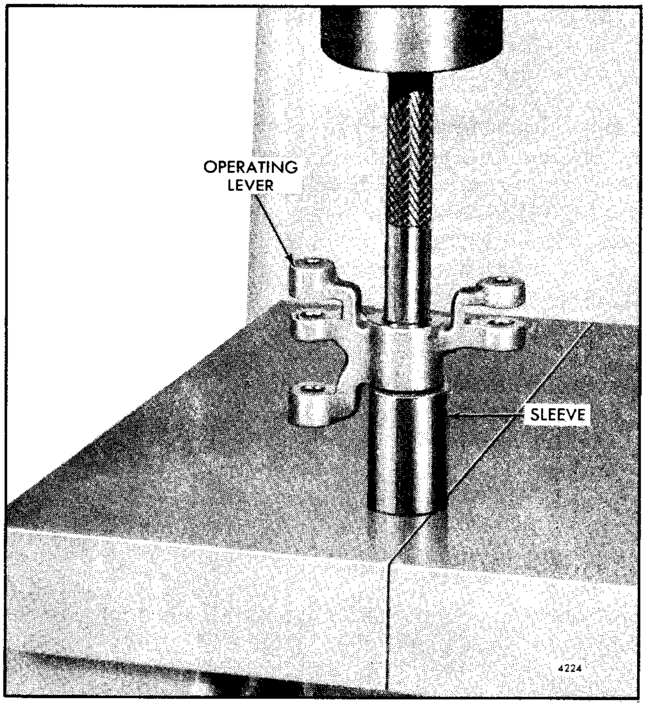


Fig. 8 - Removing Control Link Operating Lever Bearings using Tool J 8985

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 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:

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 press the shaft into the fork until 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.

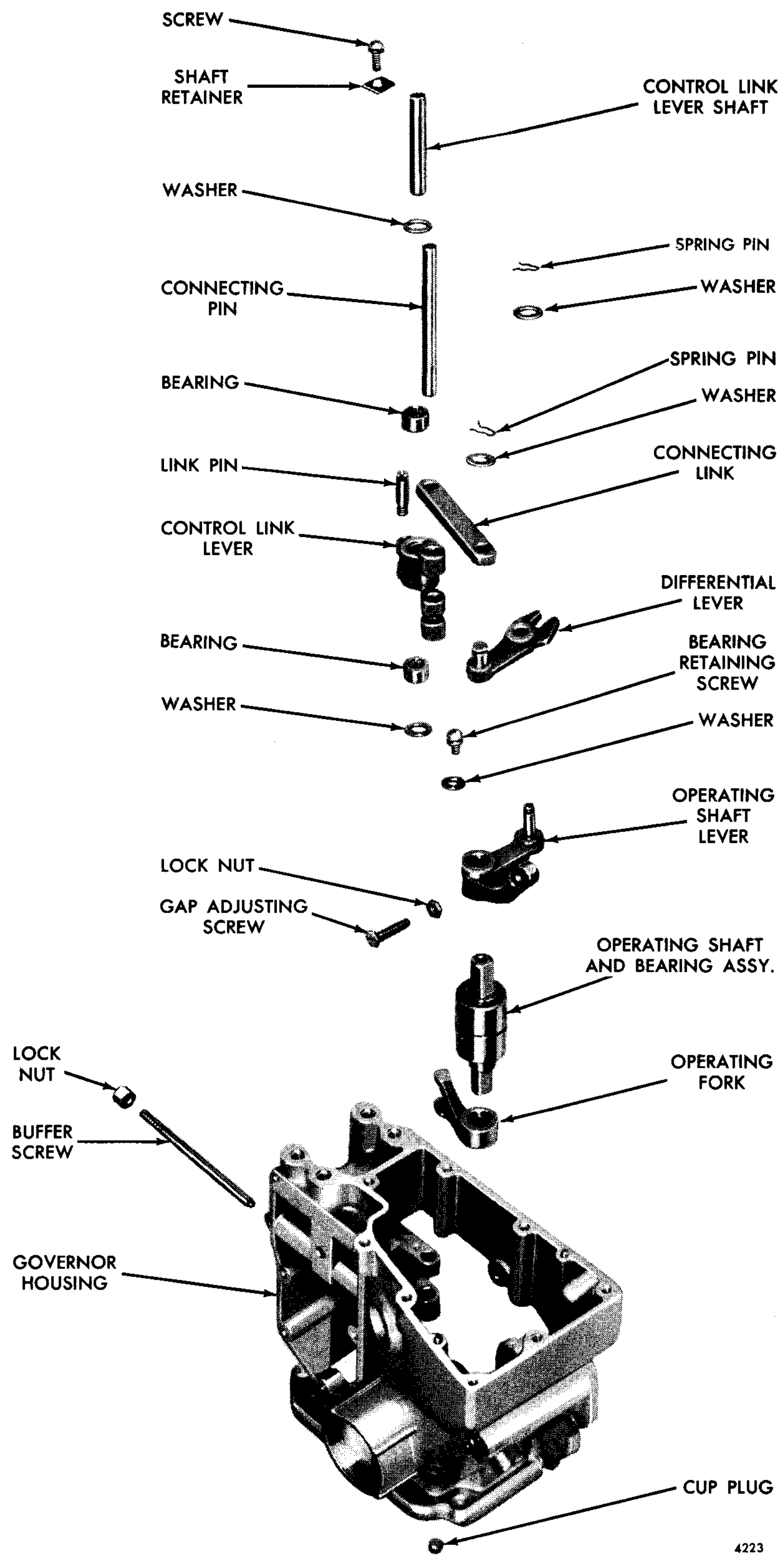


Fig. 9 - Governor Housing and Operating Shaft Details and Relative Location of Parts

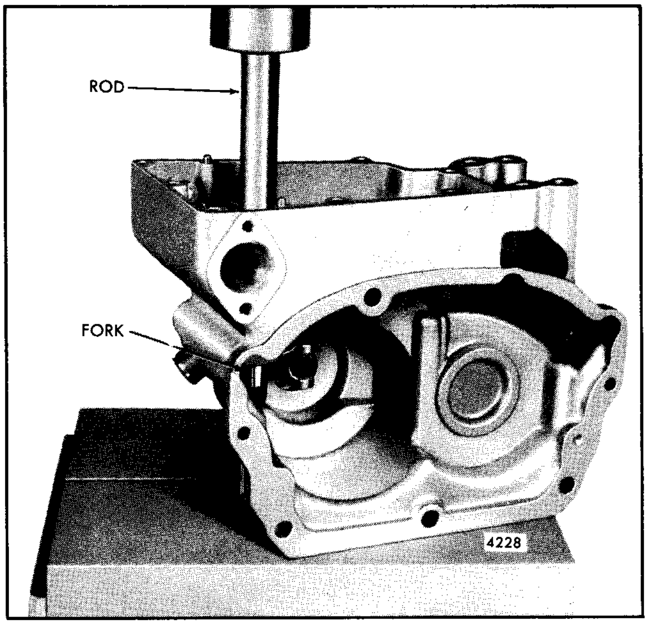


Fig. 10 - Installing Governor Operating Shaft Fork on Operating Shaft and Bearing Assembly using Tools J 21995-1 and J 21995-2

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 in the bearing and press the bearing into the lever until it is flush with the top surface of the lever (Fig. 11). 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.

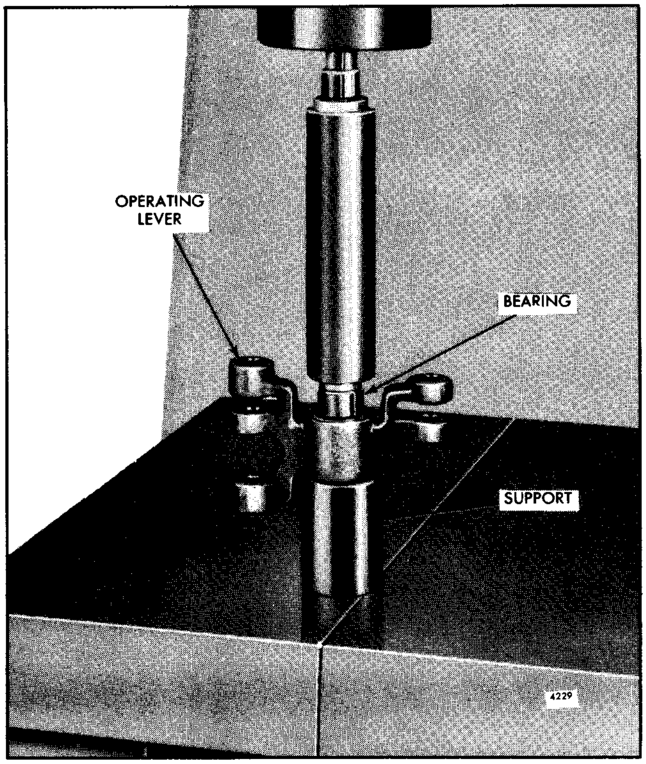


Fig. 11 - Installing Control Link Operating Lever Bearings in Lever using Tool J 21068

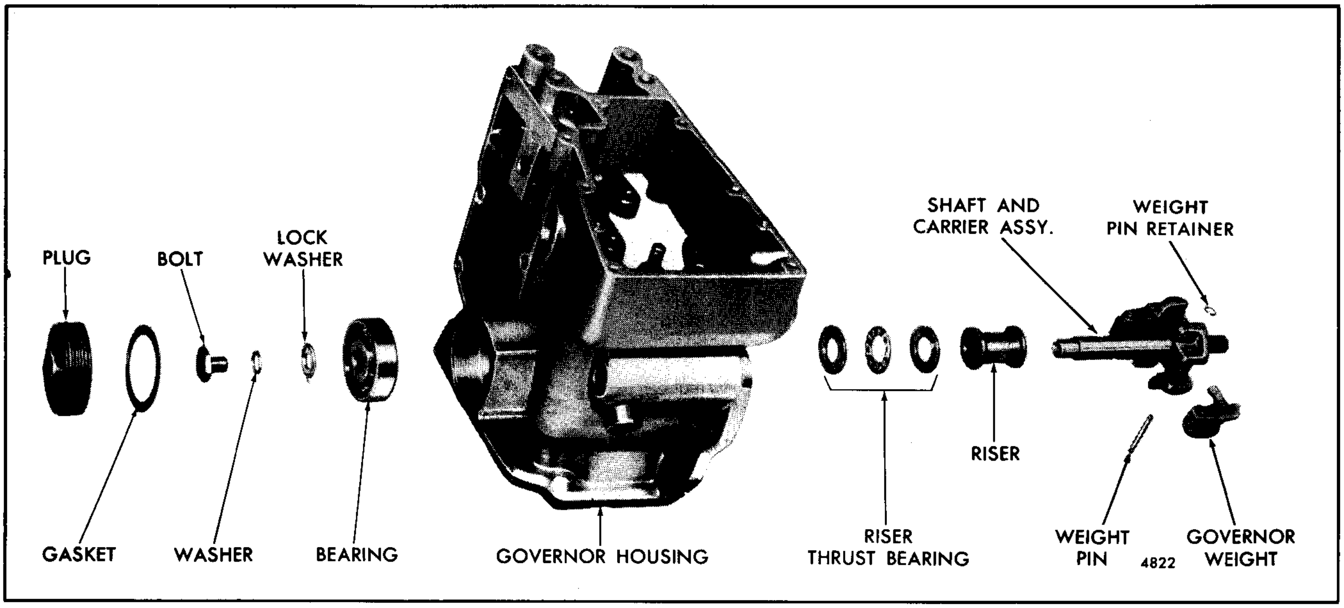


Fig. 12 - Governor Housing and Weight Details and Relative Location of Parts

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 inner race 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

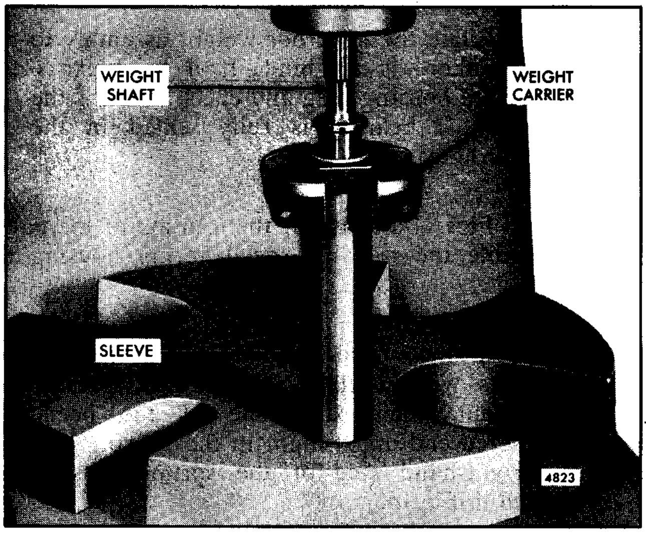


Fig. 13 - Installing Governor Weight Shaft in Weight Carrier

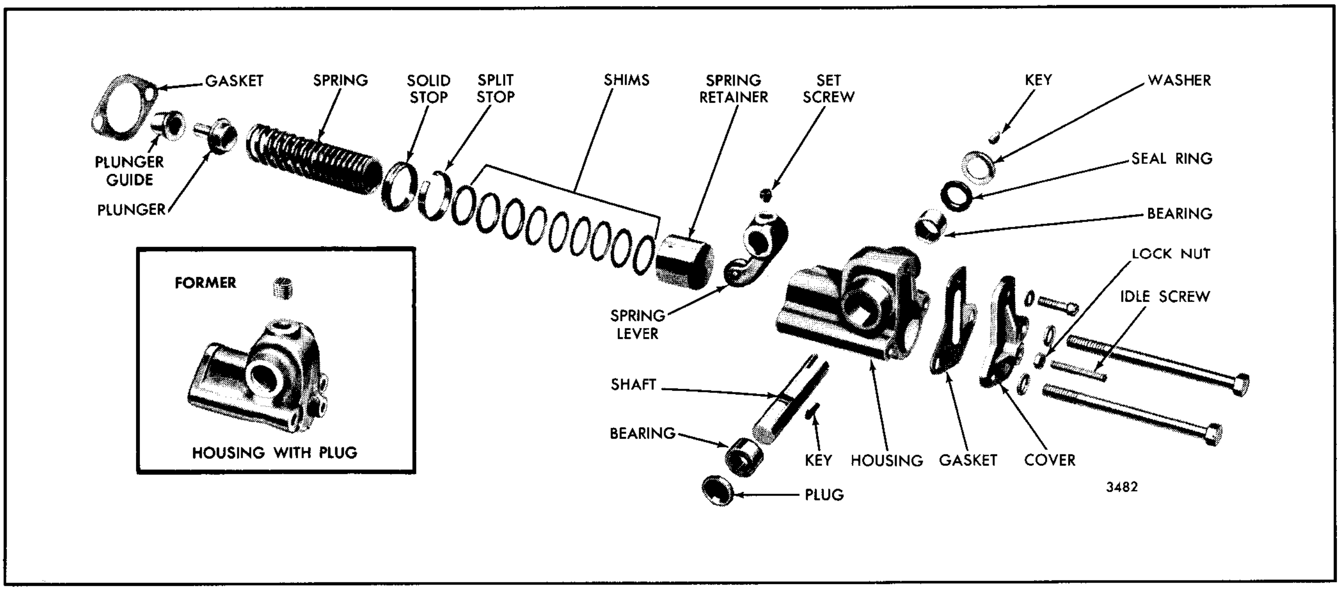


Fig. 14 - Variable Speed Spring Housing and Shaft Details and Relative Location of Parts

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 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,

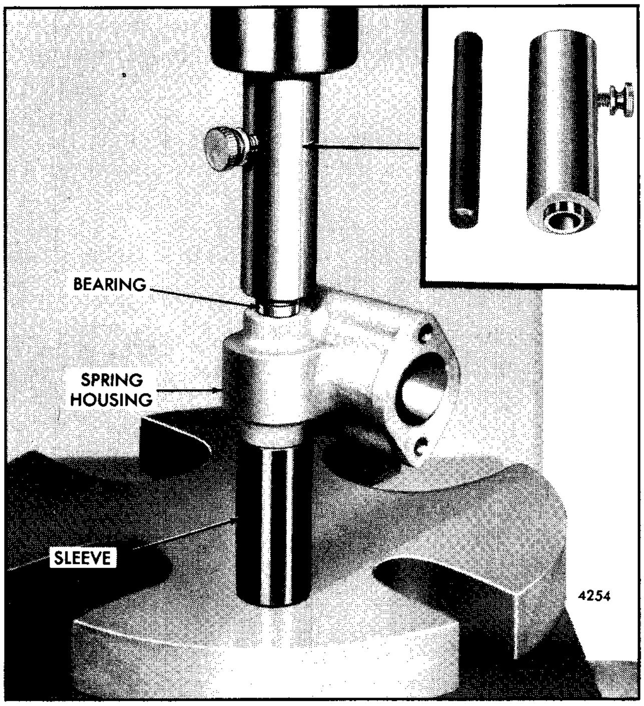


Fig. 15 - Installing Speed Control Shaft Bearing in Spring Housing using Tool J 9196

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 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 5-7 lb-ft (7-10 Nm) 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.

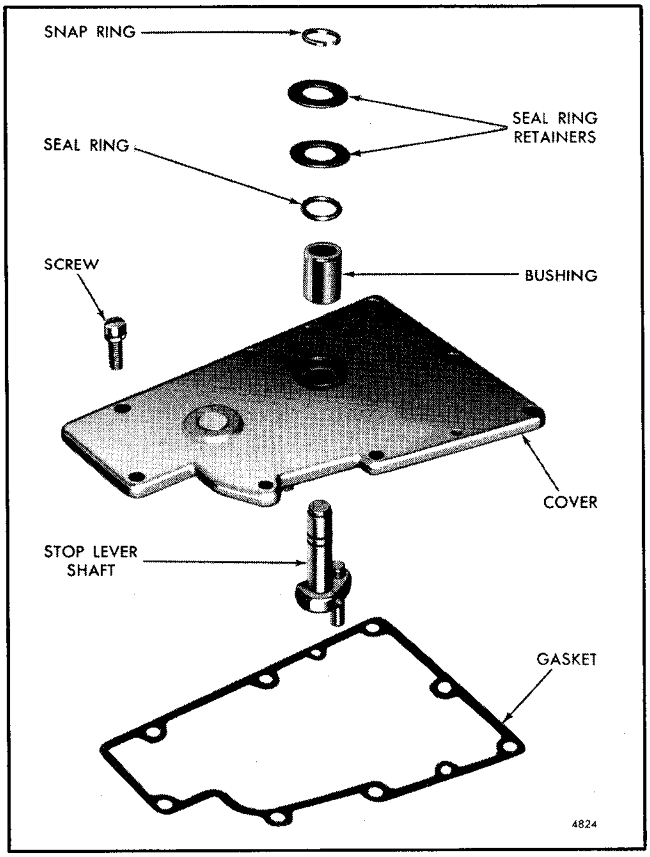


Fig. 16 - Governor Cover Details and Relative Location of Parts

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 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 (18-23 Nm) 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.

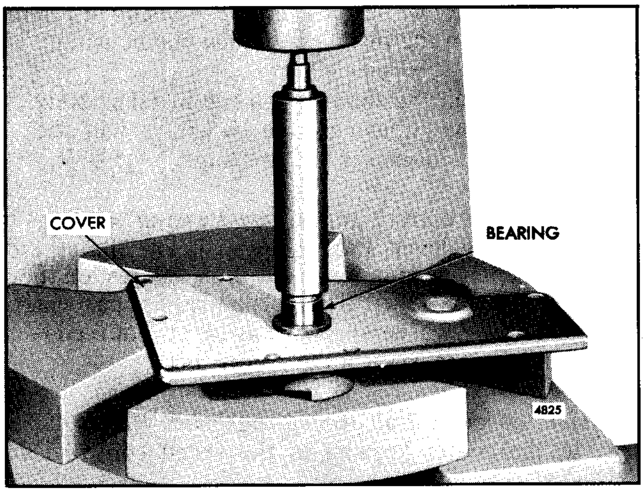


Fig. 17 - Installing Bearings in Governor Cover using Tool J 21068

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 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.

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.

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.

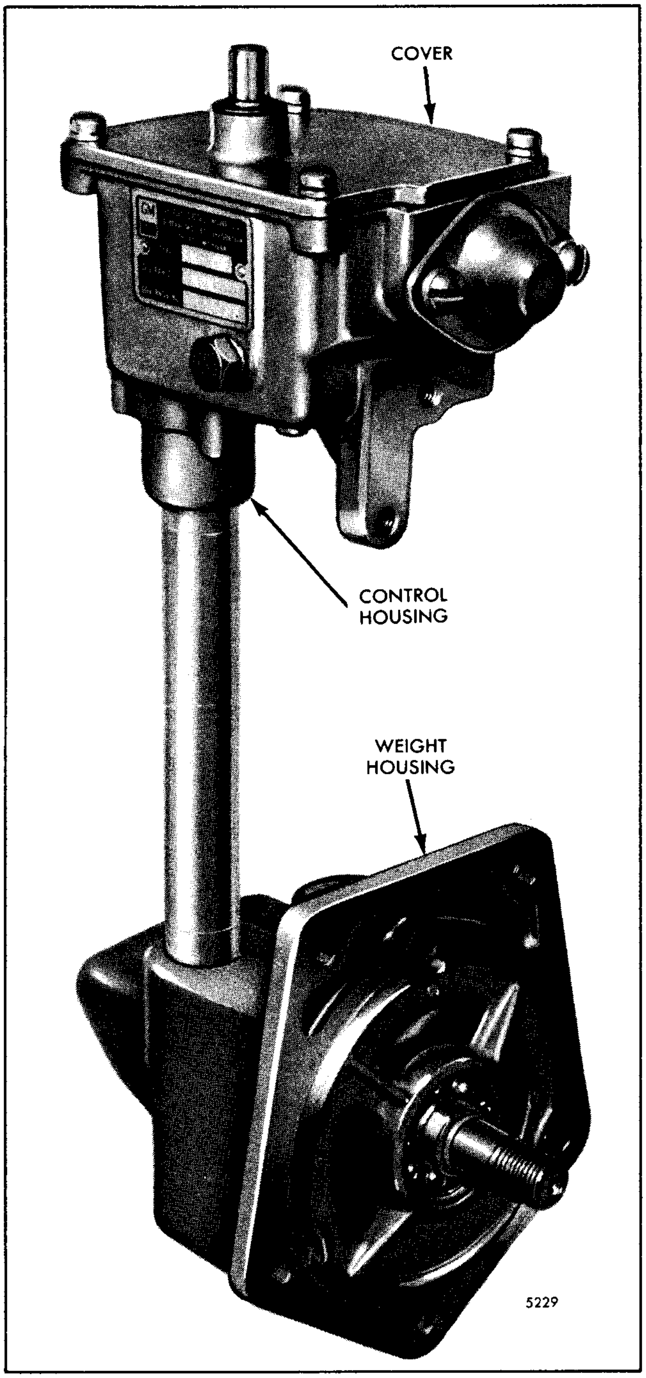


Fig. 1 - Constant Speed Governor

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 very 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, check the unit 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 and test the injector and, if necessary, replace or recondition it.

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 rods connected to the injector control tube levers, the mechanism must be free from bind throughout the entire travel of the injector racks. If friction exists in the mechanism, locate and correct it as follows:

   a. If an injector rack sticks or moves too hard, check the injector hold-down clamp. If it is too tight or improperly positioned, loosen the clamp bolt, reposition the clamp and re-tighten the bolt to 20-25 lb-ft (27-34 Nm) torque.

   b. An internal dirt accumulation, a defective plunger and bushing or a bent injector control rack can result in bind. To correct this condition, remove the injector, then recondition and test it.

   c. An improperly positioned control rack lever will result in a binding injector rack. To relieve the bind, loosen the control rack lever adjusting screws. Then relocate the lever on the control tube and position it as outlined in Section 14.

   d. If the injector control tube binds in its support brackets, it will prevent free movement of the injector control racks to their no-fuel position. Loosen and re-align the control tube supporting brackets, then tighten the bolts to correct this condition. Reposition the injector racks after re-aligning the support brackets.

   e. Replace an injector control tube return spring which has been bent or otherwise distorted. When the injector control tube and the injector racks are free from bind, the control tube will return to the no-fuel position by action of the return spring.

   NOTE: Never stretch or tamper with an injector control tube return spring to change its tension. Use a new spring.

   f. Check for bind in the pins which connect the fuel rods to the injector control tube levers. If necessary, remove the pins and polish them with fine emery cloth.

4. If neither load, engine irregularities or bind are found to be the cause of the speed variations, the trouble is probably in the governor or governor drive. Check as follows:

   a. If the speed changes noted are in rapid oscillation (governor hunting), adjust the speed droop of the governor as outlined in Section 14. This applies only if the governor is overhauled or where the speed droop has been changed from the original factory setting.

   b. 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 the blower) to vary erratically. This variation in load will be transmitted as a speed change to the governor. The governor will act to compensate for the change by moving the fuel rods. If this condition exists, inspect the blower.

c. If the speed variations are small in magnitude, check the governor drive. Excessive or insufficient clearance between the bevel drive gears can cause this condition.

d. If the speed variations are large and erratic and unaffected (except, perhaps, in magnitude) by changes in the speed droop adjustment, or if the governor fails to control the speed at all, replace or overhaul the governor.

If, after making these checks, the governor fails to control the engine properly, remove and recondition the governor.

To be certain whether the governor or engine is at fault, install a new governor (with the same part number) and check the performance of the engine.

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

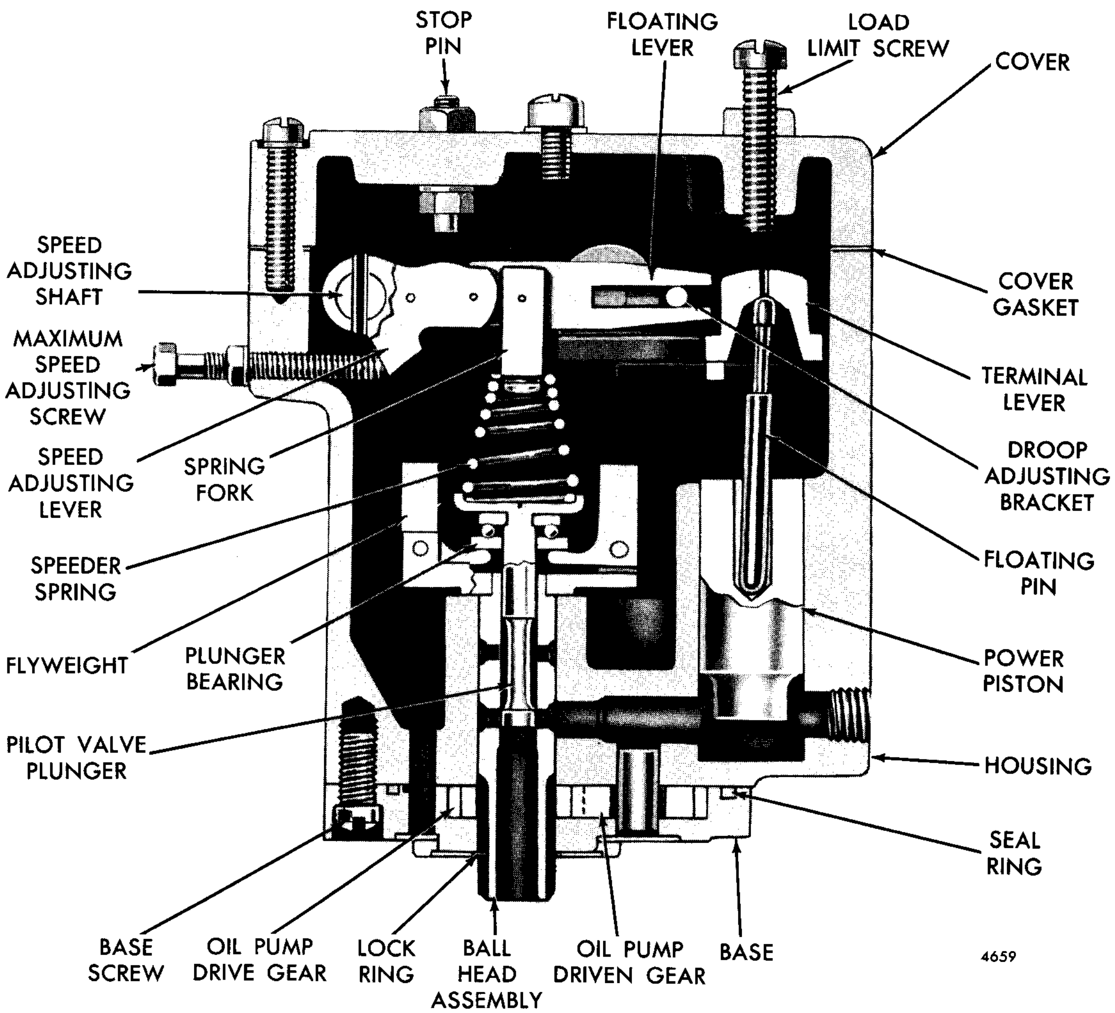


Fig. 1 - Hydraulic Governor Assembly (Current)

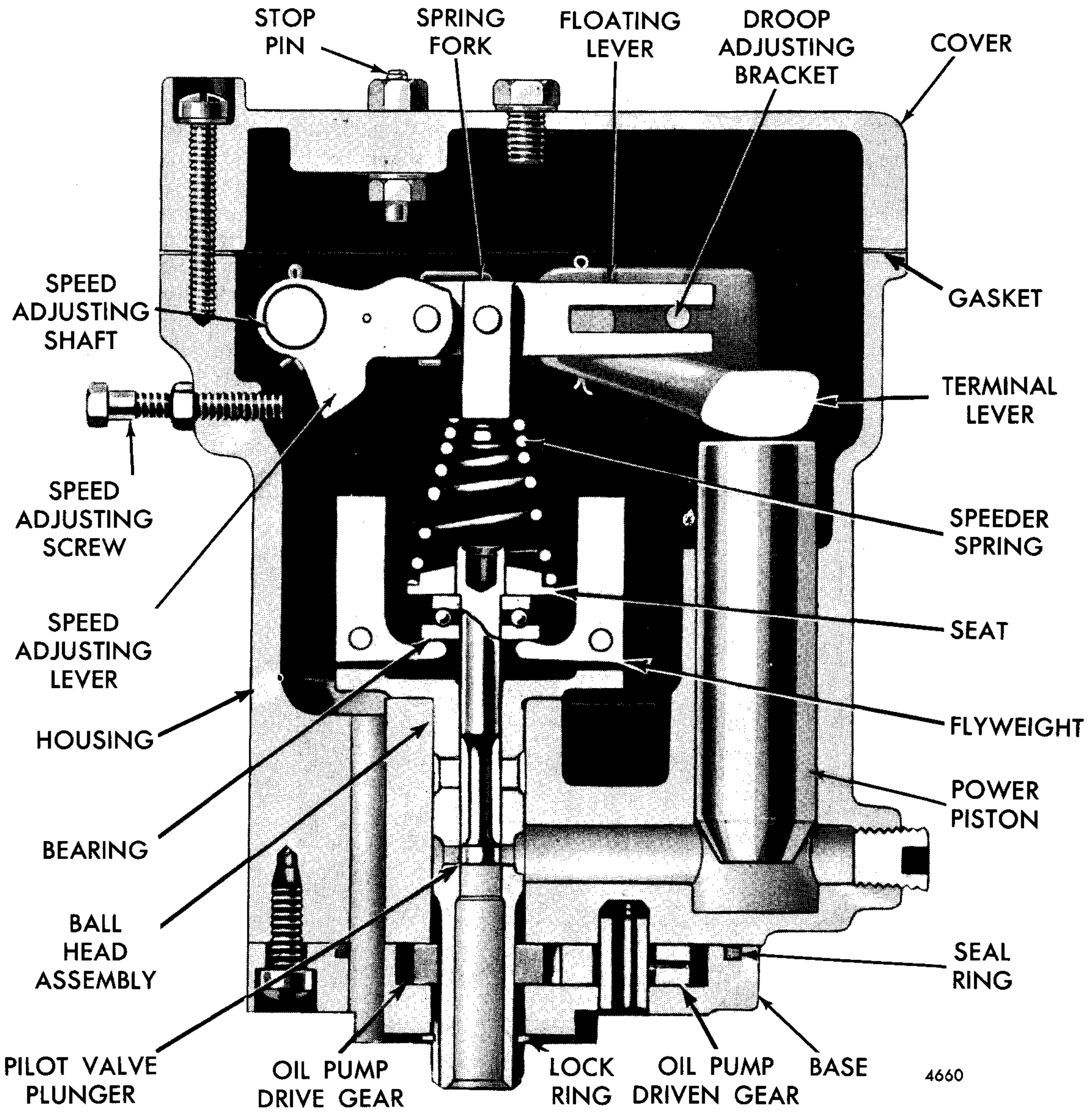


Fig. 2 - Hydraulic Governor Assembly (Former)

(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.

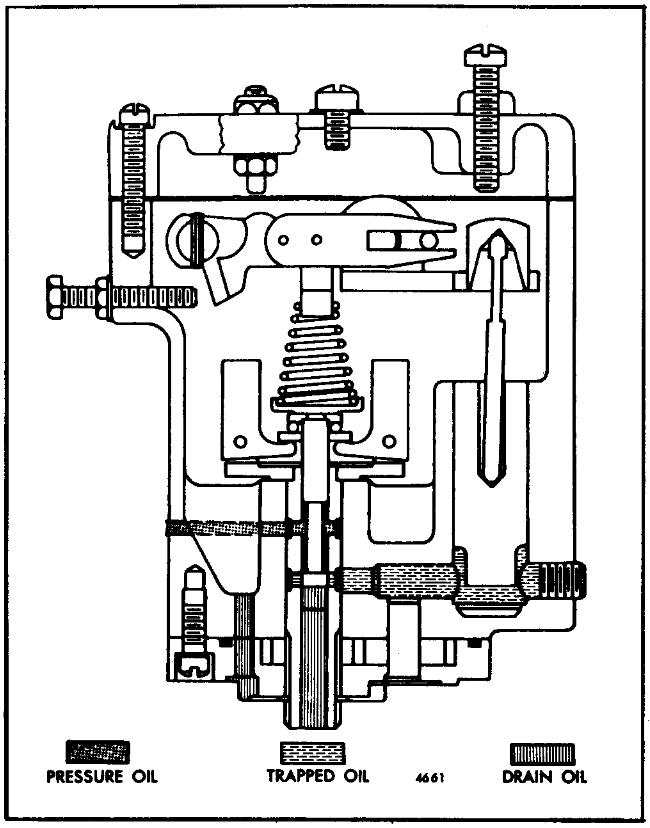


Fig. 3 - Stable Position of Governor Mechanism When Load on Engine is Constant

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.

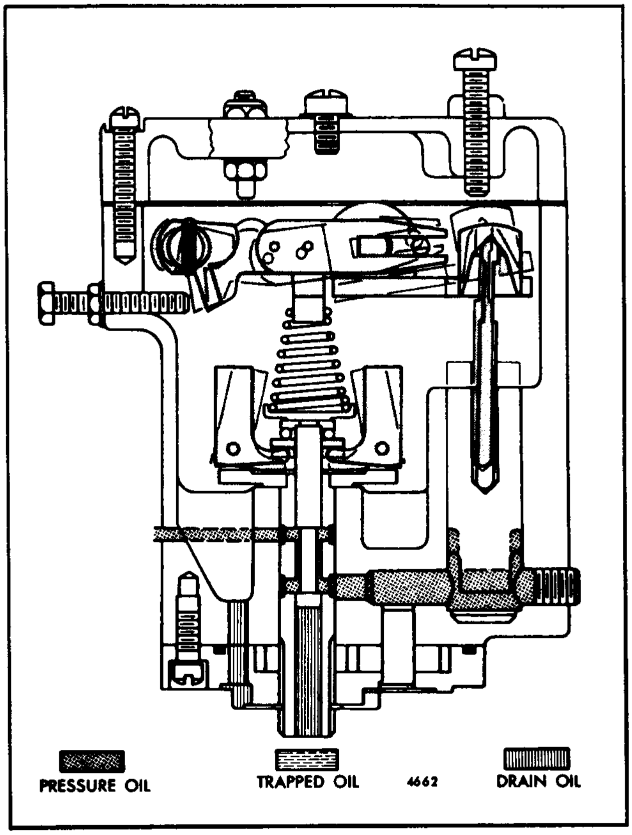


Fig. 4 - Position of Governor Mechanism as Load Increases and Engine Speed Tends to Decrease

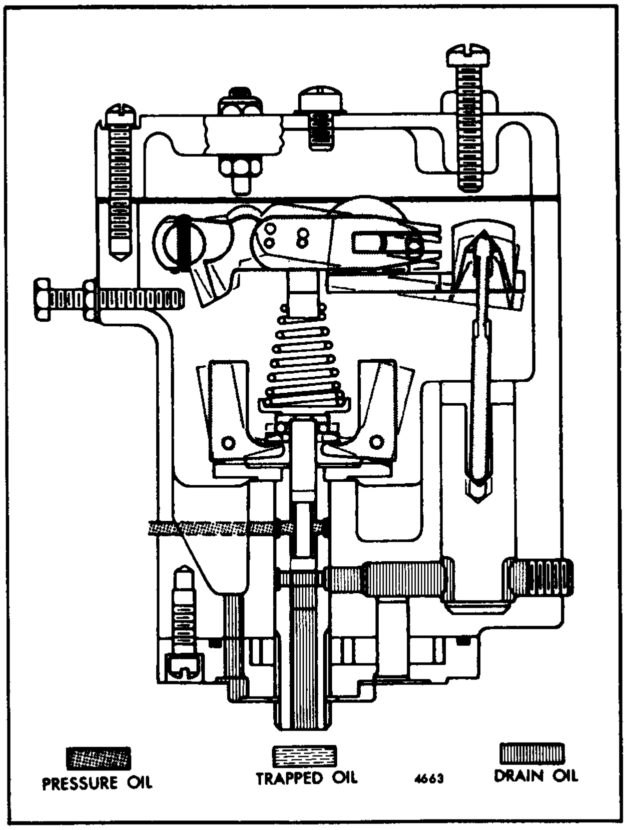


Fig. 5 - Position of Governor Mechanism as Load Decreases and Engine Speed Tends to Increase

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

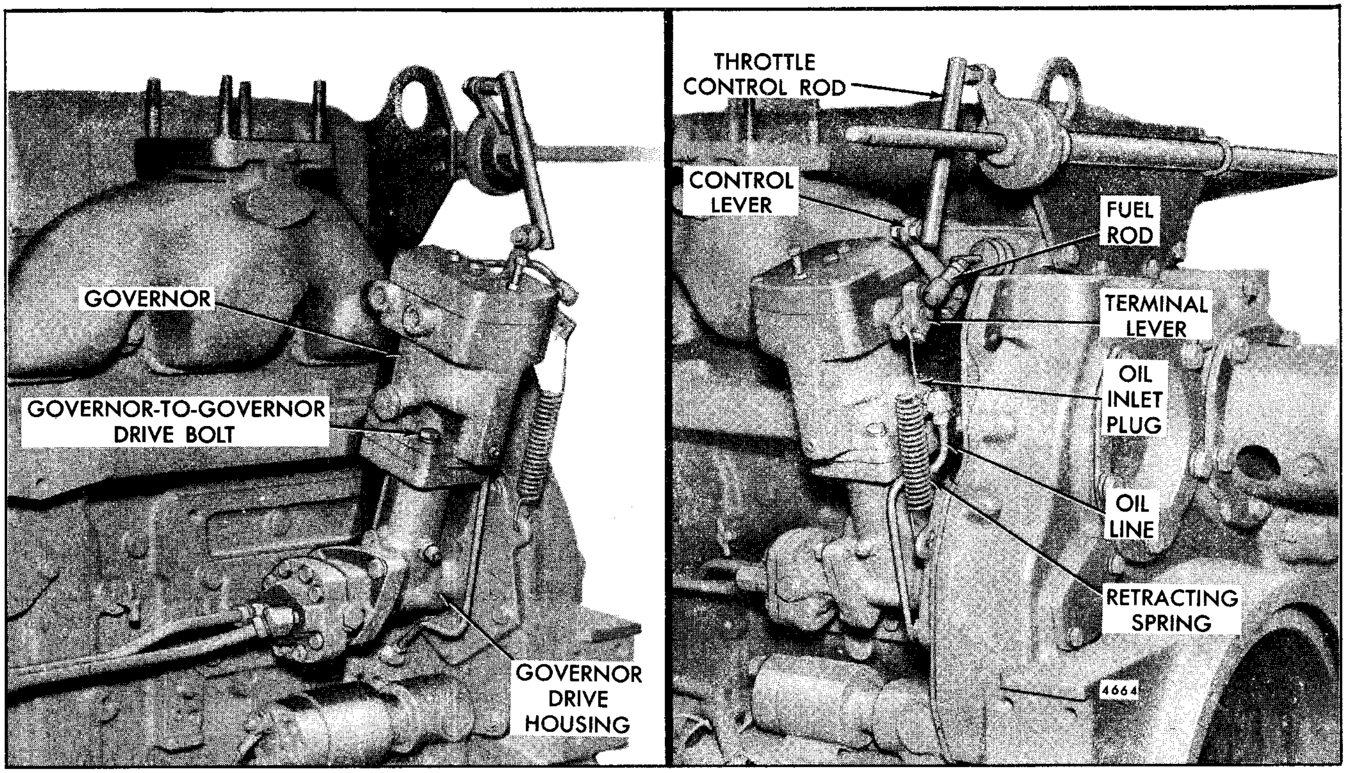


Fig. 6 - Hydraulic Governor Mounting

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:

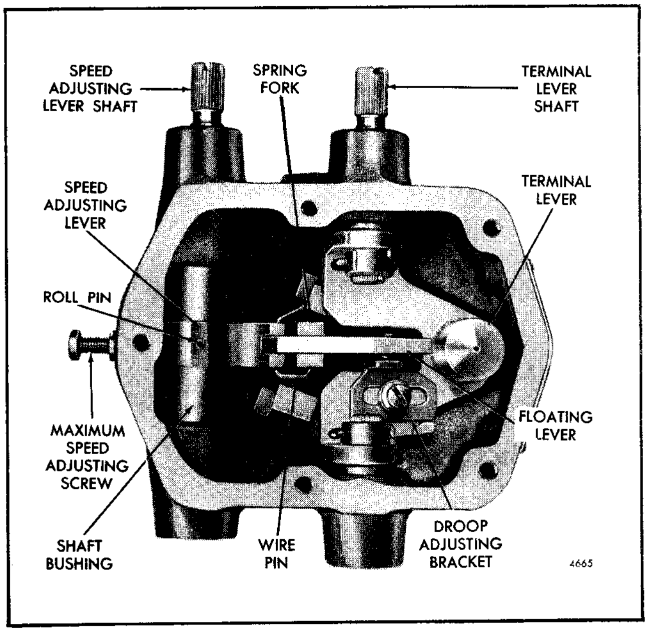


Fig. 7 - Top View of Governor With Cover Removed

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

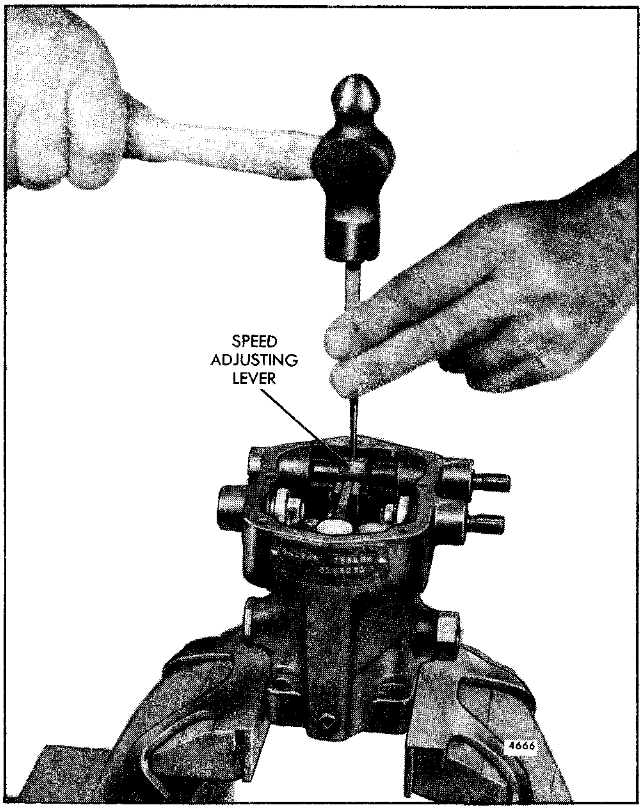


Fig. 8 - Removing Speed Adjusting Lever Roll Pin

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

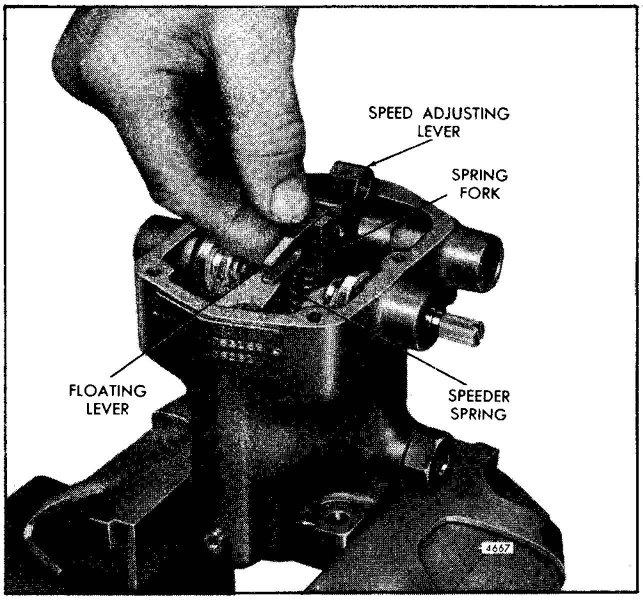


Fig. 9 - Removing Speed Adjusting Lever, Floating Lever, Spring Fork, Speeder Spring and Pilot Valve Plunger Assembly

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,

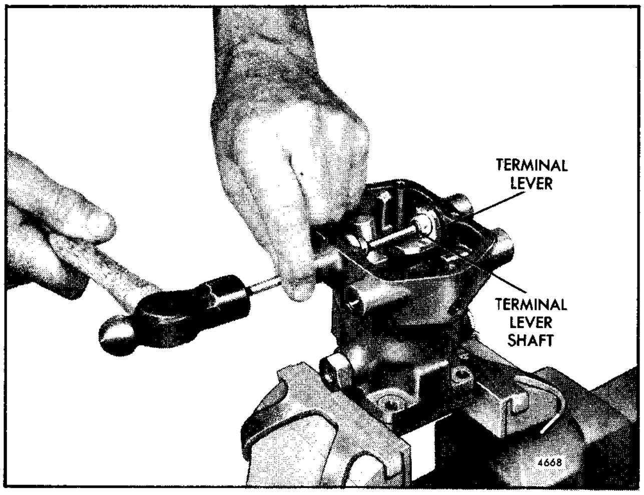


Fig. 10 - Removing Cup Plug from Governor Housing

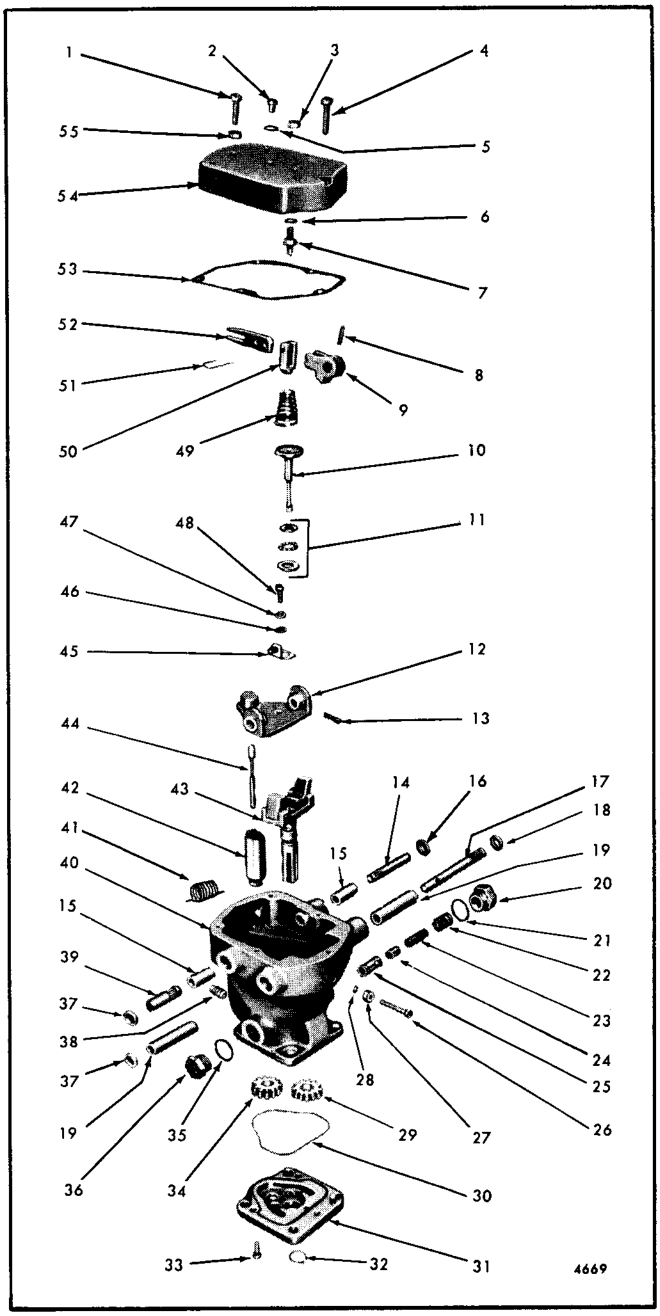


Fig. 11 - Hydraulic Governor Details and Relative Location of Parts (Current)

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.

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

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.

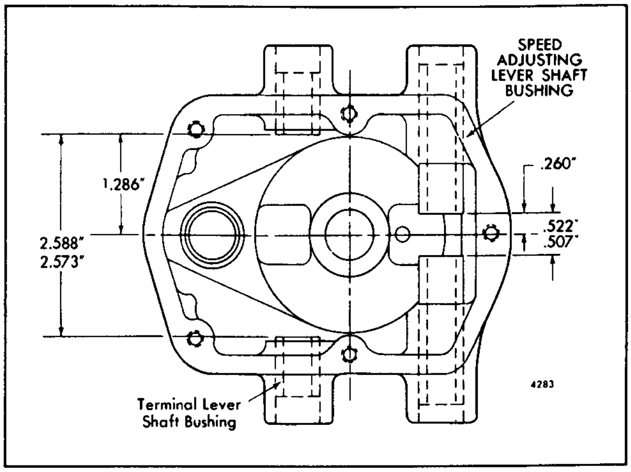


Fig. 12 - Location of Speed Adjusting Lever and Terminal Lever Shaft Bushings in Governor Housing

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 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.

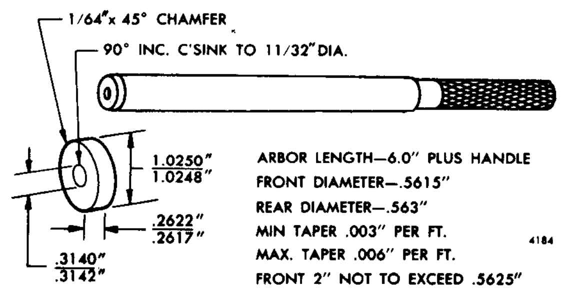


Fig. 13 - Fabrication of Governor Housing-to-Base Alignment Tool

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

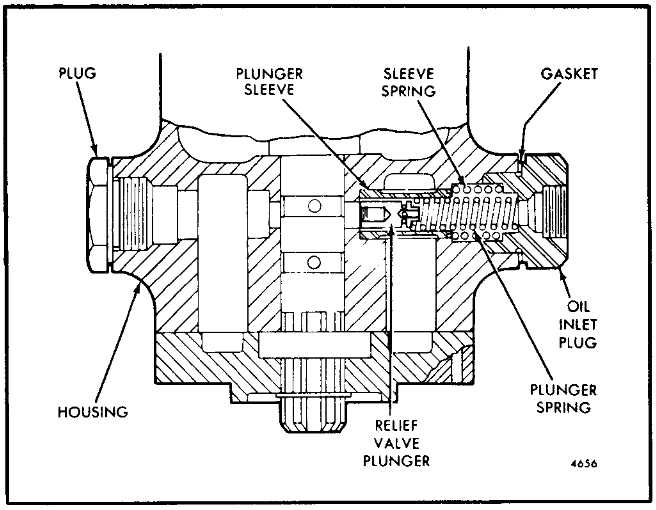


Fig. 14 - Location of Oil Relief Valve Plunger, Plunger Sleeve, Springs, Oil Inlet Plug and and Dummy Plug in Governor Housing (R.H. Governor Shown)

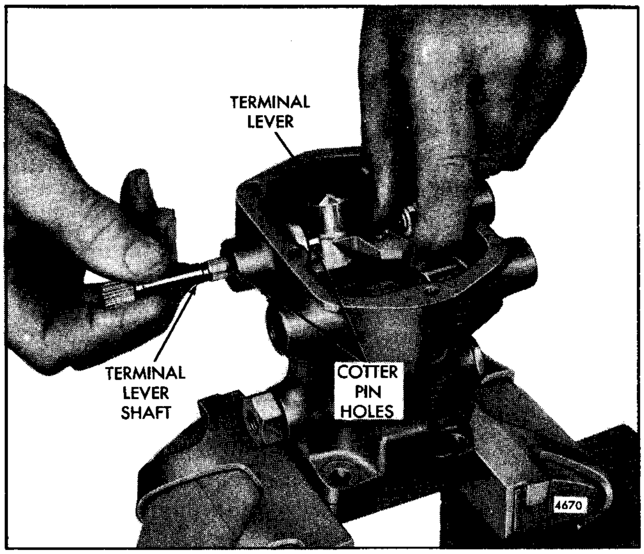


Fig. 15 - Installing Terminal Lever Shaft in Governor Housing and Terminal Lever

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

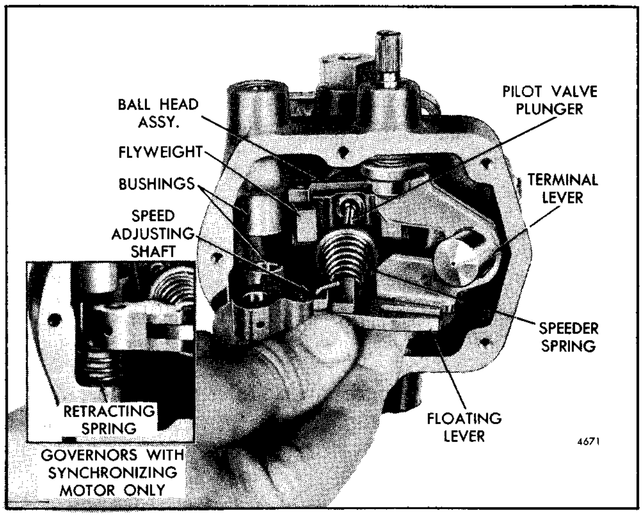


Fig. 16 - Installing Speed Adjusting Lever, Floating Lever, Speeder Spring and Pilot Valve Plunger Assembly

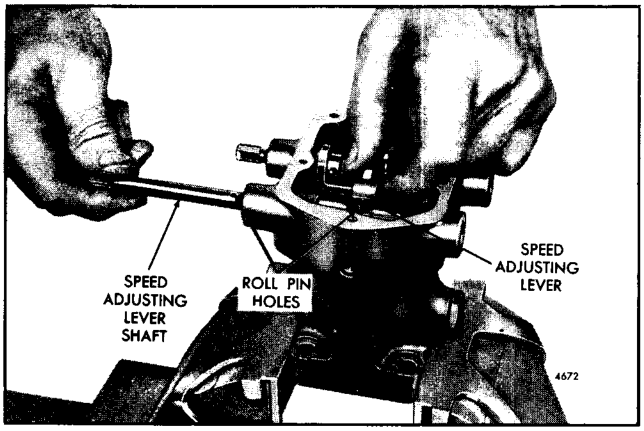


Fig. 17 - Installing Speed Adjusting Lever Shaft in Governor Housing and Adjusting Lever

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.

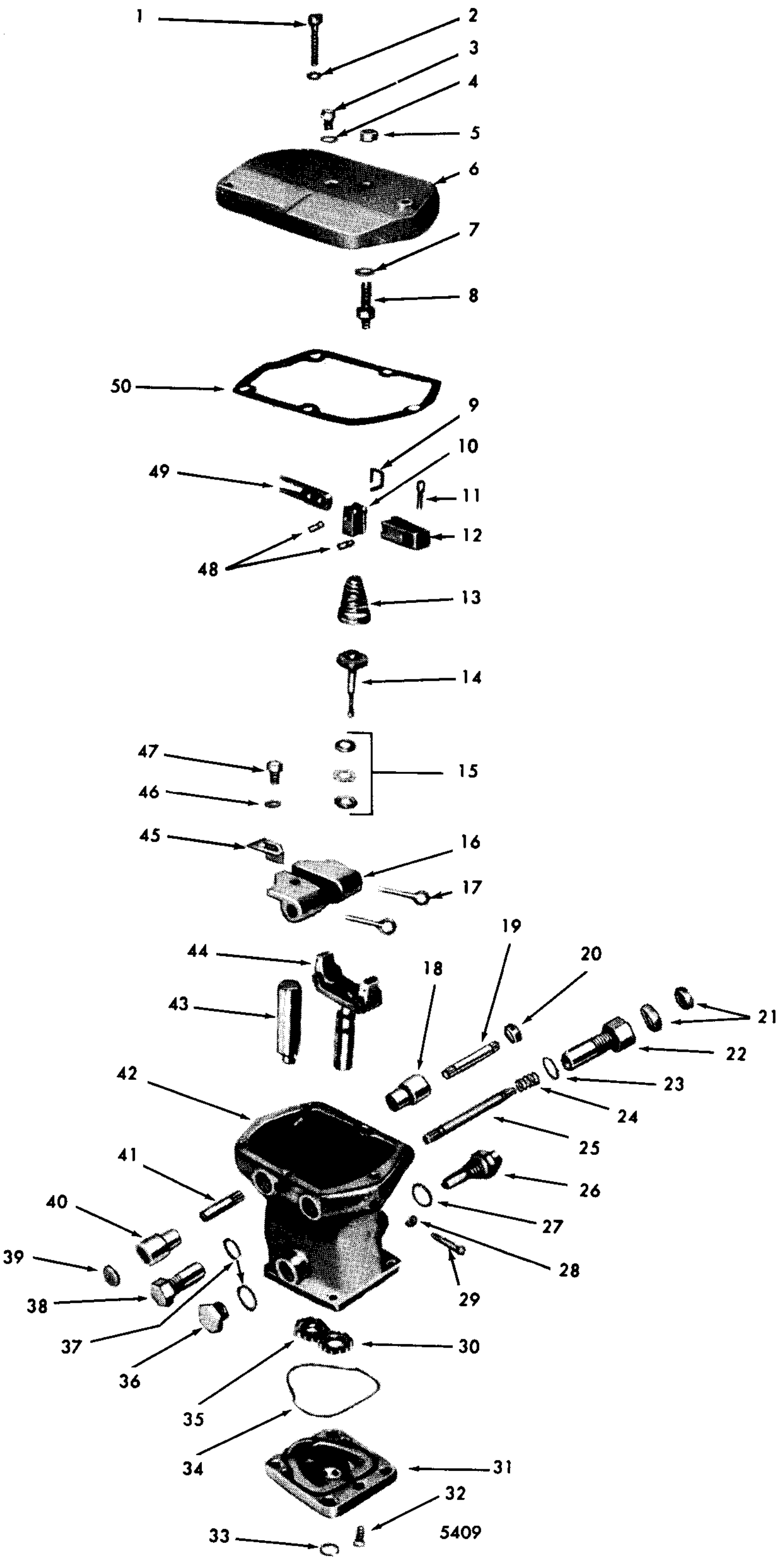


Fig. 18 - Hydraulic Governor Details and Relative Location of Parts (Former)

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 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.

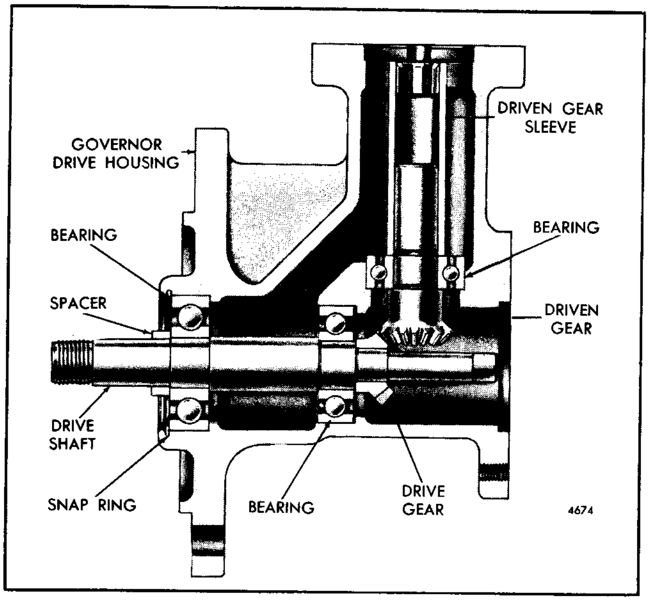


Fig. 1 - Hydraulic Governor Drive Assembly

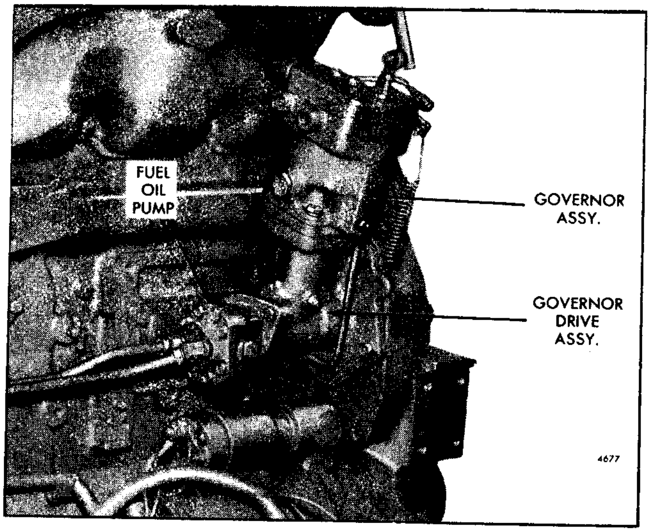


Fig. 2 - Hydraulic Governor Drive Mounting

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.

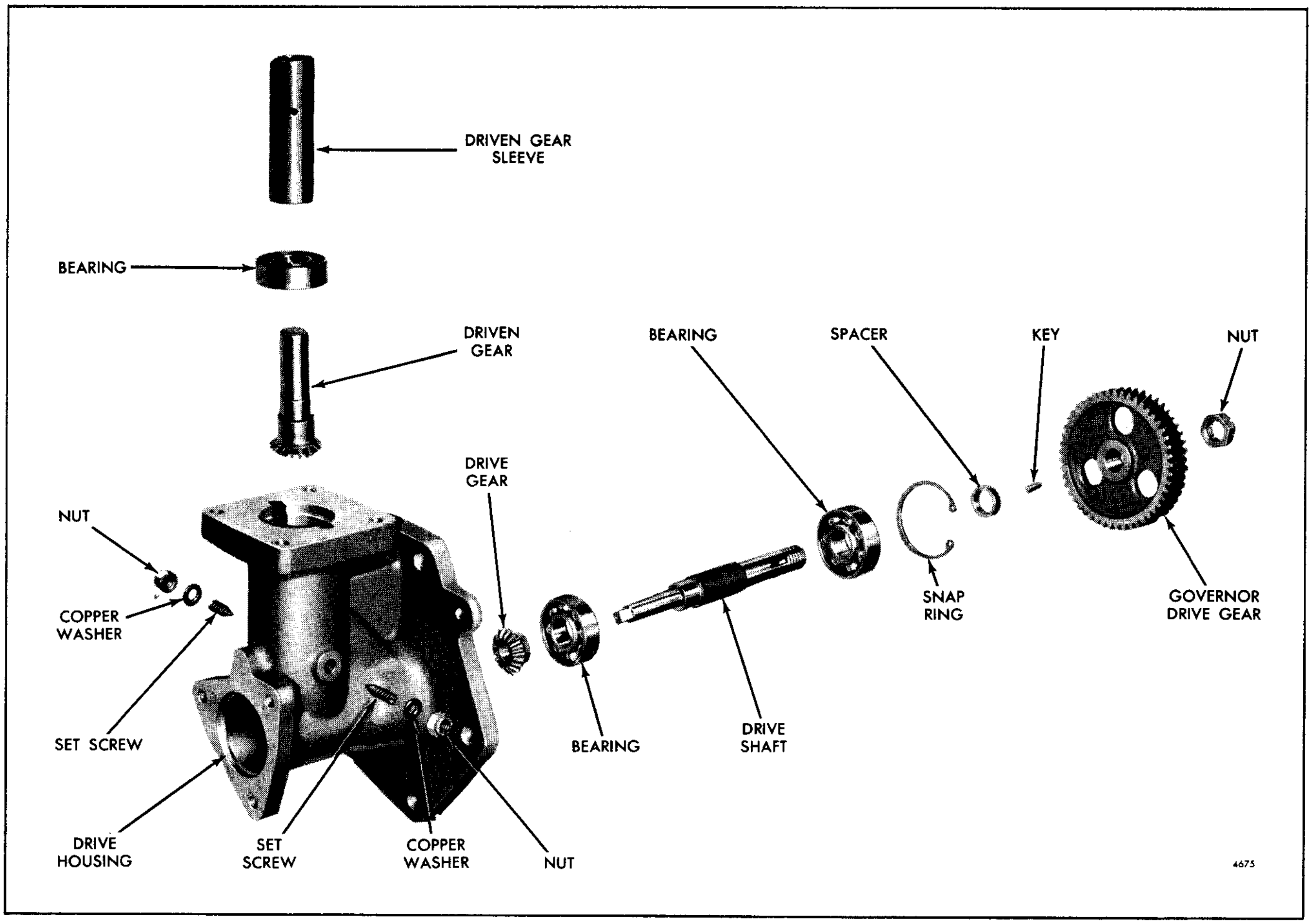


Fig. 3 - Hydraulic Governor Drive Details and Relative Location of Parts

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 (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.

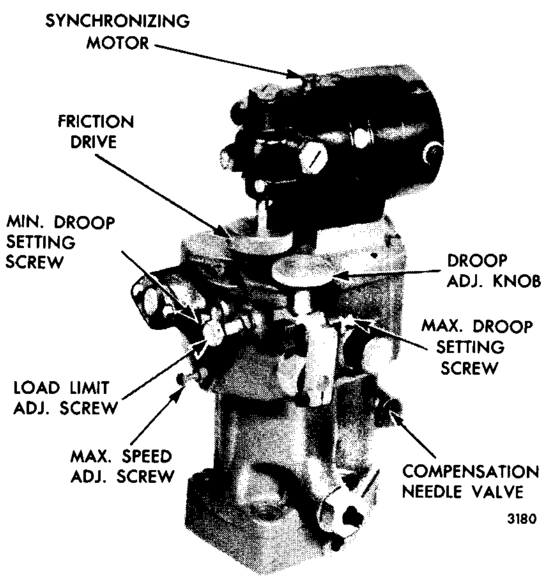


Fig. 1 - Synchronizing Motor Mounting

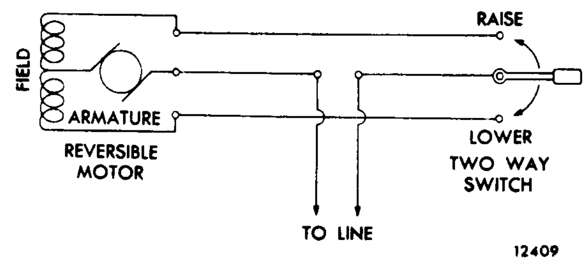


Fig. 2 - Synchronizing Motor Wiring Diagram

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 turned 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.

FUEL INJECTOR CONTROL TUBE

The fuel injector control tube assembly (Figs. 1 and 2) is mounted on the cylinder head (In-line and V-53 engines) and consists of a control tube, injector rack control levers, a return spring and injector control tube lever mounted in two bracket and bearing assemblies attached to the cylinder head.

The injector rack control levers connect with the fuel injector control racks and are held in position on the control tube with two adjusting screws. The return spring enables the rack levers to return to the no-fuel position. The injector control tube lever is pinned to the end of the control tube and connects with the fuel rod which connects with the engine governor. Refer to Section 14 for positioning of the injector rack control levers.

Certain engines use a spring-loaded injector control tube assembly (Fig. 3), similar to the above except it has a yield spring at each injector rackcontrol lever and only one screw and locknut to keep each injector rack properly positioned. This enables an engine to be brought to a lesser fuel position if there is an inoperative fuel injector rack, whereas with the non-spring loaded two screw injector control tube this could not be done. The above also permits the use of an air inlet housing with no emergency air shutoff valve as is required in some applications.

> **NOTE:** Do not replace the spring-loaded fuel injector control tube and lever assembly with the two screw design control tube assembly without including an air inlet housing that incorporates an emergency air shutoff valve. However, when the spring-loaded fuel injector control tube and lever assembly is installed on an engine and the emergency shutdown mechanism is removed from the air inlet housing, the shaft holes at each end of the housing must be plugged. Ream the shaft holes to .6290" and install a 5/8" cup plug at each end of the housing.

Engine shut down (normal or emergency) is accomplished on the spring-loaded fuel injector control tube (one screw design) by pulling the governor shutdown lever to the no-fuel position. With the two screw design injector control tube and lever assembly, emergency engine shutdown is accomplished by tripping the air shutoff valve in the air inlet housing. Normal shut down is accomplished by pulling the governor shutdown lever to the no-fuel position. Adjustment of the single screw and locknut on each injector rack control lever can be performed the same as for the two screw design rack control lever as outlined in Section 14.

Remove Injector Control Tube

1. Remove the cotter pin and clevis pin connecting the fuel rod to the injector tube control lever.

2. Remove the two attaching bolts and lock washers at each bracket. Disengage the rack levers from the injector control racks and lift the control tube assembly from the cylinder head.

Disassemble Injector Control Tube

The injector control tube, one mounting bracket, a spacer and injector control tube lever are available as a service assembly. When any part of this assembly needs replacing, it is recommended the complete service assembly be replaced. Therefore, the disassembly and assembly procedure for these items is not included in the following:

1. Remove the bracket from the injector control tube.

2. Loosen the adjusting screws or adjusting screw and locknut at each injector rack control lever.

3. With the spring-loaded injector control tube, disconnect the yield springs at each rack lever, then roll the yield springs out of the slots and notch of the control tube.

4. Disconnect the return spring from the bracket and front or rear rack lever.

5. Then, remove the yield springs and/or return spring and rack levers from the control tube.

Inspection

Wash all of the injector control tube parts in clean fuel oil and dry them with compressed air.

Examine the control tube, control lever, control tube rack control levers and brackets for excessive wear, cracks or damage and replace them, if necessary. The bearing in the bracket is not serviced separately. Examine the yield springs and/or return spring and replace them if worn or fractured.

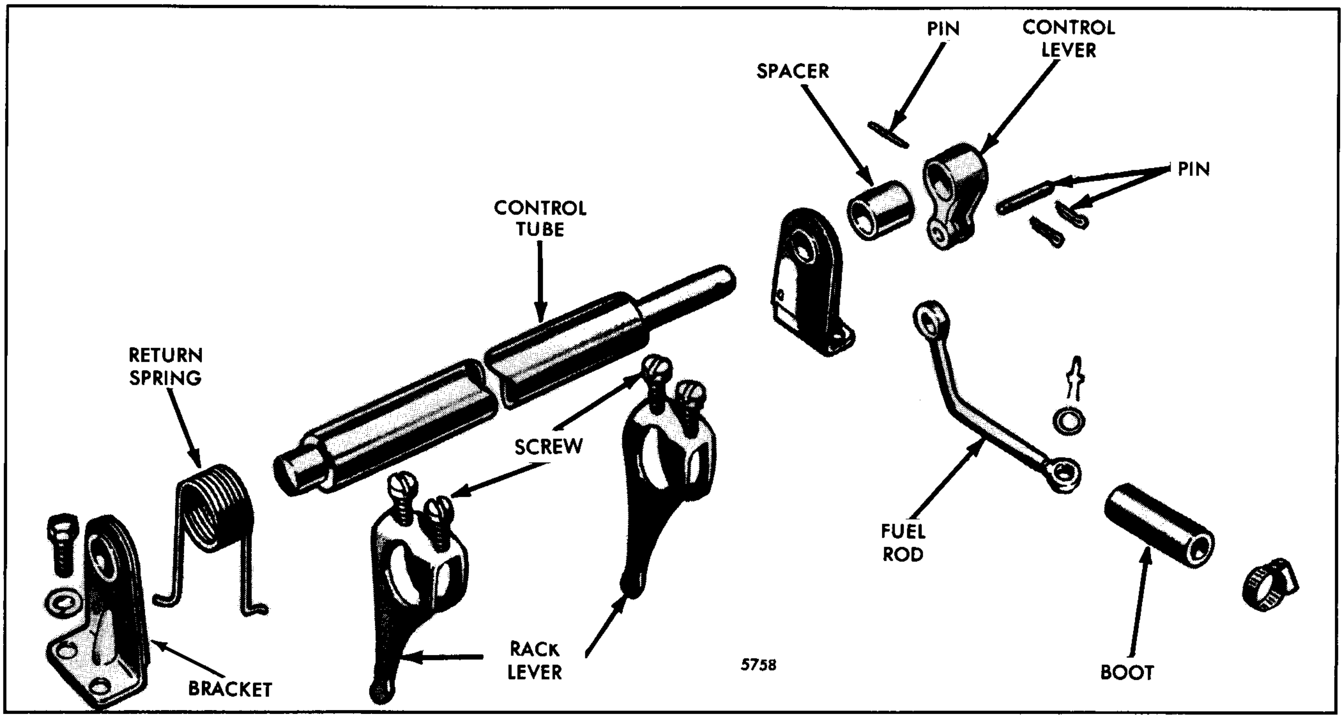


Fig. 1 - Injector Control Tube Assembly (Non-Spring Loaded - In-line Engine)

Assemble Injector Control Tube

With all of the parts cleaned and inspected and the necessary new parts on hand, refer to Fig. 1, 2 or 3 and assemble as follows:

IN-LINE ENGINE CYLINDER HEAD

1. Two Screw design injector control tube.

   Install the rack control levers on the control tube, with the levers facing the front bracket position.

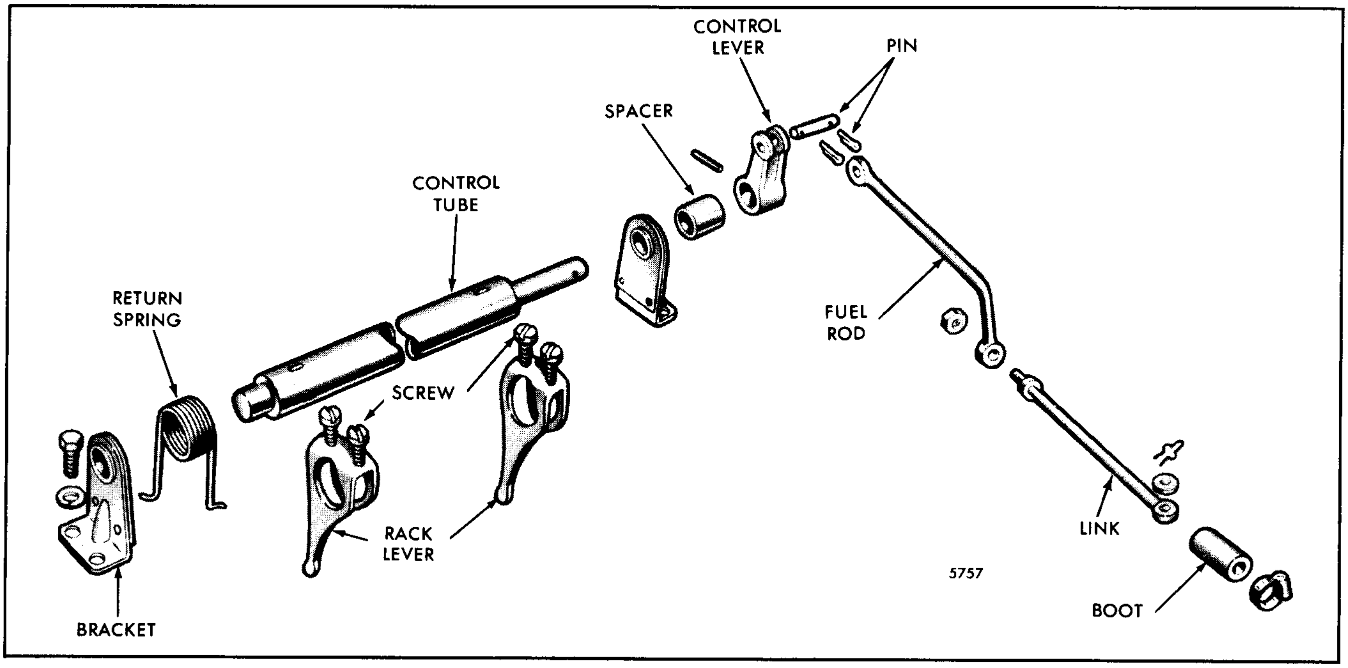


Fig. 2 - Injector Control Tube Assembly (Non-Spring Loaded - V Engine)

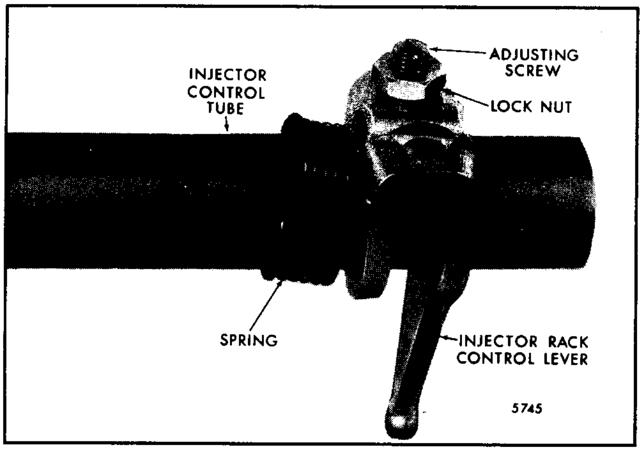


Fig. 3 - Injector Control Tube and Rack Lever (Spring-Loaded)

Turn the adjusting screws into the slots in the control tube far enough to position the levers.

One Screw and Locknut design injector control tube.

Install the rack control levers with the levers facing the front bracket position and the R.H. helix yeild springs. Then, install the odd (L.H. helix) yield spring and rack control lever with the lever facing the front bracket position.

Attach the curled end of the yield springs to the rack control levers and roll the springs into the notch (odd yield spring) and the slots (R.H. helix yield springs) in the control tube. Then, turn the adjusting screws and locknuts into the notch and slots far enough to position the levers on the control tube.

2. On both designs, install the control tube return spring and front bracket on the control tube. Attach the curled end of the return spring to the rack control lever and the extended end of the spring behind the front bracket.

LEFT BANK V-ENGINE CYLINDER HEAD

1. Install the return spring on the control tube and against the front bracket.

2. Two Screw design injector control tube.

Install the rack control levers on the control tube, with the levers facing the rear bracket position, and turn the adjusting screws in far enough to position the levers on he control tube.

One Screw and Locknut design injector control tube.

Install a rack control lever, with the lever facing the rear bracket position, and the odd (L.H. helix) yield spring. Then, install the R.H. helix yield springs and rack control levers with the levers facing the rear bracket.

Attach the curled end of the yield springs to the rack control levers and roll the yield springs into the notch (odd spring) and slots (R.H. helix springs) in the control tube. Then, turn the adjusting screws and locknuts into the slots far enough to position the levers on the control tube.

3. Attach the curled end of the control tube return spring to the rack control lever and the extended end of the spring behind the rear bracket.

4. Install the front bracket on the end of the injector control tube.

RIGHT BANK V-ENGINE CYLINDER HEAD

1. Two Screw design injector control tube.

Install the rack control levers on the control tube, with the levers facing the front bracket position. Turn the adjusting screws into the slots in the control tube far enough to position the levers.

One Screw and Locknut design injector control tube.

Install the rack control levers, with the levers facing the front bracket position and the R.H. helix yield springs. Then, install the odd (L.H. helix) yield spring and rack control lever, with the lever facing the front bracket position.

Attach the curled end of the yield springs to the rack control levers and roll the springs into the notch (odd yield spring) and the slots (R.H. helix yield springs) in the control tube. Then, turn the adjusting screws and locknuts into the notch and slots far enough to position the levers on the control tube.

2. On both designs, install the control tube return spring and front bracket on the control tube. Attach the curled end of the return spring to the rack control lever and the extended end of the spring behind the front bracket.

Indexing a New Replacement Control Lever to the Injector Control Tube

Use the following procedure to properly index and install a replacement control lever onto the injector control tube:

1. Remove the injector control tube from the engine. Then, loosen the adjusting screw for the rack lever closest to the control lever and slide the return spring and rack lever back 3 to 4 inches.

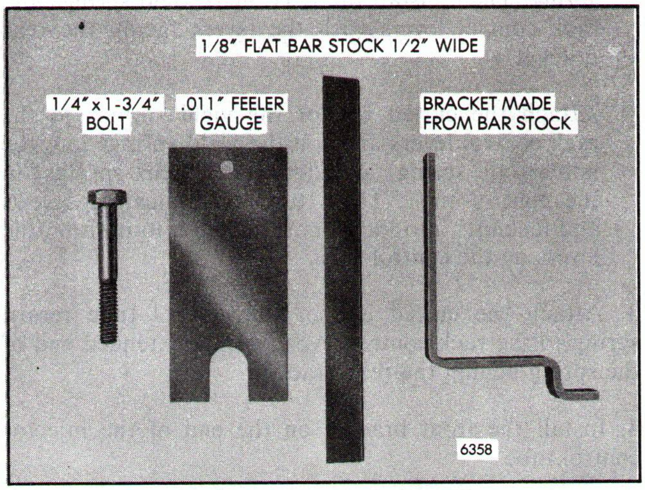


Fig. 4 - Fabricate Indexing Bracket

2. Fabricate an indexing bracket from a 5" long piece of 1/2" wide, 1/8" thick bar stock (Fig. 4). Secure the indexing bracket to the control tube with a hose clamp (Fig. 5).

3. Insert a 1/4" x 1-3/4" L. bolt through the end of the control lever. Rotate the bracket and clamp until the bracket is resting against the bolt. Tighten the clamp to hold the bracket securely against the bolt. Make sure the indexing bracket cannot be moved.

4. Remove the pin from the control lever and press the old lever off the control tube (Fig. 6).

5. Reinsert the 1/4" x 1-3/4" L. bolt through the end of a new lever and press the lever onto the control tube

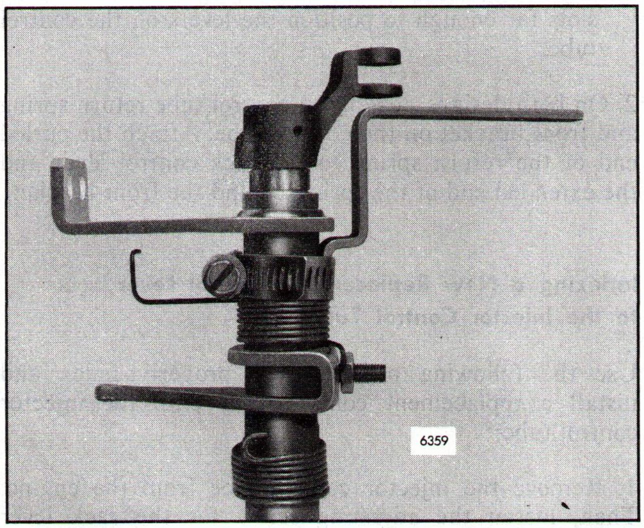


Fig. 5 - Secure Indexing Bracket to Control Tube

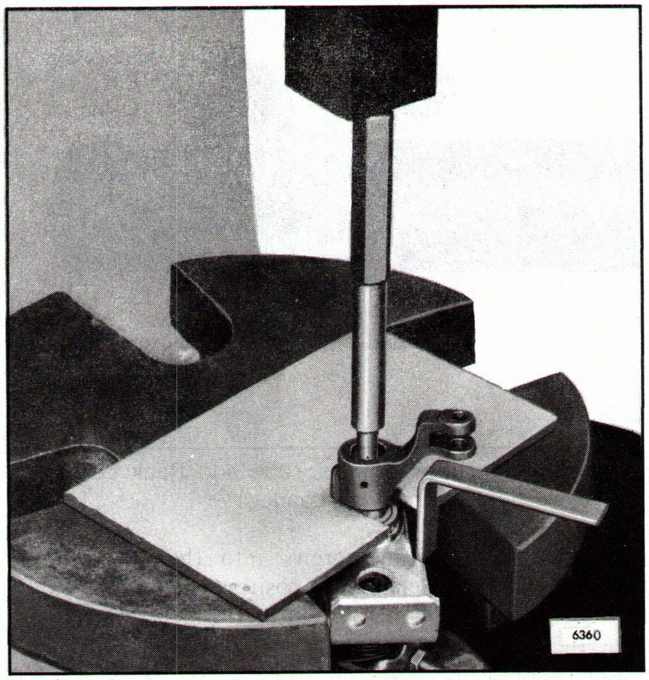


Fig. 6 - Press Old Lever off Control Tube

with the bolt resting against the indexing bracket (Fig. 7). Place a .011" feeler gage under the lever to get proper clearance between the lever and the spacer on the control tube. Before pressing on the lever, make sure the opposite end of the control tube is supported.

6. Position the control tube on the table of a drill press and drill a 1/8" hole through the control lever approximately 45° from the location of the former hole.

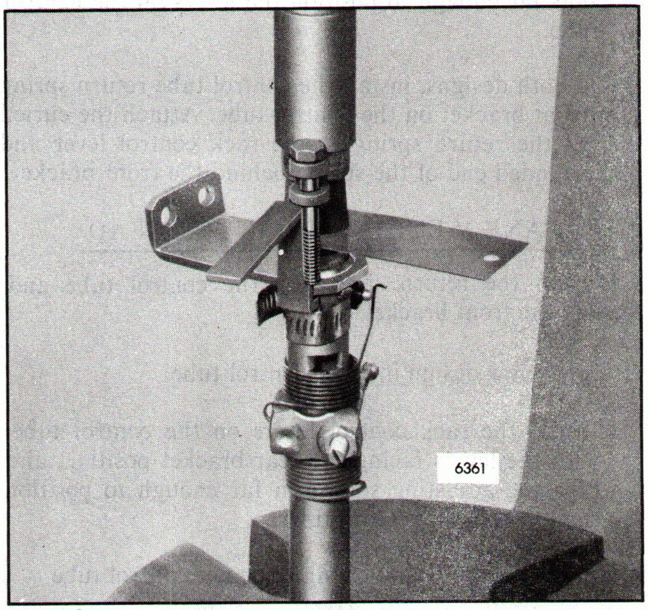


Fig. 7 - Installing New Lever

(Use the replaced lever for reference). After drilling, install a new pin.

7. Clean the control tube thoroughly and install on the engine. Adjust the injector racks as outlined in Section 14.3.

Install Injector Control Tube

1. Engage the injector rack control levers with the injector control racks and place the brackets over the mounting holes on the cylinder head.

2. Install the two 1/4″-20 x 5/8″ bolts and lock washers at each bracket to attach the injector control tube assembly to the cylinder head. Tighten the bolts to 10-12 lb-ft (14-16 Nm) torque.

3. Check the control tube to be sure it is free in the brackets. Tap the control tube lightly to align the bearings in the bracket, if necessary.

4. Connect the fuel rod to the injector tube control lever with a clevis pin and a new cotter pin.

5. Refer to Section 14 and position the injector rack control levers. Be sure the injector rack control levers can be placed in a no-fuel position before restarting the engine.

CAUTION: Loss of shutdown control could result in a runaway engine which could cause personal injury.

SHOP NOTES - TROUBLESHOOTING

SPECIFICATIONS - SERVICE TOOLS

SHOP NOTES

INJECTOR CALIBRATOR READINGS

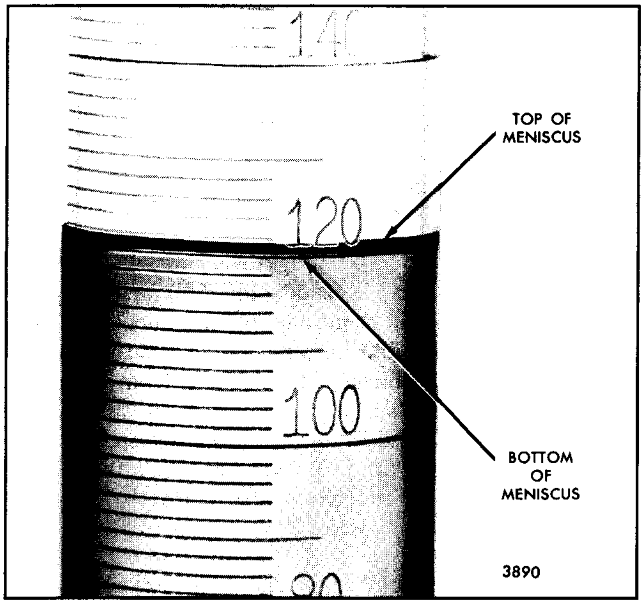


Fig. 1 - Checking Fuel Output

Several factors affect the injector 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. 1.

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 should be set to divert the injector output at 1,000 strokes, but must be reset for 1,200 strokes to check 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 should always be used. If regular diesel fuel oil (or any other liquid) is used, variations are usually noted because of the effect of the oil on the solenoid valve and other parts.

The fuel oil introduced into the test oil when the fuel injector is placed in the calibrator for a calibration check contaminates the test oil. Therefore, it is important that the test oil and test oil filter be changed every six months, or sooner if required.

In addition, other malfunctions such as a slipping drive belt, low level of test oil, a clogged filter, a defective pump or leaking line connections could cause bad readings. A frequent check should be made for any of these tell-tale conditions.

CHECKING INJECTOR TESTER J 23010 or J 9787

The injector tester J 23010 or 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 26400. 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 (16 536-17 225 kPa). Close the valve on the fuel supply line. After a slight initial drop, 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 (J 9787). The pump check valve in J 23010 must be 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 hclding 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

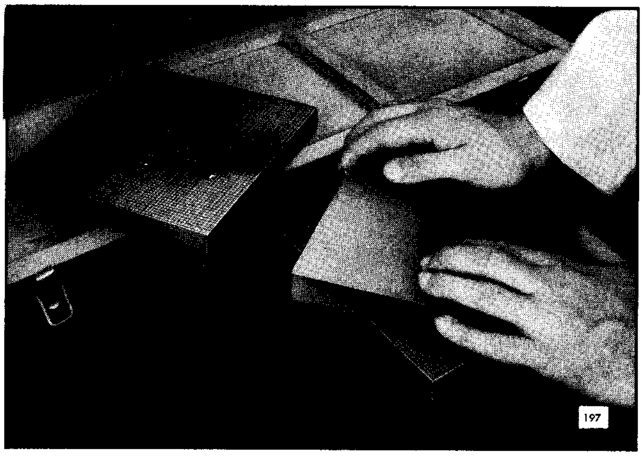


Fig. 2 - Refinishing Lapping Blocks

As the continued use of the lapping blocks will cause worn or low spots to develop in their lapping surfaces, they should be refinished from time to time.

It is 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 (Fig. 2). 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 finished, 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.

EFFECT OF PREIGNITION ON FUEL INJECTOR

Preignition 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 preignition occurs, remove all of the injectors and check for burned spray tips or enlarged spray tip orifices.

Before replacing the injectors, check the engine for the cause of preignition to avoid recurrence of the problem. Check for oil pull-over from the oil bath air cleaner, damaged blower housing gasket, defective blower oil seals, high crankcase pressure, plugged air box drains, ineffective oil control rings or dilution of the lubricating oil.

INJECTOR TIMING

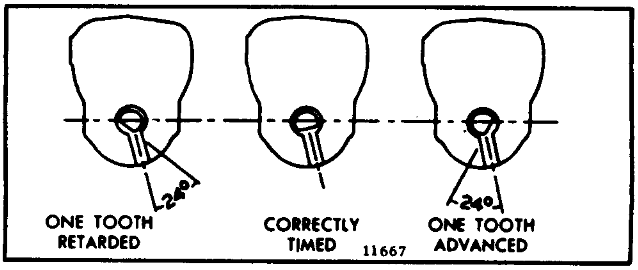


Fig. 3 - Injector Rack-to-Gear Timing

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. 3) and appears in the "advanced" or "retarded" position, disassemble the injector and correct the rack-to-gear timing.

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 25600 may be used to select a spray tip that will increase or decrease fuel injector output for a particular injector after it has been rebuilt and tested on the calibrator.

INJECTOR PLUNGERS

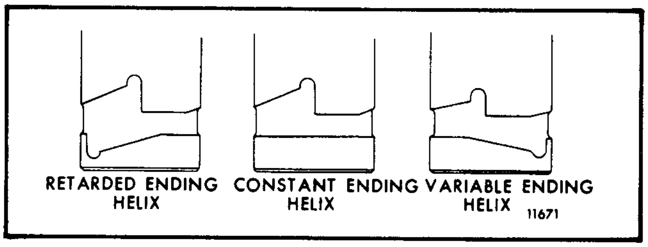


Fig. 4 - Types of Injector Plungers

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.

MASTER INJECTOR CALIBRATING KIT

Use Master Injector Calibrating Kit J 26298 to determine the accuracy of the injector calibrator.

With the test fluid temperature at 100°F ±1°(38°C ±1°) and each injector warm after several test cycles, run the three injectors contained in the kit. Several readings should be taken with each injector to check for accuracy and repeatability. If the output readings are within 2% of the values assigned to the calibrated masters, the calibrator can be considered accurate. Injector testing can be carried out now without any adjustment of figures. However, when testing new injectors for output, any difference between the calibrator and the masters should be used to compute new injector calibration. If more than a 2% variation from the masters is noted, consult the calibrator manufacturer for possible causes.

The calibrated masters should only be used to qualify injector output calibration test equipment.

REFINISHING INJECTOR FOLLOWER FACE

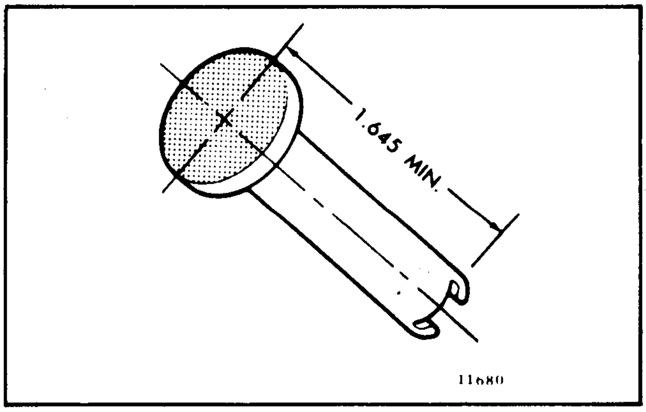


Fig. 5 - Injector Follower

When refinishing the face of an injector follower, it is extremely important that the distance between the follower face and the plunger slot is not less than 1.645" minimum as shown in Fig. 5. If this distance is less than specified, the height of the injector follower in relation to the injector body will be altered and proper injector timing cannot be realized.

FUEL LINES

Flexible fuel lines are used 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, run the engine long enough to determine whether or not all connections are sufficiently tight. If any leaks occur, tighten the connections only enough to stop the leak. Also check the filter cover bolts for tightness.

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 line in the fuel tank which would cause the pump to draw air.

Presence of an air leak may be detected by observing 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.

PRESSURIZE FUEL SYSTEM - CHECK FOR LEAKS

Always check the fuel system for leaks after injector or fuel pipe replacement and any time the fuel connections under the rocker cover are suspected of leaking. Failure to correct a serious fuel leak in this area can lead to dilution of the lube oil and bearing and/or cylinder kit damage.

Prime and Purge

Prime and/or purge the engine fuel system before starting the fuel leak check. *Prime* the system by blocking or disconnecting the line from the fuel pump, then apply fuel under pressure (60-80 psi or 413-552 kPa) to the inlet of the sceondary filter. If the system is to be *purged* of air as well, allow the fuel to flow freely from the fuel return line until a solid stream without air bubbles is observed.

Check for Leaks

Use one of the following methods to check for leaks.

Method 1. Use when the engine has been operating 20-30 minutes.

After operating the engine, shut it off and remove the rocker covers. Inspect the lube oil puddles that normally form where the fuel connectors join the cylinder head and where the fuel pipes join the fuel pipe nuts.

If there is any leakage at these connections, the lube oil puddles will be smaller or thinner than the puddles on the connectors that are not leaking. Disassemble, inspect and correct or replace the suspect part (connector washer, connector, injector or jumper line). Test and reinspect.

Method 2. Use when the engine is not operating, such as during or after repairs.

Remove the rocker covers. Pour lube oil over all fuel pipes and connectors which would normally be splashed with oil during engine operation. This will cause oil puddles to form at the joining surfaces as mentioned in Method 1.

Block off the fuel return line and disconnect the fuel pump supply line at the secondary filter. Install a pressure gage in the filter adaptor, then apply 60-80 psi (413-552 kPa) fuel to the outlet side of the secondary filter with the inlets plugged. Severe leaks will show up immediately. Minor leaks caused by nicks or burrs on sealing surfaces will take longer to appear. After maintaining 40-80 psi (276-552 kPa) for 20 to 30 minutes, a careful puddle inspection should reveal any suspect connectors. Inspect and repair or replace connectors as necessary. Test and reinspect (see note).

Method 3. Use while the engine is operating at 400-600 rpm.

Apply an outside fuel source capable of 60-80 psi (413-552 kPa) to the outlet side of the secondary filter. Pour lube oil over jumper lines and connectors so that oil puddles form where lines and connectors meet. Install a valve and a pressure gage in the fuel return line. With the engine idling, close the valve enough to raise the engine fuel pressure to 70 psi (483 kPa). After 10 to 20 minutes inspect the oil puddles to see if any have become smaller or run off completely. The undiluted oil will hang the same as when the oil was poured on. Repair and retest.

NOTE: With the engine at rest, as in Method 2 all injectors will leak to some extent when pressurized. The leakage occurs because there is no place else for the pressurized fuel to go. When the low and high pressure cavaities in the injector are subjected to the high test pressure, fuel is forced past the plunger into the rack and gear cavaity. Result: Droplets of fuel form at the rack and drip off.

Slightly worn plungers may leak more under these conditions. This leakage will not occur while the engine is running because of the dynamic and pressure conditions that exists.

If injectors are suspected of leaking and contributing to dilution of the lube oil, they should not be tested by pressurizing the fuel system as in Method 2. Injectors should be removed from the engine and tested for pressure-holding capability (see Section 2).

Points to Remember

Lube oil puddle inspection is the key to pressure testing the fuel system for internal leaks. This test can be performed any time the rocker covers are removed, after the fuel pipes and connectors have been splashed with oil and there is normal fuel pressure in the system. The weak or missing puddles show where the leaks are.

All leakage or spilage of fuel during leak detection testing further dilutes the lube oil, so the final step in maintenance of this type should include lube oil and lube oil filter changes.

DETECTING INTERNAL FUEL LEAKS

Used lube oil analysis often identifies a potential source of engine trouble before it occurs. One of the most serious conditions this test can uncover is the presence of excessive fuel in the lubricating oil. Inadequate bearing surface lubrication caused by lube oil dilution is a potential cause of engine malfunction and damage.

While used lube oil analysis can indicate the presence of fuel in engine lubricating oil, other methods must be used to determine its source. Two particularly effective methods involve the use of dye additives.

Red LTO 1140 Dye

The use of Red LTO 1140 dye (a product of Chemserve Corporation, 9505 Copland Ave., Detroit, MI 48209) is effective when bench pressure-testing complete cylinder head assemblies or when pressure testing head assemblies on new or newly overhauled *operating* engines which have *new, clean lubricating oil.* The red dye is most visible when clean lube oil is used. Prepare the dye as follows:

Mix two (2) ounces (59 ml) of Red LTO 1140 dye with fine (5) gallons (18.93 liters) of clean No. 1 or No. 2 diesel fuel in a clean container. The container should be marked "Test Fuel" to prevent accidental use and be resealable to prevent contamination when not in use.

Bench Testing

1. To bench test a complete cylinder head assembly, fill a fuel system priming pump (J 5956 or equivalent) with the red dye/fuel mixture.

2. Connect the outlet hose of the priming pump to the fuel inlet manifold. Connect a drain hose from the fuel outlet back to the test fuel container. Make sure that the required restricted fitting is installed in the fuel outlet. This will allow sufficient fluid pressure to build up.

3. Prime the cylinder head fuel system and check for leaks. The test fuel will show up as bright red.

4. Eliminate the cause of any leaks discovered. Wipe off the head components and retest until no further leaks occur.

Running Test

1. To pressure test the cylinder head on a new or newly overhauled engine, isolate the fuel system so that the fuel supply and return lines are connected only to the test container.

2. Start and run the engine on the test fuel at maximum no-load speed for approximately five minutes to bring it to operating temperature. Periodically check the level in the test fuel container to ensure an adequate supply. If necessary, replenish the test fuel by adding one ounce (30 ml) of Red LTO 1140 dye to each 2.5 gallons (9.463 liters) of make-up fuel. Three to five engines can normally be tested before replenishing the fuel.

3. Stop the engine and remove the rocker covers. Check the cylinder head and all fuel connections for any sign of fuel leakage. The test fuel will show up as bright red.

4. If any leaks are discovered, eliminate their cause. Wipe all head surfaces and fuel connections clean, then start the engine and retest.

5. When all leaks have been eliminated, replace the rocker covers, reinstall the original fuel lines and connect the engine to its normal fuel source. It is not necessary to change the fuel filter or strainer. Start and run the engine to purge any air from the system.

J 28431 Fluorescent Dye

The use of J 28431 fluorescent dye and a "black light" (ultraviolet light) is preferable when testing an engine that has been in service and has dark lubricating oil (from engine operation). Use the following procedure:

1. Mix four (4) ounces (11 ml) of fluorescent dye additive J 28431 with four (4) gallons (15.14 liters) of clean No. 1 or No. 2 diesel fuel in a clean container. The container should be marked "Test Fuel" to prevent its accidental usage and be resealable to prevent contamination when not in use.

2. Isolate the engine fuel system so that the supply and return lines are connected only to the test fuel container.

3. Start and run the engine on the test fuel at maximum no-load speed for approximately five minutes to bring it to operating temperature. Periodically, check the level in the test fuel container to ensure an adequate supply. If necessary, replenish the test fuel by adding one ounce (30 ml) of fluorescent dye for each gallon (3.79 liters) of make-up diesel fuel. Normally, three to five units can be tested before replenishing the fuel.

4. With the engine idling and the rocker covers removed, shine the "black light" over the head assembly. Lube oil will show up as a dull blue. A fuel leak will glow a bright yellow. This type of test is best conducted in a darkened or shadowed area. The darker the area surrounding the unit being tested, the easier it is to see the fluorescent dye.

5. If bright yellow dye is detected, determine the cause of the fuel leak and eliminate it. Wipe the cylinder head and fuel connections clean, start and idle the engine and reckeck the head area.

6. When all leaks have been eliminated, reinstall the original fuel lines and connect the engine to its normal fuel source. It is not necessary to change the fuel filter or strainer. Start and run the engine to purge any air from the fuel system.

Normal Fuel Weepage

Some fuel weepage may normally be encountered from the follower and/or rack on DDA injectors while performing this test. Special consideration must be given to this weepage and the fact that it should not be allowed to exceed the DDA guidlines for pressure holding test (see Section 2.1.1) and the specification for lube oil dilution (2.5%).

> **NOTE:** Since all leakage or spillage of fuel during leak detection testing dilutes the lube oil, the final step in maintenance of this type should include lube oil and lube oil filter changes.

TROUBLESHOOTING

FUEL PUMP

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 and filter gaskets. 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 the pump flange drain hole, 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 valve and its bore or seat. This permits the fuel 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. Reinstall the valve.

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 hose from the fitting at the fuel tank and hold the open end in a convenient receptacle (Fig. 6).

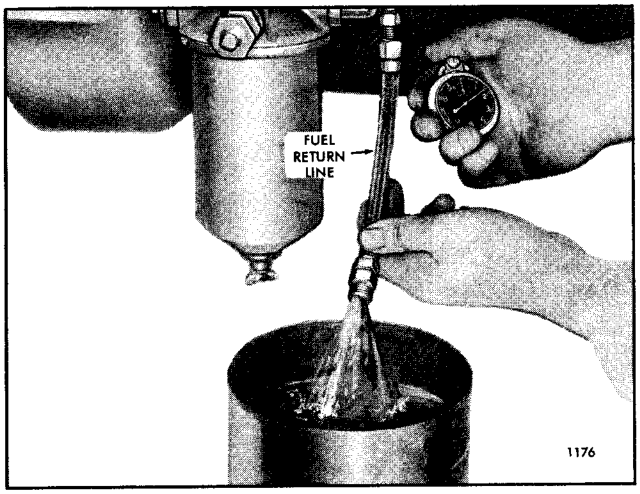


Fig. 6 - Measuring Fuel Flow

2. Start and run the engine at 1200 rpm and measure the fuel flow. Refer to Section 13.2 for the specified quantity per minute.

3. Immerse the end of the fuel hose 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 screwdriver. 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.

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.

AIR-OPERATED VARIABLE HIGH SPEED GOVERNORS

The most common condition is that the minimum rpm is too high. This is especially true on kit installations to an unknown governor. The most frequent causes are these:

1. **Lack of enough air pressure to completely overcome the high speed spring preload.**

Series 53 engines require 90 psi (621 kPa) or more. This air pressure is required at the governor after the regulator. The regulator must have an operating range of 0-120 psi (0-827 kPa).

2. **An interaction between the idle circuit and the high speed circuit.**

Many Detroit Diesel Allison governors were designed to idle as low as 350 rpm. If these older design governors are being modified, a low minimum control with the VHS cannot be obtained, especially if a high normal idle is used. All engines supplied by Detroit Diesel Allison with the VHS feature installed as original equipment have a compatible governor which will allow control from no-load to within 100 rpm of idle.

NOTE: Minimum certified idle values should not be violated.

Single weight governors capable of accepting the VHS are also capable of reducing the minimum rpm to within 100 rpm of idle.

3. **Idle screw protrudes beyond VHS position, or elastic stop nut is not tight.**

Determine if the idle screw or piston hits the VHS cover.

If idle screw hits the VHS cover, raise the idle until the screw is flush with the end of the piston. In certain cases the idle screw may have to be shortened to meet the criteria of being flush and acquire the desired idle speed.

If the piston hits first, the elastic stop nut is not properly adjusted. Readjust, making sure that the piston is bottomed, then proceed to adjust the elastic stop nut (see Section 2.7.1.5).

4. **Engine overshoot.**

This usually relates to the non-synchronized engagement of the throttle lock and the regulated air supply to the VHS housing. A variable orifice (needle valve type) in one of the air supply lines will provide capability for synchronization as follows:

In cases of *overshoot*, the variable orifice is installed in the supply line to the throttle lock.

In case of *undershoot*, the variable orifice is installed in the regulated air pressure line to the VHS housing.

5. **Lowered idle or no-load.**

Usually caused by air from the air supply leaking into or being trapped in the VHS housing. Any pressure in the VHS housing will lower both the no load and idle. Recheck the air plumbing.

6. **Lack of normal power.**

The elastic stop nut is screwed in too tight, pulling the high speed plunger off its seat. This will cause low power but no change in the no-load rpm. Readjust the elastic stop-nut.

7. **No-load increased.**

Interference of the piston and idle screw. Check to be sure that the screw is free as it protrudes through the piston.

TROUBLESHOOTING CHART (Crown Valve Injector)

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 SPRAY TIP ORIFICES

SUGGESTED REMEDY

1. A worn or eroded valve seat may be lapped, but not excessively as this would reduce 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 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.

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 size of the spray tip orifices. Then, using tool J 4298-1 with the proper size wire, clean the orifices.

TROUBLESHOOTING CHART (Crown Valve Injector)

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 (75-88 Nm) 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.

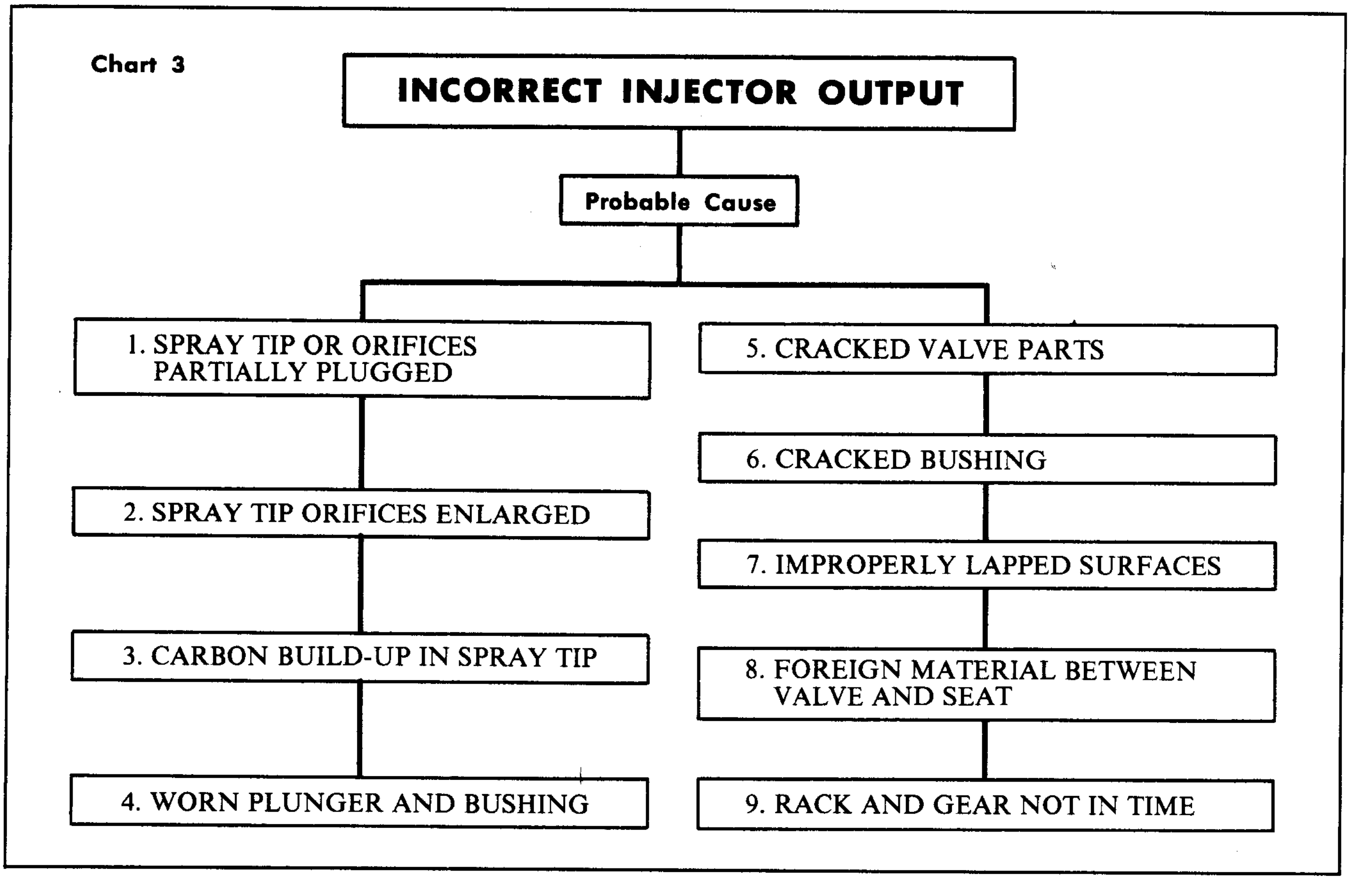
9. Install new body plugs.

10. Replace the filter gaskets and tighten the filter caps to 65 to 75 lb-ft (88-102 Nm) torque.

11. Clean up the sealing surfaces or replace the filter caps, if necessary.

12. Disassemble the injector and clean all of the parts.

TROUBLESHOOTING CHART (Crown Valve Injector)



SUGGESTED REMEDY

1. Clean the orifices with tool J 4298-1, using the proper size wire.

2. Replace the spray tip.

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.

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.

5. Replace the cracked parts.

6. Replace the plunger and bushing assembly.

7. Lap the sealing surfaces.

8. Disassemble the injector and clean all of the parts.

9. Assemble the gear with the drill spot mark on the tooth engaged between the two marked teeth of the rack.

TROUBLESHOOTING CHART (Needle Valve Injector)

Chart 4

LOW OR HIGH VALVE OPENING PRESSURE

LOW VALVE OPENING PRESSURE

Probable Cause

1. WORN OR ERODED NEEDLE VALVE OR VALVE SEAT IN SPRAY 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 SPRAY TIP ORIFICES

SUGGESTED REMEDY

1. Replace the needle valve and spray tip assembly.
2. Replace the needle valve and spray tip assembly.
3. Replace the spring seat.
4. Replace the valve spring.
5. Disassemble the injector and clean all of the parts.
6. Remove the carbon in the spray tip with tip reamer J 9464-01 which is especially designed and ground for this purpose.
7. Check the size of the spray tip orifices. Then, using tool J 4298-1 with the proper size wire, clean the orifices.

TROUBLESHOOTING CHART (Needle Valve Injector)

Chart 5

INSUFFICIENT INJECTOR HOLDING TIME

Probable Cause

1. POOR BUSHING TO BODY FIT
2. INJECTOR NUT NOT TIGHTENED TO SPECIFIED TORQUE
3. EXCESSIVE PLUNGER TO BUSHING CLEARANCE
4. CRACKED SPRAY TIP
5. WORN OR ERODED NEEDLE VALVE
6. WORN OR ERODED NEEDLE VALVE SEAT IN SPRAY TIP
7. WORN OR BROKEN NEEDLE VALVE QUILL
8. WORN OR BROKEN VALVE SPRING
9. WORN OR DAMAGED VALVE SPRING SEAT
10. DEFECTIVE SEAL RINGS
11. BODY PLUG LEAKS
12. FILTER GASKETS LEAK
13. POOR SEALING SURFACES ON FUEL FITTINGS
14. DIRT OR FOREIGN MATERIAL IN INJECTOR

SUGGESTED REMEDY

1. Lap the injector body.

2. Tighten the injector nut to 75-85 lb-ft (102-115 Nm) torque. Do not exceed the specified torque.

3. Replace the plunger and bushing.

4, 5, 6 and 7. Replace the needle valve and spray tip assembly.

8. Replace the valve spring.

9. Replace the valve spring seat.

10. Replace the seal rings.

11. Install new body plugs.

12. Replace the filter cap gaskets and tighten the filter caps to 65-75 lb-ft (88-102 Nm) torque.

13. Clean up the sealing surfaces or replace the filter caps, if necessary. Replace the filter if a cap is replaced.

14. Disassemble the injector and clean all of the parts.

TROUBLESHOOTING CHART (Needle Valve Injector)

Chart 6

INCORRECT INJECTOR OUTPUT

Probable Cause

1. SPRAY TIP OR ORIFICES PARTIALLY PLUGGED
2. SPRAY TIP ORIFICES ENLARGED
3. CARBON BUILD-UP IN SPRAY TIP
4. WORN PLUNGER AND BUSHING
5. WORN OR DAMAGED NEEDLE VALVE QUILL
6. WORN OR DAMAGED NEEDLE VALVE SPRING SEAT
7. WORN OR BROKEN VALVE SPRING
8. CRACKED CHECK VALVE CAGE, SPRING CAGE OR SPRAY TIP
9. CRACKED BUSHING
10. IMPROPERLY LAPPED SURFACES
11. FOREIGN MATERIAL BETWEEN VALVE AND SEAT
12. RACK AND GEAR NOT IN TIME
13. SPRAY TIP - PLUNGER AND BUSHING COMBINATION PROVIDES INCORRECT OUTPUT

SUGGESTED REMEDY

1. Clean the spray tip as outlined under *Clean Injector Parts.*

2. Replace the needle valve and spray tip assembly.

3. Clean the spray tip with tool J 1243.

4. After the possibility of an incorrect or faulty spray 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.

> **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.

5. Replace the needle valve and spray tip assembly.

6. Replace the spring seat.

7. Replace the valve spring.

8. Replace the cracked parts.

9. Replace the plunger and bushing assembly.

10. Lap the sealing surfaces.

11. Disassemble the injector and clean all of the parts.

12. Assemble the gear with the drill spot mark on the tooth engaged between the two marked teeth on the rack.

13. Replace the spray tip and the plunger and bushing assembly to provide the correct output.

SPECIFICATIONS

STANDARD BOLT AND NUT TORQUE SPECIFICATIONS

THREAD SIZE	260M BOLTS TORQUE (lb-ft)	Nm	THREAD SIZE	280M OR BETTER TORQUE (lb-ft)	Nm
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

12252

BOLT IDENTIFICATION CHART

EXCEPTIONS TO STANDARD BOLT AND NUT TORQUE SPECIFICATIONS

APPLICATION	THREAD SIZE	TORQUE (lb-ft)	TORQUE (Nm)
Governor control housing to flywheel housing	5/16-18	10-12	14-16
Blower drive assembly to flywheel housing	3/8 -16	20-25	27-34
Injector clamp bolt	3/8 -16	20-25	27-34
Fuel line connector	3/8 -24	20-28	27-38
Fuel pipe nut (V-engine)	3/8 -24	12-15	16-20
Rocker arm bracket bolts	7/16-14	50-55	68-75
Governor drive gear retaining nut (In-line engine)	5/8 -18	125-135	170-183
Injector filter cap	5/8 -24	65-75	88-102
Injector nut (crown valve)	15/16-24	55-65	75-88
Injector nut (needle valve)	15/16-24	75-85	102-115

SERVICE TOOLS

TOOL NAME	TOOL NO.
Injector	
Auxiliary injector tester ("N" injectors)	J 22640
Fuel pipe socket	J 8932-01
Fuel system primer	J 5956
Injector body reamer	J 21089
Injector body thread reconditioning set	J 22690
Injector calibrator	J 22410
Injector nut seal ring installer	J 29197
Injector service set (includes *tools)	J 1241-07
Injector service set ("N" injectors - includes §tools)	J 23435-02
*Deburring tool	J 7174
§*Fuel hole brush	J 8152
§*Injector nut socket wrench	J 4983-01
§*Injector nut and seat carbon remover set	J 9418
§*Injector spray tip driver	J 1291-02
*Injector tip cleaner	J 1243-01
§*Pin vise	J 4298-1
§*Rack hole brush	J 8150
§*Spray tip carbon remover	J 9464-01
*Spray tip seat remover	J 4986-01
*Spray tip wire (.005")	J 21459-01
§*Spray tip wire (.0055")	J 21460-01
§*Spray tip wire (.006")	J 21461-01
§*Wire sharpening stone	J 8170
Injector test oil (Available in 5, 15, 30 and 55 gallons)	J 26400
Injector tester	J 9787
Injector tester	J 23010
Injector tester modification package (J 23010 only)	J 23010-194
Injector tip concentricity gage	J 5119
Injector vise and rack freeness tester	J 22396
Injector vise jaws (offset body)	J 8912
Injector vise jaws (standard body)	J 1261
Lapping Block set	J 22090-A
Polishing compound ("N" injectors)	J 23038
Polishing stick set ("N" injectors)	J 22964
Spray tip flow gage	J 25600
Spray tip gage ("N" injectors)	J 9462-02
Spring tester	J 22738-02
Wire brush (brass)	J 7944
Injector Tube	
Injector tube service tool set	J 22525
Injector tube service tool set (for power equipment)	J 22515
Fuel Pump	
Fuel pump primer	J 5956
Fuel pump tool kit	J 34607
Fuel pump tool set	J 1508-03
Fuel pump wrench	J 4242

TOOL NAME	TOOL NO.
Mechanical Governor	
Adjustable spanner wrench	J 5345
Control link operating lever bearing remover/installer	J 8985
Governor cover bearing installer	J 21068
Governor cover bearing remover/installer	J 21967-01
Governor weight spacer (6V-53 engine)	J 8984
Spring retainer nut wrench	J 5895
Variable speed spring housing bearing installer set	J 9196

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.

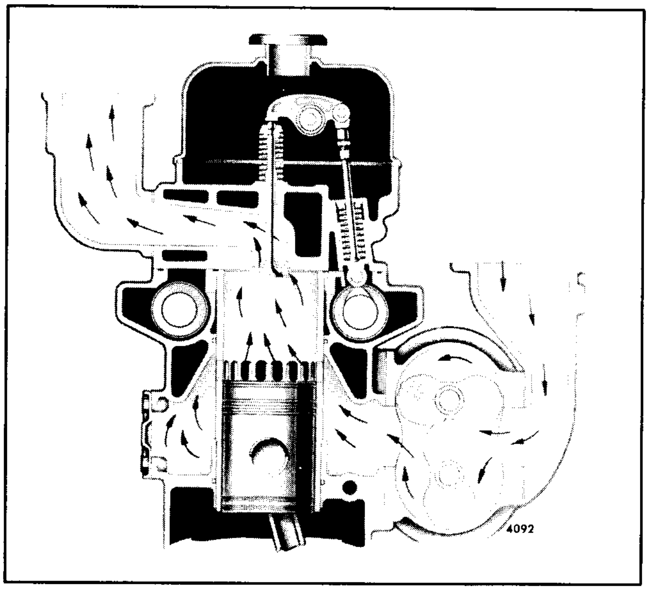


Fig. 1 - Air Flow Through Blower and Engine (In-Line Engine)

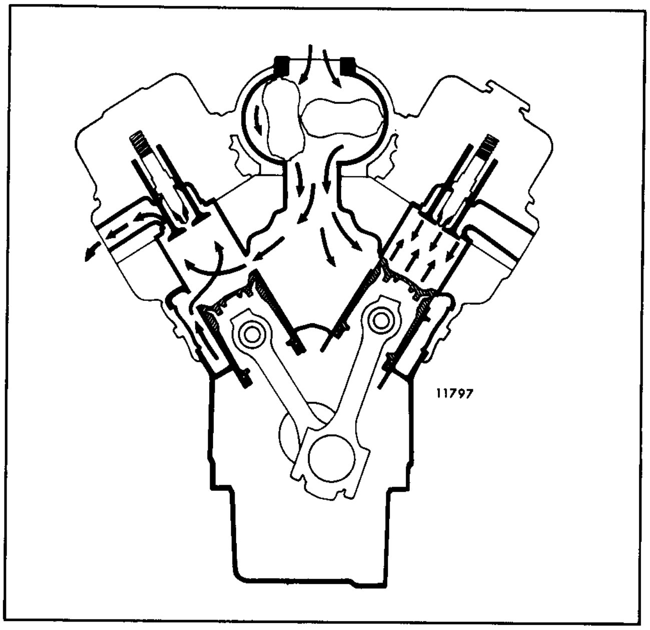


Fig. 2 - Air Flow Through Blower and Engine (V-Type Engine)

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 their efficiency for a reasonable period of time before requiring service.

The importance of keeping dust and grit-ladden air out of an engine cannot be over-emphasized since clean air is so essential to satisfactory engine operation and long engine life. The air cleaner must be able to remove fine materials such as dust and blown sand as well as coarse materials such as chaff, sawdust, or lint from the air. It must also have a reservoir capacity large enough to retain the material separated from the air to permit operation for a reasonable period before cleaning and servicing are required.

Dust and dirt entering an engine will cause rapid wear of piston rings, cylinder liners, pistons and the exhaust valve mechanism with a resultant loss of power and high lubricating oil consumption. Also, dust and 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 pistons and valves due to incomplete combustion.

Air Cleaner Mounting

Air cleaner mountings vary in accordance with the air cleaner installation and the engine units on which they are employed. The light duty oil wetted type, oil bath type and the dry type air cleaners are mounted on the air inlet housing. Heavy duty air cleaners are remotely mounted from the air inlet housing and are connected to it by air tight ducts.

Current design heavy duty air cleaners may be mounted in parallel to the same air inlet elbow for additional air cleaner capacity. Some earlier installations introduced an additional cleaner into the system between the main cleaner and the blower inlet. The heaviest cleaning job was imposed upon the main cleaner, whereas the additional cleaner, called the after cleaner, filters out any dirt particles that may have passed through the main cleaner.

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 bypass 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 the dry type cleaner, 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 a rubber hose is employed, cement it in place. Use a 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 Oil Bath Type Air Cleaner

The light duty oil bath type air cleaner consists essentially of a wire screen element supported inside a sylindrical housing which contains an oil bath directly below the element (Fig. 1). Air drawn through the cleaner passes over the top of the oil bath. The air stream direction reverses when the air impinges on the oil in the sump and is then directed upwards by baffles. During this change in the direction of air flow, much of the foreign matter is trapped by the oil and is carried to the sump where it settles out. The air passes upward through the metal-wool elements where more dust and the entrained oil are removed. A second change of air direction, at the top of the cleaner directs the air downward through the center tube and into the blower inlet housing.

Service (Light-Duty)

To service the light duty air cleaner, loosen the wing bolt 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 elements and the lower section is made up of the oil sump, removable baffle and the center tube.

The upper shell and metal-wool elements may be cleaned by soaking the entire section in kerosene or fuel oil. This will loosen the oil and dust in the elements and facilitate flushing out the dirt. The oil should be emptied from the sump, the baffle removed, and the sump and baffle cleaned in kerosene or fuel oil to remove all sediment. A lintless cloth should be pushed through the center tube of the cleaner before the baffle is installed and the sump refilled to the oil level mark with clean engine oil. NEVER use cotton waste to wipe the center tube. Use the same viscosity and grade of oil that is used in the engine crankcase. All gaskets and sealing surfaces should be checked and cleaned to ensure air-tight seals.

After the filter element has been thoroughly drained of the flushing fluid, the cleaner should be assembled. However, before installing the cleaner on the engine, the air inlet housing and blower inlet screen should be checked for the presence of dirt accumulations. If the service period has been too long, or dust-laden air has been leaking past the seals, the inlet housing and screen will be dirty. This will serve as a good check on the maintenance of the air cleaner installation. When installing the cleaner (and its seal) on the inlet housing, be sure that the cleaner seats properly, then tighten the wing bolt securely until the cleaner is rigidly mounted.

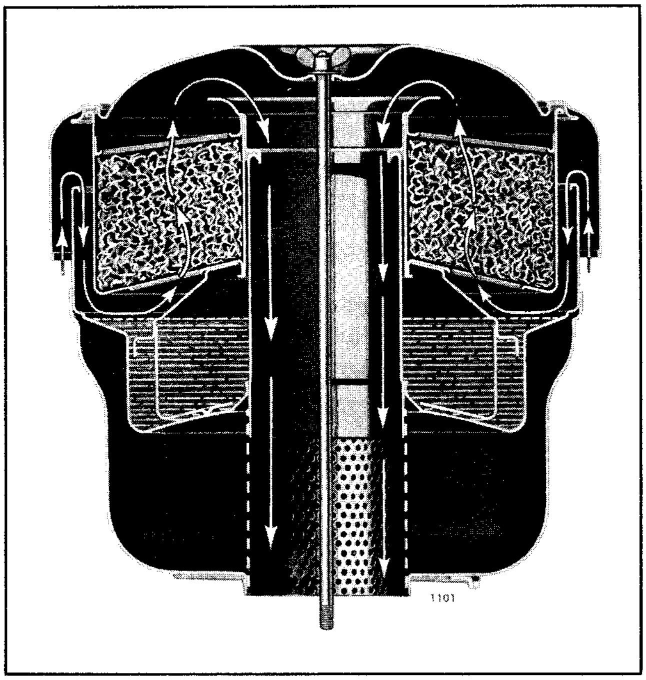


Fig. 1 - Light Duty Oil Bath Type Air Cleaner

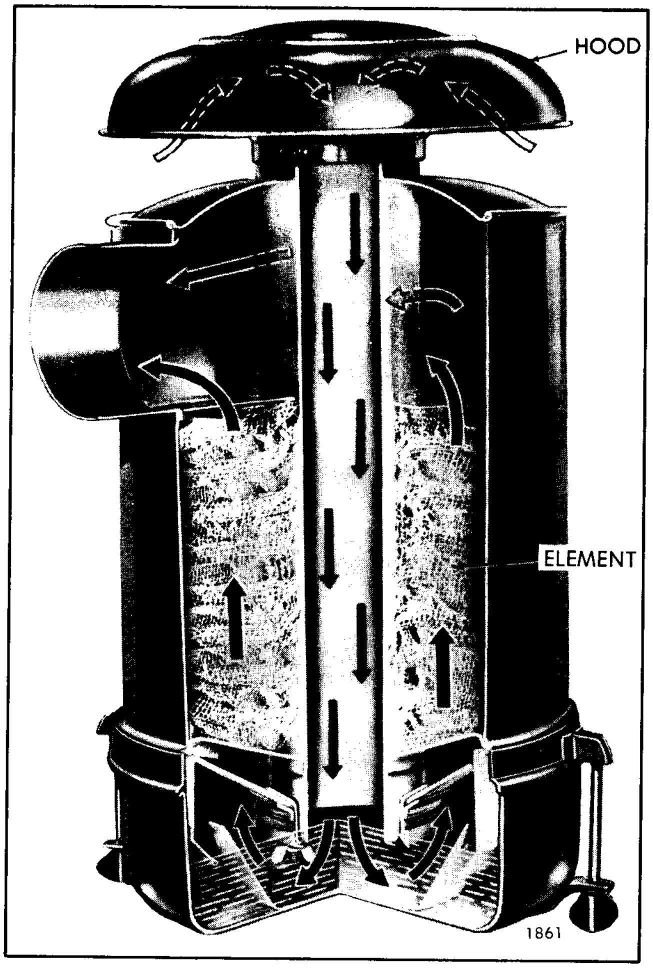


Fig. 2 - Heavy Duty Oil Bath Type Air Cleaner

Heavy Duty Type Air Cleaner

In all heavy duty air cleaners air is drawn through the air inlet hood, which acts as a cleaner and down through the center tube (Fig. 2). At the bottom of the tube, the direction of air flow is reversed and oil is picked up from the oil reservoir cup. The oil laden air is carried up into the separator screen where the oil which contains the dirt particles is separated from the air by collecting on the separator screen.

A low pressure area is created toward the center of the air cleaner as the air passes a cylindrical opening formed by the outer perimeter of the central tube and the inner diameter of the separator screen (Fig. 3). This low pressure is caused by the difference in air current velocity across the opening. The low pressure area, plus the effect of gravity and the inverted cone shape of the separator screen, causes the oil and dirt mixture to drain to the center of the cleaner cup. This oil is again picked up by the incoming air causing a looping cycle of the oil, however, as the oil is carried toward another cycle, some of the oil will overflow the

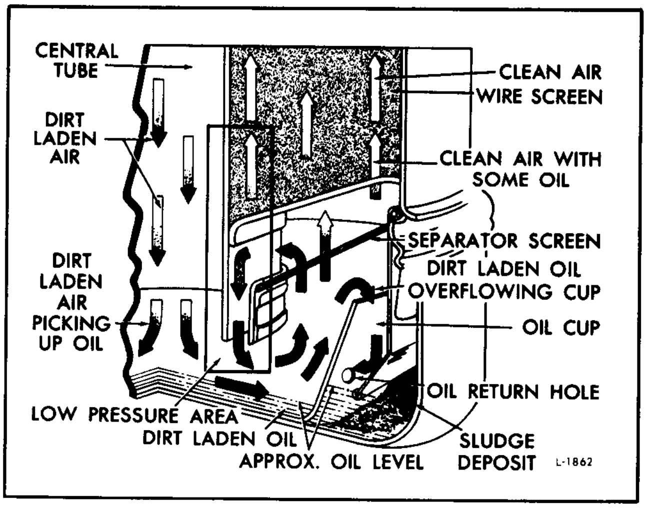


Fig. 3 - Air Flow Through Heavy Duty Oil Bath Air Cleaner

edge of the cup carrying the dirt with it. The dirt will be deposited in the outer area surrounding the cup. Oil will then flow back into the cup through a small hole located in the side of the cup. Above the separator screen, the cleaner is filled with a wire screen element which will remove any oil which passes through the separator screen. This oil will also drain to the center and back into the pan. The clean air then leaves the cleaner through a tube at the side and enters the blower through the air inlet housing.

An air inlet hood or pre-screener must be used with the heavy duty air cleaners, depending upon operating conditions. This equipment normally requires cleaning more frequently than the main air cleaner. The usual installation employs an air inlet hood which serves only to prevent rain, rags, paper, leaves, etc., from entering the air cleaner. The smaller cleaners employ a spherical-shaped hood. Air enters the hood through a heavy screen which forms the lower portion of the hood, and the air is reversed in the hood and pulled downward into the air cleaner. The hood is mounted on the air cleaner inlet tube and is held in place by the fit of the hood in the inlet tube.

The larger cleaners use a dome-shaped hood. A heavy screen inside the dome guards against large pieces of foreign material entering the cleaner. The hood is mounted on the air inlet tube of the cleaner and is secured to it by a screw-clamp. As previously mentioned, the hoods serve only to prevent rain and large pieces of foreign material from entering the cleaner. The openings in the hoods should be kept clear to prevent excessive restriction to air flow.

A pre-screener should be used on the inlet tube of the air cleaner instead of the inlet hood for those operations in which the air cleaner elements load up with lint or chaff. The purpose of the pre-screener is to remove as much of the lint or chaff as possible before the air enters the cleaner.

Service (Heavy-Duty)

The air inlet hoods used on heavy-duty air cleaners are not intended to do any cleaning. However, some dirt will collect on the heavy screens and in the hood itself. Therefore, it will be necessary to remove the hood occasionally for cleaning by brushing or with compressed air.

Some applications may be equipped with a pre-screener. The pre-screener catches the lint and chaff on the screen surrounding the shell. This screen can be removed by unhooking the retaining springs, and cleaned by brushing or with compressed air. The shell can be cleaned, if necessary, by wiping it with a lintless cloth. The pre-screener may then be assembled and installed on the cleaner inlet tube.

Although the pre-screener will remove most of the lint and chaff from the air, some may still find its way into the main cleaner. Therefore, it is essential that the fixed element of the main cleaner be checked, each time the cleaner is serviced, to prevent excessive lint deposits.

When the oil sump is removed on some heavy-duty air cleaners, a tray type screen attached to the tube will be visible. It may be removed by loosening the wing nuts and rotating the tray so that it unlocks from the tube. On other heavy duty models, the tray rests on the lip of the inner oil cup of the sump and is not retained by wing nuts.

The efficiency of the tray type oil bath air cleaner can be greatly reduced unless the fibrous material caught in the tray is removed. It is extremely important that the tray be cleaned regularly and properly.

If a tray is plugged with lint or dirt, wash the tray in a solvent or similar washing solution and blow out with high velocity compressed air or steam (Fig. 4). An even pattern of light should be visible through the screens when a clean tray is held up to the light (Fig. 4). It may be necessary, 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.

It is advisable to have a spare tray on hand to replace the tray that required cleaning. Having an extra tray available makes for better servicing and the plugged tray can be cleaned thoroughly at leisure.

Check for dirt accumulation in air cleaner center tube. Remove dirt by passing a lintless cloth through the center tube. Some tubes have a restricted portion at the lower end and care must be exercised not to damage this end.

Check oil sump for any dirt accumulation in both the inner and outer cups and clean if necessary.

At some regular period of engine service, remove the entire air cleaner from the engine and clean the fixed element. This can be done by passing a large quantity of clean solvent through the air outlet and down into the fixed element. When clean, allow element to dry thoroughly before installing cleaner.

When all of the components have been cleaned, the cleaner is ready for assembly. The removable screen should be installed and the oil sump should be filled with clean engine oil to the indicated level and installed on the cleaner. Care should be exercised that all gaskets and joints are tight. All connections from the cleaner to the engine should be checked for air leaks to prevent any air bypassing the air cleaners.

If it is found that unfiltered air is being admitted into the engine through the duct work of an air cleaner installation, the following procedure may be used for finding air leaks in an air duct system. The air cleaning system does not have to be dismantled, thus effecting a saving in time.

To make this check, it is necessary that suitable plugs be provided to block the air cleaner system inlet and outlet. The air cleaner inlet plug should contain a suitable air connection and shutoff valve to maintain two pounds pressure in the air duct system. The outlet plug need only be of sufficient size to form a completely air-tight seal at the outlet end of the system. Then check the system as follows:

1. Remove the air inlet hood or pre-screener.

2. Insert the plug (with the fitting for the air hose) in the air cleaner inlet to form an air-tight seal.

3. Insert the other plug in the outlet end of the system to form an air-tight seal.

4. Attach an air hose to the plug in the air cleaner inlet and regulate pressure not to exceed 2 psi (14 kPa).

5. Brush a soapsuds solution on all air duct connections. Any opening which would allow dust to enter the engine can then be detected by the escaping air causing bubbles in the soapsuds solution. All leaks thus discovered should be remedied until the system checks "air-tight".

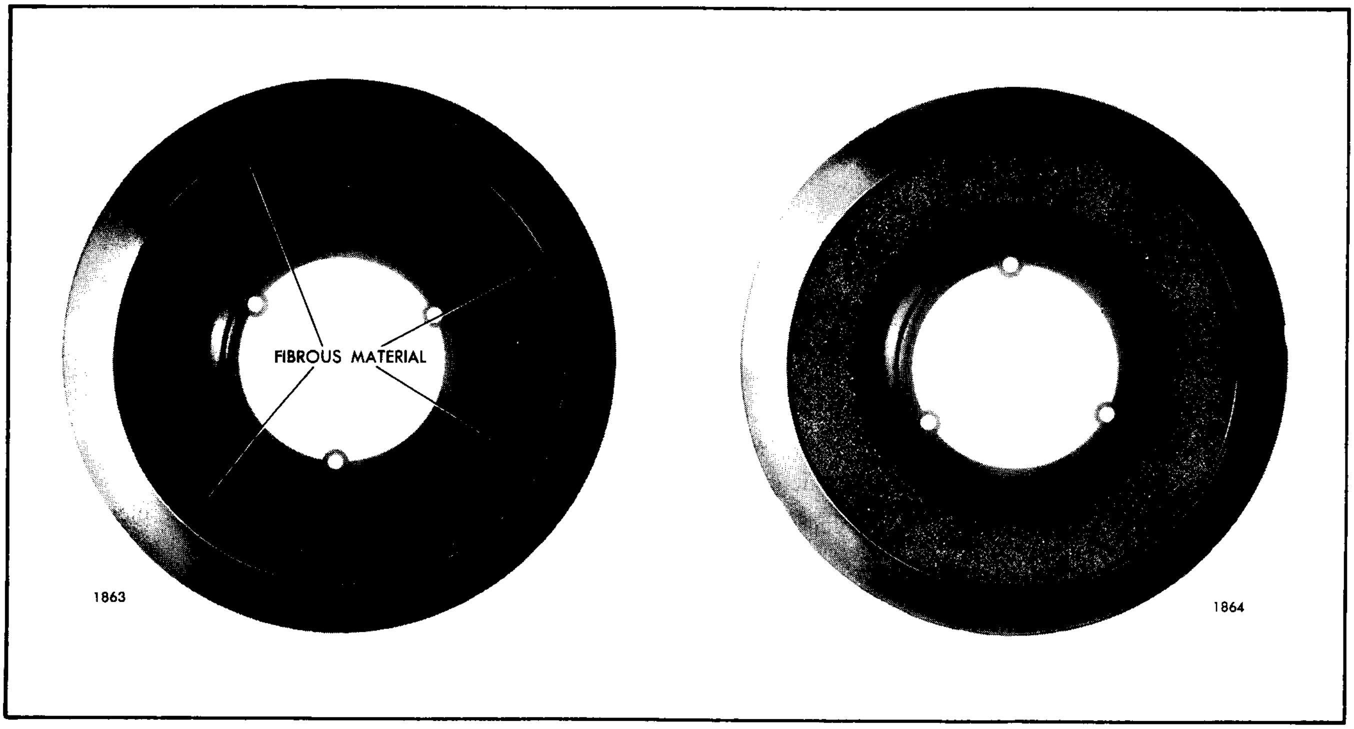


Fig. 4 · Comparison of Air Cleaner Trays

6. Remove plugs and install air inlet hood or pre-screener.

A rotational type of service program may be followed on heavy duty air cleaner installations that employ a main and after cleaner, in accordance with the following procedure, since the heaviest cleaning job is imposed upon the main cleaner.

1. Remove and clean the sump and removable screen of the main cleaner.

2. Check all joints and tubes of the main cleaner and ensure that they are air-tight.

3. Install the cleaned removable screen on the main cleaner.

4. Remove the sump of the after cleaner and install it on the main cleaner.

5. Remove and clean the removable screen of the after cleaner.

6. Check all joints and tubes of the after cleaner and ensure that they are air-tight.

7. Install the remaining screen and sump on the after cleaner.

The design and function of the heavy duty air cleaners is such that the fixed elements tend to be self-cleaning. However, it may be necessary, occasionally, to remove the entire cleaner from its mountings and clean these elements. If the fixed elements require too frequent cleaning, it is advisable to relocate the air intake to provide a cleaner air supply.

Proper selection of air cleaners and good air cleaner maintenance go "hand-in-hand" in providing long engine life and trouble-free operations.

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.

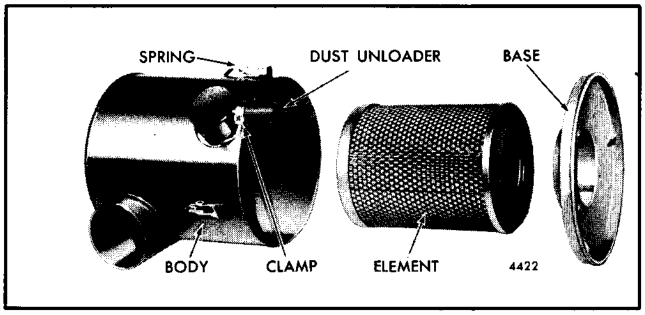


Fig. 5 - United Specialties Dry Type Air Cleaner

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 manintenance.

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.

NOTE: 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 or 689 kPa) 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.

NOTE: 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 or 689 kPa) 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 or 276 kPa) until the water runs clean to rinse all loosened foreign mataerial from the element. Shake out excess water from the element and allow it to dry thoroughly.

NOTE: 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.

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

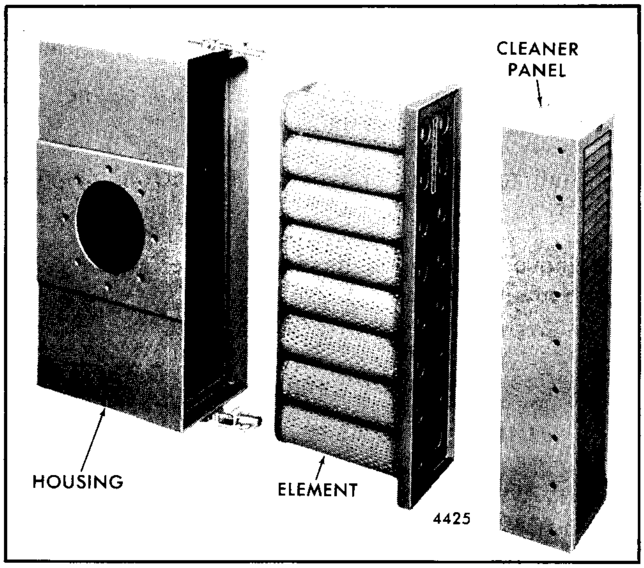


Fig. 6 - Farr Dry Type Air Cleaner

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 bypass 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.

DONALDSON AIR CLEANER

The Donaldson dry type air cleaners shown in Figs. 7, 8 and 9 are designed to provide highly efficient air filtration under all operating conditions. The cleaners have a replaceable impregnated paper filter element that can be cleaned.

The fins on the element give high speed rotation to the intake air, which separates a large portion of the dust from the air by centrifugal action. The plastic fins, the element and the gasket make up a single replaceable element assembly.

The dust is swept through a space in the side of the baffle and collects in the lower portion of the body or dust cup. The dust remaining in the precleaned air is removed by the element.

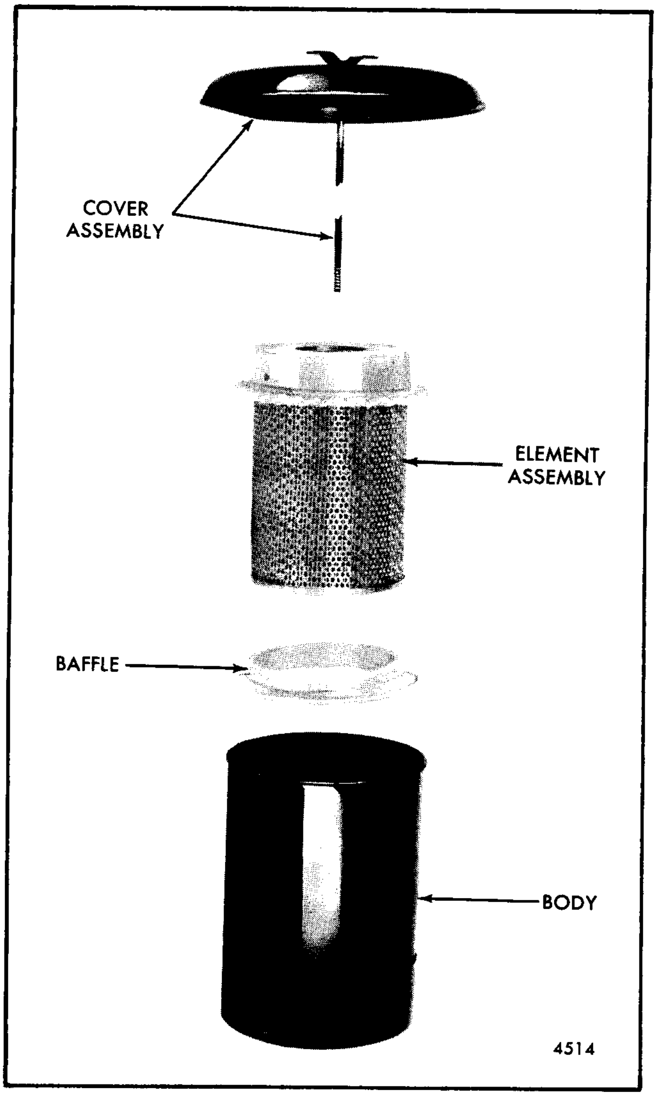


Fig. 7 - Dry Type Air Cleaner

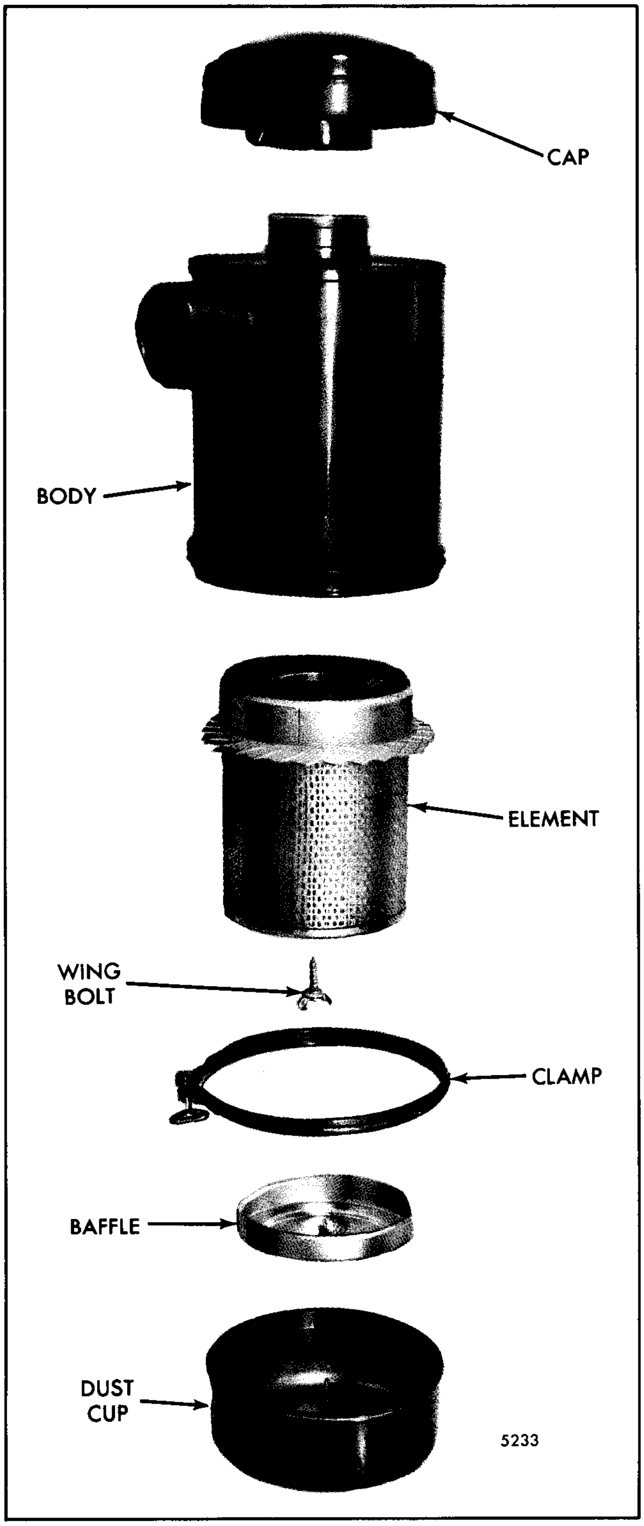


Fig. 8 - Dry Type Air Cleaner (Heavy Duty)

The dry type cleaner *cannot be used* where the atmosphere contains oil vapors, or fumes from the breather can be picked up by the air cleaner.

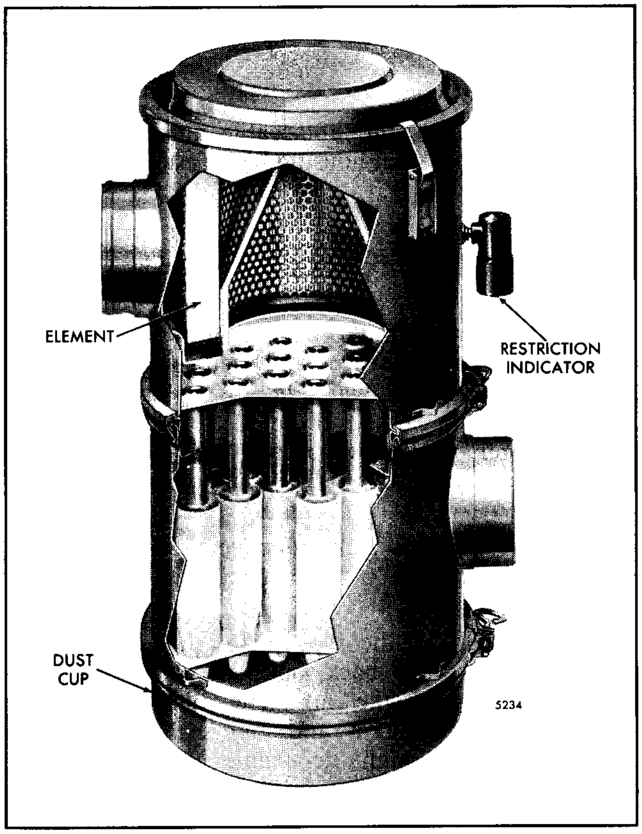


Fig. 9 - Dry Type Air Cleaner (Extra Heavy Duty)

Service (Dry Type)

The air cleaner should be serviced as operating conditions warrant. See Section 15.1 for element change intervals.

Under no engine operating conditions should the maximum allowable air intake restriction shown in Section 13.2 of the service manual be exceeded. Check restriction with a water manometer using the procedure outlined under "final RUN-IN" in Section 13.2.1. In addition, inlet restriction should be adjusted for high altitude conditions (see **Table 1**). A clogged air cleaner element will cause excessive intake restriction, reduce air supply to the engine, poor performance and higher valve and cylinder temperatures.

Disassemble the cleaner as shown in Fig. 7 as follows:

1. Loosen the cover bolt and remove the cover and bolt as an assembly.

2. Remove the element assembly and baffle from the cleaner body.

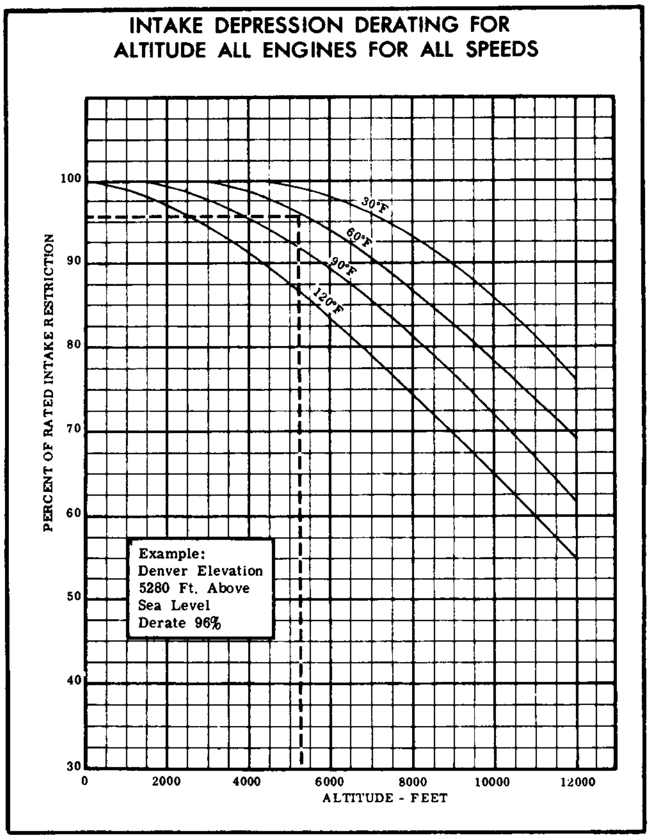


TABLE 1

3. Remove the dust and clean the cleaner body thoroughly.

Disassemble the cleaner in Fig. 8 as follows:

1. Loosen the dust cup clamp and remove the dust cup.

2. Loosen the wing bolt in the dust cup and remove the baffle from the dust cup.

3. Remove the wing bolt from the cleaner body and remove the element assembly.

4. Remove the dust and thoroughly clean the cleaner body, dust cup and baffle.

The paper pleated element assembly can be cleaned as follows:

NOTE: The pre-cleaning fins are not removable.

1. The element can be dry cleaned by directing clean air up and down the pleats on the clean air side of the element.

NOTE: Air pressure at the nozzle of the air hose must not exceed 100 psi (689 kPa). Maintain a reasonable distance between the nozzle and the element.

2. To wash the element, use the Donaldson Filter Cleaner or a non-sudsing equivalent. Proportions are 2 ounces of cleaner to 1 gallon of water. For best mixing results, use a small amount of cool tap water then add it to warm (100 °F or 38 °C) water to give the proper proportion. Soak the element for 15 minutes, then rinse it thoroughly with clean water from a hose (maximum pressure 40 psi or 135 kPa). Air dry the element completely before reusing (a fan or air draft may be used, but *do not heat* the element to hasten drying).

The filter manufacturer has no control over the field cleaning method or procedure. Therefore, it is the responsibility of the person or shop cleaning the element to assure the reliability of the filter after cleaning. It is also the responsibility of the installer to assure proper sealing of the gaskets.

Donaldson advises that elements used in on-highway applications should not be washed or reused. The reason for this is that on-highway trucks operate in an environment contaminated by a mixture of fine dust and exhaust carbon. To better enable dry type air cleaners to handle this type of contaminant, most on-highway truck air cleaners contain special chemically treated elements. Washing can remove the chemical treatment and shorten element life. Consequently, on-highway air cleaner elements should not be washed and reused.

Most Donaldson primary elements used in off-highway applications do not receive the same chemical treatment. These can be cleaned and reused according to the manufacturer's recommendations. Secondary (safety) elements should not be cleaned or reused.

3. Inspect the cleaned element with a light bulb after each cleaning. Thin spots, pin holes, or the slightest rupture will admit sufficient air borne dirt to render the element unfit for further use and cause rapid failure of the piston rings. Replace the element assembly if necessary.

4. Inspect the gasket on the end of the element. If the gasket is damaged or missing, replace the element.

Reassemble the air cleaner in reverse order of disassembly. Replace the air cleaner body gasket, if necessary.

NOTE: Do not use oil in the bottom of the cleaner body.

The element assembly should be replaced after six (6) cleanings, or annually.

Element Life

The recommended product life (shelf life plus service life) of Donaldson dry type air cleaner elements is three years. Consequently, Donaldson elements should be put into service no later than two years from the date of manufacture. Farr air cleaner elements should be put into service within one year from the date of manufacture.