DETROIT DIESEL

V-92 Service Manual

DETROIT DIESEL
CORPORATION

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FOREWORD

This manual contains instructions on the overhaul, maintenance and operation of the basic V–92 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 subassemblies 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 Corporation Service Outlet* for information on the latest revisions. The right is reserved to make changes at any time without obligation.

October, 1988

SCOPE AND USE OF THE MANUAL

This manual covers the basic V–92 diesel engines built by the Detroit Diesel 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 V–92 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 Fig. 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.

SERVICE PARTS AVAILABILITY

Genuine Detroit Diesel service parts are available from authorized Detroit Diesel 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 judgment 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

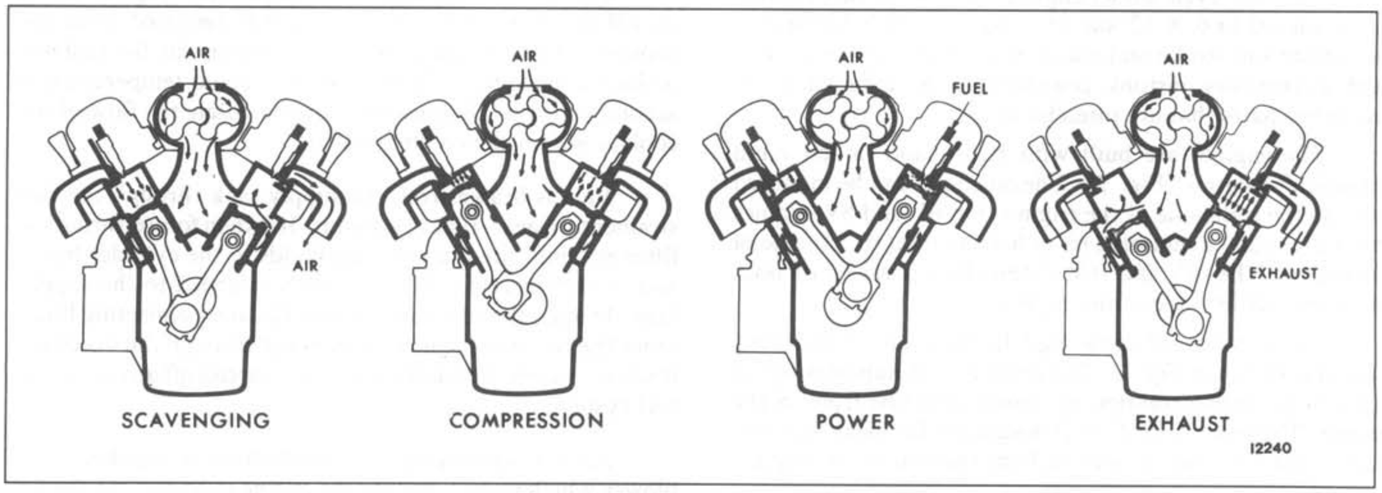


Fig. 1 – The Two-Stroke Cycle

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 (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 (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 (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 (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 fuel injected 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 (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".

GENERAL DESCRIPTION

The two–cycle diesel engines covered in this manual are produced in 6, 8, 12 and 16 cylinder models having the same bore and stroke and many of the major working parts such as injectors, pistons, connecting rods, cylinder liners and other parts that are interchangeable.

The engines are built with right–hand or left–hand crankshaft rotation (Fig. 2). The oil cooler can be mounted only on the right side of the engine. On 6V and 8V engines the starter can be mounted on either the right or left side of the engine. The 12V and 16V engines have a starter on both the right and left side of the engine.

The meaning of each digit in the model numbering system is shown in Fig. 2. 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 location of the starter and oil cooler as viewed from the rear of the engine.

Each engine is equipped with oil coolers, lubricating oil filters, fuel oil strainer, fuel oil filter, air cleaners, governor, heat exchanger and raw water pump or fan and radiator, and starting motor.

Full pressure lubrication is supplied to all main, connecting rod and camshaft bearings, and to other moving parts within the engine. A gear–type pump draws oil from the oil pan through an intake screen, through the oil filter, and then to the oil cooler. From the oil cooler, the oil flows through passages that connect with the oil galleries in the cylinder block and cylinder heads for distribution to the bearings, rocker arm mechanism and other functional parts.

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 radiator or heat exchanger. Control of the engine temperature is accomplished by thermostats which regulate the flow of the coolant within the cooling system.

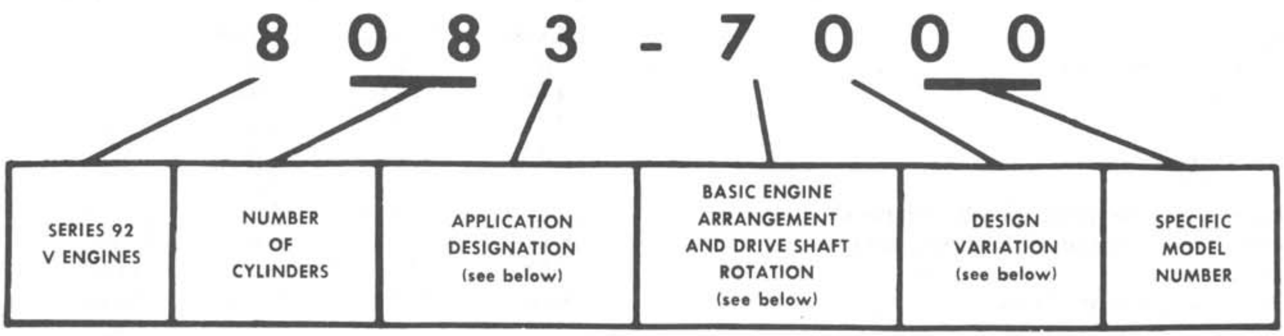
Fuel is drawn from the supply tank through the fuel strainer by a gear–type fuel pump. It is then forced through a filter and into the fuel inlet manifolds in the cylinder heads and to the injectors. Excess fuel is returned to the supply tank through the fuel outlet manifolds and connecting lines. Since the fuel is constantly circulating through the injectors, it serves to cool the injectors and also carries 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.

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

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

MODEL DESIGNATION



APPLICATION DESIGNATIONS:

8082-7000	MARINE
8083-7000	INDUSTRIAL F-F
8085-7000	GENERATOR
8087-7000	VEHICLE F-F
8088-7000	VEHICLE F-F

DESIGN VARIATIONS:

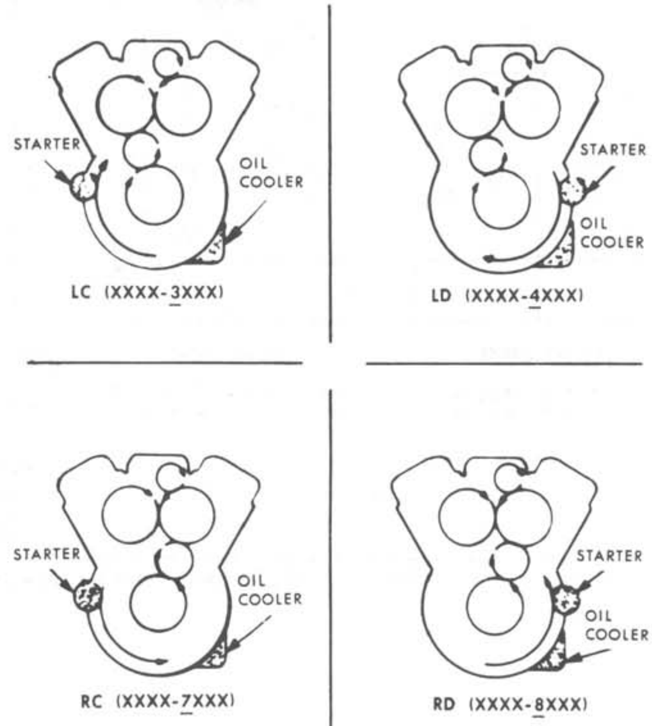
8083-7000	4 VALVE HEAD ENGINE
8083-7300	TURBOCHARGED ENGINE
8083-7400	AFTERCOOLED ENGINE
8083-7500	CUSTOMER SPECIAL ENGINE
8087-7700	CONSTANT HORSEPOWER (TT)
8087-7800	CONSTANT HORSEPOWER (TTA) (CALIFORNIA AND FEDERAL CERTIFIED)
8087-7A40	DDEC I (TA)
8087-7B40	DDEC II (TA)

BASIC ENGINE ARRANGEMENTS:

Rotation: L (left) and R (right) designates rotation viewed from the front of the engine.

Type: A-B-C-D designates location of starter and oil cooler as viewed from the rear (flywheel) end.

Cylinder Bank: Left and right cylinder banks are determined from rear of engine.



ALL ABOVE VIEWS FROM REAR OF ENGINE

L-11472

Fig. 2 – Model Numbering, Rotation and Accessory Arrangements

GENERAL SPECIFICATIONS

	6V	8V	12V	16V
Type	2 Cycle	2 Cycle	2 Cycle	2 Cycle
Number of Cylinders	6	8	12	16
Bore (inches)	4.84	4.84	4.84	4.84
Bore (mm)	123	123	123	123
Stroke (inches)	5	5	5	5
Stroke (mm)	127	127	127	127
Comp. Ratio (Nominal) (Turbo. Engines)	17 to 1	17 to 1	17 to 1	17 to 1
Comp. Ratio (Nominal) (N/A Engines)	19 to 1	19 to 1	19 to 1	19 to 1
Total Displacement – cubic inches	552	736	1104	1472
Total Displacement – liters	9.05	12.07	18.10	24.14
Number of Main Bearings	4	5	7	10

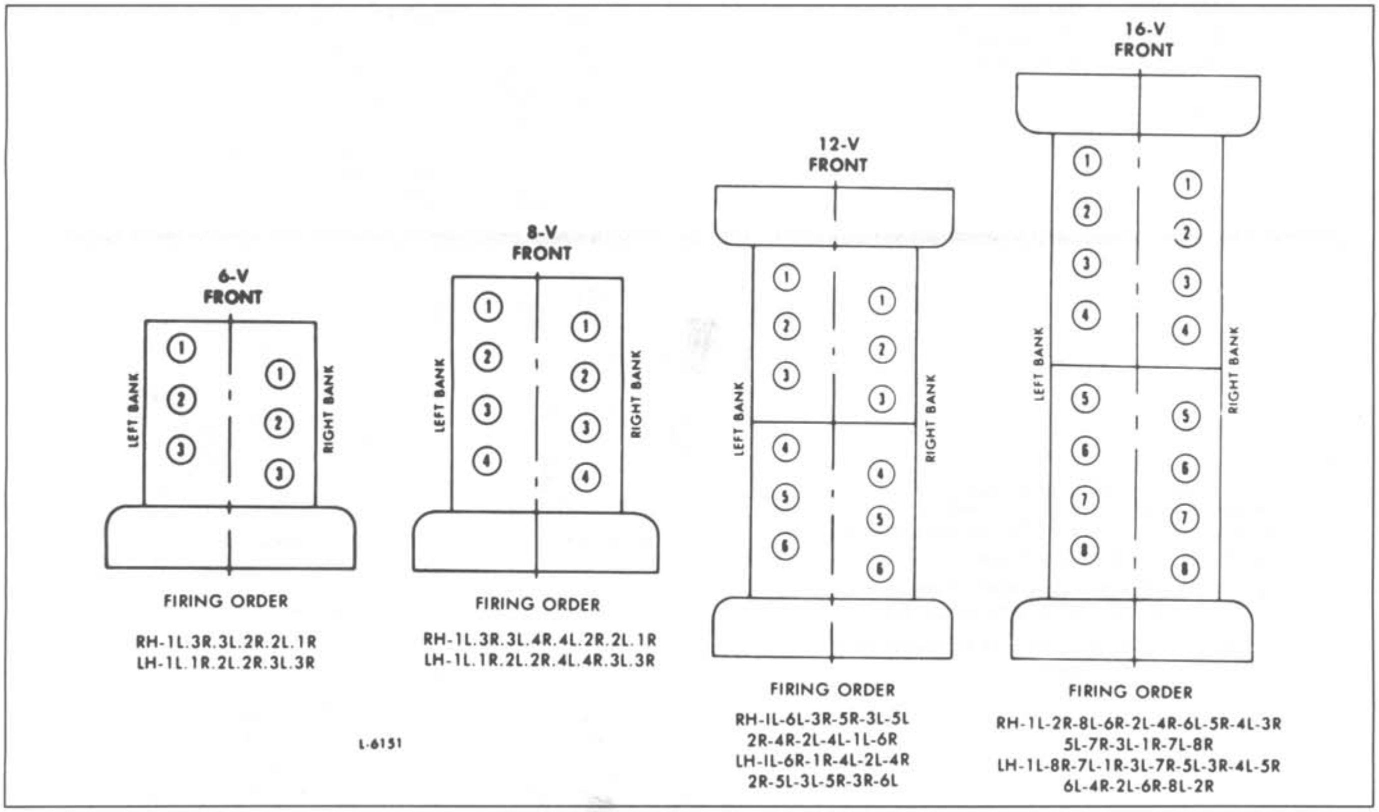


Fig. 3 – V–92 Engine Cylinder Designation and Firing Order

ENGINE MODEL, SERIAL NUMBER AND OPTION PLATE

The engine serial number and number are stamped on the upper right front corner of current 6V and 8V cylinder blocks (Fig. 4) and on the right rear side of current 12V and 16V blocks and *former* 6V and 8V blocks (Fig. 5).

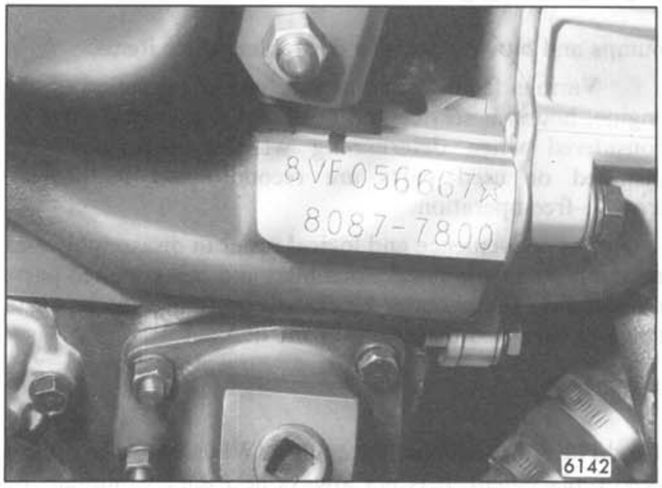


Fig. 4 – Typical 8V–92 Engine Serial Number and Model Number

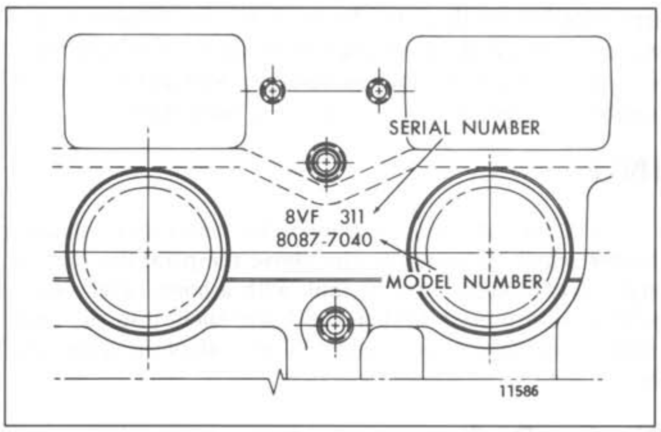


Fig. 5 – Typical Engine Serial Number and Model Number As Stamped on Cylinder Block

Option Plate (Metal Labels)

An option plate, attached to one of the valve rocker covers, carries the engine serial number and model number and, in addition, lists any optional equipment used on the engine (Fig. 6).

On–highway vehicle engines also carry an exhaust emission certification label next to the option plate. It is separate from the option plate and 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*

Fig. 6 – Option Plate

removed from the rocker cover. Refer to Section 14 for further information regarding emission 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 a unit are standard for the engine model unless otherwise listed on the option plate.

Power takeoff 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.

Option Plate (Paper Labels)

A new paper/laminate engine option label has replaced the metal option plate. In conjunction with the new option label, the following paper/laminate labels are also being used: **bar code labels** for engine serial number and customer specification number; **emissions label** (when applicable) and **disclaimer label**.

Distributors will provide their own label(s) in order to notify the customer of any distributor–made changes to Detrot Diesel–manufactured engines. Distributor–typed label(s) will indicate the distributor name, address and the group/type revisions that reflect their changes to engines as originally manufactured by Detroit Diesel.

Attaching Lables

Labels must be placed on rocker covers. Labels are designed to fit in the same space provided for the former stamped or current cast rocker cover option plate holder. Replacement option labels can be placed directly over existing option labels. *Make certain the labels are applied to clean, dry, oil–free surfaces to assure adhesion and retention.* Laminate should completely cover the label to provide a good seal.

The option plate holder on cast rocker covers is held to the cover by rivets in blind holes. Therefore, the option plate holder can be removed and the labels applied directly to the rocker covers. The option plate holder on stamped rocker covers is retained by spot welding. This option plate holder should not be removed, since it can leave open holes which will allow the leakage of lube oil.

NOTICE: Extreme heat from components such as turbocharger exhaust piping can cause the labels to darken, discolor or deteriorate over a period of time. Therefore, labels should be installed at alternate rocker cover locations.

GENERAL PROCEDURES

In many cases, a service technician is justified in replacing parts with new material rather than attempting repair. However, there are times where a slight amount of reworking or reconditioning may save a customer considerable added expense. Crankshafts, cylinder liners and other parts are in this category. For example, if a cylinder liner is only slightly worn and within usable limits, a honing operation to remove the glaze may make it suitable for reuse, 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. On engines cooled by a heat exchanger, the fresh water system and raw water system must both be drained. Lubricating oil should also be drained from any transmission attached to the engine.

To perform a major overhaul or other extensive repairs, the complete engine assembly, after removal from the engine base and drive mechanism, should be mounted on an engine overhaul stand; then the various 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.

Tank Cleaning

A tank of sufficient size to accomodate 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 alkaline cleaner 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 the 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, 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. 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 when specifically stated in the manual.*

WORK SAFELY

A service technician 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, in the case of vehicle application, by being bumped by another vehicle is minimized.

Some Safety Precautions To Observe When Working On The Engine

1. Consider the hazards of the job and wear protective gear such as safety glasses, safety shoes, hard hat, etc. to provide adequate protection.
2. When lifting an engine, make sure the lifting device is fastened securely. Be sure the item to be lifted does not exceed the capacity of the lifting device.
3. Always use caution when using power tools.
4. When using compressed air to clean a component, such as flushing a radiator or cleaning an air cleaner element, use a safe amount of air. Recommendations regarding the use of air are indicated throughout the manual. Too much air can rupture or in some other way damage a component and create a hazardous situation that can lead to personal injury.
5. Avoid the use of carbon tetrachloride, carbon disulfide, methylene, chloride, perchloroethylene and trichloroethylene as cleaning agents because of harmful vapors they release. Use 1,1,1–Trichloroethane. However, while less toxic than other chlorinated solvents, use it with caution. Be sure the work area is adequately ventilated and use protective gloves, goggles or face shield and an apron.

Exercise caution against chemical burns when using acids (Oxalic, phosphoric and nitric) and alkaline cleaners. Use protective gloves, goggles or face shield and an apron.

CAUTION: Mineral spirits or mineral spirits based solvents are highly flammable. They must be stored and used in "No Smoking" areas away from heat, sparks and open flames.

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.

FABRICATING, ALTERING, REMOVING AND DISPOSING OF GASKETS

Many gasket materials contain bonded asbeston, which in itself presents no health hazard when handled properly. A health hazard may exist, however, if the asbestos in such materials is liberated and becomes airborne. This may occur if gaskets are fabricated or altered using the following improper methods: drilling, grinding, saw cutting or using practically all types of power operated machines and hand tools.

Gasket manufacturers and industrial hygienists prescribe specific methods for handling gasket material. The following guidelines are based on their recommendations. Detroit Diesel recommends that these guidelines be followed when fabricating or altering any gaskets.

1. Unless it is known otherwise, treat all gasket material as though it contains asbestos.
2. When cutting strips or blocks from sheets (blanking), hand cut with scissors, knife or paper cutter. Avoid creating dust.
3. Form outside dimensions with a punch die or hand cut with scissors, knife or compass.
4. For internal hubs use a punch die, hand cut with scissors, knife or compass, or punch by hand with a ballpeen hammer or ball bearing.
5. When stripping gaskets from parts, do not grind or file off the material or abraid it off with a wire brush or

CAUTION

CONTAINS ASBESTOS

AVOID OPENING OR BREAKING CONTAINER

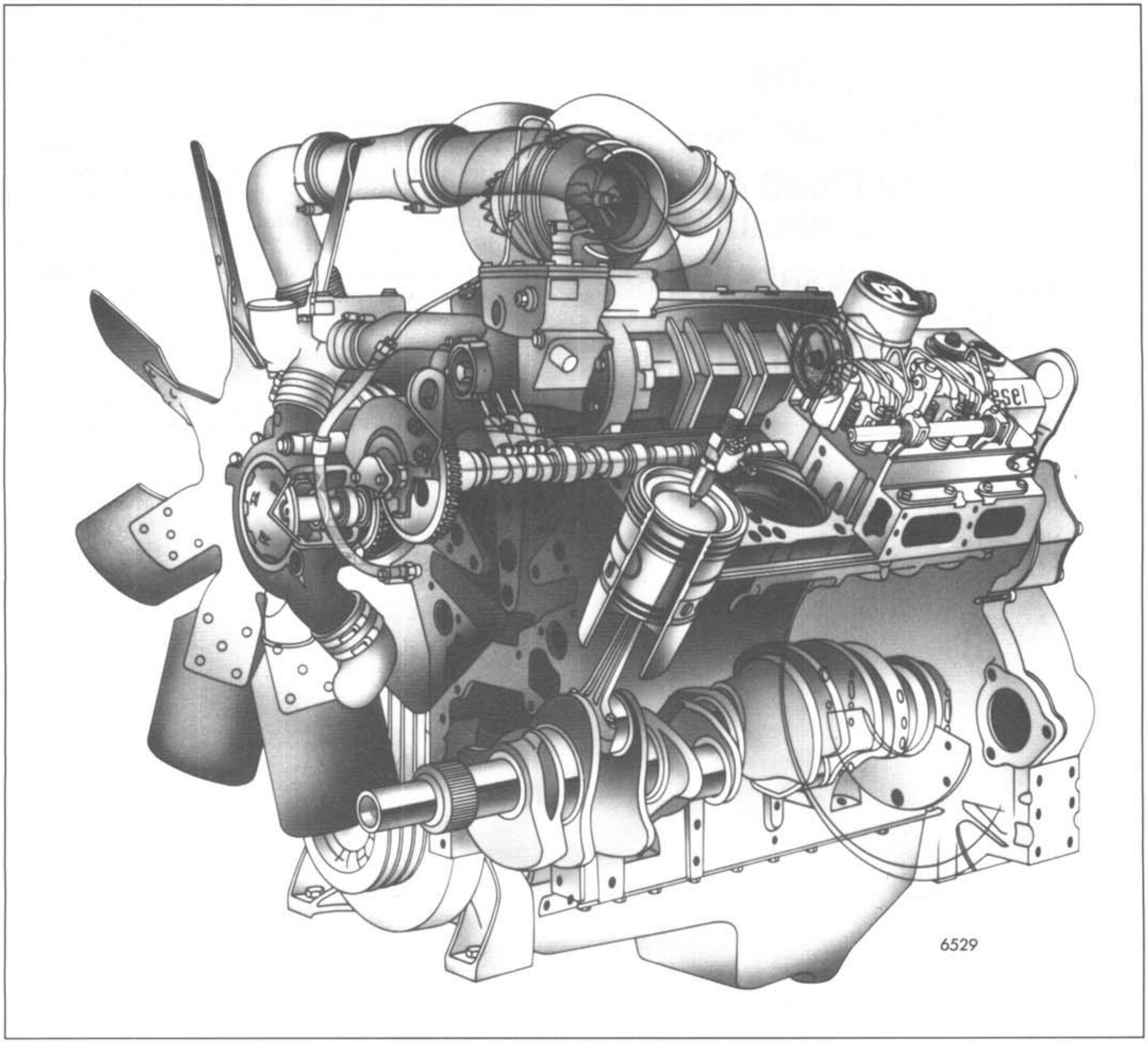
BREATHING ASBESTOS IS HAZARDOUS TO YOUR HEALTH

DATE FILLED ____________

Fig. 6 – Caution Label

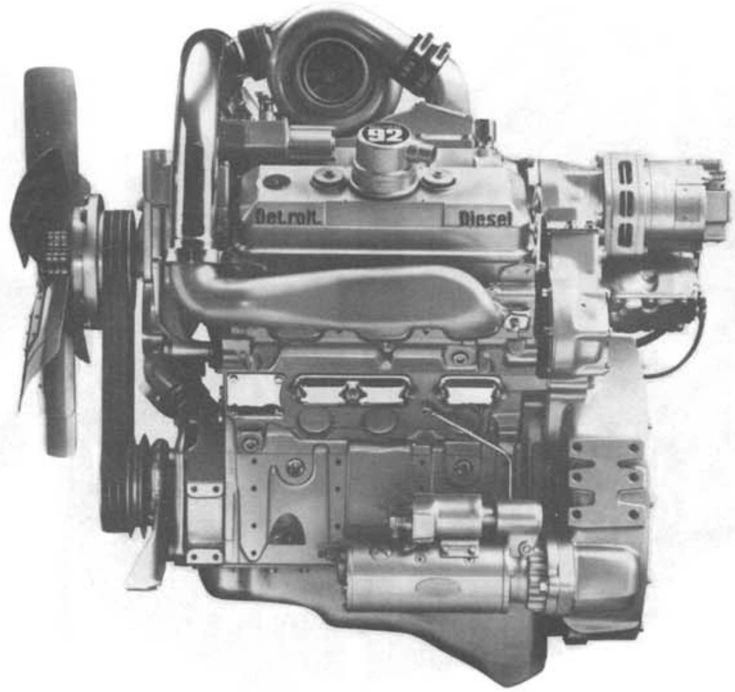
5. When stripping gaskets from parts, do not grind or file off the material or abraid it off with a wire brush or wheel. Use a putty knife to remove the gasket after it has been wetted with water or oil.
6. After fabricating or altering a gasket, clean the area to remove any particles which may have been generated. This should be done by wiping the area with a rag wetted with water or a water–based detergent. If large areas need to be cleaned, remove gasket dust and debris using an "HEPA" (High Efficiency Particulate Arrestor) vacuum cleaner. Do not clean the area by blowing with compressed air or brushing.

Place the rags containing the waste and any scrap gasket material in an impervious container labeled with the OSHA (Occupational Health and Safety Administration) designated caution (Fig. 6) and dispose of it in a solid waste disposal facility (land fill) which will accept asbestor material. Heavy plastic garbage bags (6 mills thick), each sealed separately, or other closed and impermeable container may be used.



Three-Quarter Cutaway View (8V-92)

6V-92



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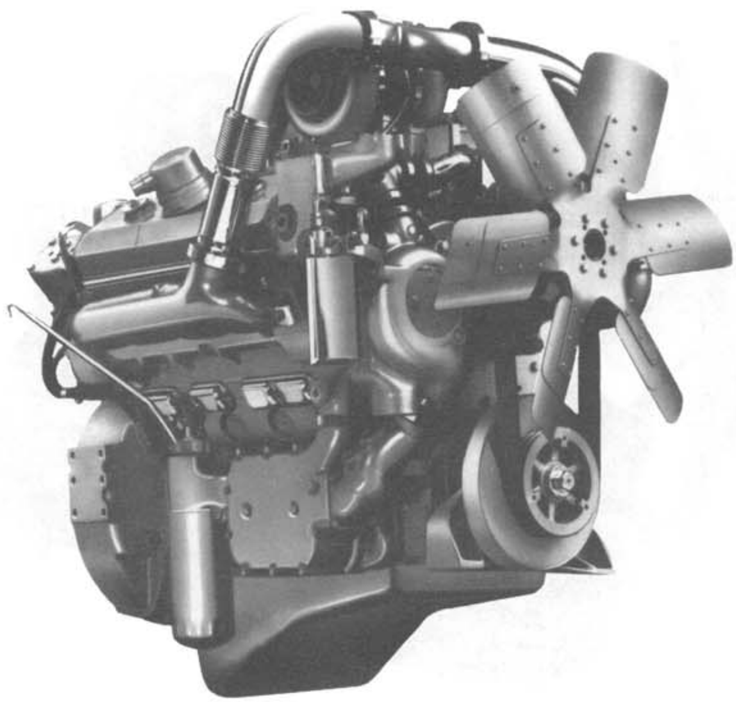
8V-92



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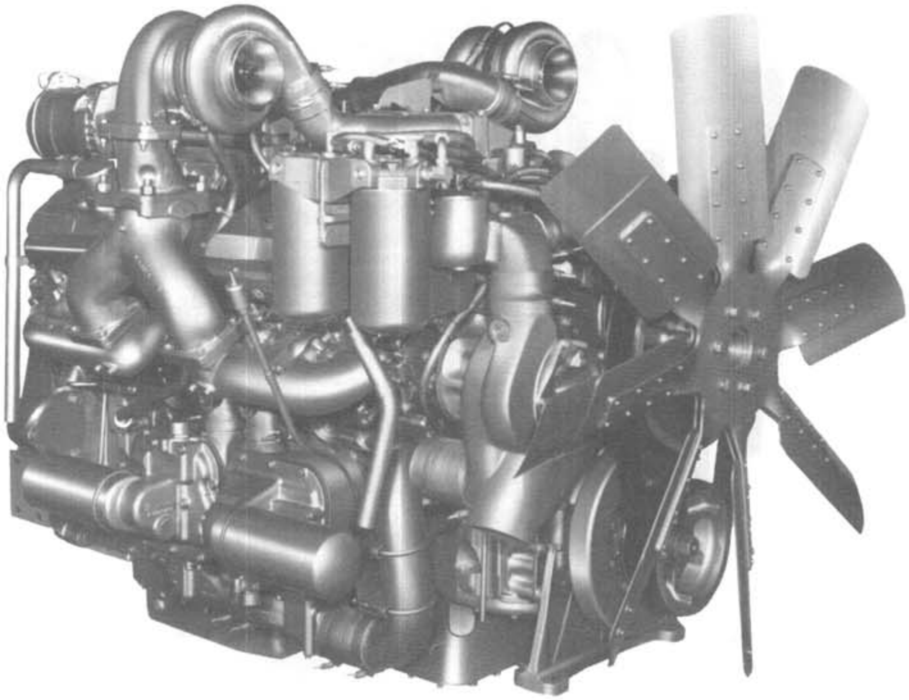
Typical Turbocharged Engines

12V-92



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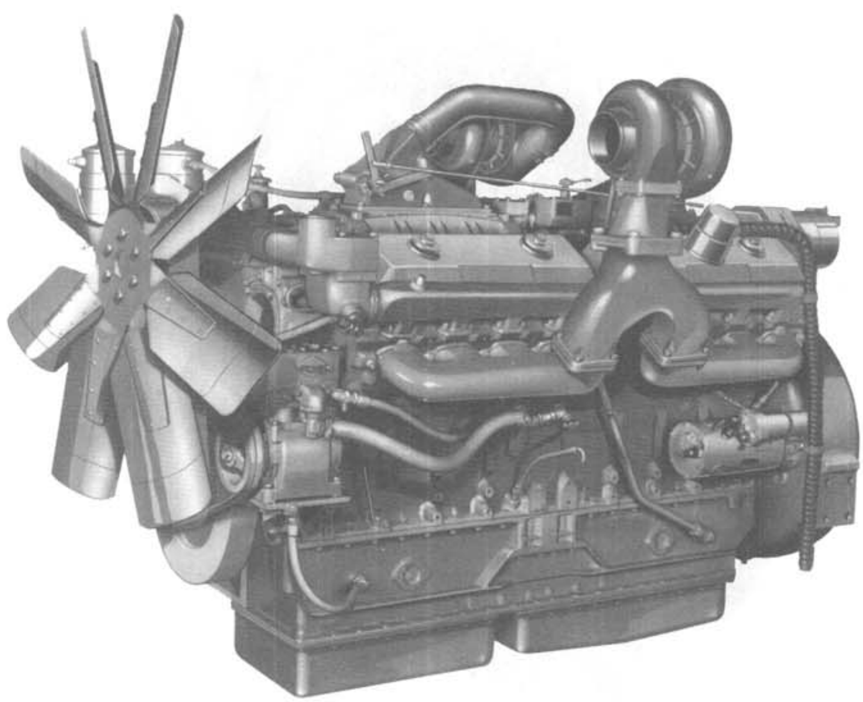
16V-92



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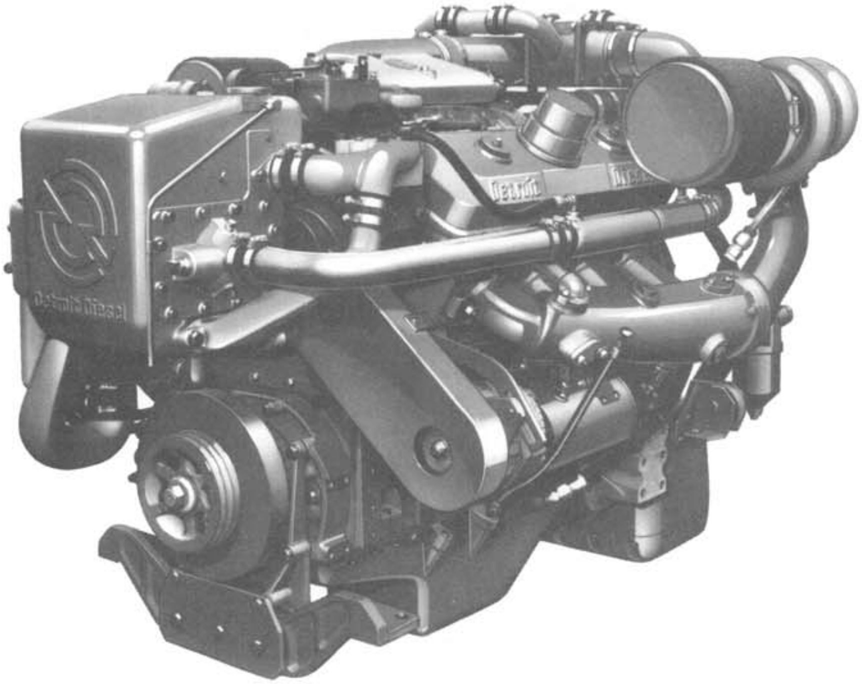
Typical Turbocharged Engines



8V-92

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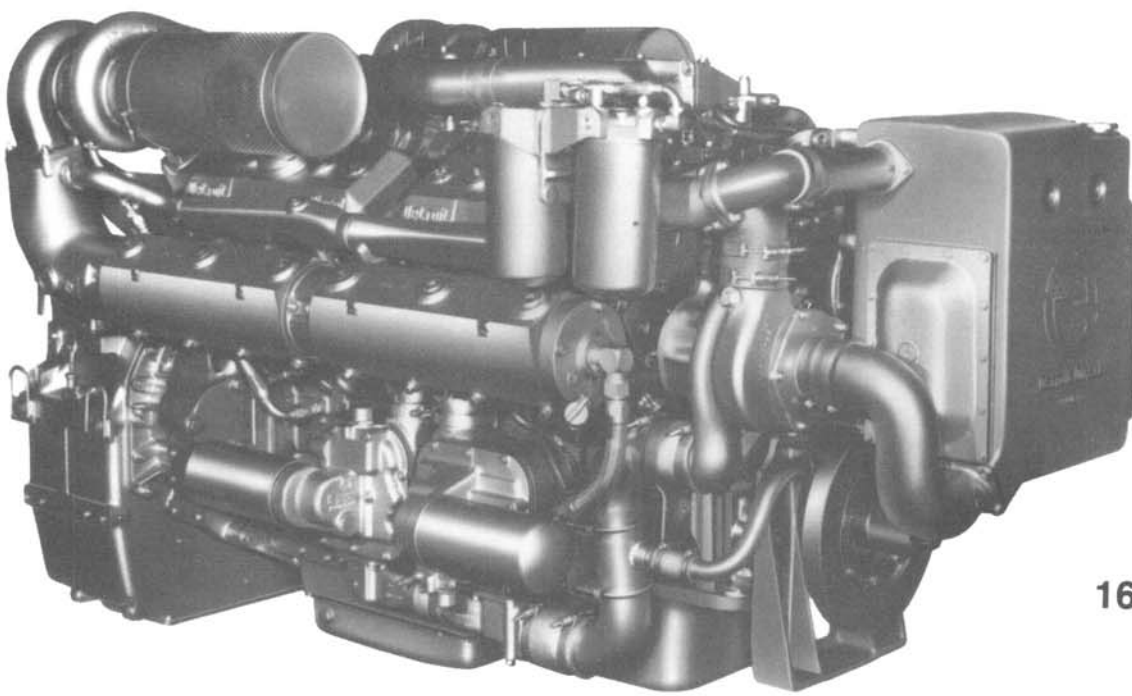

16V-92

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Typical Turbocharged Marine Engines

SECTION 1

ENGINE (LESS MAJOR ASSEMBLIES)

CONTENTS

JACOBS BRAKE SERVICE

Service, if required, is available from a worldwide organization of Jacobs Brake distributors. Their locations are provided in a service directory available from authorized Detroit Diesel service outlets under form number 20SE75, or from:

The Jacobs Manufacturing Co.
Bloomfield, Conn. 06002

CYLINDER BLOCK

The cylinder block serves as the main structural part of the engine (Fig. 1). Transverse webs provide rigidity and strength and ensure alignment of the block bores and bearings under load.

The cylinder block is a wet type above the cylinder liner ports and a dry type below the cylinder liner ports. The water jacket and air box are sealed off by two seal rings compressed between the cylinder liner and the grooves in the block.

An air box between the cylinder banks and extending around the cylinders at the air inlet port belt conducts the air from the blower to the cylinders. Air box openings on each side of the block permit inspection of the pistons and compression rings through the air inlet ports in the cylinder liners. The air box openings in the cylinder block assembly are approximately 1 7/8" x 3 1/8" and are covered with cast covers.

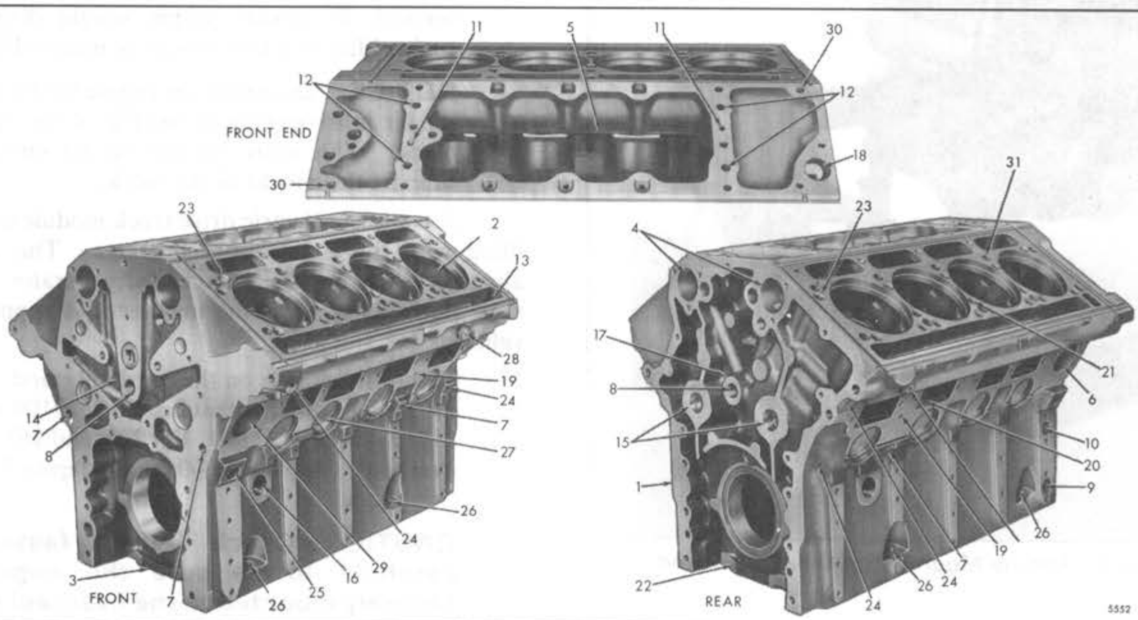
To prevent leakage at the air box covers, new gaskets and bolts are now being used. The new polyacrylic and cork gaskets replace the former asbestos gaskets. The new lock and seal coated bolt replaces a stud, nut, flat washer and lock washer.

The former and new gaskets are interchangeable on an engine, but only the new gaskets are serviced.

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 forexternal piping.

The top surface of each cylinder bank 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. The same size seal rings are used at all counterbored oil and water holes in the cylinder block.



1. Cylinder Block
2. Bore for Cylinder Liner
3. Front Main Bearing Cap
4. Bores for Camshafts
5. Air Box
6. Water into Block
7. Water Drain
8. Main Oil Gallery
9. Oil Passage from Pump to Oil Filter
10. Oil Passage from Oil Cooler to Engine
11. Oil Supply Passages to Blower
12. Oil Drain Passages from Blower
13. Oil Drain from Cylinder Head
14. Oil Drain Passages
15. Oil Passage (Idler Gear Bearing)
16. Oil Return Passages to Crankcase
17. Crankcase Breather Cavity
18. Crankcase Breather Outlet
19. Air Box Drain
20. Inspection Hole Opening
21. Water Passages to Cylinder Head
22. Rear Main Bearing Cap
23. Oil Passage to Cylinder Head
24. Oil Gallery
25. Oil Gallery
26. Dipstick Hole or Oil Return Passage to Crankcase
27. Core Hole for Water Jacket
28. Water Jacket Drain-Rear
29. Water Jacket Hole
30. Oil Gallery Passage to End Bearing
31. Cylinder Head Bolt Hole

Fig. 1 – Cylinder Block (8V–92 Engine)

Each cylinder liner is retained in the block by a flange at its upper end. The liner flange rests on an insert located in the counterbore in the block bore. An individual compression gasket is used at each cylinder.

When the cylinder heads are installed, the compression gaskets compress sufficiently to form a tight seal between the heads and the cylinder block.

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 provides a convenient support when stripping a cylinder block (Fig. 2). 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.

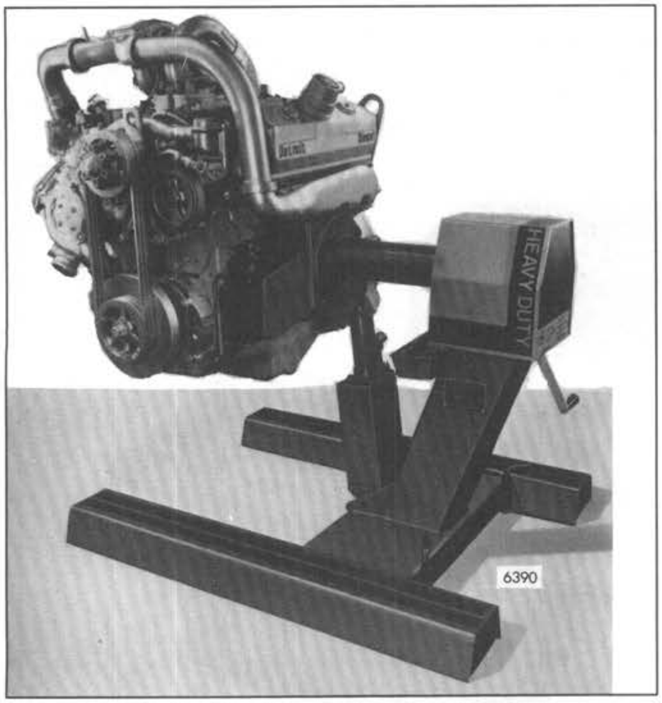


Fig. 2 – Engine Mounted on Overhaul Stand

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 cleaner and mounting brackets.
5. Remove the turbocharger, if used.
6. Disconnect the exhaust piping and remove the exhaust manifolds.
7. Disconnect the throttle controls.
8. Disconnect and remove the starting motor, battery–charging alternator and other electrical equipment.
9. Remove the air compressor, if used.
10. Remove the radiator and fan guard and other related cooling system parts.
11. Remove the air box drain tubes and fittings.
12. Remove the air box covers.
13. Disconnect any other lubricating oil lines, fuel lines or electrical connections.
14. Separate the engine from the transmission or other driven mechanism.
15. Remove the engine mounting bolts.
16. Use a spreader bar with a suitable sling and adequate chain hoist to lift the engine from its base (Fig. 3). 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.

    NOTICE: Do not lift the engine by the webs in the air inlet opening at the top of the cylinder block. The webs are not strong enough to support the weight of the block.

A complete electric drive truck module must never be lifted with the engine lifter brackets. This could effect alignment between the engine and generator. A module must be lifted in the same manner it is supported in the vehicle.

17. Mount the engine on the overhaul stand. For 6V and 8V engines, use overhaul stand J 29109 with adaptor J 8601–01 or J 33850. For 12V and 16V engines, use overhaul stand J 9389–04 and adaptor J 8650.

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

18. With the engine mounted on the overhaul stand, remove all of the 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.

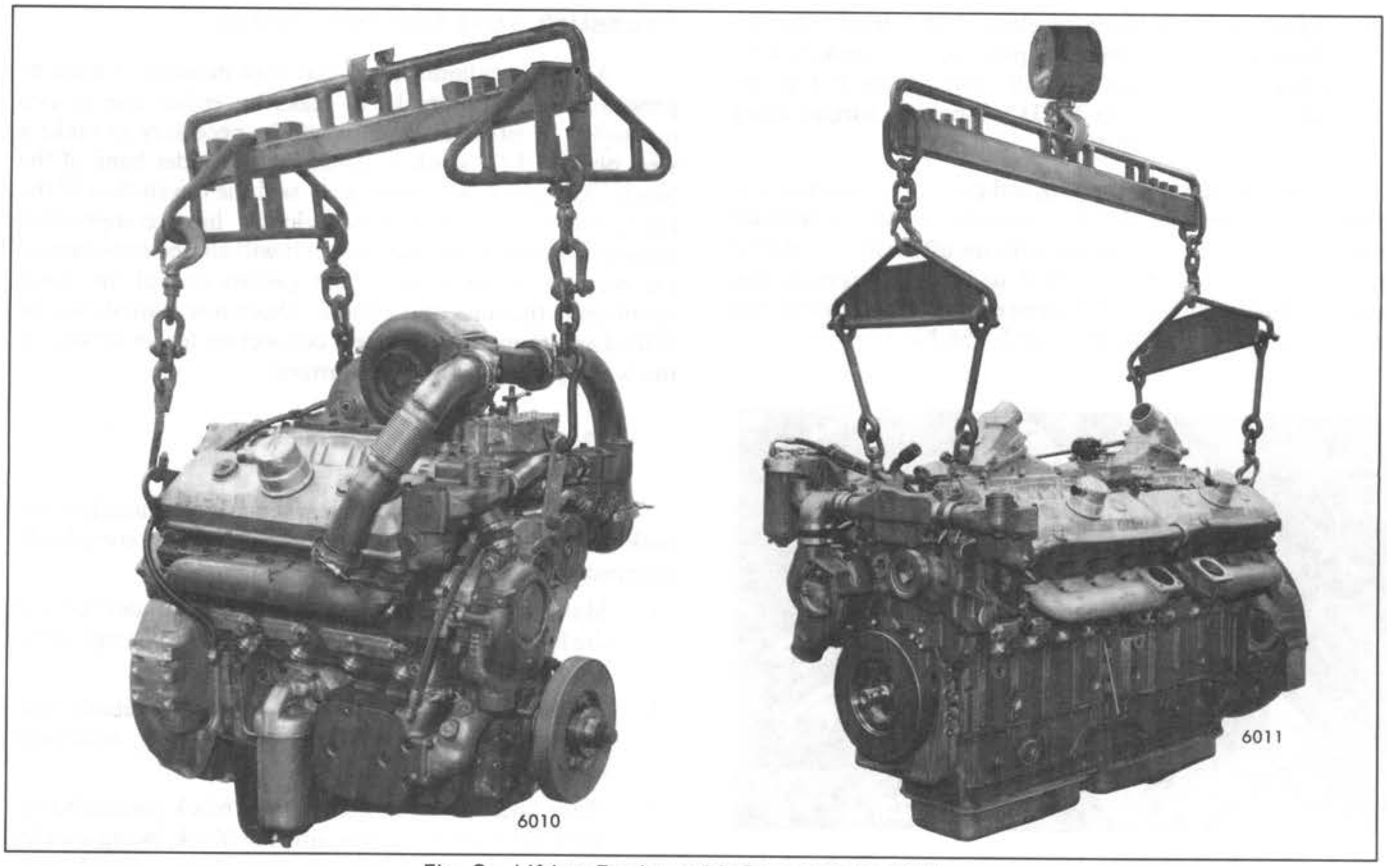


Fig. 3 – Lifting Engine with Spreader and Sling

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

Clean Cylinder Block

Scrape all gasket material from the cylinder block. Then remove all oil gallery plugs and core hole plugs (except cup plugs) to allow the cleaning solution to contact the inside of the oil and water passages. This permits more efficient cleaning and eliminates the possibility of the cleaning solution attacking the aluminum core hole plug gaskets.

If a core hole plug is difficult to remove, hold a 3/4" drift against the plug and give it a few sharp blows with a one pound hammer. With a 1/2" flexible handle and a short extension placed in the countersunk hole in the plug, turn the plug slightly in the direction of tightening. Then turn it in the opposite direction and back the plug out.

Clean the cylinder block as follows:

1. Remove the grease by agitating the cylinder block in a hot bath of commercial heavy–duty alkaline cleaner solution.
2. Rinse the block in hot water or steam clean it to remove the alkaline cleaner solution.
3. If the water jackets are heavily scaled, proceed as follows:
   a. Agitate the block in a bath of inhibited phosphoric acid.
   b. Allow the block to remain in the acid bath until the bubbling stops (approximately 30 minutes).
   c. Lift the block, drain it and reimmerse it in the same acid solution for ten (10) minutes.
   d. Repeat Step "C" until all scale is removed.
   e. Rinse the block in clear hot water to remove the acid solution.
   f. Neutralize the acid that may cling to the casting by immersing the block in an alkaline bath.
   g. Wash the block in clean water or steam clean it.
4. Dry the cylinder block with compressed air.

CAUTION: To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.

5. Make certain that all water passages, oil galleries and air box drain openings have been thoroughly cleaned. The above cleaning procedure may be used on all ordinary cast iron and steel parts of the engine. Mention will be made of special cleaning procedures whenever necessary.

6. After the block has been cleaned and dried, coat the threads of the air box core plugs and the gaskets with clean engine oil and reinstall. Tighten the 2 1/2"–16 plugs to 230–270 lb–ft (312–366 Nm) torque using plug installer J 23019.

A water inlet adaptor plug and gasket replaces the rear (flywheel housing end) 2 1/2" core hole plug in the cylinder block air box floor on engines with an aftercooler (refer to Section 3.5.3). Use tool J 25275 to install or remove the adaptor plug. Lubricate with clean engine oil and tighten the adaptor plug to 230–270 lb–ft (312–366 Nm) torque.

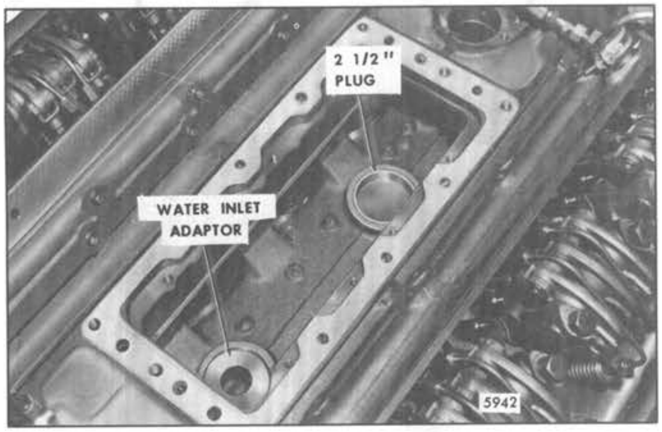


Fig. 4 – Installing Aftercooler Water Plug

When a new service cylinder block is used for an aftercooled engine, it will be necessary to remove the 2 1/2" plug in the rear core hole in the bottom of the air box and the 2 1/4" plug in the top deck of the block in front of the blower mounting pad (Fig. 4). Then, install the water inlet adaptor in the rear air box hole and the water outlet elbow and gasket in the opening in the top deck of the block.

NOTICE: Excessive torque applied to tapered pipe plugs may result in cracks in the water jacket.

The 2 1/2" cup plug and the solid aftercooler inlet adaptor will remain available to service the blocks.

If for any reason the cup plugs in the water jackets were removed, install new plugs as follows:

a. Clean the cup plug holes and apply Loctite Pipe Sealant with Teflon® (J 26558), or equivalent, to the outer diameter of the plugs.

b. Drive the plugs in place with handle J 7079–02 and adaptor J 24597 (2 1/2" diameter cup plugs – Fig. 4) or adaptor J 21850 (1 5/8" diameter cup plugs).

c. Drive the aftercooler adaptor plug in place, using tool J 28711.

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. The plates will adequately seal the top surface of the block when used with new cylinder 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 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 jackets can be pressurized.

METHOD "A"

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

1. Make sure the seal ring grooves in the cylinder bores of the block are clean. Then, install new seal rings in the grooves (above the air inlet ports).
2. Apply a light coating of hydrogenated vegetable type shortening or an ethylene glycol base antifreeze solution to the seal rings.
3. Place liner inserts in the cylinder block counterbores. 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 block.
4. Secure the plates to the block with 11/16"–11 bolts and flat washers. Tighten the bolts to 250–260 lb–ft (339–352 Nm) torque.
5. Seal off the water inlet and outlet holes air tight. This can be done by using steel plates and suitable *rubber gaskets* held in place by bolts. Drill and tap one cover plate to provide a connection for an air line. A new service tool (J 29592) has been released to aid in pressure testing the aftercooled engine cylinder blocks. When properly installed, the new tool seals off the aftercooler water inlet adaptor plug in the air box floor.
6. Immerse the block for twenty (20) minutes in a tank of water heated to 180°–200°F (82°–93°C).
7. Apply 40 psi (276 kPa) air pressure to the water jackets and observe the water in the tank for bubbles which will indicate the presence of cracks or leaks in the block. A cracked cylinder block must be replaced by a new block.
8. After the pressure test is completed, remove the block from the water tank. Then remove the plates, gaskets, liners and inserts and blow out all of the passages in the block with compressed air.
9. Dry the cylinder liners and inserts with compressed air and coat them with oil to prevent rust.

CAUTION: To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.

METHOD "B"

This method may be used when a large water tank is unavailable, or when it is desired to check the block for cracks without removing the engine from the equipment which it powers. However, it is necessary to remove the cylinder heads, blower, oil cooler, air box covers and oil pan.

1. Attach sealing plates and gaskets as in Method "A". However, before attaching the last 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.

   NOTICE: Do not use a methoxy propanol base antifreeze as it is detrimental to the water seals.

2. Install the remaining sealing plate and tighten it securely.
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 the 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 and inserts with compressed air and coat them with oil to prevent rust.

CAUTION: To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.

Inspect Cylinder Block

After cleaning and pressure testing, inspect the cylinder block.

Since most of the engine cooling is accomplished by heat transfer through the cylinder liners to the water jacket, a good liner–to–block contact must exist when the engine is operating. Whenever the cylinder liners are removed from an engine, the block bores must be inspected.

1. Check the cylinder block bores:
   a. Measure the bore of each cylinder with cylinder bore gage J 5347–B which has a dial indicator calibrated in .0001" increments. Dial bore gage setting master tool J 23059–01 may be used for setting the cylinder bore gage. Make sure the seal ring grooves in the cylinder block bores are thoroughly clean. Then, inspect the grooves and lands for evidence of pitting and erosion. Seal rings are used in the two grooves above the air inlet ports. If the grooves are eroded to the extent that sealing is affected, the block must be replaced.
   b. Measure each cylinder block bore, at the positions indicated in Fig. 5, on axis 90° apart. If the diameter does not exceed 5.3620" (new) or 5.3635" (used) at position "A", 5.3385" (new) or 5.3395" (used) at position "B" (lower two seal ring lands), 5.2175" (new) or 5.2185" (used) at position "C" and 5.2180" (new) or 5.2185" (used) at position "D", and a sealing problem has not occurred at position "B", the block may be reused. The above measurements are average gage readings at each position. Also, the taper and out–of–roundness must not exceed .0010".

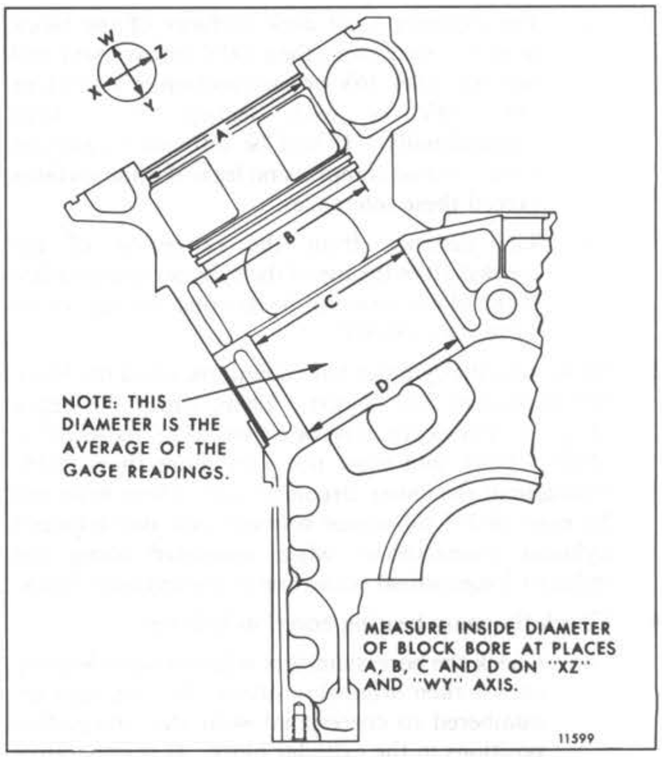


Fig. 5 – Cylinder Block Bore Measurement Diagram

At time of major engine overhaul, the cylinder block bore measurements should be made with the block flat on the floor rather than on an engine overhaul stand. The main bearing caps should also be in place and the bolts torque to 230–240 lb–ft (312–325 Nm).

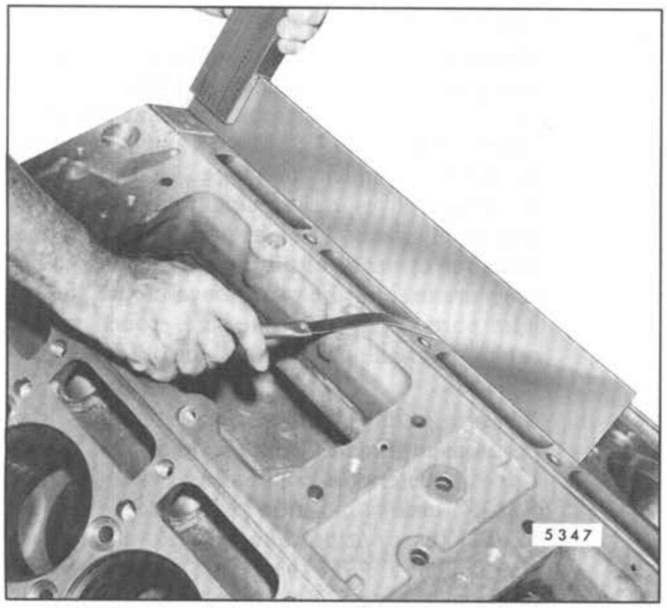


Fig. 6 – Checking Top Surface of Cylinder Block

2. Check the top of the block (cylinder head contact surfaces) for flatness with an accurate straight edge and a feeler gage (Fig. 6).
   a. The cylinder head deck surfaces of the block must not vary more than .003" transversely and not over .006" (6V or each section of a 12V), or .007" (8V or each section of a 16V) longitudinally. It will be difficult to prevent water, oil and compression leaks if these surfaces exceed these tolerances.
   b. The distance from the centerline of the crankshaft to the top of the cylinder head surface of the block must not be less than 16.184" or no more than 16.189".
3. Make sure the cylinder liner counterbores in the block are clean and free of dirt. Then, check the depth (Fig. 7). The depth must be either .4755" to .4770" or .4905"–.4920" and must not vary more than .0015" throughout the entire circumference. There must not be over .0015" 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

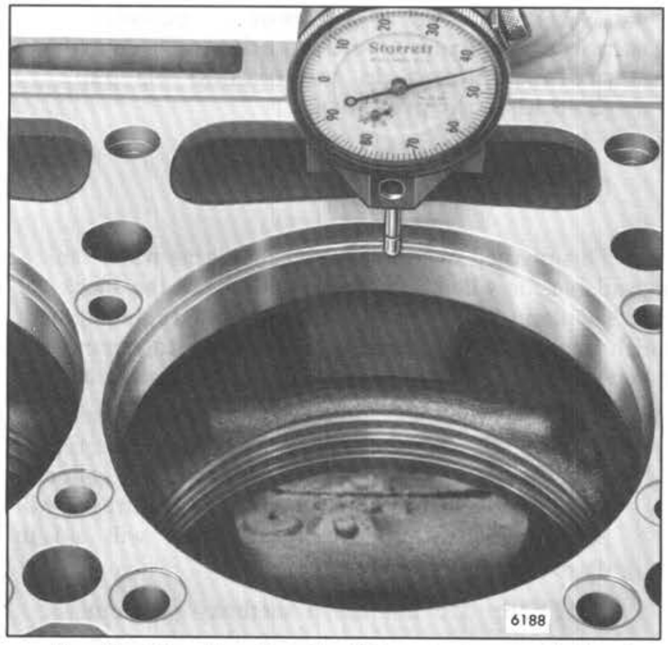


Fig. 7 – Checking Depth of Counterbore with Tool J 22273

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. 8). Lubricate the bolt threads and bolt head contact areas with a small quantity of International Compound No. 2, or equivalent. Main bearing cap bolts are especially designed for this purpose and must not be replaced by ordinary bolts. Then, install and tighten the 11/16"–11 bolts to 230–240 lb-ft (312–325 Nm) torque. When making this check, do not install the main bearing cap stabilizers. The specified bore diameter is 4.812" to 4.813". If the bores do not fall within these limits, the cylinder block must be rejected.

At time of major engine overhaul, the cylinder block main bearing bore measurements should be made with the block in an *upside down* position on the floor rather than on an engine overhaul stand.

   b. Finished and unfinished main bearing caps are available for replacing broken or damaged caps. 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. 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.

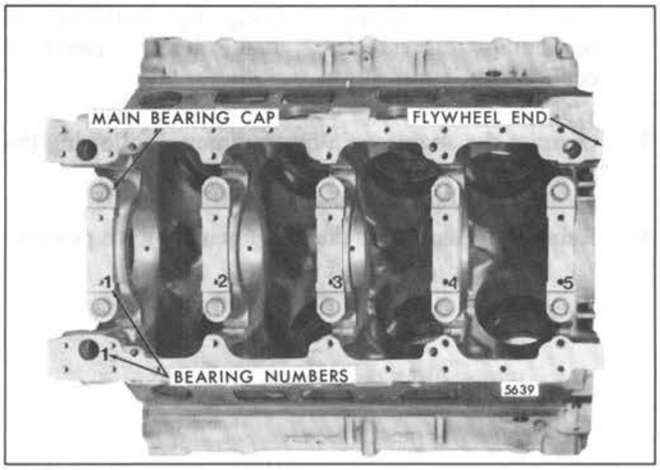


Fig. 8 – Cylinder Block Markings

c. Main bearing bores are line–bored with the bearing caps in place and thus are in longitudinal alignment. If a main bearing bore is more than .001" maximum overall misalignment or .0005" maximum misalignment between adjacent bores, the block must be line–bored (see Shop Notes – 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. (see Shop Notes – Section 1.0).

5. Refer to the *Cylinder Block Plugging Instructions* (Shop Notes – Section 1.0) and install the necessary plugs and dowels. Use tool J 33420 to install the 1" cup plug in the oil gallery to correct depth of 3.40". Use tool J 34650 to install the 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 .630" from the 6V and 8V cylinder blocks or .880" from the 12V and 16V cylinder blocks.

The dowels used to retain the crankshaft thrust washers in the rear main bearing cap must extend .110" to .120" from the surface of the bearing cap. 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. Examine the cylinder head retaining bolt holes. If the threads are damaged, use a tap to "clean–up" the threads or install a helical thread insert.

8. The tapped holes in the water–below–port cylinder blocks may be tapped with an 11/16"–11 thread tap. The unplugged bolt holes must have the thread extending 1.850" below the block surface. If the bolt hole in the block is plugged, the plug must be a minimum of 1.980" to 2.070" maximum below the surface of the block and threaded the full distance. When replacing a bolt hole plug in the water–below–port block, refer to *Shop Notes* in Section 1.0.

9. Check the remaining cylinder block surfaces and threaded holes. Check all of the mating surfaces, or mounting pads, for flatness, nicks and burrs. Clean–up damaged threads in tapped holes with a tap or install helical thread inserts, if necessary.

An insert thread repair kit J 29513 is now available for installing an 11/16"–11 helicoil thread insert in the cylinder head retaining bolt holes and the main bearing cap retaining bolt holes of the cylinder block.

10. 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

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

CAUTION: To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.

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

1. Mount the cylinder block on the overhaul stand.
2. If a new service replacement block is used, stamp the engine serial number and model number on the right–hand side of the cylinder block. Also, stamp the position numbers on the main bearing caps (Fig. 8) and the position of the No. 1 bearing on the oil pan mounting flange of the block.
3. Install all of the required cylinder block plugs and drain cocks. Use a suitable non–hardening sealant on the threads of the plugs and drain cocks. Install the plugs flush with or below the surface of the block. Make sure the cup plug, which blocks the oil cooler adaptor inlet from the adaptor outlet, is installed in the vertical passage.

4. Clean and inspect all engine parts and subassemblies and, using new parts as required, install them on the cylinder block by reversing the sequence of disassembly. 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. Complete the engine build–up by installing all remaining accessories, fuel lines, electrical connections, controls etc.
7. Operate the engine on a dynamometer, following the *run–in* procedure outlined in Section 13.2.1.
8. Reinstall the engine in the equipment which it powers.

CYLINDER BLOCK DISASSEMBLY AND ASSEMBLY PROCEDURE 12V AND 16V ENGINES

Disassemble Cylinder Block

1. Remove the block from the overhaul stand.
2. Refer to Fig. 9 and remove the two "B" bolts and special washers from the oil drain back cavity.

   CAUTION: NEVER use eye bolts or any other commonly purchased hardware to lift the cylinder block. Due to the weight of the blocks, it is important that the lifting brackets are constructed as shown in Fig. 10 and that all weld joints are magnafluxed prior to and periodically after initial use. Severe injury to personnel and destruction of engine parts will result if the engine breaks away from the lifting brackets.

3. Attach a suitable lifting bracket (Fig. 10) to the end of the front cylinder block with two (2) 1/2"–13 x 2" bolts and two (2) 3/8"–16 x 2" bolts.
4. Attach a chain hoist to the lifting bracket, then lift the cylinder blocks into a *vertical* position and rest the end of the rear cylinder block on a clean flat surface.
5. Refer to Fig. 9 and remove the seven (7) remaining bolts A, C, D and E securing the two cylinder blocks together. Also, remove the two (2) spacers used on the two (2) "D" bolts shown in inset "D" of Fig. 9. Then lift the front cylinder block off the rear cylinder block and remove the seal strip from the groove in the rear block.

Inspection

Clean the cylinder blocks as outlined under *Clean Cylinder Block* in this Section.

Examine the entire contact surface of each cylinder block (new or used). Remove any burrs with a suitable file or stone.

Check and clean the attaching bolt holes in each cylinder block with compressed air.

Examine and clean the cylinder block attaching bolts. Replace any of the bolts that are damaged or rusted.

Refer to the *Cylinder Block Plugging Instructions* (Shop Notes – Section 1.0) and install the necessary plugs and dowels.

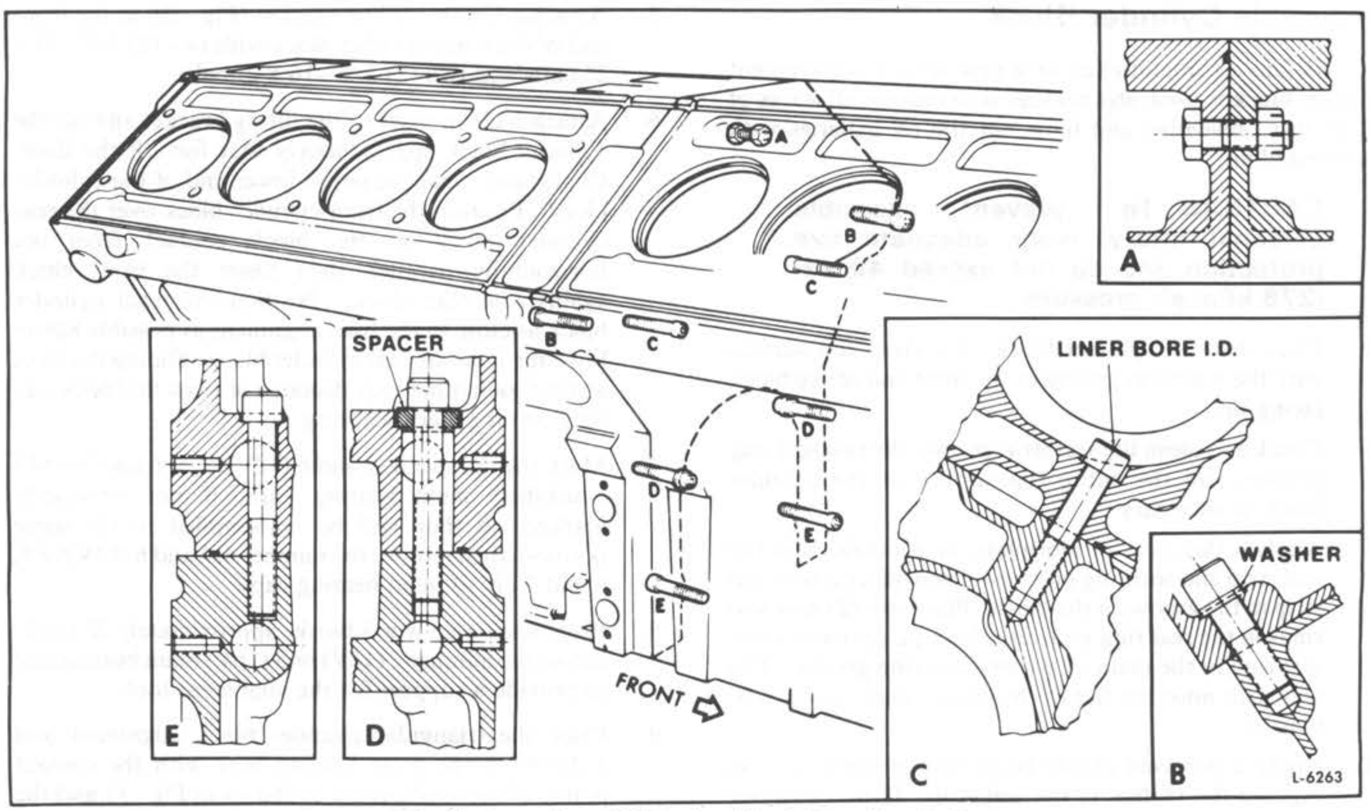


Fig. 9 – Location of Cylinder Block Attaching Bolts

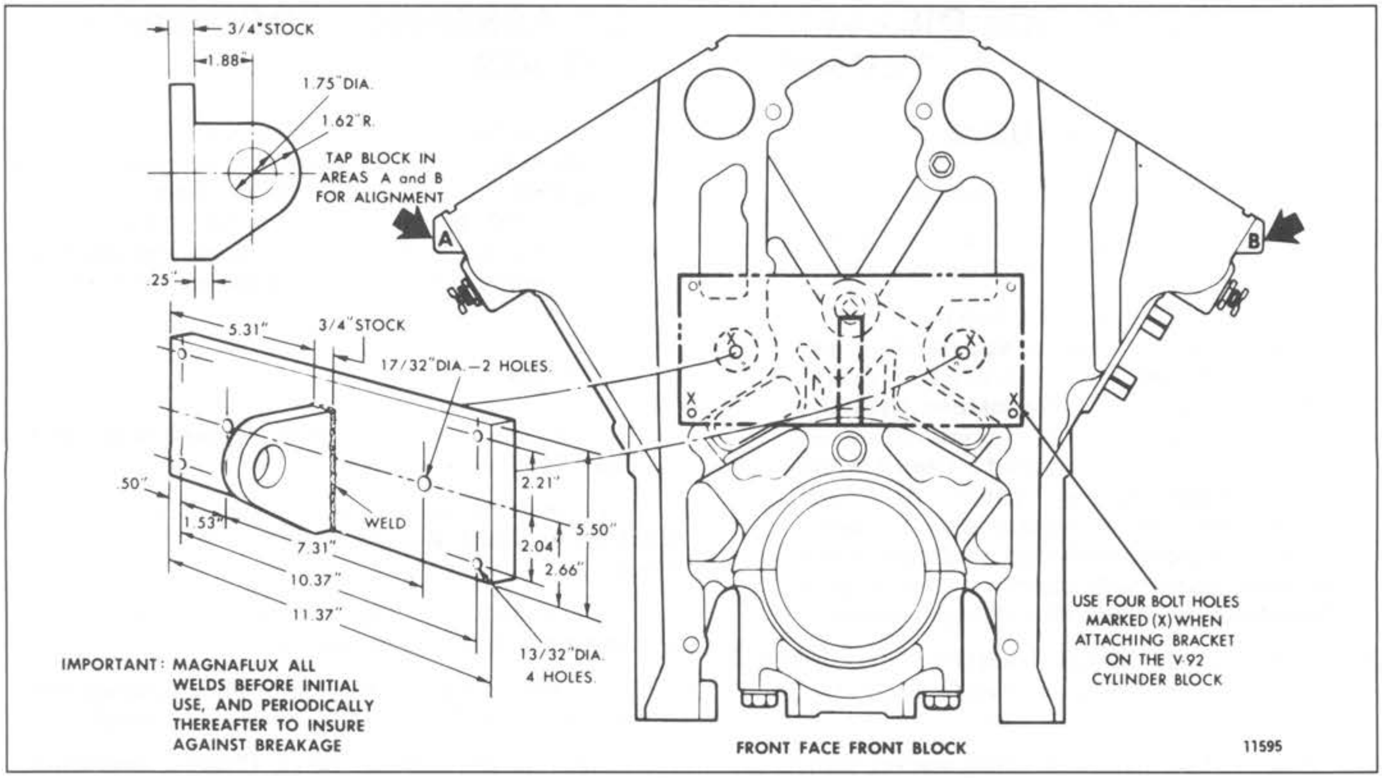


Fig. 10 – Details of Cylinder Block Lifting Bracket

Assemble Cylinder Block

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

CAUTION: To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.

1. Place the rear cylinder block on a clean flat surface with the seal strip groove in the front end of the block facing up.
2. Check and clean the seal strip groove, the two seal ring grooves and the entire top surface of the cylinder block, if necessary.
3. Apply a thin coat of lubriplate, or equivalent, in the seal strip and seal ring grooves. Then, place a new seal strip in the groove in the block. Place two (2) new seal rings in the seal ring grooves. Also, place one (1) new seal ring in the main oil gallery seal ring groove. The seal strip must lay flat in the groove and must not be twisted.
4. Apply a thin coat of lubriplate, or equivalent, on the exposed flat surface of the seal strip. Then, clean any excess lubriplate from the cylinder block.
5. Attach a suitable lifting bracket (Fig. 10) to the front end of the front cylinder block with two (2) 1/2"–13 x 2" bolts and two (2) 3/8"–16 x 2" bolts.
6. Attach a chain hoist to the lifting bracket and lift the cylinder block approximately four feet off the floor. Check and clean the entire lower end of the cylinder block. Position the front cylinder block over the rear cylinder block so the block contact faces are horizontally parallel, then lower the front block against the rear block. Position the front cylinder block as close to the final alignment as possible before lowering it on the rear cylinder block. Sliding the faces against each other may dislodge or twist the block seal strip or oil gallery seal ring.
7. Mark the number 4, 5 and 6 (12V) or 5, 6 and 7 (16V) crankshaft main bearing caps, if not previously marked, so they will be reassembled in the same position, then remove the number 4, 5 and 6 (12V) or 5, 6 and 7 (16V) main bearing caps.
8. Place a suitable wood block, approximately 3" thick, across the number 7 (12V) or 8 (16V) main bearing cap to provide a support for the alignment tool.
9. Place the triangular cylinder block alignment tool J 21799 in the main bearing bore with the contact points of the tool located as shown in Fig. 11 and the lower end of the tool resting on the wood block.

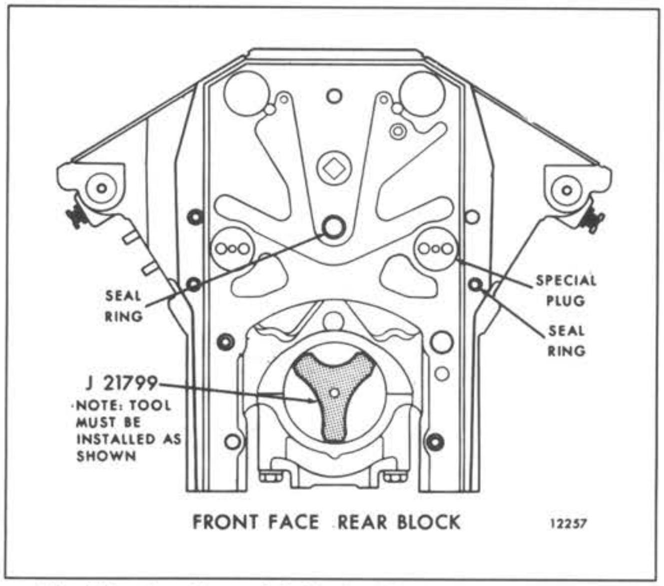


Fig. 11 – Position of Cylinder Block Alignment Tool (J 21799)

10. Install the number 4, 5 and 6 (12V) or 5, 6 and 7 (16V) crankshaft main bearing caps in their *original* positions and tighten the bolts to 230–240 lb–ft (312–325 N•m) torque.

11. Lubricate the threads and the contact face of the cylinder block attaching bolts "A", "C", "D" and "E" with a small amount of International Compound No. 2, or equivalent. Place a spacer on each "D" bolt as shown in inset "D" of Fig. 9. Then, refer to Fig. 9 for their location and install all of the bolts, except the two "B" bolts. Do not tighten the bolts at this time. If it becomes necessary to shift the front cylinder block when installing the attaching bolts, use a soft hammer and tap at points "A" and "B" (Fig. 10).

12. Move a dial indicator across the bottom faces (oil pan rail) of the cylinder blocks. The mismatch, if any, between the bottom faces of the two blocks must be equal on both sides of the cylinder block assembly within .002". If it is necessary to shift the front cylinder block when checking the alignment, tap at points "A" and "B" (Fig. 10) with a soft hammer to align the blocks.

13. Tighten the four (4) "C" and "D" bolts to 160–170 lb–ft (217–231 N•m) torque first, then tighten the two (2) "E" bolts to 160–170 lb–ft (217–231 N•m) torque. Now tighten the "A" bolt nut to 165–175 lb–ft (224–238 N•m) torque.

14. Repeat the cylinder block alignment check as outlined in Step 12. If the alignment is not satisfactory, loosen all of the attaching bolts, realign the blocks and retighten the attaching bolts as outlined in Step 13.

15. When cylinder block alignment is satisfactory, cut the excess lengths of the block seal strip off flush with the bottom face of the block.

16. Remove the cylinder block alignment tool J 21799 and the wood block.

17. Lift the cylinder block assembly with a chain hoist and place it in a *horizontal* position on a clean flat surface.

18. Install the "B" bolts and washers (Fig. 9) using Power Universal Socket J 25451–4 and Hex Bit J 25451–5. After the bolts are installed, they should be tightened to 240–250 lb–ft (325–339 N•m) torque, using wrench J 25451–7.

NOTICE: Do not use socket J 25451–4 when torquing these bolts as damage to the socket may result.

CYLINDER BLOCK END PLATES

A flat steel plate, one bolted to each end of the cylinder block (Fig. 1), provides a support for the flywheel housing at the rear and the balance weight cover at the front of the engine. The rear end plate has a 3" diameter breather hole for crankcase ventilation. Gaskets are used between the block and each end plate. On current engines, the left bank accessory drive mounting hole in the rear end plate is omitted, unless an accessory drive is specified.

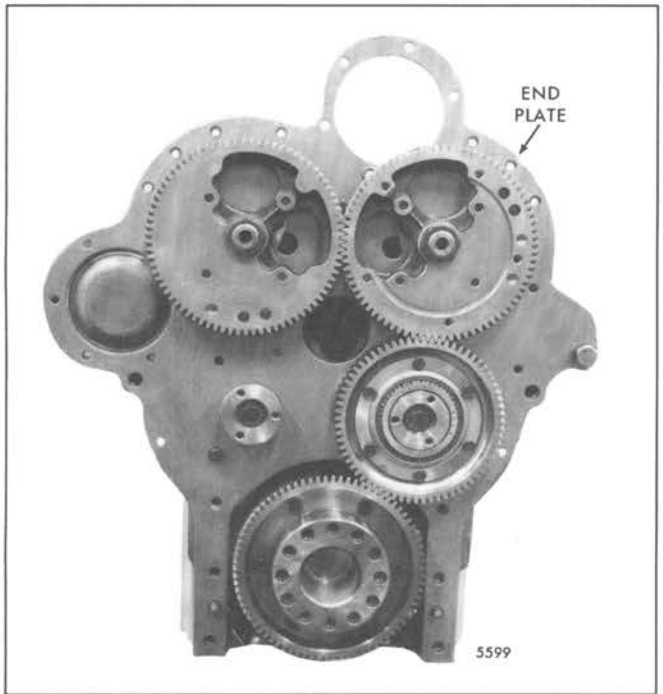


Fig. 1 – Cylinder Block Rear End Plate

Inspection

When an 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 each end plate for nicks, dents, scratches or score marks and check the end plates for warpage. Check the plug nuts in the end plates for cracks or damaged threads. If nicks or scratches on the sealing surfaces of the end plates are too deep to be cleaned up, or the plug nuts are damaged, replace the end plates 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 Plates

1. Affix new gaskets to the ends of the cylinder block. Also attach the small round gasket to the corner at the front end of the cylinder block.

   NOTICE: If the flywheel housing does not have a pressure pad, use Permatex No. 2, or equivalent, non–hardening sealer at the upper right rear of the block face and corresponding area on the rear end plate.

2. Attach the front end plate to the cylinder block with bolts and lock washers. Tighten the bolts finger tight.

3. Insert the right bank camshaft end bearing through the SMALL bearing bore in the end plate and into the bore of the block to accurately align the end plate with the cylinder block as shown in Fig. 2.

   NOTICE: The holes in the front and rear end plates for the camshaft end bearings are not the same size. The smaller hole is accurately machined for alignment purposes and is always located on the right side of the engine as viewed from the rear.

4. With the bearing in place, tighten the 1/2"–13 end plate–to–cylinder block bolts to 71–75 lb–ft (96–102 N•m) torque. Tighten the 3/8"–16 bolts to 30–35 lb–ft (41–47 N•m) torque. Then remove the camshaft bearing which served as a pilot while attaching the front end plate.

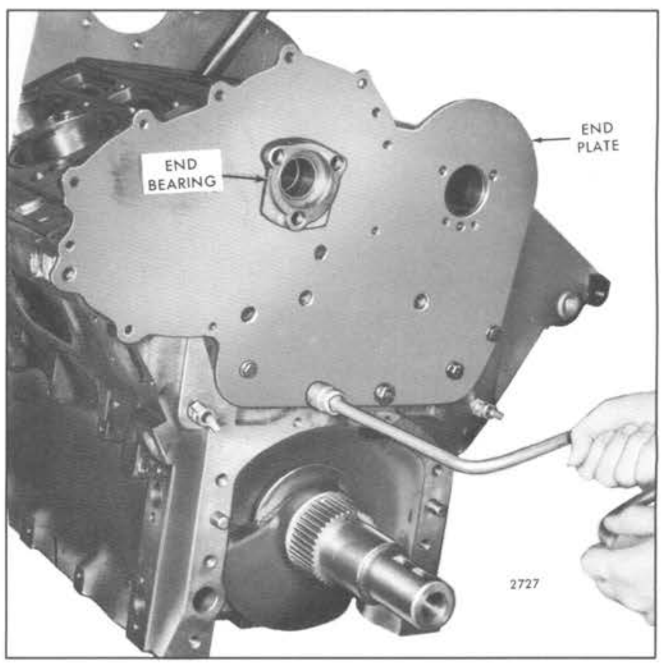


Fig. 2 – Installing Front End Plate (8V Engine)

5. Install the rear end plate in the same manner as outlined above for the front end plate.

6. Install the 5/8"–11 x 1" bolt on the right rear side of the end plate. Tighten it to 103–110 lb–ft (140–149 N•m) torque.

NOTICE: If used, attach the small cover to the cylinder block side of the rear end plate with two bolts and copper washers prior to installing the end plate. Use a new gasket between the cover and the end plate.

7. Trim off any excess gasket material.

AIR BOX DRAINS

During normal engine operation, water vapor from the air charge, as well as a slight amount of fuel and lubricating oil fumes, condense and settle on the bottom of the air box. This condensation is removed by air box pressure through air box drain tubes mounted on the sides of the cylinder block (Figs. 1, 2, 3 and 4).

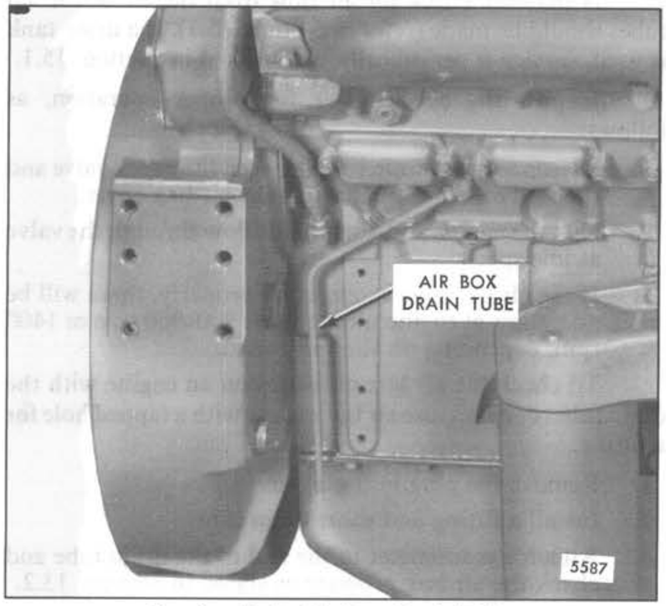


Fig. 1 – Early Air Box Drain Tube

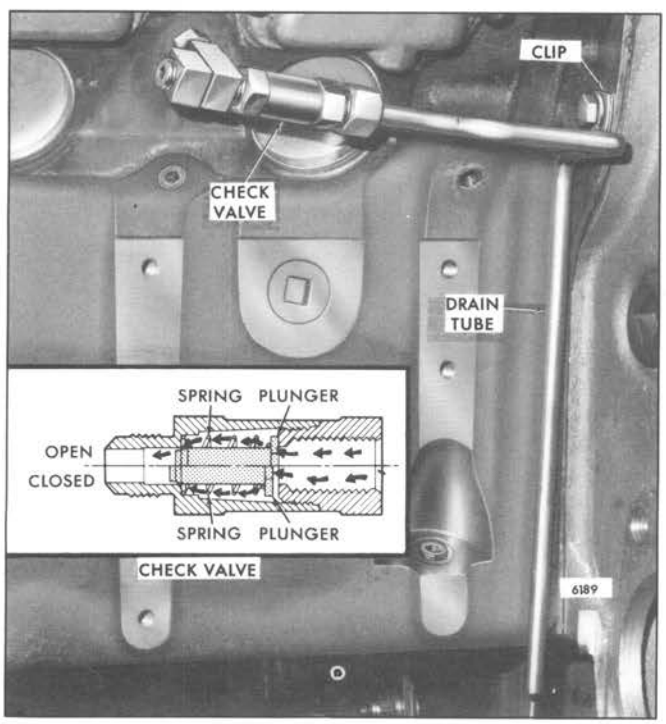


Fig. 2 – Open Air Box Drain Tube and Check Valve System

Certain engines are equipped with a drain tank to collect and retain the sediment from the air box.

A check (control) valve is installed in the air box drain fitting on each side of the engine to allow drainage only at low air box pressures.

The check valve cutaway shows the valve operating at engine idle speed (Fig. 2). As the engine speed and air box pressure increase, the valve moves forward and seats, blocking air–flow. Two valves with different pressure settings are available.

NOTICE: Early V–92 vehicle engines built without the air box drain check valves and engines built with drain tubes routed to the crankcase via the dipstick adaptor (Fig. 4) should be updated with the current open air box drain system (Fig. 3).

Two left–bank airbox drains (Fig. 5) are installed on all 6V–92 inclined coach engines, effective with unit number 6VF0146004. The two left–bank drains are similar to the former single drain, but are installed in two new airbox covers. A horizontal slot near the bottom of the large airbox cover permits drainage between the two adjacent airbox

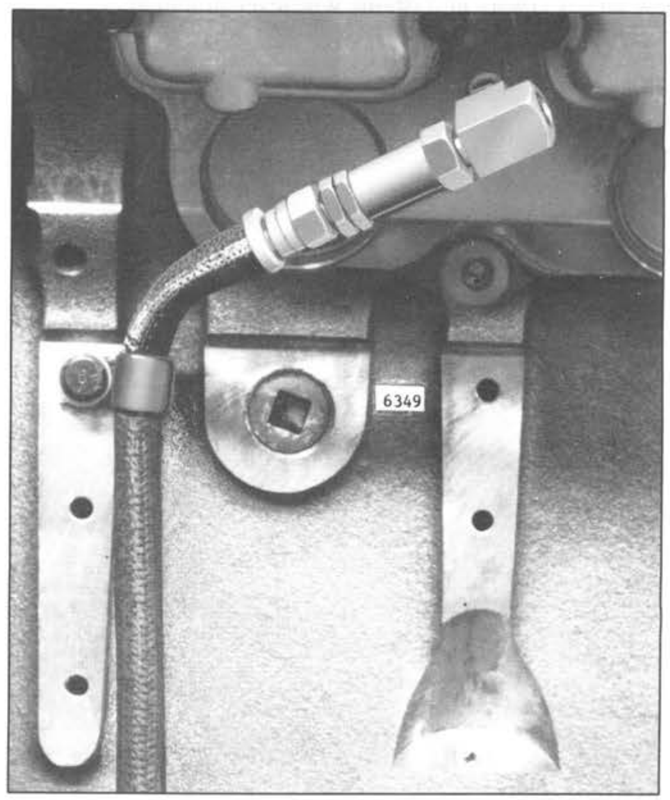


Fig. 3 – Current Open Air Box Drain Tube and Check Valve System

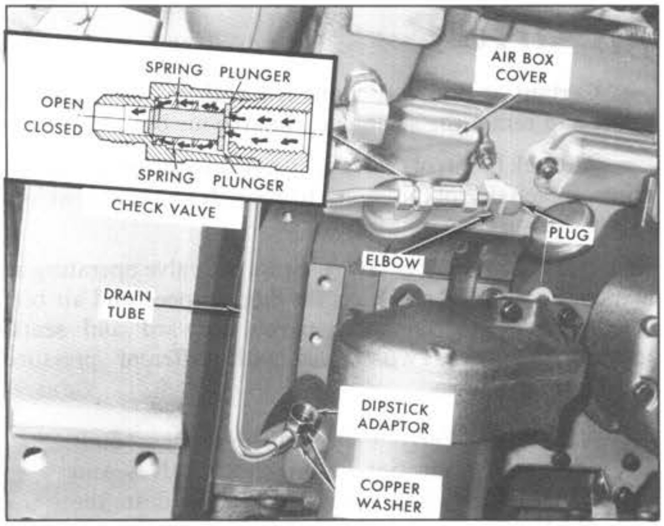


Fig. 4 – Former Closed Air Box Drain Tube and Check Valve System

access holes. The former single airbox drain was installed in the block, between the large and small covers. This opening is now plugged.

Because of the significant improvement in airbox drainage that results from this change, DDC recommends retrofitting existing 6V–92 inclined coach engines with the new airbox covers and drains whenever practical.

NOTICE: To insure efficient airbox drainage, install airbox covers with the drilled drain openings down and the slot in the large cover facing inboard. Install check valves at an angle of 30° to 45°. *Do not install check valves in a horizontal position.*

Inspection

A periodic check for air flow from the air box drain tubes should be made (refer to Section 15.1). If a drain tank is used, service it periodically, as outlined in Section 15.1.

Inspect the check valve for proper operation, as follows:

1. Disconnect the drain tube between the check valve and the air box drain tube nut at the air box cover.
2. Run the engine and note the air flow through the valve at idle speed.
3. If the check valve is operating properly, there will be no airflow at engine speeds above 900–950 rpm or 1400 rpm, depending on the valve used.

To check the air box pressures on an engine with the drain tubes or hoses, use air box covers with a tapped hole for a fitting.

1. Remove the plug in the cover.
2. Install a fitting and short drain tube.
3. Attach a manometer to the end of the drain tube and check the air box pressure as stated in Section 13.2.

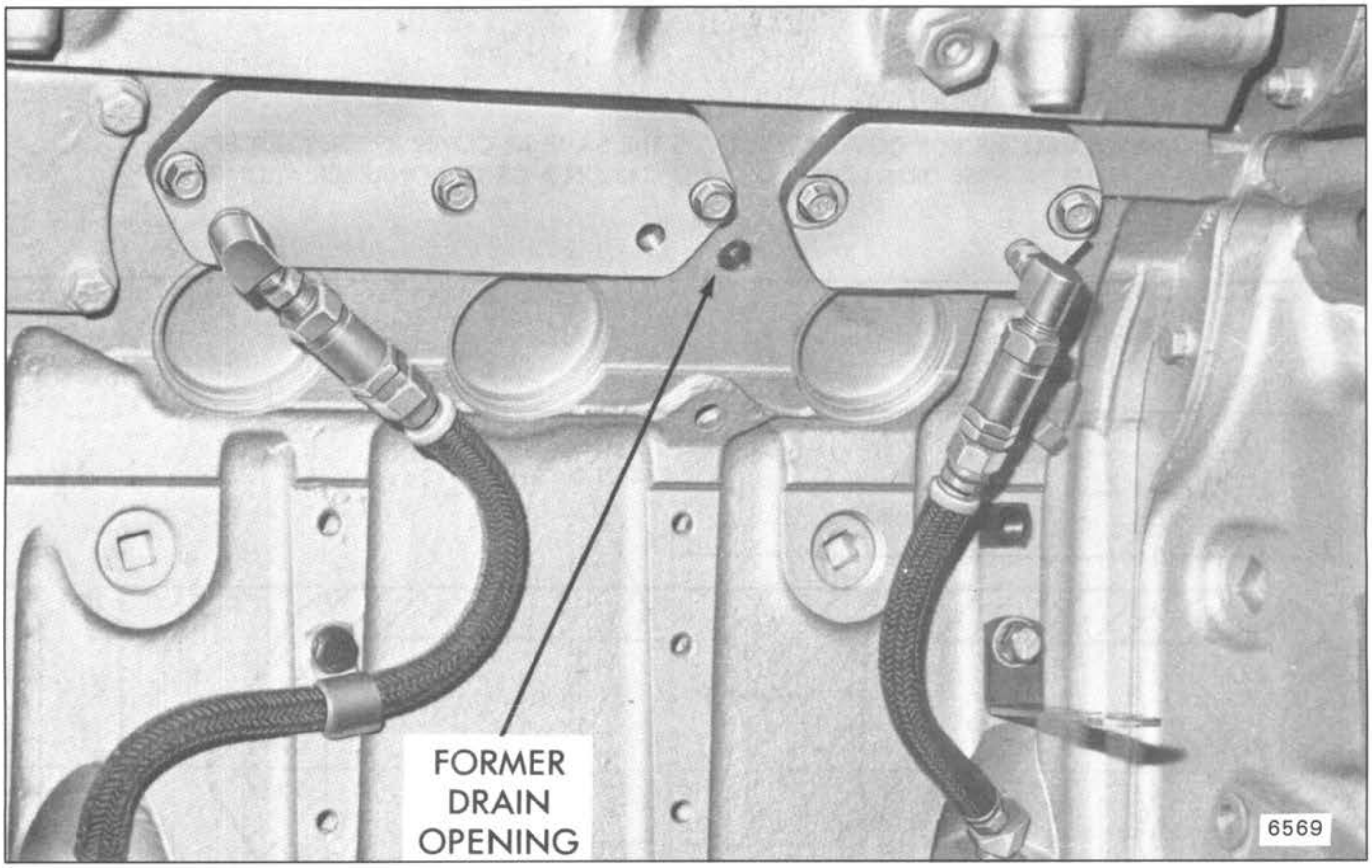


Fig. 5 – Left-Bank Airbox Drains and Covers (6V–92 Inclined Coach Engines)

CYLINDER HEAD

The cylinder head (Figs. 1 and 2), one on each cylinder bank, is a one–piece casting securely held to the cylinder block by special 11/16"–11 bolts and hardened washers or by special 11/16"–11 washer faced bolts.

The exhaust valves, fuel injectors and the valve and injector operating mechanism are located in the cylinder head. The four exhaust valves (per cylinder) are arranged in a trapezoidal configuration, with two valves set farther apart than the others.

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 (Fig. 3). 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 seal ring. The sealed upper end and flared lower end of the injector tube prevent water and compression leaks.

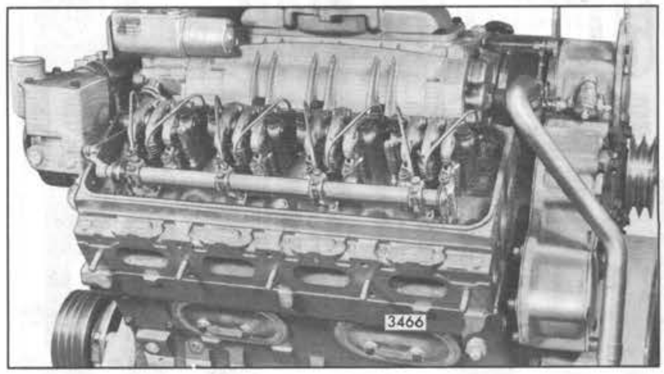


Fig. 2 – Cylinder Head Mounting

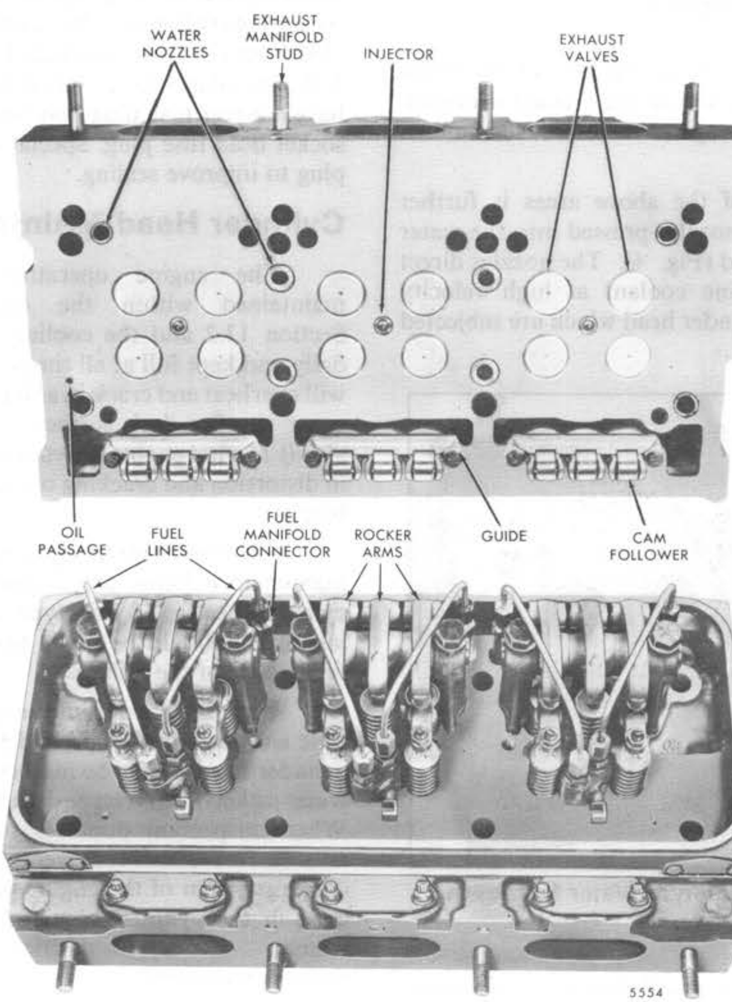


Fig. 1 – Typical Cylinder Head Assembly

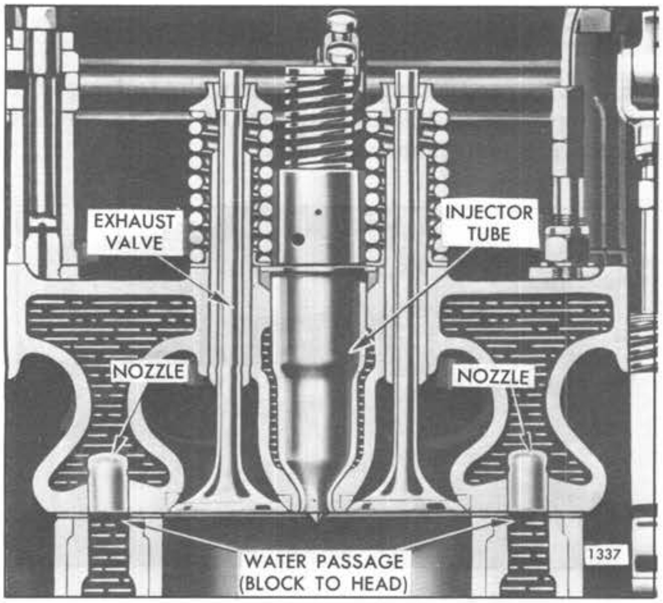


Fig. 3 – Coolant Passages Around Exhaust Valves and Fuel Injectors

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 cylinder head (Fig. 4). 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.

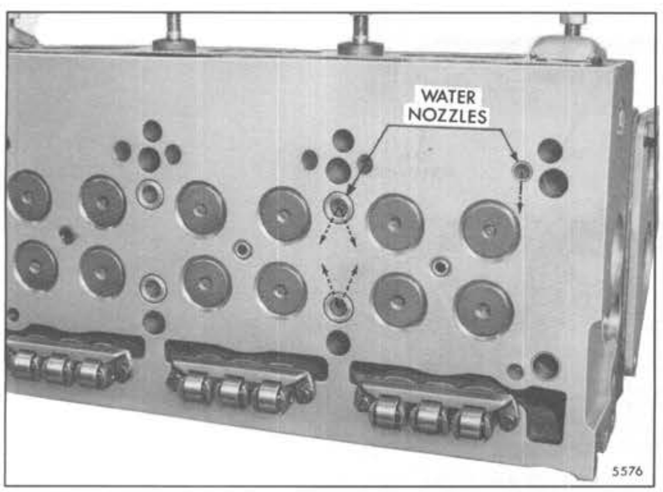


Fig. 4 – Location and Position of Water Nozzles in Cylinder Head

New cylinder heads with small diameter, one–piece, double–jet water nozzles are being used on Series 92 engines effective with serial numbers 6VF–72972, 8VF–65910 and 16VF–4322 (Fig. 5). Water nozzle hole diameters have been reduced from .812" to .540", leaving more material between nozzle holes and bolt holes. With the change to the new cylinder heads, nozzle–to–head sealing has been improved.

The fuel inlet and outlet manifolds are cast as an integral part of the cylinder heads. Tapped holes are provided for connection of the fuel lines at various points along each manifold. The water flow is all internal on the 6V and 8V end outlet cylinder heads. On 12V and 16V engines, a water manifold is attached to each cylinder head.

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 the same size silicone seal rings which fit into counterbored holes in the block. A synthetic rubber seal fits into a milled groove near the perimeter of the block.

•Fuse Plugs

Heat–sensitive fuse plugs are installed in the exhaust manifold side of all Series 92 cylinder heads. The insert in these plugs will melt if the "critical" temperature of the head (257°F or 125°C) is exceeded. Former cylinder heads used a 1/8" fuse plug with a slotted head. Current cylinder heads have a larger fuse plug hole and use a 1/4" recessed square socket head fuse plug. Special sealant is applied to the new plug to improve sealing.

Cylinder Head Maintenance

The engine operating temperature should be maintained within the operating range shown in Section 13.2 and 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 non–corrosive 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 engine coolant recommendations.

Loose or improperly seated injector tubes may result in compression leaks into the cooling system and also result

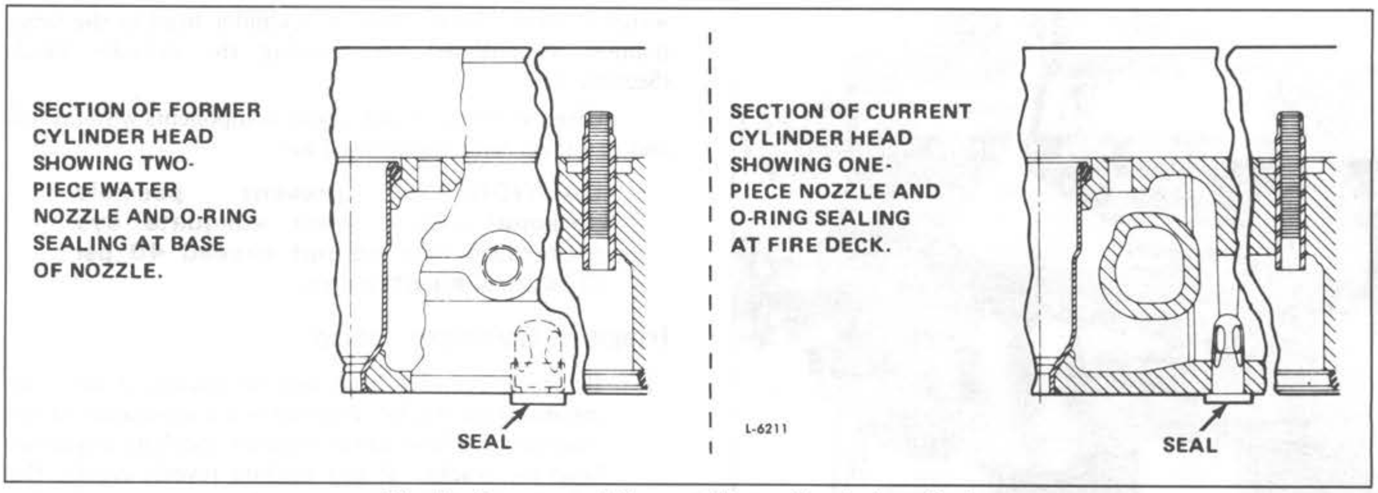


Fig. 5 – Former and Current Water Nozzle Installation

in loss of engine coolant. The tubes must be tight to be properly seated. Refer to Section 2.1.4.

- The presence of a melted fuse plug insert is a sure sign that the engine has experienced an overheated condition and that cylinder head damage may have occurred. If a melted fuse plug insert is found in a cylinder head, *both* cylinder heads must be removed and checked for serviceability. All water nozzles and injector hole tubes should be replaced and the proper fuse plugs installed before cylinder heads are reused.

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.

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 a camshaft.

Due to the various optional and accessory equipment used, only the general steps for removal of a 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. On turbocharged engines, remove the connections from the exhaust manifold to the turbocharger. Remove the turbocharger, if necessary.
3. Disconnect the fuel lines at the cylinder head.
4. Loosen the hose clamps and remove the hose attached to the thermostat housing cover.
5. Loosen the hose clamps at each end of the water bypass tube and remove the tube.
6. Remove the thermostat housing assembly.
7. Clean and remove the valve rocker cover and governor cover. Discard the gaskets.
8. Disconnect the fuel rod from the injector control tube lever and the governor. Remove the fuel rod.
9. Loosen the fuel rod cover hose clamps. Then, slide the hose up on the fuel rod cover toward the governor.
10. Remove the exhaust manifold.
11. Remove the water manifold, if used.
12. Remove the injector control tube and brackets as an assembly.
13. 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 2.1.1 for removal of the injectors.

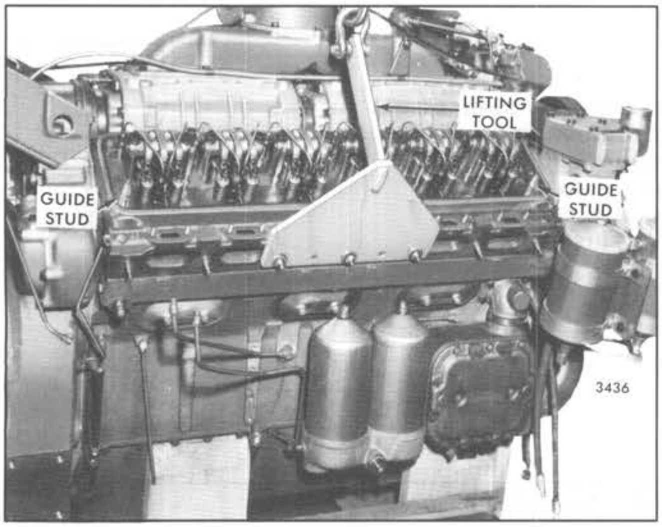


Fig. 6 – Removing or Installing Cylinder Head using Tool J 22062-01

14. Check the torque on the cylinder head bolts before removing the head. Then, remove the bolts and washers and lift the cylinder head from the cylinder block with tool J 22062-01 (Fig. 6). If interference is encountered between the rear end of the right-bank cylinder head and any of the flywheel attaching bolts, loosen the bolts. 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.

    NOTICE: 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" wood blocks.

15. Remove and discard the cylinder head compression gaskets, support shims and the oil seals and water seals.
16. 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 the cylinder head components with fuel oil and dry them with compressed air.

CAUTION: To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.

Inspect Cylinder Head

1. Before a cylinder head can be reused, it must be inspected for cracks. Anyone or a combination of the following methods can be used for checking a cylinder head for cracks. 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 (1) to thirty (30) 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 five (5) to fifteen (15) minutes.

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

If cracks are visable in the head, *Do Not* use the Pressure Test Method.

Pressure Test Method – Cylinder Head Disassembled:

When overhauling a cylinder head, use *Cylinder Head Disassembled* pressure test method. When a cylinder head is removed to assist in other repairs, the cylinder head can be pressure tested using the method described in *Cylinder Head Assembled and Removed from Engine.*

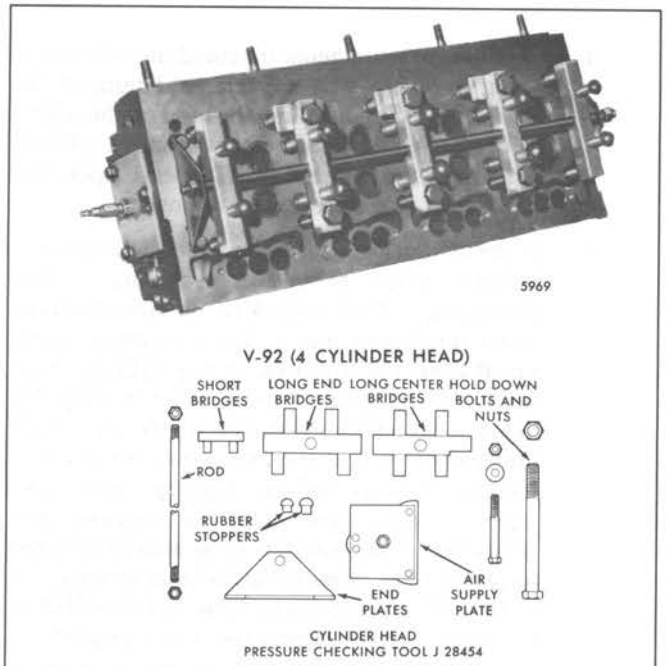


Fig. 7 – Cylinder Head Prepared for Pressure Testing using Tool J 28454

1. Install the rubber stoppers on the bridges.
   a. Large stoppers are installed on the long center bridge feet opposite the notch and on the long end bridge feet closest together.
   b. Small stoppers are installed opposite the large stoppers on center bridge and end bridge feet and on all short bridges.
2. Install the necessary parts, loosely, on the cylinder head.
3. Tighten the hold down bolts until the stoppers start to distort. A 5 lb–ft (7 N•m) torque is usually sufficient. Do not over–tighten the hold down bolts. The rubber stopper could distort enough to seal both the inner and outer diameter of the water nozzles. If the outer diameter is sealed, a leak from the outer diameter would not be detected.
4. Install the air supply plate.

NOTICE: Do not hook onto the pressure checking tool, or any part of it, to move the cylinder head from one location to another. If this is done it could result in permanent damage to the tool.

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 N•m) torque.

C. Apply 40 psi (276 kPa) air pressure to the water jacket. Before immersing the cylinder head in the water tank, first check for fire deck cracks and for leakage around the copper water nozzle. This check should be performed at room temperature (not in the hot water tank) because the hot tank temperature could cause the nozzle to seal. Then, immerse the cylinder head in a tank of water, previously heated to 180–200°F (82–93°C), for about twenty (20) 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 at the top and bottom of the cylinder head.

D. Relieve the air pressure and remove the cylinder head from the water tank. Then, remove the plates, gaskets and injectors and dry the head with compressed air.

CAUTION: To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.

Pressure Test Method – Cylinder Head Assembled and Removed from Engine:

A. To seal off water holes in the cylinder head, assemble tool set J 28454 as follows:
   1. Install the rubber stoppers on the bridges.
      a. Large stoppers are installed on the long center bridge feet opposite the notch and on the long end bridge feet closest together.
      b. Small stoppers are installed opposite the large stoppers.
   2. Install necessary parts, loosely, on the cylinder head.

3. Tighten the hold down bolts until the stoppers start to distort. A 5 lb–ft (7 N•m) torque is usually sufficient. Do not overtighten the hold down bolts. The rubber stopper could distort enough to seal both the inner and outer diameter of the water nozzles. If the outer diameter is sealed, a leak from the outer diameter would not be detected.
4. Install the air supply plate to water jacket opening.

B. Apply 40 psi (276 kPa) air pressure to the air supply plate connection. Check for leaks, using Leak Tek solution or equivalent, at the tops and bottoms of the injector tubes, oil gallery, exhaust ports and fuel manifolds.

C. Relieve the air pressure slowly. Then remove all plates and gaskets.

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. 8). Refer to Table 1 for maximum allowable warpage. Also, look at the fire deck to make sure it is free of pitting caused by excess coolant entering the cylinders.

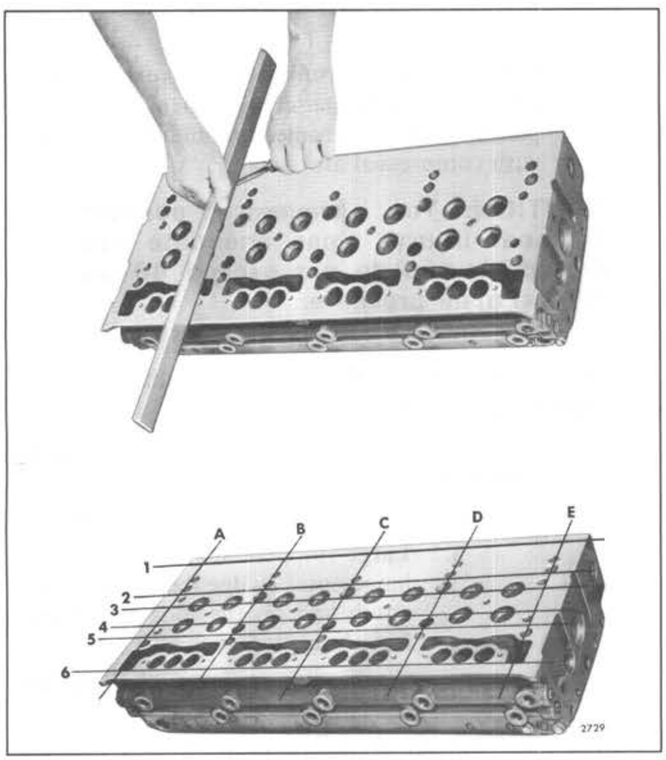


Fig. 8 – Checking Bottom Face of Cylinder Head

Engine	Maximum Longitudinal Warpage	Maximum Transverse Warpage
6V 8V & 16V	.0055" .0080"	.0040" .0040"

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 cylinder head is to be refaced, remove the injector tubes prior to machining. Any machining of the fire deck can be done with the water nozzles in place. Do not remove more metal from the fire deck of any cylinder head below the minimum distance of 3.536" (Fig. 9). 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. Also, deburr the water nozzles.

3. Install new injector tubes (Section 2.1.4) if the old tubes leaked or the cylinder head was refaced. If the engine overheated, injector tubes in both cylinder heads must be replaced.

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

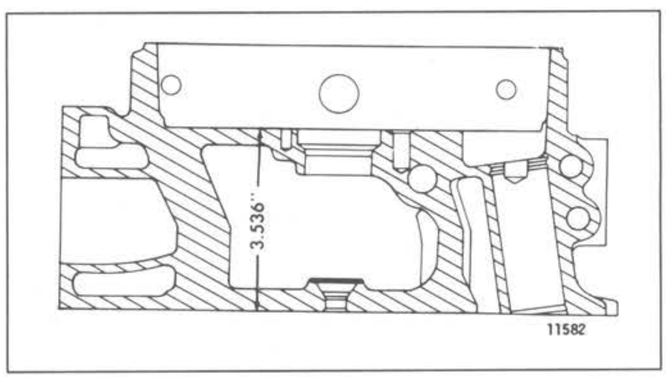


Fig. 9 – Minimum Distance Between Top and Bottom Faces of Cylinder Head

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 cam followers and bores to determine the follower–to–bore clearances (refer to *Specifications* in Section 1.0). The cam follower–to–cylinder head clearance must not exceed .006" with used parts (refer to *Specifications* in Section 1.0). If the bores are excessively scored or worn, replace the cylinder head.
6. Check the water hole nozzles to be sure they are not loose. If the enigne overheated, the former water nozzles must be replaced in both cylinder heads. 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 intermediate nozzle holes are reamed and must not be cleaned with a drill. This could result in leakage of water into the lubricating oil. Use a soft bristle brush to clean the intermediate water nozzle holes.
   c. Install water nozzles of the former style with installing tool J 24857. The current water nozzle should be pressed into place.
   d. Fig. 4 shows the location and position of the nozzles in the cylinder head. The former nozzles must be .004" recessed to flush with the bottom face of the cylinder head and the sealing area of the cylinder head around the nozzles flat within .002". The current water nozzles must be .015" recessed to flush.
7. Replace broken or damaged studs. Apply sealant to the threads of new studs and drive them to 10–25 lb–ft (14–34 N•m) torque (water manifold cover studs) or to 25–40 lb–ft (34–54 N•m) torque (exhaust manifold studs).
8. Pilot sleeves are used in the mounting bolt hole at each end of the cylinder head (on the camshaft side of the head). Make sure the sleeves are flush or recessed below the fire deck of the cylinder head. Replace damaged sleeves. The sleeves, which act as a hollow dowel to provide a closer fit between the mounting bolts and the cylinder head, help to guide the head in place without disturbing the seals and gaskets.
9. 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, pilot sleeves, bridge guides, valve spring seats and the necessary plugs. In addition, shims strips, studs, cover plates, gaskets, lock washers and nuts are provided to seal the water outlet openings that are not required on certain engines. A length of flexible fuel hose and fittings are also included where required.

Assemble Cylinder Head

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

1. Refer to the *Cylinder Head Plugging Chart* (Section 1.0 – Shop Notes). Coat the threads of the plugs with Loctite Pipe Sealant with Teflon®, then install the necessary plugs and tighten them to the specified torque (see *Specifications* in Section 1.0). Drive headless plugs flush to .0625" below the surface of the cylinder head. The 3/8" socket head oil gallery plug, at each end of the head, must not protrude more than .0625", and a .2187" diameter rod placed in the vertical oil feed hole must pass the inner face of the plug. Use tool J 24560 to instll 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. Visually inspect the fuel connectors for cracks, nicks and defective threads. Place new washers on the fuel connectors. Then, install the connectors and tighten them to 40–45 lb–ft (54–61 N•m) torque.
   d. The fuel injectors, fuel pipes, injector control tube assembly and water manifold, if used, 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.
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.

   NOTICE: The 2.00" diameter cup plug (thermostat housing end) in a new service head for the 6V and 8V engine must be removed prior to installation to prevent blocking the coolant flow out of the head.

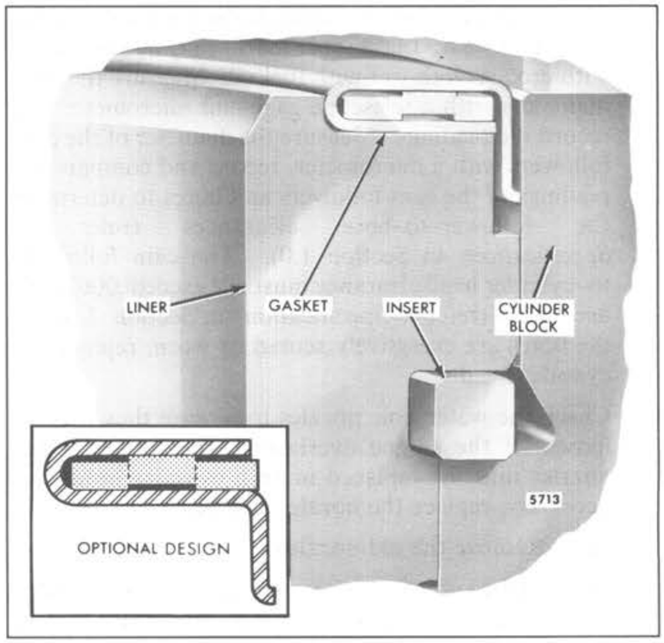


Fig. 10 – Compression Gasket Mounting in Cylinder Block

Install Cylinder Head

1. Install the water and oil seal rings, support shims and compression gaskets as follows:
   a. Place a new compression gasket on top of each cylinder liner. Never install used compression gaskets or seals. New compression gaskets are color coded (red, black or no–paint) on the outside diameter to identify gaskets in a particular thickness range. Only gaskets of one color code should be used under any one cylinder head. It is also important that the liner height be checked (refer to Section 1.6.3). There must not be over .0015" difference between any two adjacent liners when measured along the cylinder longitudinal center line.

A new–sourced, optional design cylinder liner compression gasket has been released (Fig. 10). The new optional gasket will be of one thickness with the "no paint" identification. It can be intermixed on an engine under the same head only with the current "no paint" compression gasket.

   b. To prevent end cylinder head bolt breakage, support shims are attached at each end of the cylinder block (two per cylinder bank) – (Fig. 11). Remove the adhesive paper and place the support shims, adhesive side down, in position at each end of the cylinder block. The scallop in the shim placed at the rear of the block must be at the oil supply hole (Fig. 11).
   c. 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

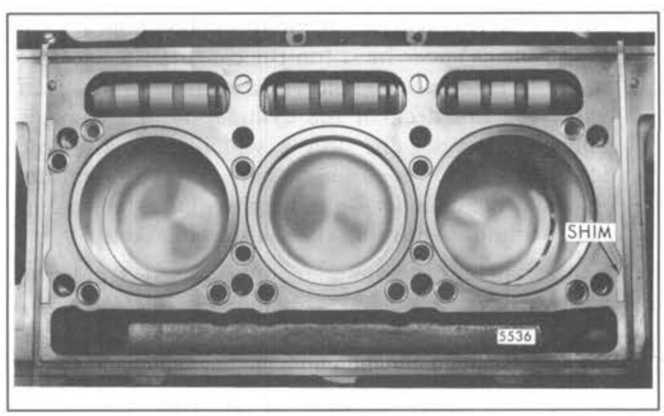


Fig. 11 – Cylinder Head Support Shims in Place

#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. 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.

d. 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. Install the seal in the groove with the color side of the seal facing away from the cylinders or to the outer perimeter of the cylinder block. This installation procedure is necessary to assure oil sealing capabilities between the cylinder head and block. 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 cylinder head installtion.

2. To install the cylinder head on the engine without disturbing the gaskets and seals, install guide studs J 24748 in two outboard corner bolt holes in the cylinder block. *Do not install guide studs in the bolt holes which line–up with the pilot sleeves in the head.*

3. Attach lifting tool J 22062–01 to the cylinder head and lift the head into position above the cylinder block.

4. Make a final visual check of the compression gaskets, seals and shims 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 "blow–by" and result in poor engine performance and damage to the engine. Shim strips not in place can result in broken cylinder head bolts.

5. Wipe the bottom of the cylinder head clean. Then, lower the head over the guide studs and onto the surface of the cylinder block.

6. Apply a small amount of International Compound No. 2, or equivalent, to the threads and underside of the head of all cylinder head attaching bolts. Then, install a 6 point bolt and an 11/16" washer or 12 point washer faced bolt through each piloting sleeve at the inboard corners of the head and thread them finger tight into the cylinder block. To insure adequate head bolt clamp load, all 12 point head bolts with "LE" head identification should be replaced at this time. *Do not use the 11/16" washer with the washer faced bolt.* However, the bolts can be mixed in a cylinder head. Cylinder head bolts are especially designed for this purpose and must not be replaced by ordinary bolts.

7. After the cylinder head is in place, begin installing the bolts on the camshaft side of the head to take up tension on the push rod springs. Remove the guide studs and lifting fixture and install the remaining bolts. With a speed handle tighten the bolts to 15–20 lb–ft (20–27 N•m) torque.

To prevent misalignment of the cylinder heads on 12V and 16V engines, use an alignment fixture (Fig. 12). Install the cylinder heads with the attaching bolts finger tight. Then, install the fixture and tighten the head bolts (see Step 8). Remove the fixture and proceed with assembly of the engine.

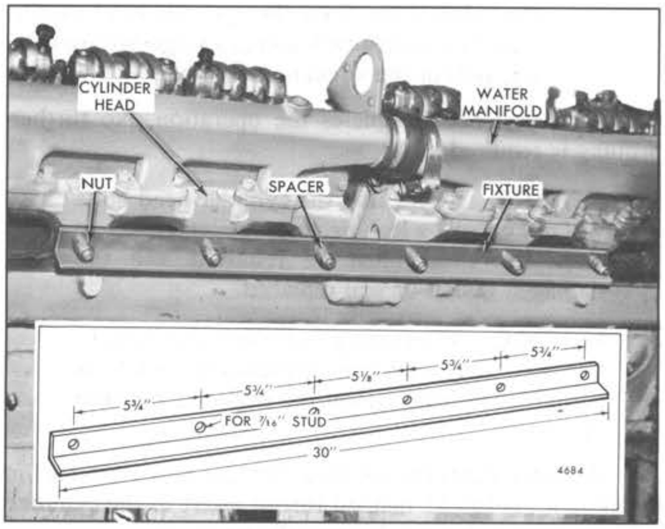


Fig. 12 – Cylinder Head Alignment Fixture for 12V and 16V Engines

•8. Tighten the cylinder head atttaching bolts by using the torque–turn method, as follows:

a. *Tighten* the 11/16"–11 cylinder head bolts to 100 lb–ft (136 N•m) torque in sequence (Fig. 13). 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 designed thickness.

b. *Repeat* the tightening sequence to 100 lb–ft (136 N•m) torque at least once, because the first bolts tightened in the sequence may lose clamp load during tightening of the remaining bolts.

NOTICE: Failure to repeat the bolt torquing sequence may result in difficulties, such as compression leaks, when the engine is put into service.

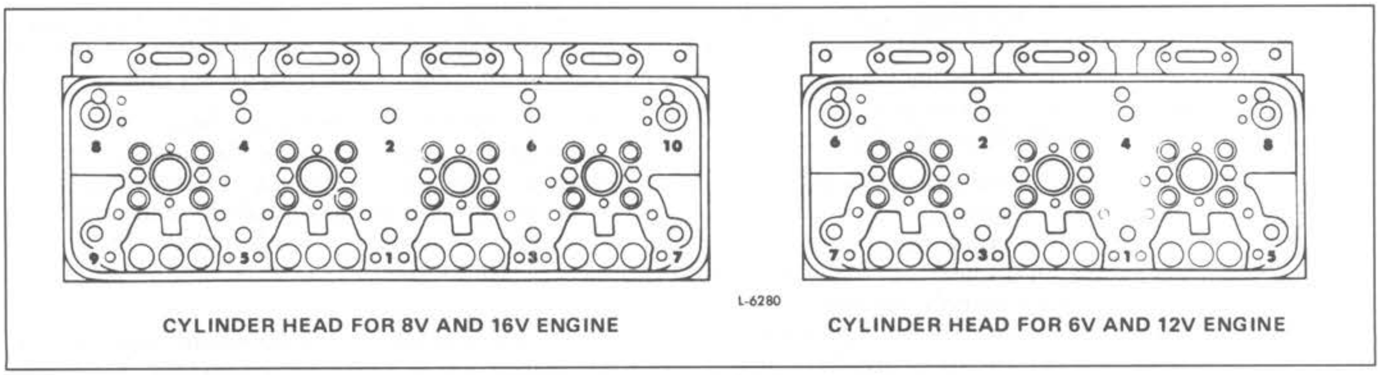


Fig. 13 – Cylinder Head Bolt Tightening Sequence

c. *Mark* the position of each bolt head in relation to the cylinder head profile face.

d. *Turn* each bolt clockwise, in sequence, 90° from the original mark on the cylinder head profile face. Try to turn each bolt in a single 90° arc with one pull of the wrench, if possible.

This sequence completes the operation. No further torquing is required.

NOTICE: 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.

NOTICE: Attempting to tighten the bolts in one step may result in difficulties, such as compression leaks, when the engine is put into operation.

An insert thread repair kit J 29513 is now available for installing a 11/16"–11 helicoil thread insert in the cylinder head retaining bolt holes in the cylinder block.

9. On 12V and 16V engines, install the fuel and water connectors between the cylinder heads. Dry seal connectors are used at the fuel connection between the cylinder heads (Fig. 14). Make sure the tapped holes in the water hole plugs in the ends of the cylinder heads are in alignment.

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

11. Adjust the exhaust valve bridges as outlined in Section 1.2.2.

12. Tighten the rocker arm bracket bolts to the specified torque (see *Specifications* in Section 1.0).

•13. Align the fuel pipes and connect them to the injectors and the fuel connectors.

•NOTICE: DDC recommends that the original fuel pipes not be reused. New flared end fuel pipes should be installed. When installing flared end fuel pipes, use fuel pipe nut wrench J 8932–01 and "clicker" type torque wrench J 24405 (calibrated in inch– pounds) to apply proper torque and avoid damaging the fuel pipes. Refer to the chart for torque specifications. Fuel leakage from damaged or improperly installed fuel pipes can cause lube oil dilution, which may result in serious engine damage.

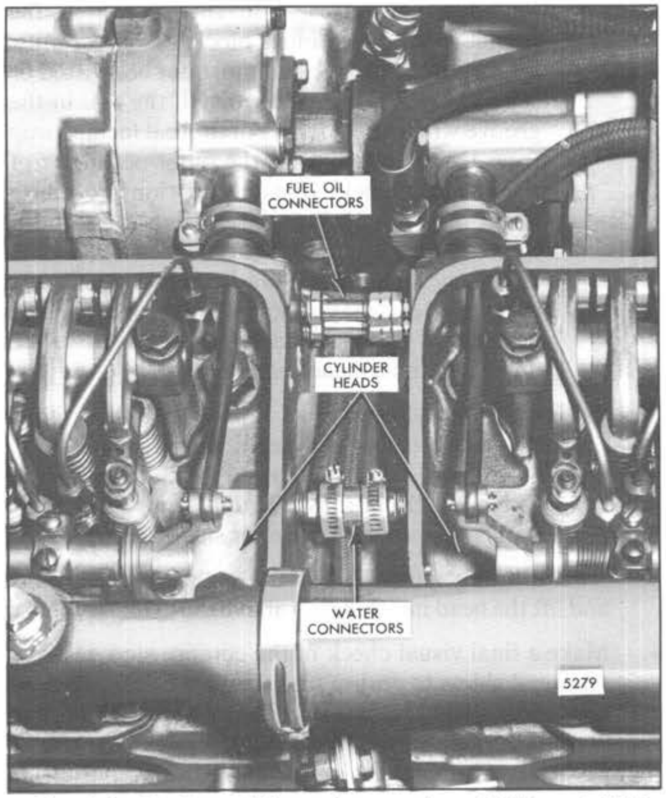


Fig. 14 – Fuel and Water Connections (12V and 16V Engines)

To help insure more consistent fastening, tighten fuel pipe nuts on fuel pipes to the single torque values shown on the chart. Use fuel line nut wrench J 8932–01 and "clicker" type torque wrench J 24405 (calibrated in inch–pounds).

NOTICE: Because of their low friction surface, Endurion®–coated nuts on fuel pipes must be tightened to 130–lb–in (14.69 N•m torque, instead of the 160 lb–in (18.3 N•m) required with uncoated nuts. To avoid possible confusion when tightening fuel pipe nuts, do not mix lines with uncoated and Endurion®–coated nuts on the same cylinder head.

Jacobs brake fuel pipes and those used with load–limiting devices do not have coated nuts. Tighten these to the values shown on the Chart.

Fuel Pipe Usage	Torque
Endurion®–coated	130 lb–in. (14.69 N•m)
Uncoated	160 lb–in. (18.3 N•m)
Jacobs Brakes*	120 lb–in. (13.6 N•m)
Load limiting devices	160 lb–in. (18.3 N•m)
DDEC Engines	145 lb–in. (15.6 N•m)

**Not serviced. Available from Jacobs Manufacturing Company.*

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 (refer to *Fuel Jumper Line Maintenance and Reuse and Pressurize Fuel System – Check for Leaks* in Section 2.0).

14. Set the injector control tube assembly in place on the cylinder head and install the attaching bolts finger tight (see Section 2.9). 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 N•m) torque.
15. 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.
16. Install the fuel rods. Then, slide the fuel rod cover hoses in place and tighten the clamps.
17. Connect the fuel lines.

New Teflon® stainless steel fuel crossover lines are being used on all upright and tilt coach engines, effective with engine serial numbers 6VF–106261 and 8VF–85643. The new hose assemblies replace the steel tube assemblies formerly used between the cylinder heads. When replacing either steel tube assembly, both lines *must* be changed. A Teflon® stainless steel hose assembly cannot be used in conjunction with a steel tube assembly.

18. Install the thermostat housing and thermostat.
19. Install the water manifold, if used.
20. Install the water bypass tube, hoses and clamps.
21. Install the thermostat housing cover, hose and clamps.
22. Install the exhaust manifold and connect the exhaust piping.
23. Install any other equipment that was previously removed.
24. Refer to Section 13.1 under *Preparation for Starting Engine First Time* and fill the cooling system and lubrication system.
25. Before starting the engine, perform an engine tune–up as outlined in Section 14. 2.24

VALVE AND INJECTOR OPERATING MECHANISM

Three rocker arms are provided for each cylinder; the two outer arms operate the exhaust valves and the center arm operates the fuel injector.

Each set of three rocker 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).

A shot peened injector rocker arm assembly is used on engines equipped with 115 mm (9215) or larger fuel injectors.

This injector rocker arm can be identified by a yellow stripe at the top of the arm and a shot peened stress relief cut on the pallet side of the arm.

- To improve lubrication, a new rocker arm shaft replaced the former shaft on all *6V and 8V–92 DDEC engines,* effective with unit serial numbers 6VF0150868 and 8VF0118481. Former and new shafts are dimensionally identical, except that the new has an extra 1/8" lubrication passage cross–drilled through the center. This hole intersects the main oil gallery of the shaft and is perpendicular to the three vertical cross–drilled oil holes. Former and new shafts are completely interchangeable and may be mixed in an engine.

- A new injector rocker arm assembly is used on *6V–92 coach engine models 8067–3421 and 8067–4423,* effective with unit number 6VF0154319. The new assembly has a larger O.D. clevis pin bushing which provides a greater bearing surface for longer life and improved lubrication. The entire clevis end is also pre–lubricated during assembly to minimize the chance of bushing damage at initial engine start–up.

- The new injector rocker arm assembly (identified by a blue or bright pink paint stripe on the back) and the former assembly (orange paint stripe identification) are completely interchangeable and may be mixed in an engine. However, because of the extended bushing life it provides, DDC recommends replacing the former assembly with the new on 6V–92 coach engine models 8067–3421 and 8067–4423 at overhaul or whenever practical.

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 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 (Fig. 2).

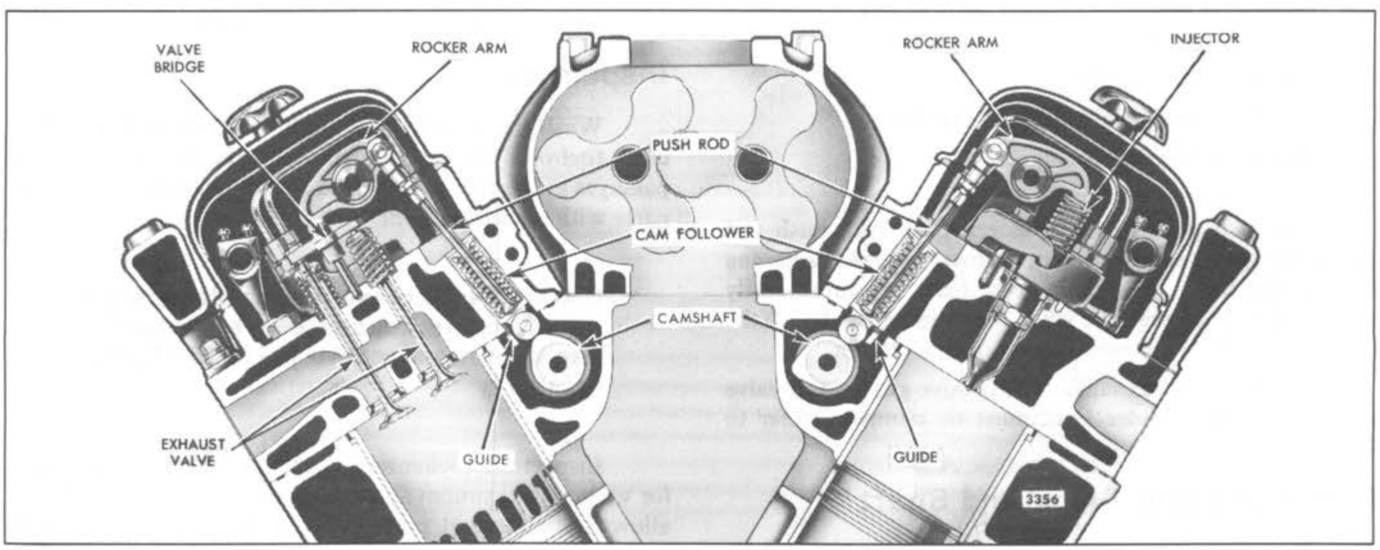


Fig. 1 – Valve and Injector Operating Mechanism

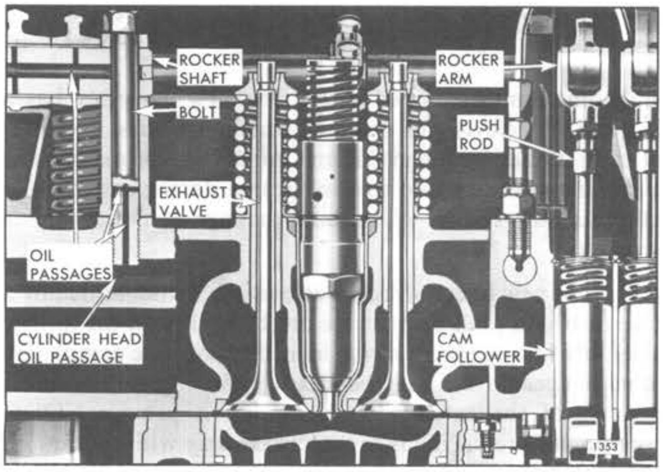


Fig. 2 – Lubrication of Valve Operating Mechanism

Overflow oil from the rocker arms lubricates the exhaust valves, valve bridges 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 milled slots in the camshaft intermediate bearings.

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 or adjust an exhaust valve bridge or replace a valve bridge guide.
4. Replace a rocker arm.
5. Replace a rocker arm shaft or bracket.
6. 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, valve guides and valve seat inserts, the cylinder head must be removed (refer to Section 1.2.2).

Remove Rocker Arms And Shaft

1. Clean and remove the valve rocker cover. Discard the gasket.
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. 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 could be loosened.

   CAUTION: To reduce the risk of personal injury when barring over or "bumping" the starter while performing an engine tune–up, personnel should keep their hands and clothing away from the moving parts of the engine as there is a remote possibility the engine could start.

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

CAUTION: To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.

Inspect the rocker arm shaft and rocker arm bushings for wear. A maximum shaft to bushing clearance of .004" is allowable with used parts (refer to Section 1.0). Service replacement 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 for wear.

Inspect the rocker arm shaft brackets for cracks.

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. 3).
6. Unscrew the locknut to release the spring. Then, remove the nut, flat washer and tool from the push rod.

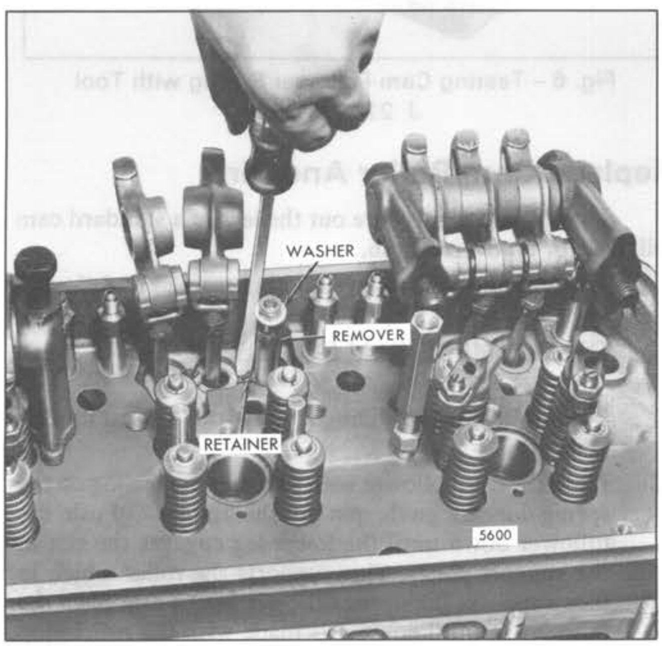


Fig. 3 – Removing Push Rod from Upper Side of Cylinder Head using Tool J 3092–01

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.

1. Rest the cylinder head on its side and remove the cam follower guide (Fig. 4).

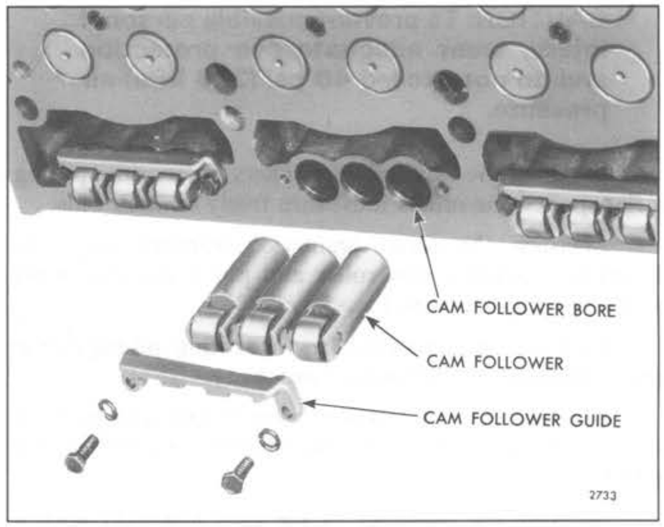


Fig. 4 – Cam Followers and Guide

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.

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.

CAUTION: To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.

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. 5.

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 *Specifications* in Section 1.0).

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.

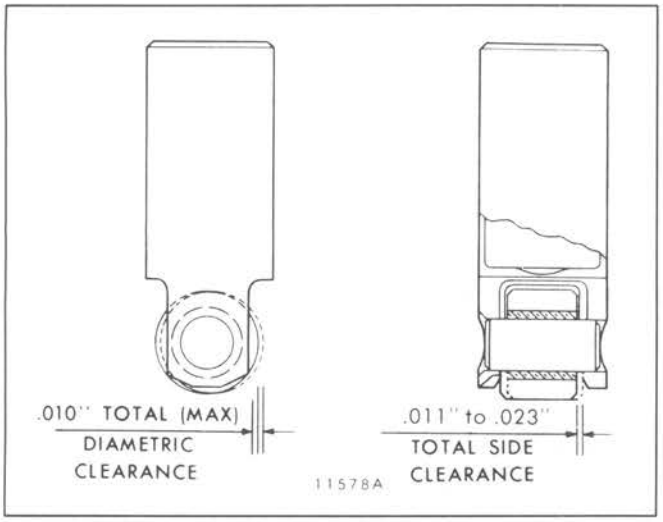


Fig. 5 – Cam Roller Clearances

Inspect the push rods and spring seats for wear. The push rods have milled wrench flats and a bright "turned" finish and the lower spring seats are serrated along the push rod contact surfaces.

Examine the cam follower springs for wear or damage and check the spring load. Replace a spring when a load of less than 250 lbs. will compress it to a length of 2.1406". Use spring tester J 22738–02 to check the spring load (Fig. 6).

Fig. 6 – Testing Cam Follower Spring with Tool J 22738–02

Replace Cam Roller And Pin

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

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

<u>DISASSEMBLE CAM FOLLOWER</u>

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.

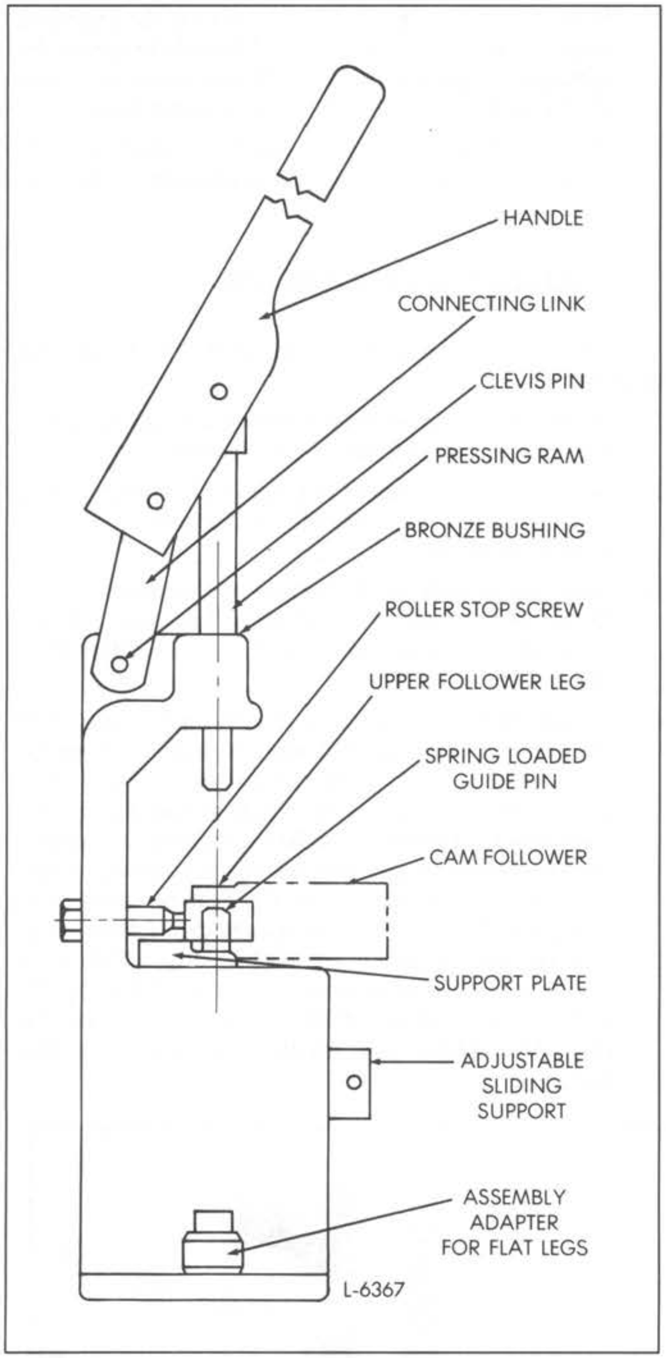


Fig. 7 – Removing or Installing Cam Follower Roller using Tool J 33421

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 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. 5). 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. 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. 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.

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 (Fig. 9), slide the cam follower in position in the cylinder head.

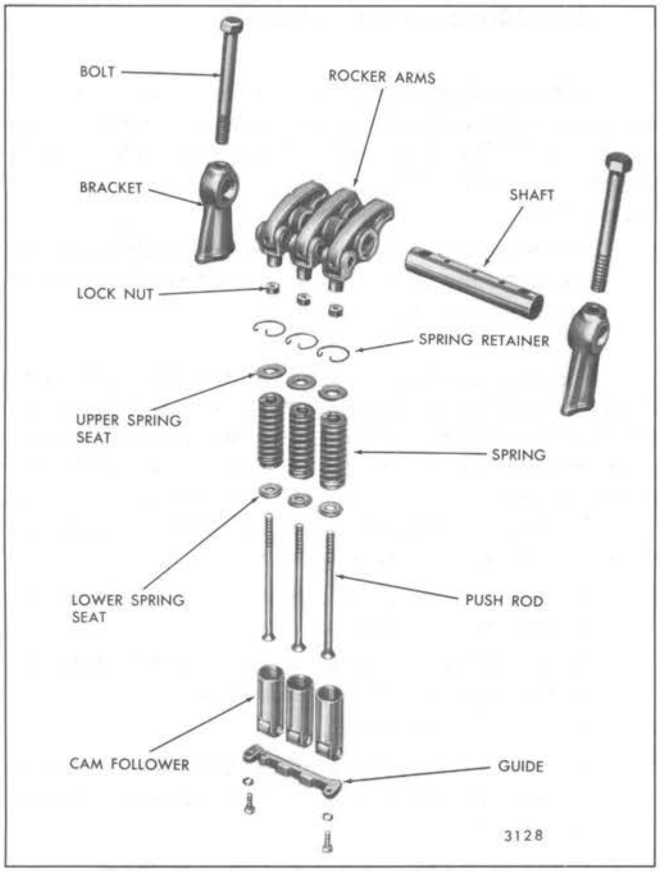


Fig. 8 – Valve and Injector Operating Mechanism and Relative Location of Parts

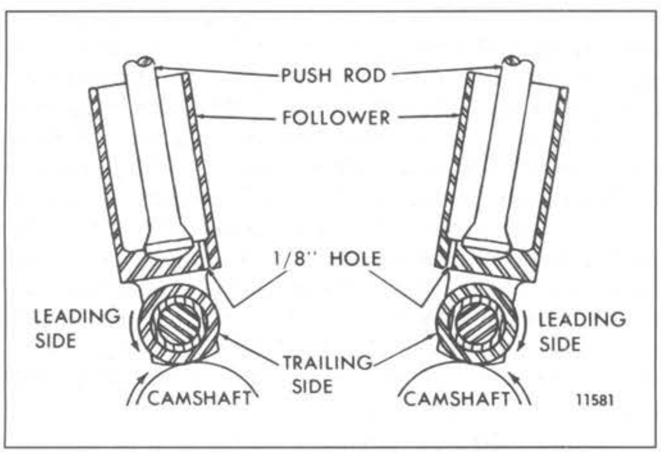


Fig. 9 – Installation of Cam Followers

2. Assemble the *serrated* lower spring seat, spring and upper spring seat on the push rod.
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. Install the retainer with the tangs facing the notch in the cylinder head.
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:

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

1. Assemble the *serrated* lower spring seat, spring, upper spring seat and locknut on the push rod.
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 (Fig. 9), 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. It is important to use the correct bolt as specified in the Parts Book. The hardened bolt is necessary to obtain the proper torque and to withstand the stress imposed on it during engine operation. Check to be sure there is at least .005" clearance between the cam follower legs and the cam follower guide (Fig. 10). If there is insufficient clearance, loosen the guide bolts slightly and tap each corner of the guide with a brass rod (Fig. 11). Then, retighten the bolts to the specified torque.

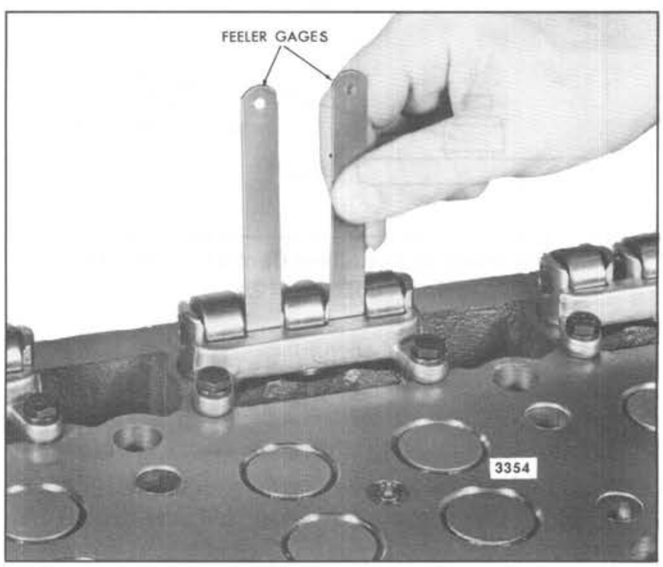


Fig. 10 – Checking Cam Follower to Guide Clearance

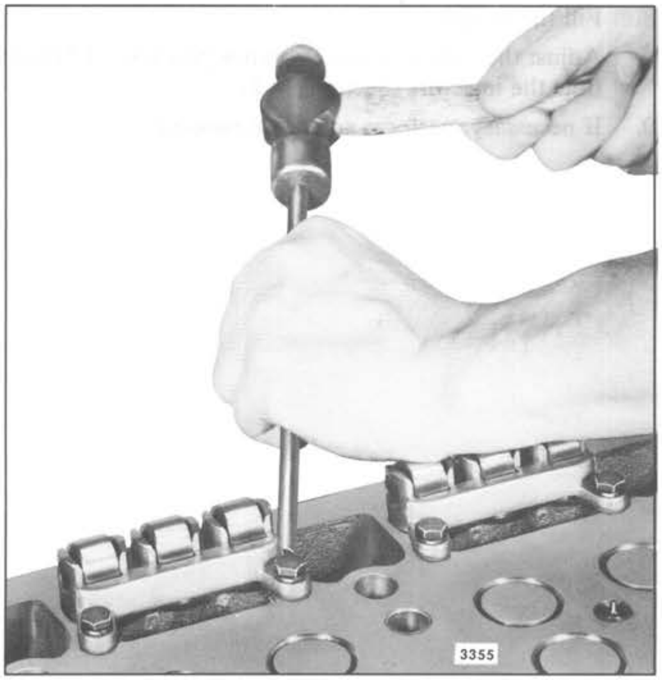


Fig. 11 – Adjusting Cam Follower Guide

Install Rocker Arms And Shaft

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. The exhaust valve rocker arms also have a flat spot beneath the rocker shaft hole to ensure clearance with the valve bridge.

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.

When replacing the injector rocker arm shaft assemblies on 6V and 8V–92TA *coach* engines, only the new cross–drilled rocker arm shaft assembly should be used. The new shaft assembly is cross–drilled at the injector rocker arm (center) position. The injector rocker arm shaft assemblies can be mixed in the same coach engine.

NOTICE: If the rocker arm is damaged or breaks, the push rod should *always* be changed when a 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. Lubricate the valve bridge guides with sulphurized oil (E.P. type) and position the valve bridges in place on the guides. Refer to *Exhaust Valve Bridge Adjustment* in Section 1.2.2 and adjust the valve bridges.
4. If removed, install the fuel injectors.
5. 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.
6. Insert the rocker arm bracket bolts through the brackets and the shaft. Tighten the bolts to the specified torque (refer to *Specifications* in Section 1.0).
7. •Align the fuel pipes and connect them to the injectors and fuel connectors. Fuel pipes may be reused if they are not bent, twisted, restricted and if flared ends are not distorted or otherwise damaged. When installing reusable lines, replace them in the same location and on the same connections from which they were removed.

   To help insure more consistent fastening, tighten fuel pipe nuts on new or reusable fuel pipes to the single torque values shown on the chart. Use fuel line nut wrench J 8932–01 and "clicker" type torque wrench J 24405 (calibrated in inch–pounds).

   NOTICE: Because of their low friction surface, Endurion®–coated nuts on fuel pipes must be tightened to 130–lb–in (14.69 N•m) torque, instead of the 160 lb–in (18.3 N•m) required with uncoated nuts. To avoid possible confusion when tightening fuel pipe nuts, do not mix lines with uncoated and Endurion®–coated nuts on the same cylinder head.

Jacobs brake fuel pipes and those used with load–limiting devices do not have coated nuts. Tighten these to the values shown on the chart.

Fuel Pipe Usage	Torque
Endurion®–coated	130 lb–in. (14.69 N•m)
Uncoated	160 lb–in. (18.3 N•m)
Jacobs Brakes*	120 lb–in. (13.6 N•m)
Load limiting devices	160 lb–in. (18.3 N•m)
DDEC Engines	145 lb–in. (15.6 N•m)

*Not serviced. Available from Jacobs Manufacturing Company.

Jumper Line Nut Torque

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.

EXHAUST VALVES

Four exhaust valves are provided for each cylinder (Fig. 1). The valve heads are heat treated and ground to the proper seat angle and diameter. The valve stems are ground to size and hardened at the end which contacts the exhaust valve bridge.

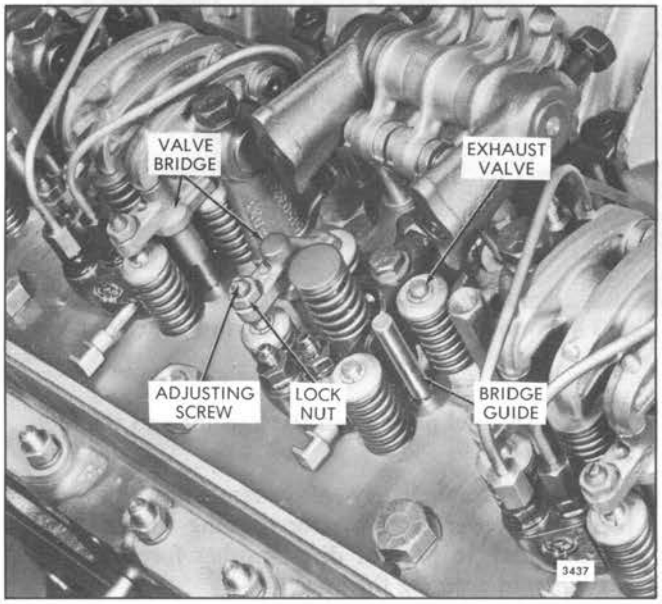


Fig. 1 – Location of Exhaust Valves

A new exhaust valve is now being used in all Series 92 engines effective with engines 6VF–100101, 8VF–82193, 12VF–1377 and 16VF–6069. The new exhaust valve can be identified by the letter "U" forged in the center recess of the valve face. The former and new exhaust valves are interchangeable in an engine and only the new exhaust valve will be serviced.

The exhaust valve stems are contained within exhaust valve guides which are pressed into the cylinder head (Fig. 2).

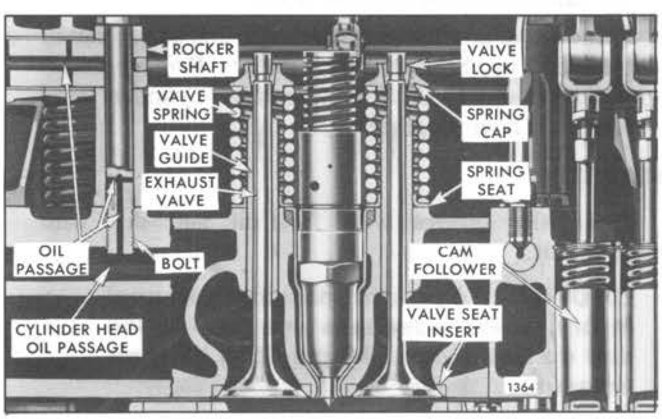


Fig. 2 – Assembly of Exhaust Valves and Guides

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 (Fig. 2).

The exhaust valve springs are held in place by the valve spring caps and tapered two–piece valve locks (Fig. 2).

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 leakproof seating, valve stems must work freely and smoothly within the valve guides and the correct valve clearance must be maintained (Section 14.1).

Proper maintenance and operation of the engine is important to long valve life. Normal engine operating temperature 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 should be changed periodically 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 be struck by the piston and become bent or broken.

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.

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. Discard the gasket.

2. Crank the engine over to bring the valve and injector rocker arms in line horizontally. When using a wrench on the crankshaft bolt at the front of the engine, do not turn the crankshaft in a left–hand direction because the bolt could be loosened.

CAUTION: To reduce the risk of personal injury when barring over or "bumping" the starter while performing an engine turn–up, personnel should keep their hands and clothing away from the moving parts of the engine as there is a remote possibility the engine could start.

Tool J 22582 bolts to the flywheel housing in the same position as the engine starter. Gear teeth on one end of the tool mesh with the flywheel ring gear. The engine can then be rotated by hand with the aid of a 3/4" drive and ratchet.

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

   NOTICE: 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 exhaust valve bridge.
6. 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.
7. Thread the valve spring compressor adaptor J 7455–7 into the rocker arm bracket bolt hole in the cylinder head (Fig. 3). Then, compress the valve spring and remove the two–piece tapered valve lock.
8. Release the tool and remove the 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.

   NOTICE: Be careful not to damage or scratch the critical sealing area around the intermediate water nozzles.

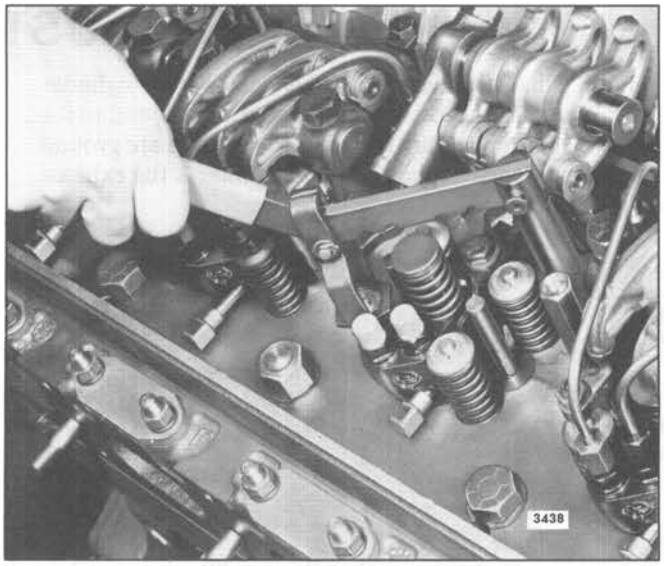


Fig. 3 – Removing Exhaust Valve Spring with Tool J 7455

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

   NOTICE: 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. Remove the exhaust valve bridges.
6. Place a block of wood under the cylinder head to support the exhaust valves. Remove the exhaust valve springs as outlined in Steps 7 and 8 above.
7. 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.
8. 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 and dry with compressed air.

CAUTION: To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.

Inspect springs. Replace a pitted or fractured spring.

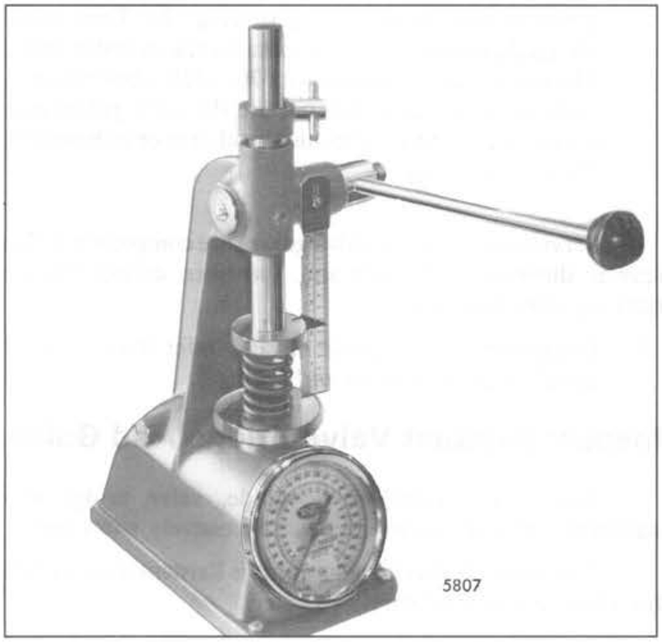


Fig. 4 – Testing Exhaust Valve Spring using Tool J 22738-02

Use spring tester J 22738-02 to check the spring load (Fig. 4). The exhaust valve spring has an outside diameter of approximately .9531". Replace the spring when a load of less than 25 pounds will compress it to 1.80" (installed length).

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

Examine the contact surfaces of the exhaust valve bridge guides, bridges and adjusting screws for wear and galling. Replace excessively worn 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 normally due to overloads, inadequate cooling, or improper timing which results in carbonization of the lubricating oil.

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

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

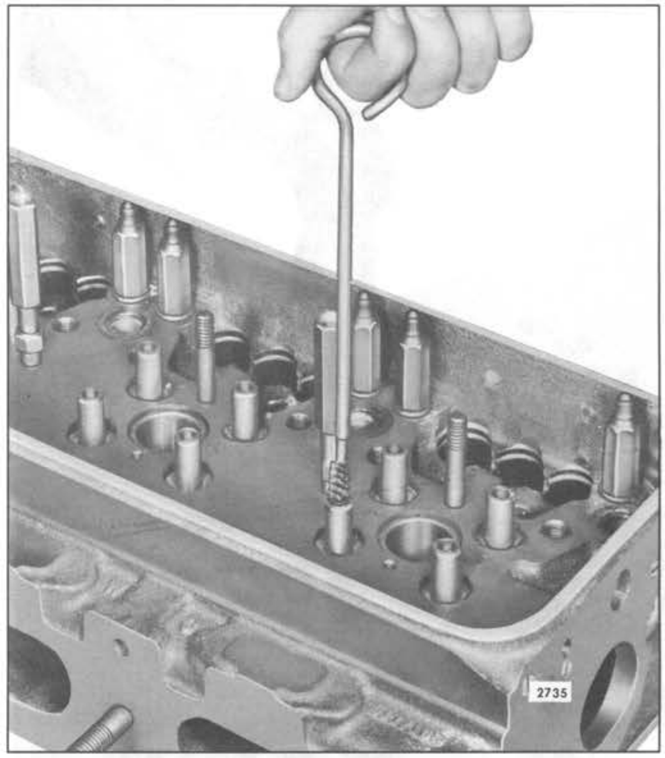


Fig. 5 – Cleaning Exhaust Valve Guide with Tool J 5437

Clean the inside diameter of the valve guides with brush J 5437 (Fig. 5). This brush will remove all gum or carbon deposits from the 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 .005", replace the valve guides.

The valve guides are machined at the upper end.

Replace Exhaust Valve Guide

Remove an exhaust valve guide as follows:

1. Remove and discard the valve guide oil seal, if used.
2. Support the cylinder head, bottom side up, on 2" thick wood blocks.
3. Drive the valve guide out of the cylinder head with tool J 6569 (Fig. 6).

Place the cylinder head right side up on an arbor press and install the valve guide as follows (Fig. 7):

1. Insert the internally threaded end of the valve guide in the valve guide installing tool J 21520.

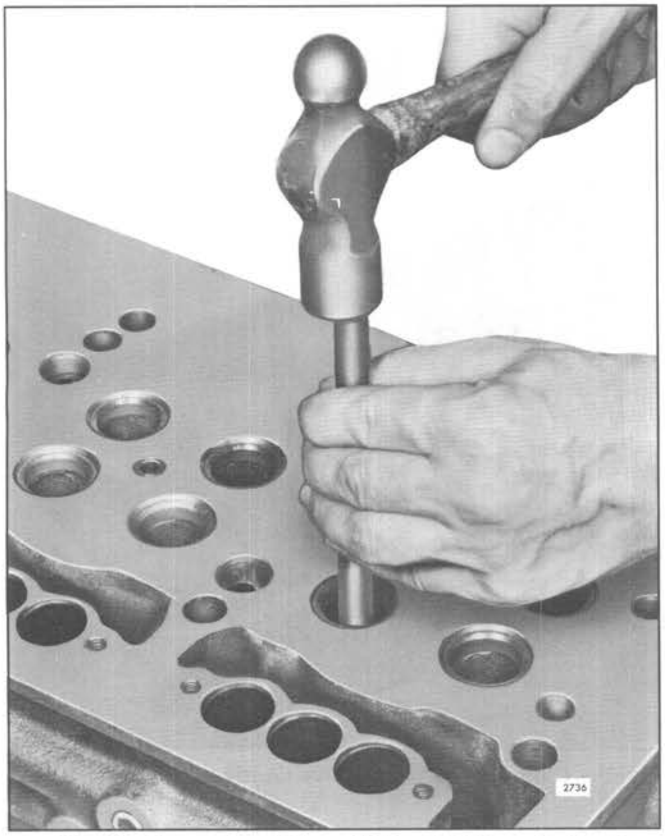


Fig. 6 – Removing Exhaust Valve Guide with Tool J 6569

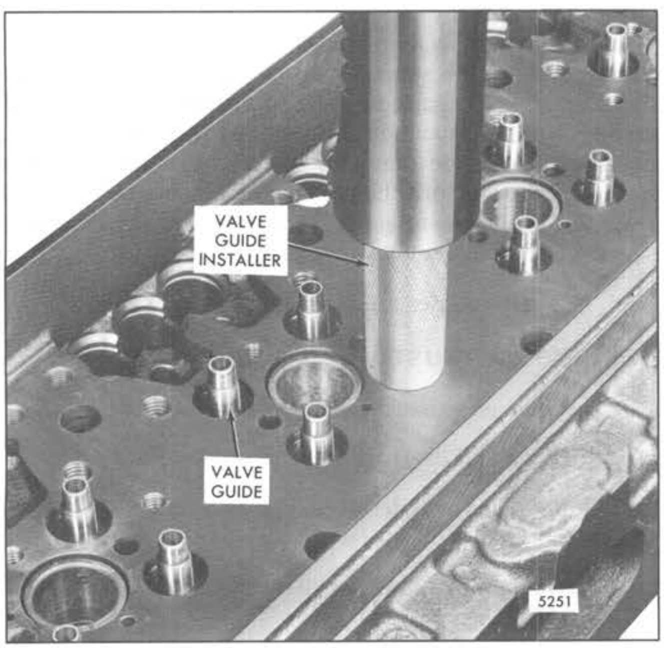


Fig. 7 – Installing Valve Guide with Tool J 21520

2. Position the valve guide squarely in the bore in the cylinder head and press the installing tool J 21520 gently to start the guide in place (Fig. 7). Then, press the guide in until the tool contacts the cylinder head. The tool installs the guide to .670"–.710" above the top of the cylinder head. Do not use the valve guides as a means of turning the cylinder head over or in handling the cylinder head.

Service replacement valve guides are completely finish reamed during manufacture and, therefore, do not require reaming after installation.

3. Install a new valve guide oil seal (refer Item 5 under *Install Exhaust Valves and Springs).*

Inspect Exhaust Valve Bridge And Guide

Inspect the valve bridge guide, valve bridge and adjusting screw for wear. Replace excessively worn parts.

The press–fit valve bridge guide is hardened steel while the valve bridge is relatively soft steel.

Remove Exhaust Valve Bridge Guide

Remove the valve bridge guide from the cylinder head as outlined below:

1. Remove the press–fit guide with tool set J 7091–01 as follows (Fig. 8):

   a. File or grind two diametrically opposite notches 1/16" deep in the side of the guide, approximately 1–1/4" to 1–1/2" from the upper end.

   b. Place spacer J 7091–3 over the guide. Then, slide the guide remover J 7091–5 over the guide and align the set screws with the notches in the guide. Tighten the set screws to hold the tool securely.

   c. Place spacer J 7091–4 over the guide remover. Thread the nut on the guide remover and turn it clockwise to withdraw the guide from the cylinder head.

To remove a broken valve bridge guide, drill a hole approximately 1/2" deep in the end of the guide with a No. 3 (.2130") drill. Then, tap the guide with a 1/4"–28 bottoming tap. Thread remover J 7453 into the guide and attach slide hammer J 2619–01 to the remover tool. One or two sharp blows with the puller weight will remove the broken guide (Fig. 9).

Install Exhaust Valve Bridge Guide

Install the press–fit bridge guide as follows:

1. Apply a sealant such as Permatex #1, 3M–EC971 or equivalent to the valve bridge guide. Start the guide (undercut end first) straight into the cylinder head.

Fig. 8 – Removing Press–Fit Exhaust Valve Bridge Guide

2. Place the installer J 7482 over the guide and drive it into place. The installer will properly position the guide to the correct height in the cylinder head.

Inspect Exhaust Valve Seat Insert

A new exhaust valve seat insert is pre–ground and only needs to be checked for concentricity after installation. Do not grind a new valve seat insert unless the runout exceeds .002".

Inspect the valve seat inserts for excessive wear, pitting, cracking or an improper seat angle. The proper angle for the seating face of the valve is 30° and the angle for the insert is 31°. When a valve seat insert has been ground to such an extent that the grinding wheel will contact the cylinder head, install a new insert.

Remove Exhaust Valve Seat Insert

Use the cam operated exhaust valve seat insert puller J 23479–492 and collet J 23479–33 to remove the insert from the cylinder head.

Install Exhaust Valve Seat Insert

1. Clean the valve insert counterbore in the cylinder head with trichloroethylene or other good solvent. Also, wash the valve seat insert with the same solvent. Dry both the counterbore and the insert with compressed air.
2. Inspect the valve seat insert counterbore in the cylinder head for cleanliness, concentricity, flatness and cracks. The counterbores have a diameter of 1.440" to 1.441" and a depth of .3395" to .3505". The counterbores must be concentric with the valve guides within .002" total indicator reading. If required, use a valve seat insert which is .010" oversize on the outside diameter.
3. Immerse the cylinder head for at least 30 minutes in water heated to a temperature of 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. Install the insert in the cylinder head while the head is still hot and the insert is at room temperature, otherwise installation will be difficult and the parts may be damaged.

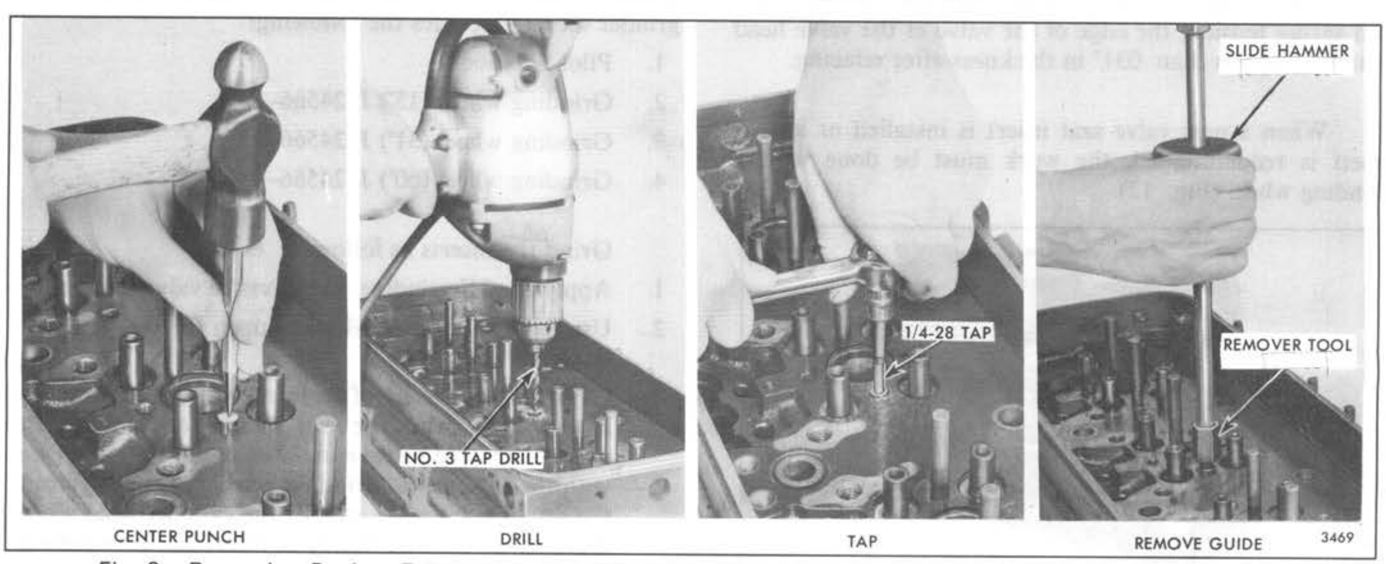


Fig. 9 – Removing Broken Exhaust Valve Bridge Guide with Tool J 7453 and Slide Hammer J 2619–01

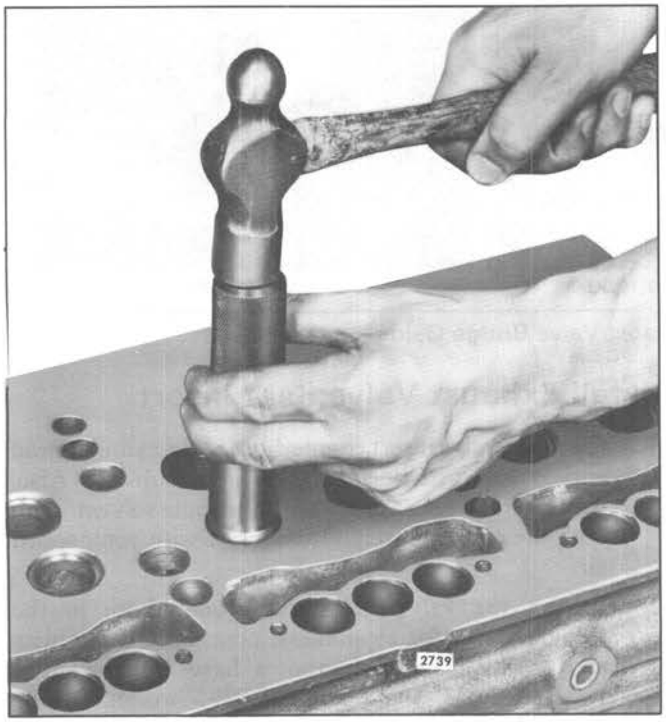


Fig. 10 – Installing Valve Seat Insert with Tool J 24357

5. Drive the insert in place with installer J 24357 (Fig. 10) until it seats solidly in the cylinder head.
6. Grind the valve seat insert and check it for concentricity in relation to the valve guide as outlined below.

Recondition Exhaust Valve And Valve Seat

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 .031" in thickness after refacing.

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

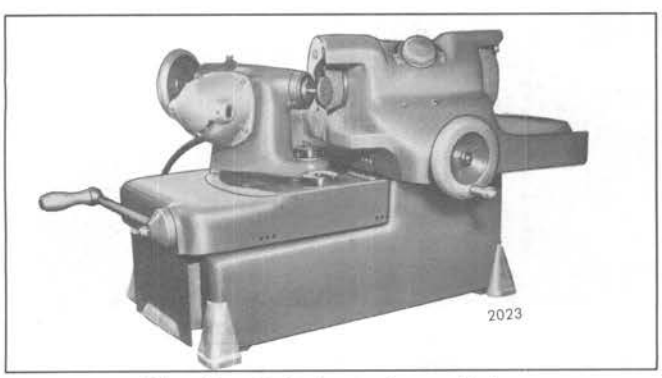


Fig. 11 – Refacing Exhaust Valve

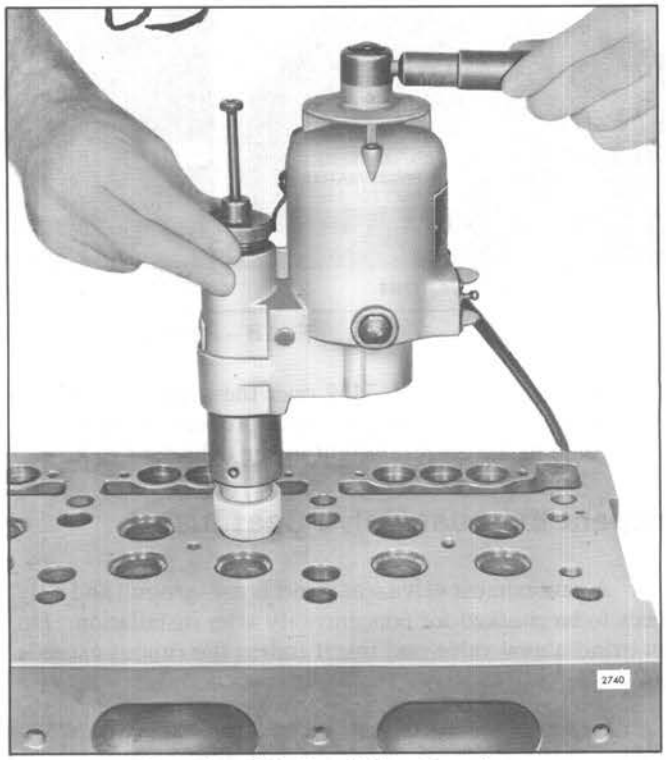


Fig. 12 – Grinding Valve Seat Insert

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

Eccentric valve seat grinder set J 7040, which includes the grinder, dress stand and pilot, and dial gage, is used to grind the inserts. An adaptor set J 24566 is used with the grinder set and includes the following:

1. Pilot J 24566–1.
2. Grinding wheel (15°) J 24566–2.
3. Grinding wheel (31°) J 24566–3.
4. Grinding wheel (60°) J 24566–4.

Grind the inserts as follows:

1. Apply the 31° grinding wheel on the valve seat insert.
2. Use the 60° grinding wheel to open the throat of the insert.
3. Grind the top surface of the insert with the 15° wheel to narrow the width of the seat. The 31° face of the insert may be adjusted relative to the center of the valve face with the 15° and 60° grinding wheels. Do not permit the grinding wheel to contact the cylinder head when grinding the inserts. When an insert has been ground to the extent that the grinding wheel contacts the cylinder head, install a new insert.

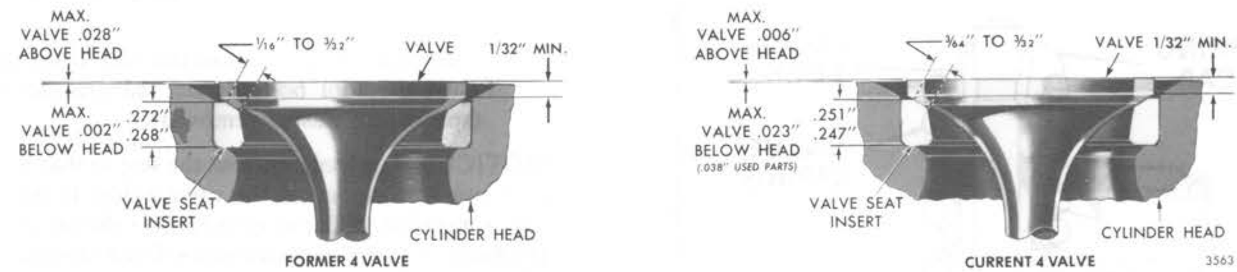


Fig. 13 – Exhaust Valve Protrusion Beyond Cylinder Head

The maximum amount the exhaust valve should protrude beyond the cylinder head (when the valve is closed) and still maintain the proper piston–to–valve clearance is shown in Fig. 13. 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 receded beyond the specified limits, replace the valve seat insert.

4. When occasion requires, the grinding wheel may be dressed to maintain the correct seat angle with the dressing tool provided with the grinder set (Fig. 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 these limits replace the valve seat insert.

5. After the grinding has been completed, clean the valve seat insert thoroughly with fuel oil and dry it with compressed air. Set the dial indicator J 8165–2 in position (Fig. 15) and rotate it to determine the concentricity of each valve seat insert relative to the valve guide. Total runout should not exceed .002". If a runout of more than .002" is indicated, check for a bent or worn valve guide before regrinding the insert.

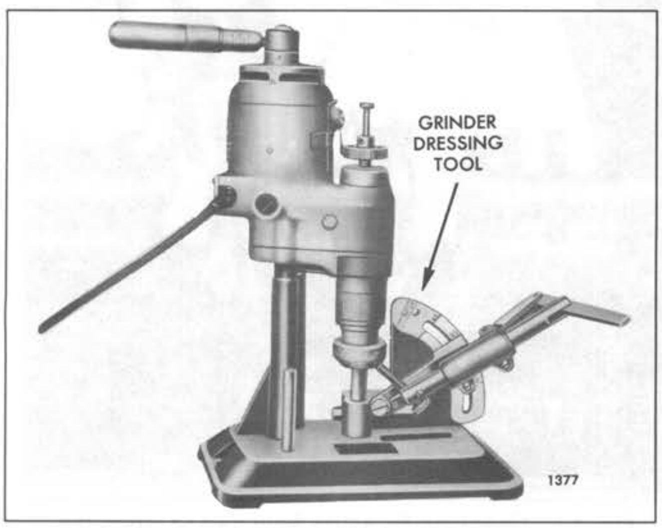


Fig. 14 – Grinding Wheel Dressing Tool of Set J 24566

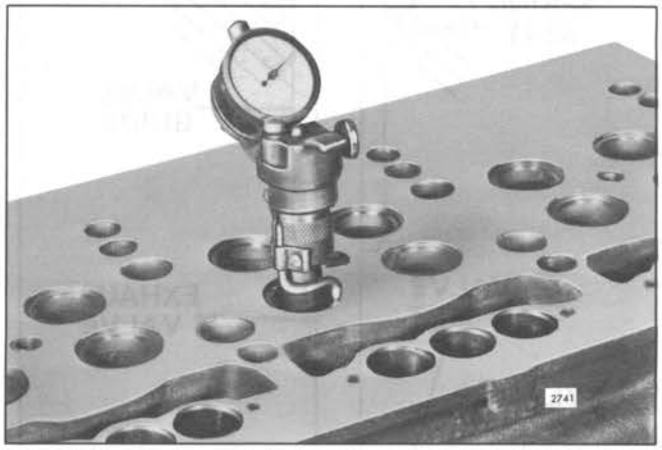


Fig. 15 – Checking Relative Concentricity of Valve Seat Insert with Relation to Valve Guide

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:

1. Apply a light coat of Prussian blue, or a similar paste, to the valve seat insert.
2. Lower the stem of the valve in the valve guide and "bounce", but do not rotate, the valve on the insert. This procedure will indicate the area of contact on the valve face. The mose desirable area of contact is at the center of the valve face. The use of valve lapping compounds is not recommended.

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

Install Exhaust Valves And Springs

Install the exhaust valves as follows:

1. Clean the valve guides. (Fig. 16).
2. Lubricate the valve stems with sulphurized oil (E.P. type) and slide the valves all the way into the guides. If reconditioned valves are used, install them in the same relative location from which they were removed.

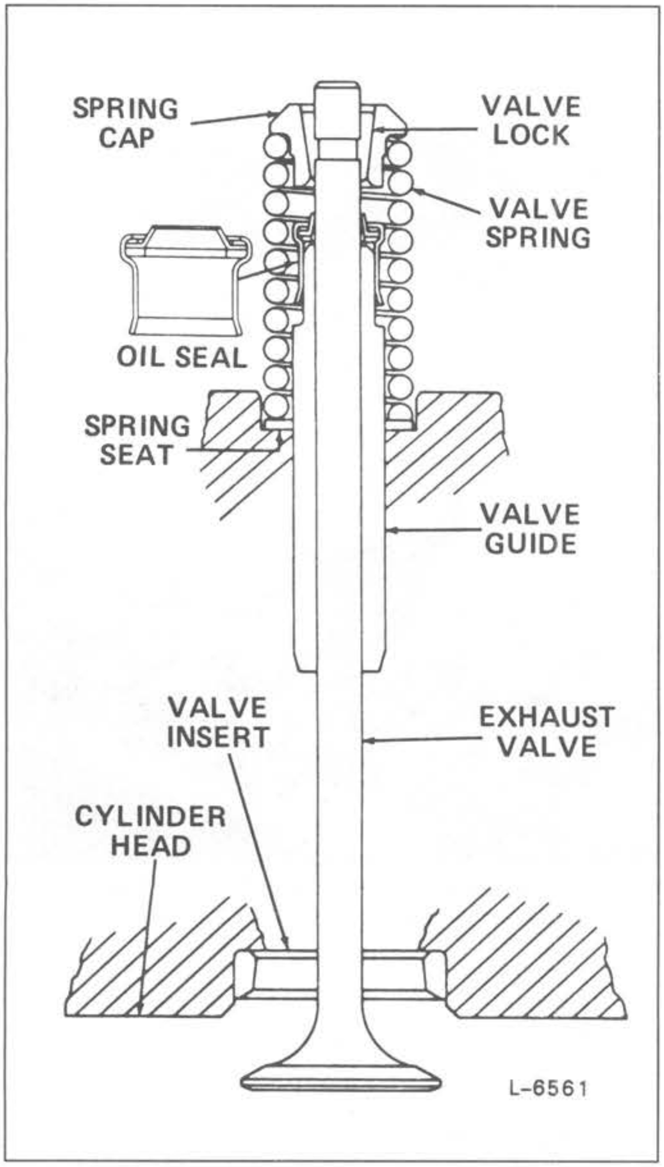


Fig. 16 – Exhaust Valve, Spring and Seal Configuration

3. Hold the valves in place with a strip of masking tape and turn the cylinder head right side up on the bench. Place a board under the head to support the valves and to provide clearance between the cam followers and the bench.
4. Install the valve spring seats.
5. Install the valve guide oil seal, if used, on the valve guide as follows:
   a. Place a plastic seal installation cap of the proper size 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 with clean engine oil and start the seal carefully over the valve stem.
   c. Using tool J 35373, push the seal down slowly until the tool *bottoms on the cylinder head* (spring seat washer removed).

   NOTICE: The tool positions the seal so that it does not bottom out on the valve guide. If the seal is installed too far so as to contact the top of the guide, it will be distorted and will not provide effective sealing.

   d. Remove the installation cap.
6. Install the valve springs and valve spring caps.
7. Thread the valve spring compressor J 7455 into one of the rocker shaft bolt holes in the cylinder head (Fig. 3).
8. 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. Give the end 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.

   NOTICE: Compress the valve spring only enough to permit installation of the valve locks. Compressing the spring too far may result in damage to the valve guide oil seal.

9. Release the tool and install the valve locks on the remaining exhaust valves in the same manner.
10. Check the position of the exhaust valve.

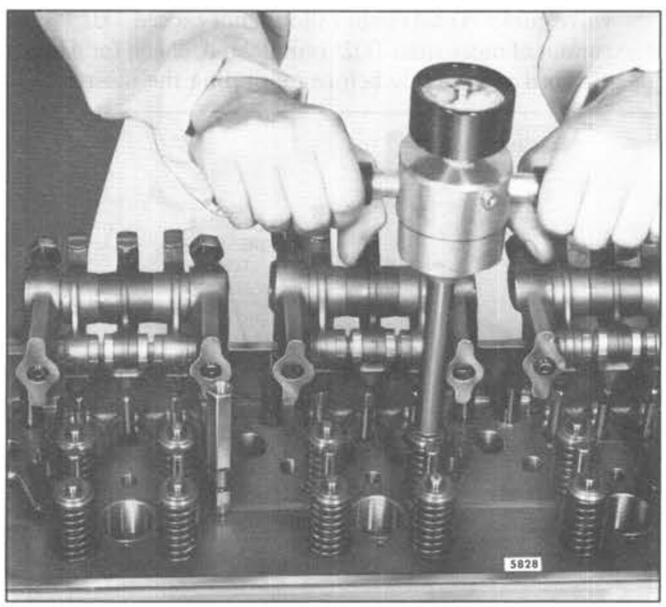


Fig. 17 – Checking Pressure Required to Open the Exhaust Valve in Cylinder Head with Tool J 25076-01

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. 17). The minimum allowable pressure required to start to open the exhaust valve must not be less than 20 pounds.
12. Install the injectors, rocker arms, shafts, brackets and any other parts previously removed from the cylinder head.
13. Install the cylinder head (see *Pre–Installation Inspection* and *Install Cylinder Head* in Section 1.2). Adjust the exhaust valve bridges as outlined below.

Exhaust Valve Bridge Adjustment

A complete valve bridge adjustment is performed as follows:

1. Place the valve bridge in a vise or bridge holding fixture J 21772 and loosen the locknut on the bridge adjusting screw.

   NOTICE: Loosening or tightening the locknut with the bridge in place may result in a bent bridge guide or bent rear valve stem.

2. Install the valve bridge on the valve bridge guide.
3. While firmly pressing straight down on the pallet surface of the valve bridge, turn the adjusting screw clockwise until it just touches the valve stem. Then, turn the screw an additional 1/8 to 1/4 turn clockwise and tighten the locknut finger tight (Fig. 18).

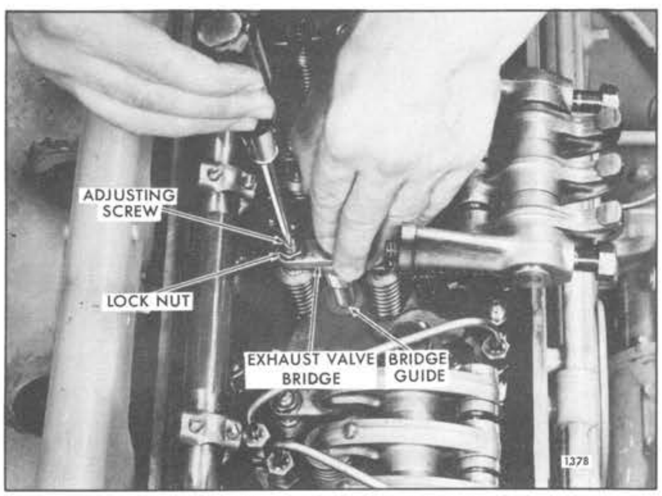


Fig. 18 – Valve Bridge Adjustment

4. Remove the valve bridge and place it in a vise. Use a screw driver to hold the adjustment screw from turning and tighten the locknut to 20–25 lb–ft (27–34 N•m) torque.
5. Lubricate the valve bridge guide and the valve bridge with engine oil.
6. Reinstall the valve bridge in its *original* position.
7. Place a .0015" feeler gage (J 23185) under each end of the valve bridge or use a narrow strip cut from .0015" feeler stock to fit in the bridge locating groove over the inner exhaust valve. While pressing down on the pallet surface of the valve bridge, both feeler gages must be tight. If both of the feeler gages are not tight, readjust the adjusting screw as outlined in Steps 3 and 4.
8. Remove the valve bridge and reinstall it in its *original* position.
9. Adjust the remaining valve bridges in the same manner.
10. Swing the rocker arm assembly into position, making sure the valve bridges are properly positioned on the rear valve stems. This precaution is necessary to prevent valve damage due to mislocated valve bridges. Tighten the rocker arm shaft bracket bolts to the torque specified (refer to *Specifications* in Section 1.0).

After the cylinder head is installed and the valve bridges adjusted, proceed as follows:

1. Refer to Section 2.1.1 under *Install Injector* and install the fuel pipes.
2. Fill the cooling system.
3. Adjust the exhaust valve clearance and time the injectors (Sections 14.1 and 14.2).
4. Start the engine and check for leaks in the fuel, cooling and lubrication systems.
5. Perform a complete engine tune–up as outlined in Section 14.

VALVE ROCKER COVER

The valve rocker cover assembly (Fig. 1) completely encloses the valve and injector rocker arm compartment at the top of the cylinder head. The top of the cylinder head is sealed against oil leakage by a gasket located in the groove of the lower rail of the current die cast rocker cover or in the flanged edge of the former stamped metal rocker cover.

An option plate is inserted in a retainer attached to one of the covers.

The current die cast rocker cover (Fig. 1) is held in place by 3/8"–16 twelve–point head shoulder bolts with a steel washer and silicone isolator. The bolts have a shoulder which bottoms out against the cylinder head or throttle delay bracket. The isolators and gasket use low compression–set materials which provide long sealing life and minimize engine noise levels. Tighten the bolts to 15–20 lb–ft (20–27 N•m) torque. The shorter rocker cover bolt, which threads

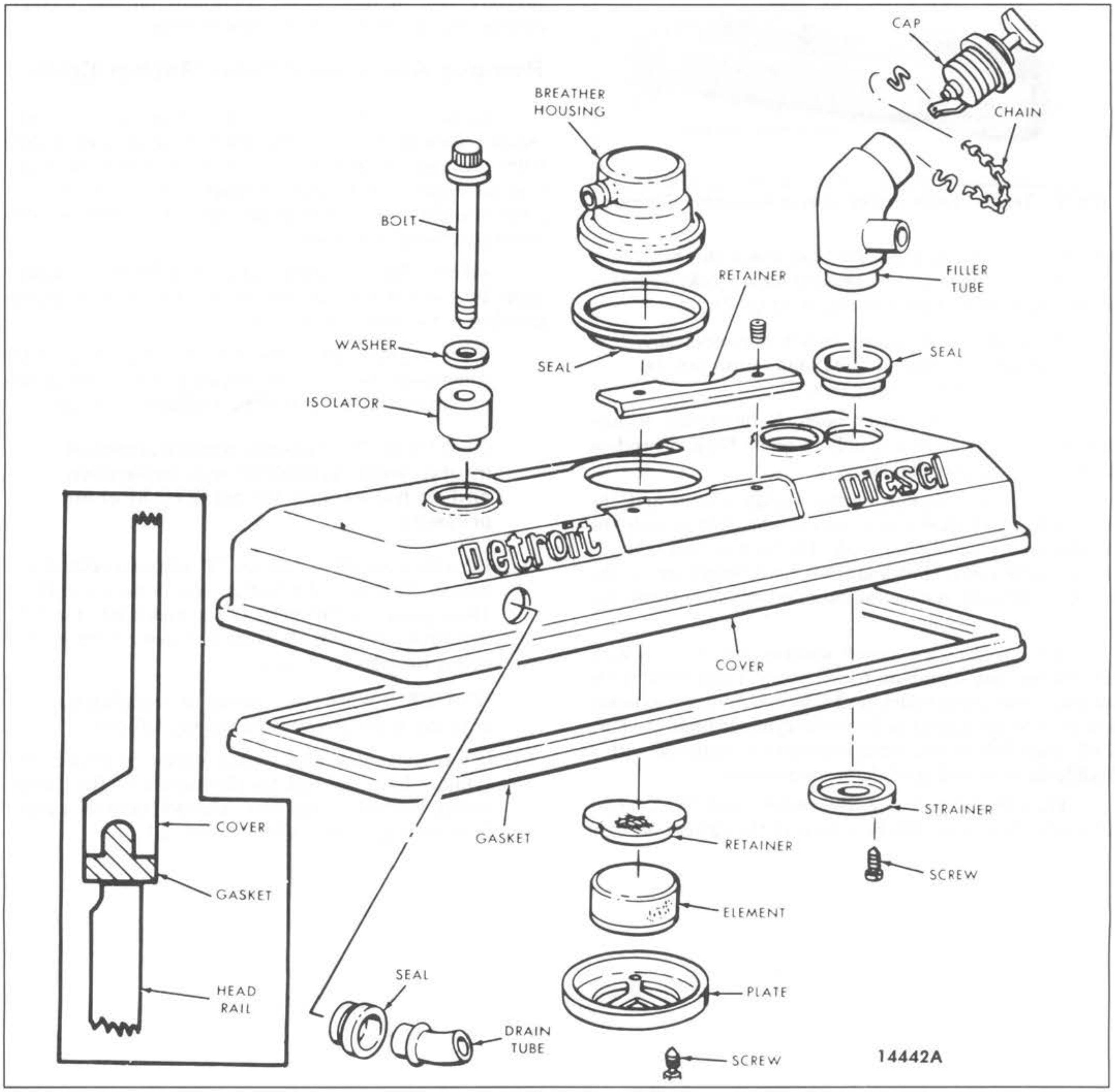


Fig. 1 – Typical Valve Rocker Cover Assembly (Current)

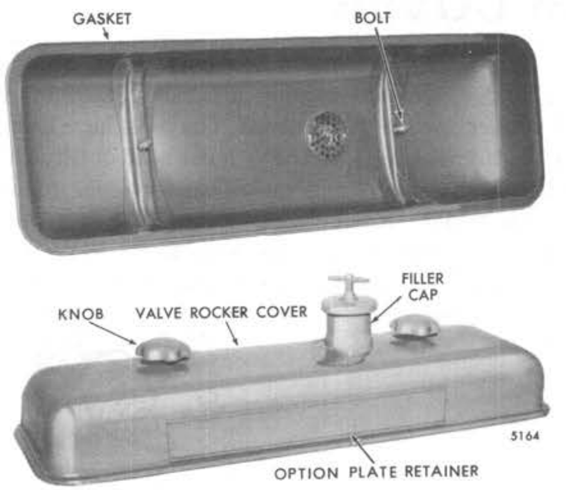


Fig. 2 – Typical Valve Rocker Cover Assembly (Former)

into the throttle delay bracket, can crack the bracket, if overtightened. The former stamped metal rocker cover is held in place with hold–down knobs (Fig. 2).

NOTICE: The rocker cover bolt is especially designed for this purpose and must not be replaced by an ordinary bolt.

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

The former stamped metal rocker covers and the current die cast rocker covers are interchangeable. Only the current covers will be serviced. The former rocker cover gaskets, hold–down knob and studs, and components of the former ventilating system and oil filler will be available for service on early engines.

When replacing a former stamped rocker cover with the new die cast aluminum rocker cover, remove the studs (adaptor) from the cylinder head. The new bolts are installed directly into the tapped holes in the cylinder head. A short (2.90" long) bolt is used when the engine is equipped with a throttle delay or fuel modulator mechanism.

The current rocker cover gaskets and the current hold–down bolts can only be used with the current die cast rocker cover. Do not use the former gasket and hold–down knobs with the die cast cover.

Effective with engine serial number 6VF–105223, the right–bank rocker cover breather and associated hardware have been removed from 6V–92TA, TTA automotive and 6V–92TA upright coach engines. Removal of the right–bank rocker cover breather affects 6V–92TA, TTA automotive and 6V–92 upright coach engines *only*. Failure to use a rocker cover breather on the left bank head can result in excessively high engine crankcase pressure. Excessive pressure can, in turn, cause crankshaft oil seal leakage and/or loss of oil through the dipstick tube.

Remove And Install Valve Rocker Cover

Clean the valve rocker covers and around the covers before removing them from the engine to avoid dust or dirt from entering the valve mechanism. Then, loosen the bolts (current engines) or the knobs (former engines) and lift each cover straight up from the cylinder head. Use a new gaskets when reinstalling the covers.

Before a die cast rocker cover is installed on a cylinder head, it is important that the silicone gasket be properly installed in its groove in the rocker cover.

1. Clean and blow out the groove in the rocker cover with compressed air. Oil in the rocker cover groove or on the silicone gasket will make it difficult to install.

   CAUTION: To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.

2. Press the stem side of the new "T" shaped gasket down into the groove at the four corners of the cover first. Then, press the remainder of the gasket into place in the groove (Fig. 1). Be sure the stem of the entire gasket bottoms in the groove.

   NOTICE: When the gasket is completely installed in the groove it should not fall out.

3. Before installing the rocker cover, lubricate the cylinder head rail and the flat surface of the gasket with a thin film of engine oil. This will keep the gasket from sticking to the cylinder head rail.

CRANKSHAFT

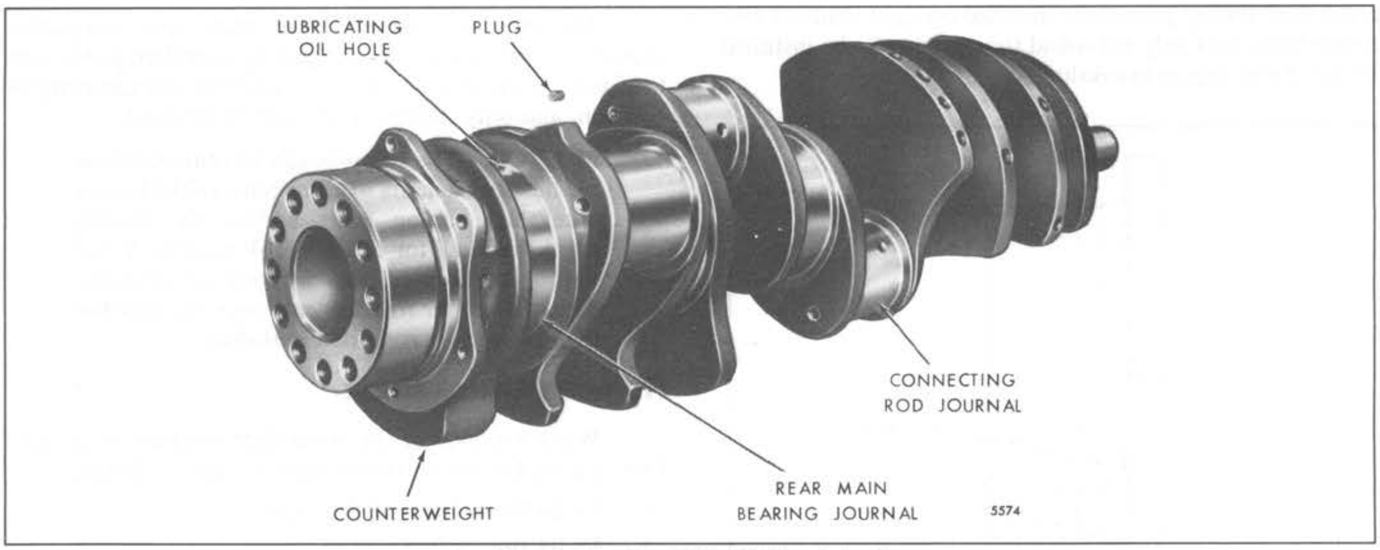


Fig. 1 – Typical 8V–92 Crankshaft

The crankshaft is a one–piece steel forging, heat–treated to ensure strength and durability (Fig. 1). A two–piece crankshaft assembly is used on the 12V–92 and 16V–92 engines. The two halves are bolted together at the center flange (Fig. 9). The main and connecting rod bearing journal surfaces and fillets on all crankshafts are induction hardened.

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 8V engines, twelve tapped holes equally spaced are provided for attaching the flywheel. No dowels are provided for locating the flywheel. On 6V–92, 12V–92 and 16V–92 engines, six tapped holes and two dowels are provided for attaching the flywheel.

Each main bearing journal is 4–1/2" in diameter and each connecting rod journal is 3" in diameter.

• New crankshafts with offset main bearing journal oil holes replaced the former crankshafts effective with engine serial numbers 6V F0123940, 8V F098671, 12V F002032, 16 VF006468.

The new crankshafts differ from the former in that the main bearing journal oil holes are relocated (offset) approximately 90° to the oil holes in the former crankshafts and are drilled at intersecting angles, instead of straight through (Fig. 2). These changes provide up to a 50% thicker

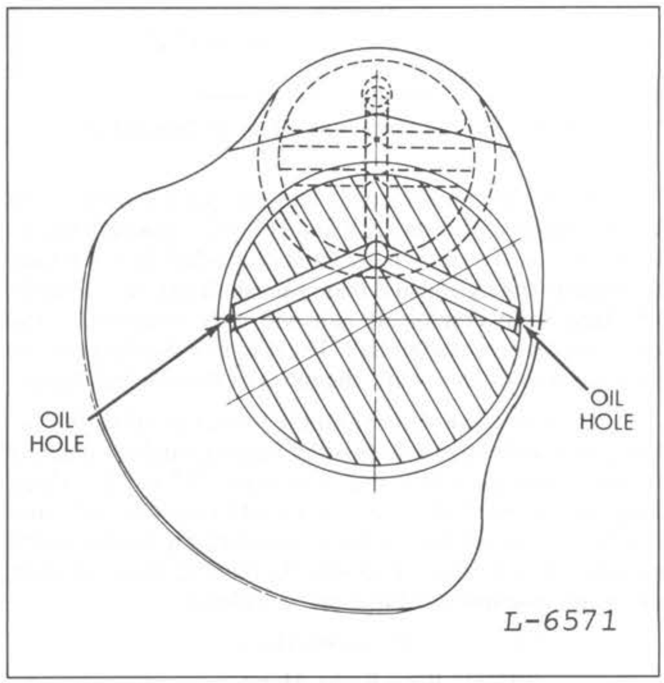


Fig. 2 – Cross–Sectional View of Crankshaft Showing Offset, Relocated Main Bearing Journal Oil Holes

oil film on the main bearing journals during engine operation.

The new crankshafts are also *undirectional.* Right–hand rotation crankshafts must be used with right–hand rotating engines, and left–hand rotation crankshafts must be used with left–hand rotating engines.

New crankshaft timing gears have been released as part of this change. The new timing gears have a hole drilled in their bolt flanges. This hole provides clearance for a new 1/4" x 3/4" L. roll pin installed in the timing gear end of the new crankshafts (Fig. 3). The pin permits only right–hand crankshaft timing gears to be installed on right–hand engine crankshafts, and only left–hand timing gears to be installed on left–hand engine crankshafts.

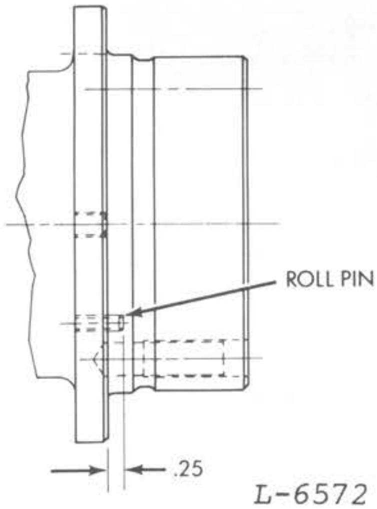


Fig. 3 – Roll Pin Installed in End of Crankshaft

A similar clearance hole and roll pin are used in the mating flanges of the new 12V and 16V–92 crankshaft halves to ensure that the right–hand front crankshaft half will only assemble to the right–hand rear crankshaft half, and that the left–hand front crankshaft half will only assemble to the left–hand rear crankshaft half. The hole is in the flange of the front crankshaft half, while the pin is in the rear half flange.

To distinguish them from the former crankshafts, the new crankshafts have a seven–digit forging number on one of the counterweights, followed by a letter "R" or "L" which designates crankshaft rotation. In addition, the 12V and 16V–92 crankshaft halves have new assembly marks which are used for alignment. These marks *must* be lined up when halves are assembled. Marks are as follows:

"FRH" Front Right–Hand

"RRH" Rear Right–Hand

"FLH" Front Left–Hand

"RLH" Rear Left–Hand

An additional feature of the new 8V–92 crankshafts is an increased diameter at the in–pan oil pump drive gear area. This was done to provide a press fit of the oil pump drive gear and eliminate the need to secure the gear in place with anaerobic adhesive (Locite). Because of the larger diameter in this area, a different oil pump drive hub is used on 8V–92 engines with front cover oil pumps. The 6V–92 crankshaft does not have the increased diameter at the oil pump drive gear area and may use the former oil pump drive hub with a front cover oil pump. New production 6V–92 engines are built with the new oil pump drive hub.

The new crankshafts with their new respective crankshaft timing gears are completely interchangeable with the former crankshafts and timing gears for the same engine rotation, and only the new parts will be serviced.

NOTICE: The roll pins can be removed from the new crankshafts to allow reuse of the former crankshaft timing gears and/or the mating crankshaft half for 12V and 16V engines. When reusing the former gears without the clearance hole, *the proper rotation gear must be matched with the proper rotation crankshaft.*

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 or eye bolts at each end of the engine, remove the engine from its base.
5. Remove all of the accessories and assemblies with their attaching parts, as necessary, to permit the engine to be mounted on an overhaul stand.
6. Mount the engine on an overhaul stand and fasten it securely to the mounting plate.

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

7. Remove the oil pan.
8. Remove the lubricating oil pump, if the pump is mounted on the main bearing caps.
9. Remove the flywheel and flywheel housing.
10. Remove the crankshaft cap or pulley retaining bolt and washer at the front end of the crankshaft. Then, remove the pulley, if used.
11. If used, remove the vibration damper (except on the 12V–92 and 16V–92 engines – refer to Step 20).
12. Remove the front engine support.
13. Remove the crankshaft front cover and oil pump assembly.
14. Remove the vibration damper inner cone or oil seal spacer.
15. Remove the cylinder heads.

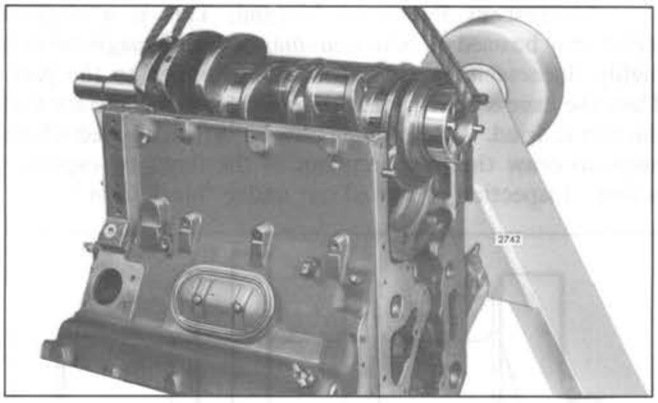


Fig. 4 – Removing or Installing Crankshaft

16. Remove the connecting rod bearing caps.
17. Remove the main bearing caps and stabilizers.
18. Remove the thrust washers from each side of the rear main bearing cap.
19. Remove the pistons, connecting rods and liners.
20. Remove the crankshaft, including the timing gear and oil pump drive gear (Fig. 4).

    NOTICE: On the 12V–92 and 16V–92 engines, remove the crankshaft, including the damper assembly, timing gear and hub (at the front end) and the oil pump driving gear and timing gear (at the rear end).

21. Refer to Section 1.7.5 for removal of the crankshaft timing gear.
22. Remove the oil pump drive gear and Woodruff keys from the crankshaft.

Inspection

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

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

CAUTION: To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.

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 plug.

Inspect the keyways for evidence of cracks or wear. Check for damage or distress at the oil pump drive keyway. Replace the crankshaft if any of these conditions are evident.

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

Check the crankshaft journal surfaces for score marks and other imperfections. If excessively scored, the journal surfaces must be reground.

Carefully, inspect the 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.

If the crankshaft oil seal contact surface is excessively worn and grooved, the seal surface can be sleeved and an oversized seal should be used.

Check the crankshaft thrust surfaces for excessive wear or grooving. If excessively worn, the thrust surfaces must be reground.

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

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.

Crankshaft bow check – If the runout limit is greater than that given in Table 1, the crankshaft must be replaced.

Adjacent Journal Alignment

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 in Table 1, the crankshaft must be replaced.

Engine	Journals Supported On	Journals Measured	Max. Run-Out (Total indicator reading)
6V	No. 1 and No. 4	No. 2 and No. 3	.002"
8V	No. 1 and No. 5	No. 2 and No. 4	.002"
		No. 3	.004"
12V	No. 1 and No. 8	No. 2 and No. 7	.002"
		No. 3 and No. 6	.004"
		No. 4 and No. 5	.006"
16V	No. 1 and No. 10	No. 2 and No. 9	.002"
		No. 3 and No. 8	.004"
		No. 4 and No. 7	.006"
		No. 5 and No. 6	.008"

TABLE 1

Journal Measurements

Measure all of the main and connecting rod bearing journals (Fig. 5). 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 or main bearing journal-to-bearing shell clearance (with new shells) exceeds .0045" (connecting rod journals) or .0055" (main bearing journals), the crankshaft must be reground. Measurements of the crankshaft should be accurate to the nearest .0002". Also, if the main bearing journal taper of a used crankshaft exceeds .0004" or the out-of-round is greater than .0005", the crankshaft must be reground. Also, measure the crankshaft thrust washer surfaces (Fig. 6).

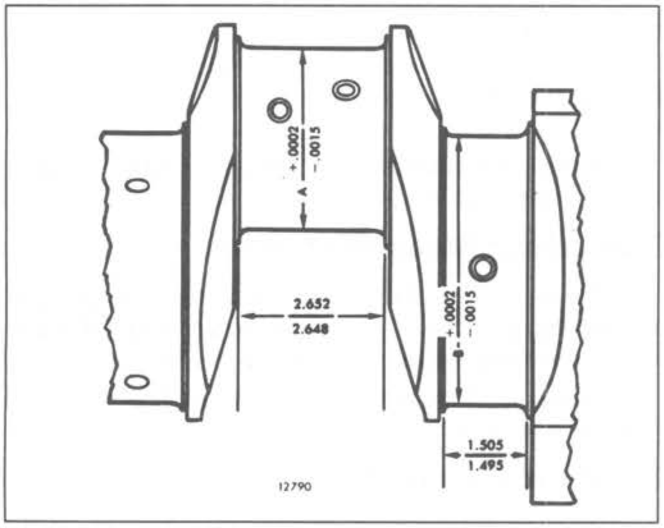


Fig. 5 – Dimensions of Crankshaft Journals

Inspection For Cracks

Carefully, check the crankshaft for cracks which start at an oil hole and follow the journal surface at an angle of 45° to the axis. Any crankshaft with such cracks must be rejected. Several methods of determining the presence of minute cracks not visible to the eye are outlined below.

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

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

Fluorescent Penetrant Method: This is a method which may be used on both *non-magnetic and magnetic* mat 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".

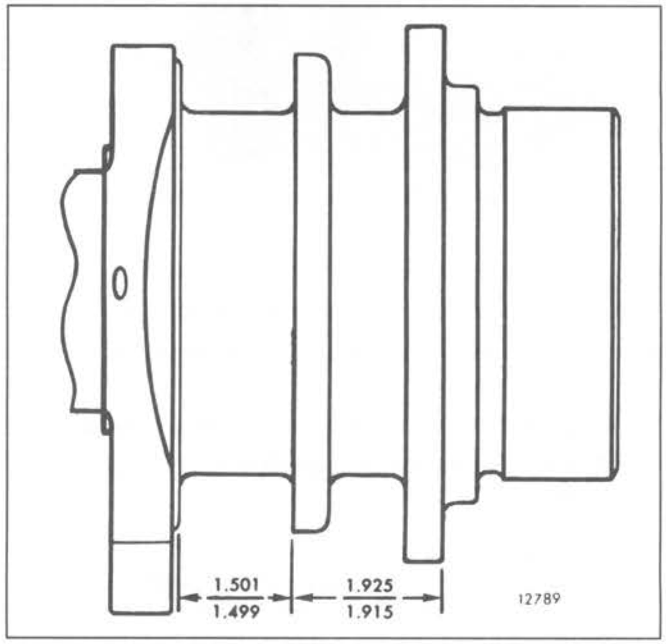


Fig. 6 – Standard Dimension at Rear Main Bearing Thrust Washers

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* forc 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. 7).

Bending fatigue failures result from bending of the crankshaft which takes place once per revolution.

The crankshaft is supported between each of the cylinders by a main bearing and the load imposed by the gas pressure on top of the piston is divided between the adjacent bearings. An abnormal bending stress in the crankshaft, particularly in the crank fillet, may be a result of misalignment of the main bearing bores, improperly fitted bearings, bearing failures, a loose or broken bearing cap, or unbalanced pulleys. Also, drive belts which are too tight will 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 main journal fillet. If main bearings are replaced due to one or more badly damaged bearings, a careful inspection must be made to determine if any cracks have started in the crankshaft. These cracks are most likely to occur on either side of the damaged bearing.

Torsional fatigue failures result from torsional vibration which takes place at high frequency.

A combination of abnormal speed and load conditions may cause the twisting forces to set up a vibration, referred to as torsional vibration, which imposes high stresses at the locations shown in Fig. 5.

Torsional stresses may produce a fracture in either the connecting rod journal or the crank cheek in the rear. Torsional failures may also occur at the front end of the crankshaft at the oil pump drive key slot. Connecting rod journal failures are usually at the fillet or oil hole 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.

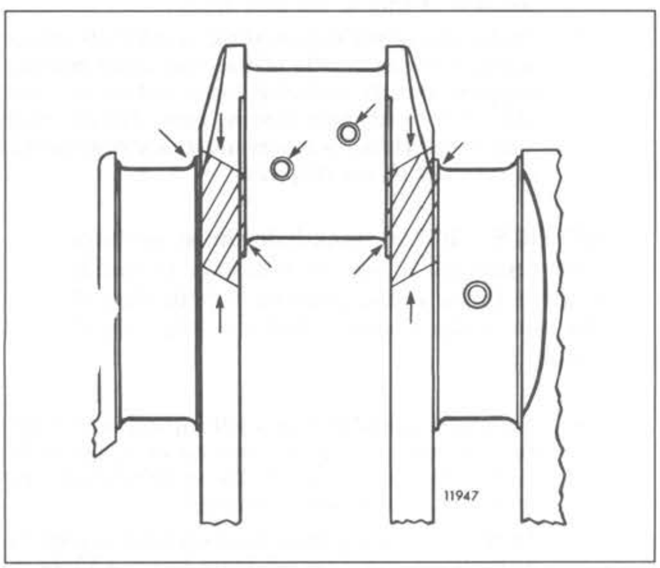


Fig. 7 – Critical Crankshaft Loading Zones

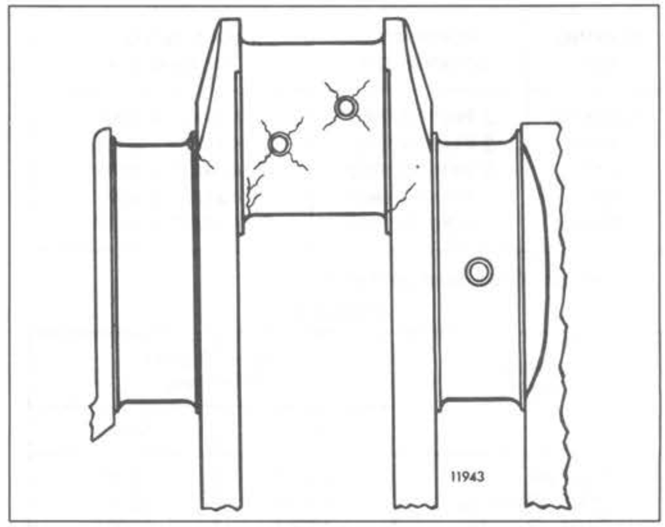


Fig. 8 – Crankshaft Fatigue Cracks

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 filletcracks at the critical areas and 45° cracks (45° with the axis of the shaft) starting from either the critical fillet locations or the connecting rod journal holes (Fig. 8). Replace the crankshaft when cracks of this nature are found.

Crankshaft Grinding

The use of properly remanufactured crankshafts is very important to maximize crankshaft main and connecting rod bearing life.

Remanufactured crankshaft are available through the Detroit Diesel Reliabuilt system and are made to the same quality specifications required of new original equipment crankshafts.

Remanufactured crankshafts procured from other than Detroit Diesel Reliabuilt sources must conform to Detroit Diesel specifications. The dimensional requirements for journal axial profile, radial chatter and oil hole washout require the confirmation with a Gould 1200 Surface Analizer (or equivalent).

> **NOTICE:** Visual inspection cannot be relied upon to confirm compliance to journal quality specifications.

The procedure of crankshaft journal polishing can easily create axial profile and oil hole washout conditions beyond specifications. Any polishing operation should be followed by Gould 1200 (or equivalent) measurements to assure conformance to remanufacture specification.

All used crankshafts that have not been reground must meet the dimensional specifications "standard" in Table 2 or be reground to Reliabilt specifications. Table 2 also applies to remanufactured crankshafts.

BEARING SIZE	CONN. ROD JOURNAL DIA.	MAIN BEARING JOURNAL DIA.
Standard	2.9985"/3.0002"	4.4985"/4.5002"
.0020"	2.9965"/2.9982"	4.4965"/4.4982"
.0100"	*2.9885"/2.9902"	*4.4885"/4.4902"
.0200"	*2.9785"/2.9802"	*4.4785"/4.4802"
.0300"	*2.9685"/2.9702"	*4.4685"/4.4702"

*Dimension of reground crankshaft.

TABLE 2

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

TABLE 3

In addition to standard size crankshaft thrust washers, .005 and .010 oversize thrust washers are available. The following dimensions apply to crankshafts with remanufactured thrust surfaces.

Remanufactured crankshafts should be stamped with the appropriate undersize dimensions for identification purposes.

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

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

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. Install or assemble the crankshaft.

ONE–PIECE CRANKSHAFT
(6V–92 and 8V–92 Engines)

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

b. Refer to Section 1.3.4 for main bearing details and install the upper *slotted* 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.

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

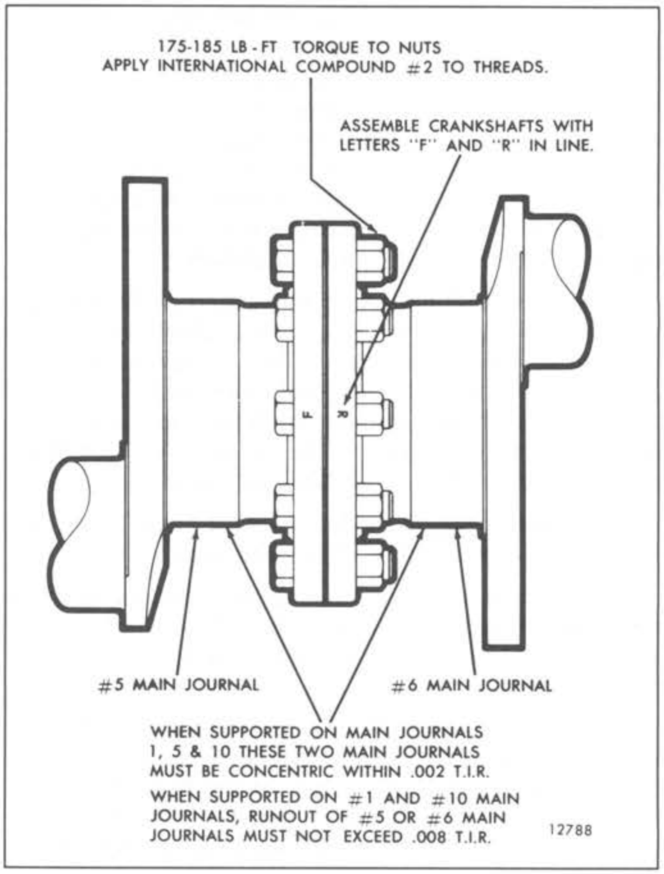


Fig. 9 – Two–Piece 12V–92 and 16V–92 Crankshaft Assembly Instructions

c. 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.

d. 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.*

NOTICE: 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. 6 and Table 3.

e. Install the lower bearing shells (no oil slot) 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.

f. Install the bearing caps and lower bearing shells as outlined under *Install Main Bearing Shells* in Section 1.3.4.

NOTICE: 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.

TWO–PIECE CRANKSHAFT
(12V–92 and 16V–92 Engines)

a. Refer to Section 1.3.4 for main bearing details and install the upper *slotted* main bearing shells in the cylinder block.

b. Apply clean engine oil 360° around all crankshaft bearing journals and place each crankshaft half in position the cylinder block.

c. 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.*

d. Install the lower main bearing shells in the bearing caps (refer to Section 1.3.4).

e. Lubricate the bolt threads on the former bolts and bolt head contact areas with a small quantity of International Compoung No. 2, or equivalent. On the current bolts, lubricate the threads and both sides of the "captured" hardened washer.

f. Install all of the bearing caps, **except** the two center caps (No. 5 and No. 6 journals), and draw the bolts up snug. Then, rap the caps sharply with a soft hammer to seat them properly.

g. Tighten each set of the former main bearing cap bolts uniformly to 250–260 lb–ft (339–352 N•m) torque. Tighten the new bolts which require a 15/16" socket to 230–240 lb–ft (312–325 N•m) torque. The former and new main bearing cap bolts should not be intermixed in an engine.

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

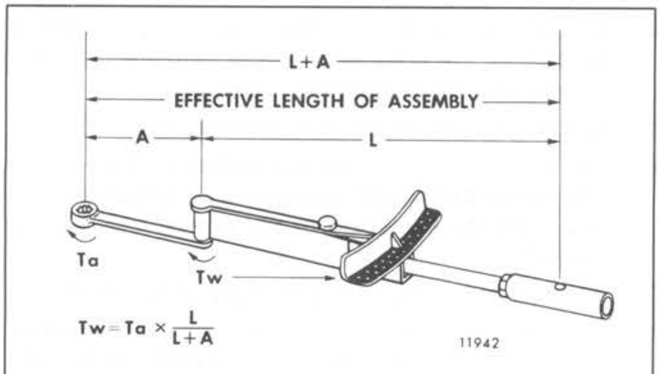


Fig. 10 – Calculating Torque When an Adaptor is Used

h. Position a dial indicator on each of the two journals (No. 5 and No. 6).

i. Rotate the crankshaft halves until the crankshaft assembly marks "F" and "R" are in alignment on the two crankshaft end flanges and install four of the bolts and nuts 90° apart (Fig. 9).

j. Snug up the four bolts and nuts and, while slowly rotating the crankshaft, tap the flanges. The two center adjacent journals must be concentric within .002" total indicator reading and must not runout more than .008" total indicator reading.

k. Install the remaining bolts and nuts. Alternately torque each nut (180° apart) until all nuts have been tightened to 175–185 lb–ft (238–251 N•m) torque. However, because of the space limitations, a torque wrench adaptor J 22898–A must be used and the torque wrench reading must be adjusted due to the increase in length of the torque wrench with the adaptor in place. Use the following formula to determine the adjusted torque readings:

Tw = Ta (L/L + A)

If the effective length of the wrench (L) – (Fig. 8) is 22 inches and the adaptor (A) is 3" long, you should have a reading of 158 lb–ft (215 N•m) on the wrench to have the bolt tightened to 180 lb–ft (244 N•m) torque.

Tw = Ta (L/L + A)
Tw = 180 (22/22 + 3)
Tw = 180 (22/25)
Tw = 158

l. Install the two center main bearing caps.

2. Check the crankshaft end play by moving the crankshaft toward the gage with a small (less than 12") pry bar (Fig. 9). Keep a constant pressure on the pry bar and set the dial indicator to zero. Then, remove and insert the pry bar on the other side of the bearing cap. Force the crankshaft in the opposite direction and note the amount of end play on the dial. The end play should be .004" to .011" with new parts or a maximum of .018" with used parts. Insufficient end play can be the result of a misaligned rear main bearing or a burr or dirt on the inner face of one or more of the thrust washers.

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

4. Install the cylinder heads (Section 1.2).

5. Install the flywheel housing (Section 1.5), then install the flywheel (Section 1.4).

6. Install the crankshaft front cover and oil pump assembly.

NOTICE: Install the oil seal spacer or inner cone *after* the crankshaft front cover is in place to avoid damage to the oil seal lip.

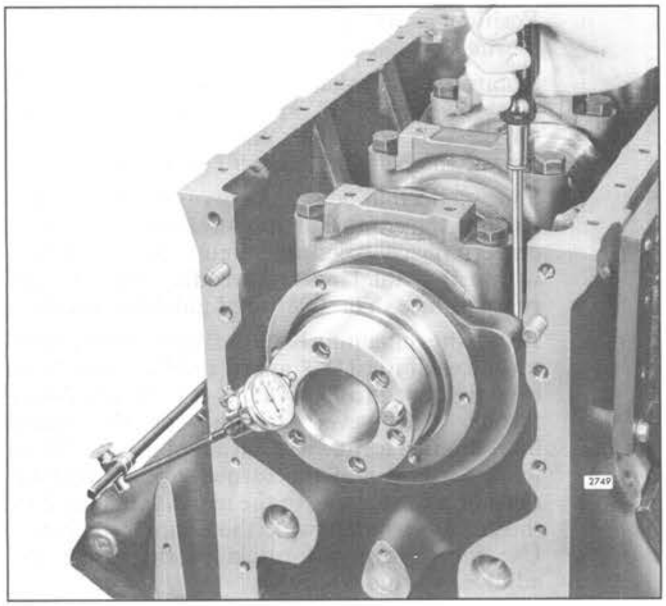


Fig. 11 – Checking Crankshaft End Play

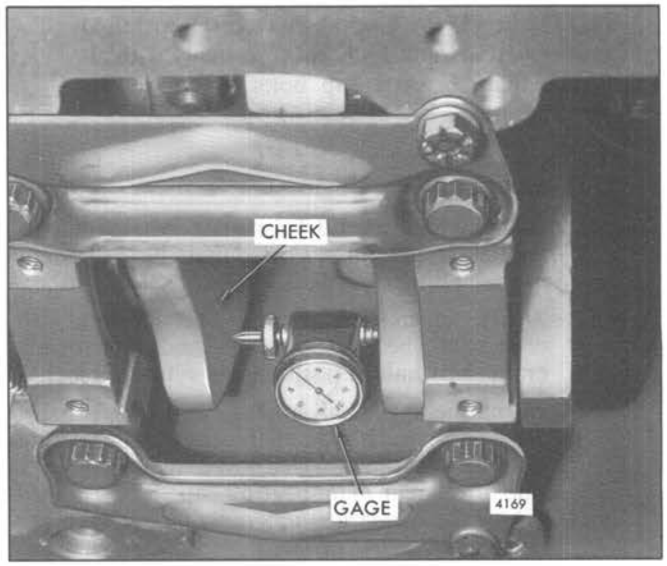


Fig. 12 – Crankshaft Distortion Measuring Gage Mounted on Crankshaft

7. Install the engine front support.
8. Install the vibration damper inner cone or oil seal spacer.
9. Install the vibration damper assembly, if used.
10. Install the crankshaft cap or pulley (see Section 1.3.7).
11. Install the 12V–92 and 16V–92 engine lubricating oil pump assembly (Section 4.1).
12. Check the crankshaft for **distortion** at the rear connecting rod journal counterweights *before* and *after* installing the power take–off reduction gear assembly, transmission or power generator. An improperly installed power take–off reduction gear assembly, transmission or power generator can distort the crankshaft and cause a crankshaft failure. Overtightened drive belts can also cause crankshaft distortion. See Section 15.1 for recommended belt tensions.

    NOTICE: While in each case one must be guided by the individual circumstances and facts that evolve, generally speaking Detroit Diesel 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

    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).

    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 variation is .0045" total indicator reading.

    NOTICE: 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 reduction gear, transmission or power generator for improper installation and realign, as necessary.

13. Affix a new gasket to the oil pan flange and install the oil pan.
14. Use a chain hoist and sling attached to the lifting bracket or eye bolts at each end of the engine and remove the engine from the overhaul stand.
15. Install all of the accessories that were removed.
16. 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.
17. Close all of the drains and fill the cooling system.
18. 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 crankshaft oil seals are held firmly, but not tight, against the crankshaft sealing surfaces by a coil spring, thus preventing oil from escaping from the engine crankcase.

The front oil seal in 6V–92 and 8V–92 engines is pressed into the crankshaft front cover (Fig. 1). In the 12V–92 and 16V–92 engines, the seal is pressed into the engine front cover or trunnion assembly. The lip of the seal bears against a removable spacer or vibration damper inner cone on the end of the crankshaft.

Two new lip–type crankshaft front oil seals have been released to service engines operated in sustained low ambient temperatures. The new service–only seals are made of a special low–temperature polyacrylic material and are *unidirectional*. That is, the right–hand designated seal must be used on right–hand rotating engines, and the left– hand designated seal must be used on left–hand rotating engines. Neglecting to observe this precaution will result in serious oil leakage. Because these seals are intended for operation in temperatures down to –25°F (–32°C), they may not provide satisfactory service life on engines operated at normal ambient temperatures.

The crankshaft rear oil seal is pressed into the flywheel housing (Fig. 2). Standard production seals seat directly on the crankshaft.

Double–lip, unidirectional Teflon oil seals are used in all production coach engines. All other production engines *with dry flywheel housings* use single–lip seals: a unidirectional seal in right–hand rotating engines, a bidirectional seal in left–hand rotating engines.

Double–lip, bidirectional oil seals are used in all production engines where there is oil on both sides of the seal. The lips of the two seals face in opposite directions.

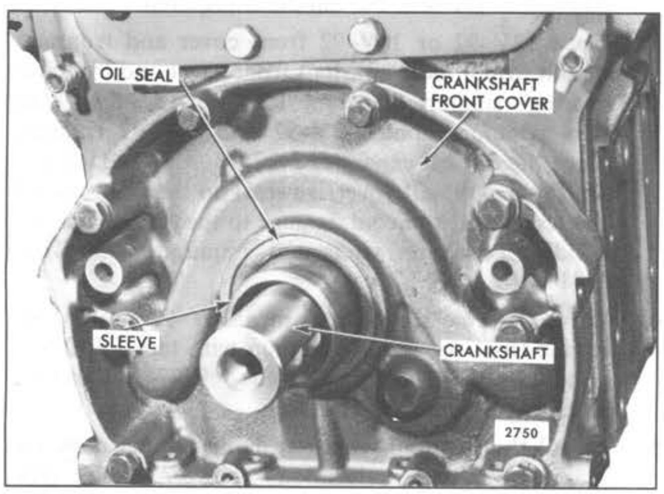


Fig. 1 – Typical Crankshaft Front Oil Seal Mounting

Oversize single and double–lip oil seals are available for service in both unidirectional and bidirectional configurations. Oversize seals *must* be used with wear sleeves installed on the crankshaft.

> **NOTICE:** Unidirectional crankshaft rear oil seals are designated for use on either right–hand or left–hand rotating engines. The direction of crankshaft rotation is normally indicated by an arrow imprinted on the seal case. Failure to observe crankshaft rotation and install the correct unidirectional seal on an engine will result in seal damage and/or serious oil leakage.

Remove Crankshaft Oil Seals

If the engine front cover (Section 1.3.5), trunnion (Section 1.3.5.1) or flywheel housing (Section 1.5) is removed from the engine, then the crankshaft oil seals may be removed, as follows:

1. Support the outer face of the cover, trunnion or housing on wood blocks.
2. Drive the oil seal out and clean the seal bore in the cover or housing.
3. Inspect the crankshaft oil seal.

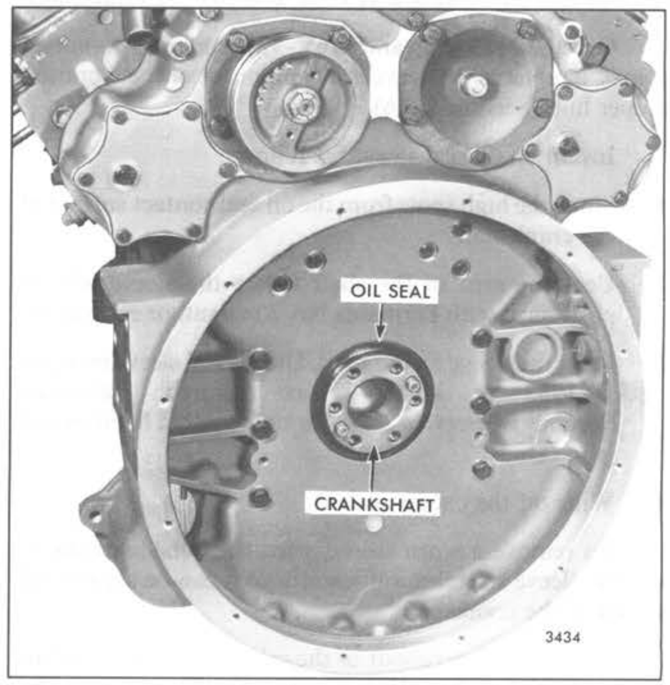


Fig. 2 – Crankshaft Rear Oil Seal Mounting

When necessary, the crankshaft oil seals may be taken out without removing the front cover, trunnion or flywheel housing. This may be done by drilling holes directly opposite each other in the seal casing and installing metal screws with flat washers. Remove the seals by prying against the flat washers with suitable pry bars.

Inspection

Oil leaks may 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, grooved sealing surfaces on the crankshaft or oil seal spacers and out of square installation. To prevent a repetition of any oil seal leaks, these conditions must be checked and corrected.

Inspect the rear end of the crankshaft for wear caused by the rubbing action of the oil seal, dirt buildup or fretting by the action of the flywheel. The crankshaft surface must be clean and smooth to prevent damaging the seal lip when a new oil seal is installed.

On 6V–92 and 8V–92 engines an oil seal sleeve may be pressed on the rear end of the crankshaft to provide a replaceable wear surface at the point of contact with the rear oil seal. The oil seal sleeve may be used with either the single–lip or double–lip type oil seal. However, an oversize oil seal must be used with the sleeve. An oversize, unidirectional rear crankshaft oil seal has been released to service right–hand rotating engines which require a crankshaft oil seal sleeve.

When required, an oil seal sleeve may also be used on the front and rear end of a 12V–92 and 16V–92 crankshaft.

On the 12V–92 and 16V–92 trunnion mounted engines, a replaceable sleeve is a component of the vibration damper hub (Section 1.3.6).

Install an oil seal sleeve, 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 Permatex No. 3 sealant, or equivalent.
3. Press the sleeve on the shaft. Use oil seal sleeve installer J 21983 or J 4194–1, as required. Reference Section 1.0 *Service Tools* for the required handles and guide studs.
4. Wipe off the excess sealant.

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

The maximum runout of the oil seal bore in the front cover or trunnion on a 12V–92 and 16V–92 engine or the flywheel housing on all V–92 engines is .008". The bore may be checked with a dial indicator mounted on the end of the crankshaft in a manner similar to the procedure for checking the flywheel housing concentricity as outlined in Section 1.5. This check must be made with the flywheel housing or 12V–92 and 16V–92 front cover or trunnion in place on the engine and the oil seal removed.

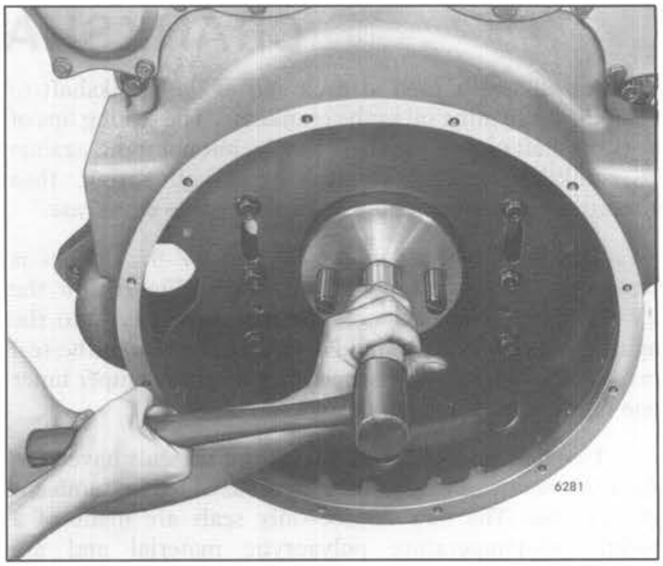


Fig. 3 – Installing Crankshaft Rear Seal with Installer Set J 21112–B and Handle J 3154–1

Install Crankshaft Front Oil Seal

1. Liberally lubricate the seal I.D. and the crankshaft with clean SAE 30 or 40 weight engine oil. Position the seal in the front cover or trunnion with the lip of the seal pointed toward the inner face of the cover.

   NOTICE: The vibration damper inner cone or oil seal spacer must be removed from 6V–92 or 8V–92 engines before installing the oil seal. Upon installation of the spacer it should also be lubricated, as above.

2. Drive a new oil seal into the crankshaft front cover on 6V–92 or 8V–92 engines with tool J 9783, which seats the oil seal in the bore. The tool is designed to drive only on the outer edge of the seal casing to prevent damage to the seal. No handle is required.
3. On a 12V–92 or 16V–92 front cover and trunnion mount install the crankshaft front cover and trunnion bearing support (Section 1.3.5 or 1.3.5.1). On non–trunnion mount 12V–92 and 16V–92 engines, place the oil seal expander J 22425–A (standard size seal) or J 4195–01 (oversize seal) on the front end of the crankshaft to avoid damage to the oil seal lip. No handles or guide studs are required with Tool J 4195–01.
4. Drive or press the oil seal in a 12V–92 or 16V–92 engine front cover and trunnion with tool J 9727–1, handle J 3154–1 and guide studs J 9727–5. This tool seats the oil seal in the bore.
5. Install the required vibration damper inner core, oil seal spacer or vibration damper hub (see Section 1.3.6).

NOTICE: A revised crankshaft oil seal expander (J 22425–A) has been released to facilitate the installation of standard sized front crankshaft oil seals on 12V–92 and 16V–92 engines. It is also used to install standard sized rear crankshaft oil seals on 6V–92, 8V–92 and 12V–92 engines. Guide stud set J 25002 is used to hold the expander in place during seal installation instead of O–rings. This change was necessary because flywheel dowel pins are no longer installed in the crankshafts.

To update tool J 22425 to J 22425–A, see *Shop Notes* in Section 1.0.

Install Crankshaft Rear Oil Seal

The crankshaft rear oil seal may be installed using either of two methods.

Method A

1. With the flywheel housing already installed on the engine (Section 1.5), place oil seal expander J 4239 (standard seal) against the end of the crankshaft. Use handle J 8092 and guide studs J 25002 with the expander. Use expander J 8682 for an oversize seal. No handle or guide studs are used with the oversize seal expander (J 8092).
2. *Non–Teflon Lip Seals.* Liberally lubricate the I.D. seal, the crankshaft or the crankshaft oil seal sleeve (if used) and the crankshaft oil seal expander with clean SAE 30 or 40 weight engine oil. Failure to adequately lubricate these areas during seal installation can result in seal lip damage at engine start–up.

   NOTICE: Series 92 crankshaft oil seals are made of an oil–resistant synthetic silicone rubber which is pre–coated with a special 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 seal case. Do not remove this coating.

   Teflon Lip Seals. Do not lubricate a Teflon seal lip or the O.D. of the crankshaft wear sleeve before seal installation. Teflon lip seals *must* be installed dry. This is to allow the transfer of the teflon to the crankshaft or wear sleeve for proper sealing.
3. With the lip of the seal pointed toward the engine, slide the seal over the expander and onto the crankshaft. Remove the seal expander and guide studs.

   NOTICE: An oversize, unidirectional rear seal must be installed only on right–hand rotating engines with crankshaft oil seal sleeves. Neglecting to observe crankshaft rotation or installing the seal improperly can result in serious oil leakage and possible engine damage.
4. Install crankshaft rear oil seal installer J 21112–2 and guide studs J 9727–5. Use handle J 3154–1. Drive the seal in place until the installer seats squarely on the butt of the crankshaft (Fig. 3). Remove the seal installer and guide studs.
5. Check the squareness of the seal in relation to the face of the crankshaft butt after seal installation. Use the following procedure:

   a. Attach magnetic base dial indicator J 7872 to the rear butt of the crankshaft (Fig. 4). Position the point of the dial indicator on the seal face. Rotate the crankshaft and note the seal face readings at the 12, 9, 6 and 3 o'clock positions. The total runout at each position should not exceed 0.015". *However, before doing this, pry the crankshaft toward one end of the block to ensure that end play is in one direction only.*

NOTICE: 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.

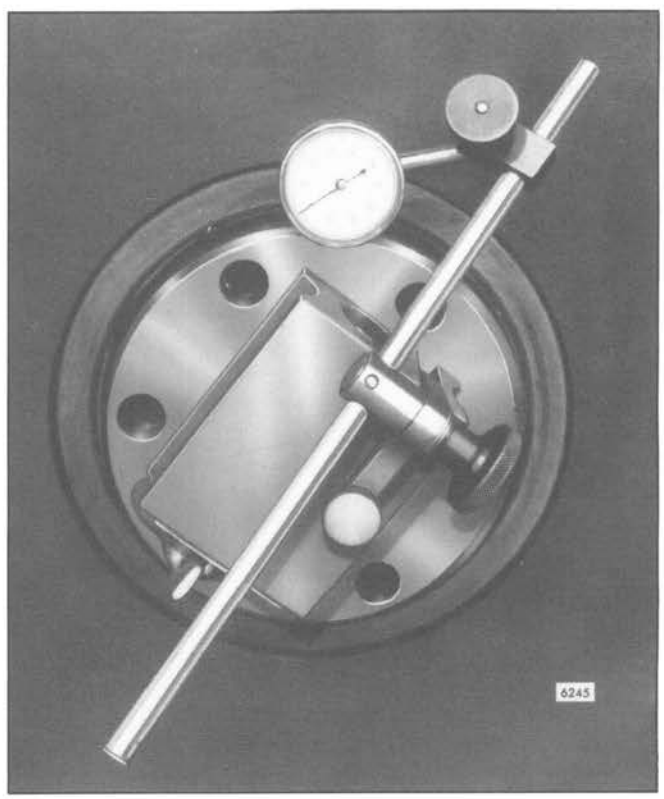


Fig. 4 – Checking Crankshaft Rear Seal Squareness

b. If any reading is over .015" place the seal installer J 21112–2 over the seal and lightly tap with a soft–faced hammer at the high points.

6. Remove any excess sealant from the flywheel housing and the seal.

Method B

1. Install guide stud set J 25002 into the butt end of the crankshaft.
2. Apply a thin, even coat of Permatex No. 3 Sealant, or equivalent, to the inside diameter of the oversize wear sleeve.
3. Using crankshaft oil seal sleeve installer J 21983 and handle J 8092, drive the sleeve onto the butt of the crankshaft. Wipe off the excess sealant.
4. If the seal has a non–Teflon seal lip, lightly lubricate the lip with new engine oil and fit over the butt of the crankshaft and wear sleeve.

   NOTICE: Do not lubricate a Teflon seal lip or the O.D. of the crankshaft wear sleeve before seal installation. Teflon lip oil seals *must* be installed dry. this is to allow transfer of the Teflon to the wear sleeve surface for proper sealing.

5. Using oil seal installer J 21112–2 and handle J 3154–1, drive the seal into place (see Fig. 1).
6. Remove the guide studs from the end of the crankshaft.

Checking Seal Installation

To minimize the chance of crankshaft rear oil seal leakage, the squareness of the seal in relation to the face of the flywheel housing must be checked after seal installation.

Procedure:

1. Attach magnetic base dial indicator J 7872 to the rear butt of the crankshaft (see Fig. 4). Position the point of the dial indicator at the outer perimeter of the seal face. Rotate the crankshaft and note the seal face readings at the 12, 9, 6 and 3 o'clock positions. The total runout across the entire seal should not exceed 0.015".
2. If any reading is over 0.015", place seal installer J 9727–1 over the seal and lightly tap the edge of the installer with a soft–faced hammer at the high point(s). Take dial readings again.
3. If the seal cannot be brought within specifications using this method, it must be replaced with a new seal and the squareness checked again.
4. Remove any excess sealant from the flywheel housing and the seal.

CRANKSHAFT CAP

A crankshaft cap is installed on the front end of the crankshaft on engines which are not equipped with a crankshaft pulley (Fig. 1). The crankshaft cap serves to securely fasten the vibration damper assembly to the crankshaft, or, when no vibration damper is used, the cap secures the oil seal spacer. The cap is attached to the crankshaft by a special bolt and washer.

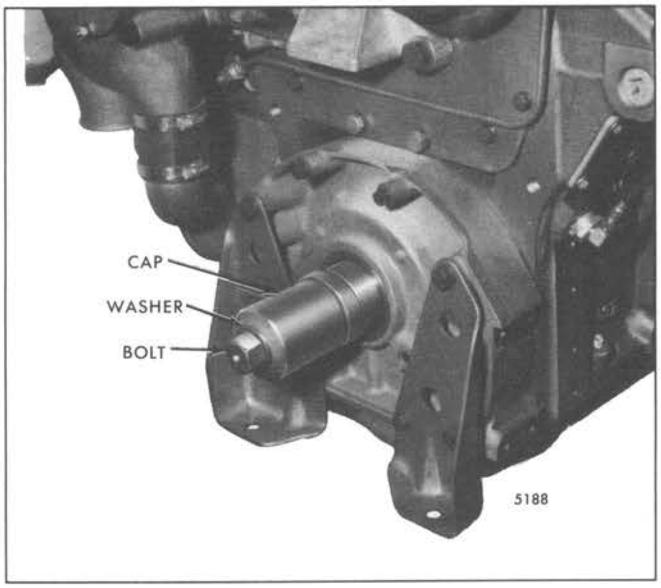


Fig. 1 – Crankshaft Cap Mounting

Engines incorporating a crankshaft pulley use a bolt and a special flat washer to retain the pulley in place. The bolt has a 7/32" center drill in the head for use of a hand tachometer when checking engine speed.

The new crankshaft bolts are now lubrite coated to prevent possible damage (galling) to the bolt threads and to increase the clamp load to the front end stack up (crankshaft pulley, vibration damper, etc). Also, the new washer (retainer) is now case hardened.

The new bolts and washer can be identified by their black color. The former bolts and washer are steel (gray) color.

Tighten Crankshaft Cap Bolt

Tighten the crankshaft cap retaining bolt as follows:

1. Tighten the bolt to 180 lb–ft (244 N•m) torque.
2. Strike the end of the bolt a sharp blow with a 2 to 3 lb. lead hammer.
3. Tighten the bolt to 300 lb–ft (407 N•m) torque and strike the bolt again.
4. Tighten the bolt to 290–310 lb–ft (393–421 N•m) torque. Do not strike the bolt after the final torque has been applied.

The hex head of the crankshaft bolt may be used to bar, or 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 during the barring operation.* Otherwise, serious engine damage may result if the vibration damper or pulley is not securely fastened to the crankshaft.

CAUTION: To reduce the risk of personal injury when barring over or "bumping" the starter while performing an engine tune-up, personnel should keep their hands and clothing away from the moving parts of the engine, as there is a remote possibility the engine could start.

CRANKSHAFT MAIN BEARINGS

The crankshaft main bearing shells (Fig. 1) are precision made and are replaceable without machining. 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.

A through slot in each upper bearing shell 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 passage in the crankshaft, then to the connecting rods and connecting rod bearings.

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

Thrust washers, on each side of the rear main bearing, absorb the crankshaft thrust (Fig. 1). 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.

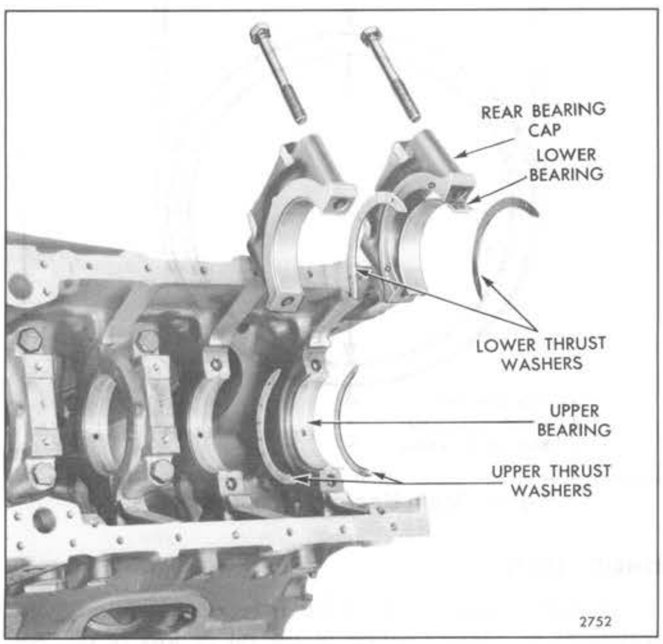


Fig. 1 – Main Bearing Shells, Bearing Caps and Crankshaft Thrust Washers

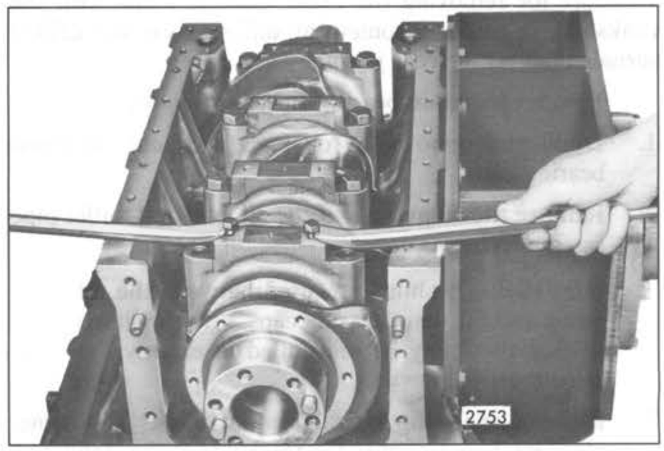


Fig. 2 – Removing Main Bearing Cap

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.

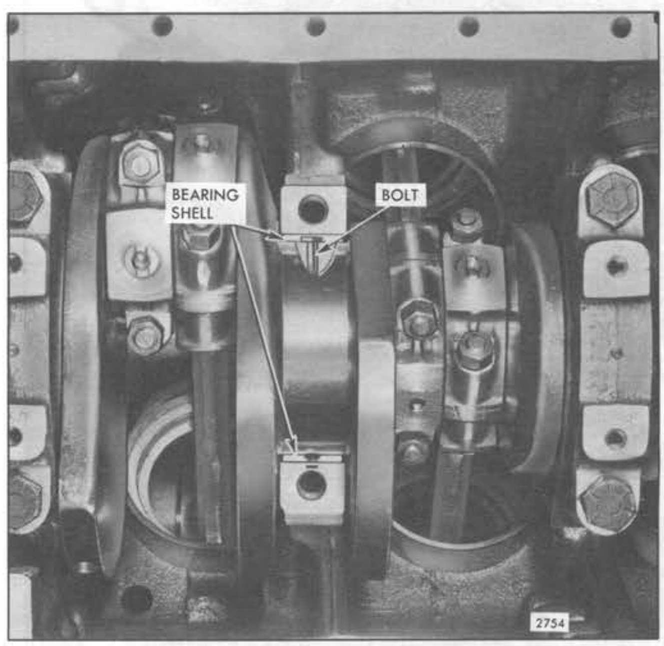


Fig. 3 – Removing Upper Main Bearing Shell (Except Rear Main)

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 and outlet pipe assemblies.

NOTICE: If shims are used between the oil pump 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 stabilizer at a time, place washers (equal to the thickness of the stabilizer) on the bearing cap bolts and reinstall the bolts.
4. Remove one main bearing cap at a time and inspect the bearing shells as outlined under *Inspection* (Fig. 2). Reinstall each bearing shell and bearing cap before removing another bearing cap:
   a. To remove all except the rear main bearing shell, insert a 5/16" x 1" bolt with a 1/2" diameter and a 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. 3). 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. 4).
   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.

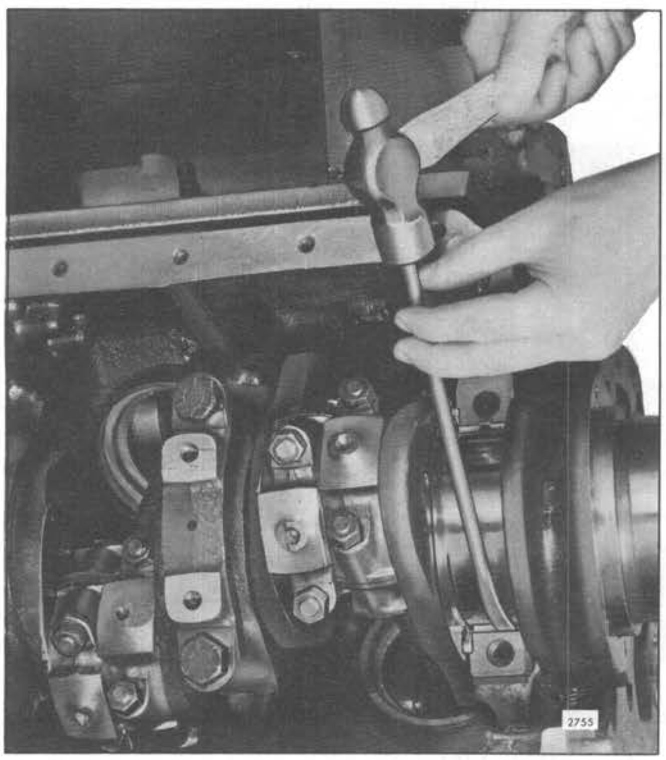


Fig. 4 – Removing Upper Rear Main Bearing Shell

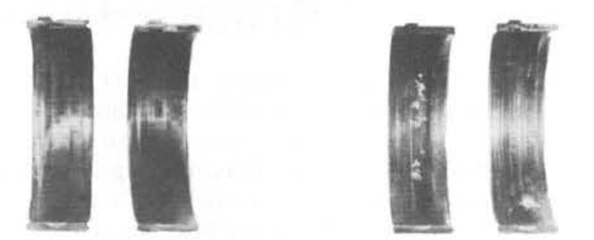


Fig. 5 – Comparison of Lower Main Bearing Shells

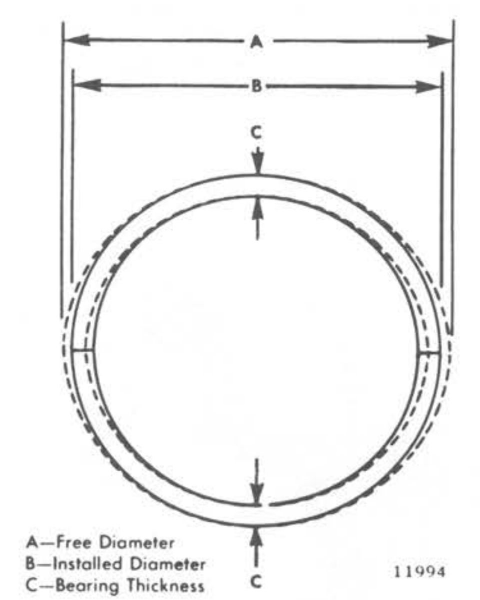


Fig. 6 – Main Bearing Measurements

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. 5). The lower bearing shells, which carry the load, will normally show signs of distress before the upper bearing shells. However, babbitt plated bearings may develop minute cracks or small isolated cavities on the bearing surface during engine operation. These are characteristics of and are not detrimental to this type of bearing. They should not be replaced for these minor surface imperfections since function of the bearings is in no way impaired and they will give many additional hours of trouble–free operation.

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. 6 and 7). 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 .1540" and, if any of the bearing shells are thinner than this dimension, replace all of the bearing shells. A new standard bearing shell has a thickness of .1545" to .1552". Refer to Table 1.

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

Bearing Size	Bearing Thickness	Minimum Thickness
Standard	.1545"/.1552"	.154"
.002" Undersize	.1555"/.1562"	.155"
.010" Undersize	.1595"/.1602"	.159"
.020" Undersize	.1645"/.1652"	.164"
.030" Undersize	.1695"/.1702"	.169"

TABLE 1

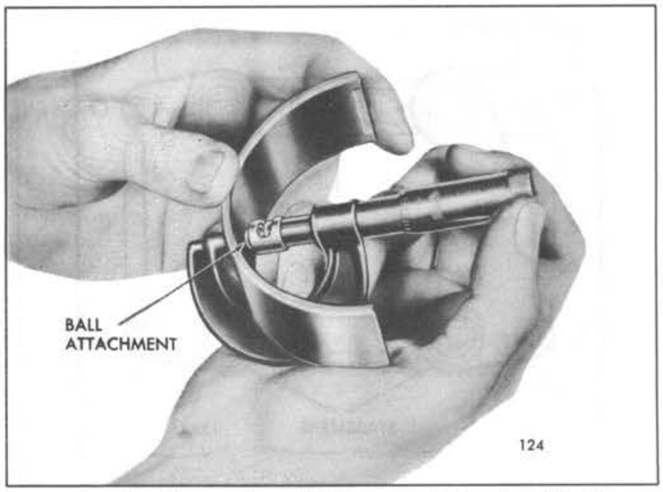


Fig. 7 – Measuring Thickness of Bearing Shell

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 .0016" to .0050" with new parts.

Before installing new replacement bearings, it is very important to thoroughly inspect the crankshaft journals. Also, damaged bearings may cause bending fatigue and resultant cracks in the crankshaft. Refer to Section 1.3 under *Crankshaft Inspection* for inspection of the crankshaft.

Do not replace one main bearing shell alone. If one bearing shell requires replacement, install all new upper and lower 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. Undersize bearings (.002") are available to compensate for slight journal wear where only slight grinding is required. Make sure the correct bearing to journal clearances are maintained when using these parts.

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

Inspect the crankshaft thrust washers. 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

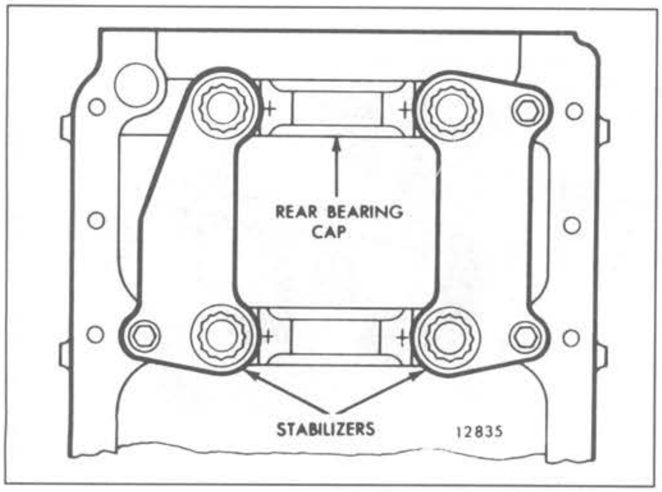


Fig. 8 – Stabilizers Mounted on Block

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.

Bearing cap stabilizers (Fig. 8) are used at all main bearing cap positions on the 6V–92, 8V–92, 12V–92 and 16V–92 engine cylinder blocks.

The main bearing cap is a press fit of .0002"–.0042" in the main bearing saddle area of the cylinder block. The saddle area is 8.4170"–8.4190" and the width of the bearing cap is 8.4292"–8.4212". The press fit allows reinstallation of the main bearing cap on the block and maintenance of specified bore alignment. If the main bearing bores are not in alignment when a replacement bearing cap is used, the block must be line–bored (refer to Section 1.0).

However, cases have occurred where main bearing caps were found slightly loose in the block at time of normal overhaul with no main bearing failure having occurred. In these cases, providing all block measurements are within Detroit Diesel Allison specifications, the cap may be reused if it is no more than .002" loose. A loose fit of .002" maximum is permitted when measured within the following guidelines:

a. The main bearing cap *must* have the main bearing bolts loosely installed for alignment when block to cap clearance is measured.

b. With the cap held down, a .002" or thinner feeler gage must produce a tight fit when the gage is between the cap and the block. The feeler gage must be parallel with the centerline of the crankshaft.

c. Before tightening the main bearing cap bolts, rotate the crankshaft to be sure it turns freely. Tighten the main bearing cap bolts as specified in Section 1.3.4. If the bearing cap has been correctly installed, the crankshaft will turn freely after the main bearing bolts have been tightened to specification.

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.

NOTICE: Upper and lower bearing shells are serviced only in sets. 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.

The upper and lower main bearing shells are not alike. The upper shell has a through slot for lubrication, the lower shell does not. Be sure to install the grooved slot 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 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. Clean both halves of the 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.

NOTICE: The main bearing caps are bored in position and marked 1, 2, 3, etc. They must be installed in their original positions in the cylinder block.

4. With the lower bearing shells installled in the bearing caps, proceed as follows:

   a. Lubricate the threads on the former bolts and the bolt head contact area with a small quantity of International Compound No. 2, or equivalent. On the current bolts, lubricate the threads and both sides of the "captured" hardened washer.

b. Install the bearing caps and bearing cap stabilizers and draw the bolts up snug. Then, rap the caps sharply with a soft hammer to seat them properly.

c. Tighten all of the former main bearing cap bolts (except the rear main bearing cap bolts) to 250–260 lb–ft (339–352 N•m) torque starting with the center bearing cap bolts and working alternately towards both ends of the block. Tighten the new bolts which require a 15/16" socket to 230–240 lb–ft (312–325 N•m) torque. The former and new main bearing cap bolts should not be intermixed in an engine.

d. Tighten the rear main bearing cap bolts to 40–50 lb–ft (54–68 N•m) torque. Then, 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.

e. Retorque all bearing cap bolts to the torque specified in Step "c" above.

f. Tighten the 7/16"–14 stabilizer bolts to 70–75 lb–ft (95–102 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 and outlet pipe assemblies.

NOTICE: If shims were used between the pump and the bearing caps, install them in their original positions. Then, check the oil pump gear clearance (Section 4.1).

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)

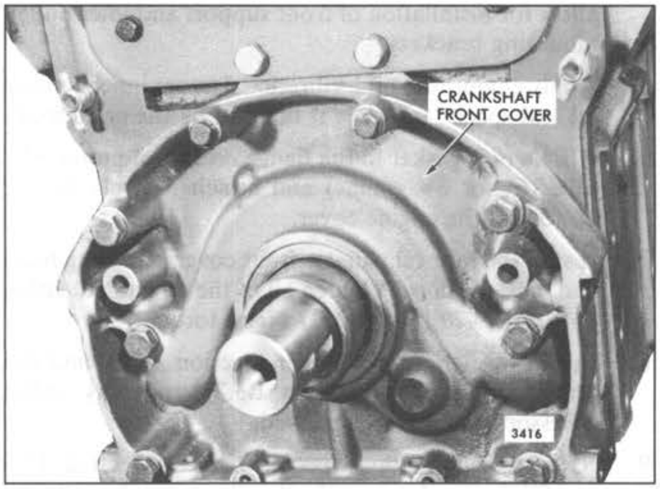


Fig. 1 – Engine Front Cover Mounting (6V–92 and 8V–92 Engines)

The engine front cover is mounted against the cylinder block at the lower front end of the engine (Fig. 1). It serves as a retainer for the crankshaft front oil seal. On 6V and 8V engines, this cover also serves as the lubricating oil pump housing. The engine is supported at the front end by engine supports attached to the front cover.

It will be necessary to remove the engine front cover to remove and install the crankshaft or when the engine is overhauled. Also, the front cover must be removed to service the lubricating oil pump on certain 6V and 8V engines. In addition, the front cover used with trunnion mounts must be removed to replace the crankshaft front oil seal.

Remove Engine Front Cover

1. Drain the oil. Then, remove the four oil pan–to–front cover attaching bolts and lock washers. Loosen all of the remaining oil pan bolts so the oil pan and gasket can be lowered approximately 1/4" at the front end of the engine.

   NOTICE: Be careful not to damage the gasket. Otherwise, it will be necessary to remove the oil pan and replace the gasket.

2. Remove the crankshaft pulley (Section 1.3.7) and vibration damper (Section 1.3.6), if used, and any other accessories that may be mounted on the front end of the crankshaft.
3. Remove the vibration damper inner cone or oil seal spacer..
4. Disconnect the lubricating oil pump inlet tube at the bottom of the front cover on 6V or 8V engines.
5. Remove the cover to cylinder block attaching bolts.
6. Strike the edges of the cover alternately on each side with a soft hammer to free it from the dowels. Then, pull the cover straight off the end of the crankshaft.
7. Remove the gasket from the cover or the cylinder block.
8. Replace the oil seal (Section 1.3.2).

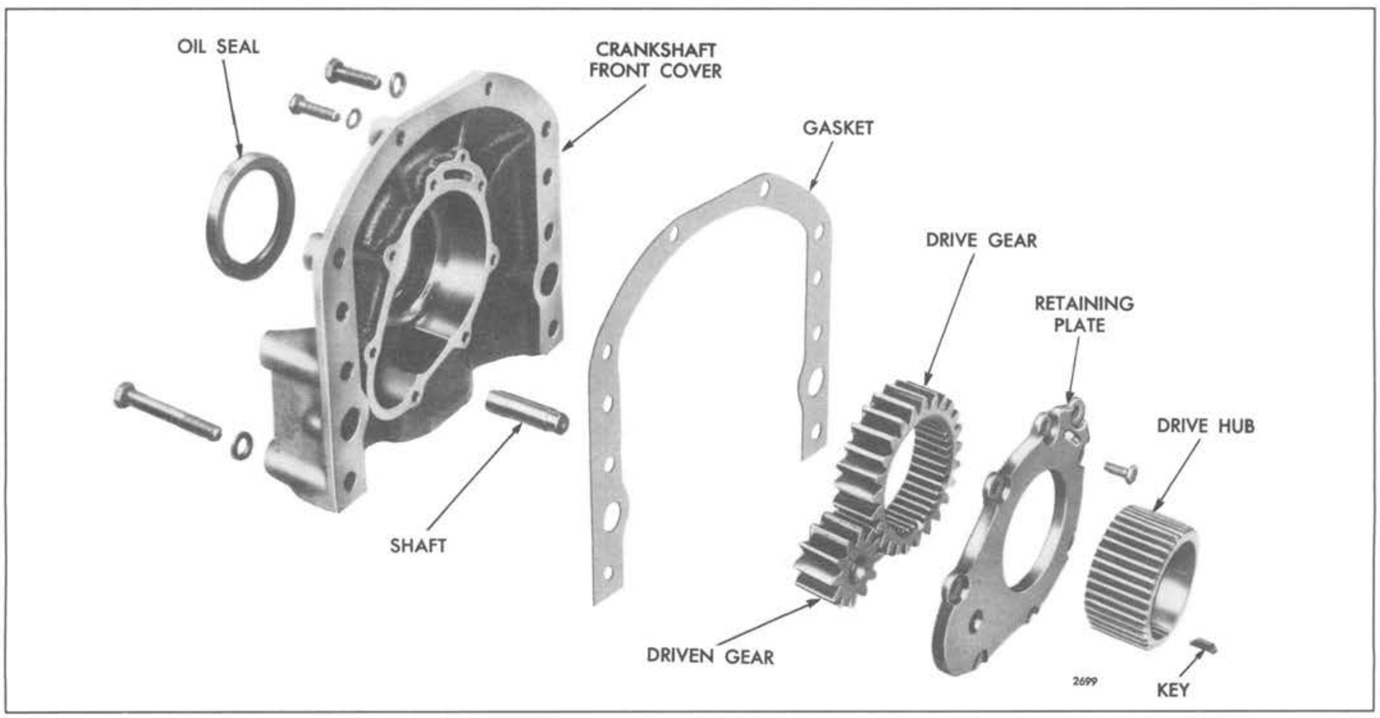


Fig. 2 – Front Cover Details and Relative Location of Parts (6V–92 and 8V–92 Engines)

Install Engine Front Cover

With the oil pump installed (6V and 8V engines, Section 4.1) and the oil seal installed, refer to Fig. 2 and install the front cover as follows:

1. Affix a new gasket to the inner face of the cover.
2. Liberally lubricate the seal I.D., the crankshaft and the crankshaft oil seal expander with clean SAE 40 or 30 weight engine oil. Failure to adequately lubricate these areas during seal installation can result in seal lip damage at engine start–up.
3. Install the front cover using oil seal expander J 22425–A with guide studs J 25002 (standard size seal) or J 4195 (oversize seal) to pilot the oil seal over the crankshaft. Position the cover over the crankshaft and up against the cylinder block. Remove the oil seal expander.
4. Install the cover attaching bolts and lock washers and tighten the 3/8"–16 bolts to 25–30 lb–ft (34–41 N•m) torque and the 1/2"–13 bolts to 80–90 lb–ft (108–122 N•m) torque. Studs are provided on certain engines to allow for installation of front support and idler pulley mounting brackets.
5. Apply engine oil to the vibration damper inner cone or oil seal spacer and slide it in place on the crankshaft.
6. Affix a new gasket to the flange on the oil pump inlet tube (6V or 8V engine) and attach the tube to the bottom of the engine cover.
7. Install the four oil pan–to–front cover attaching bolts and lock washers. Tighten all of the oil pan attaching bolts to 15–20 lb–ft (20–27 N•m) torque.
8. Install the vibration damper (Section 1.3.6) and the crankshaft pulley (Section 1.3.7) and any other accessories that were removed.
9. Refer to *Lubrication Specifications* in Section 13.3 and fill the crankcase with oil to the proper level on the dipstick.

CRANKSHAFT OUTBOARD BEARING SUPPORT (TRUNNION)

(12V AND 16V ENGINES)

A crankshaft outboard bearing support (trunnion) is provided on 12V and 16V industrial engines to give additional frontal support to the crankshaft (Fig. 1). The bearing support (trunnion), which is attached to the engine front cover, incorporates a clevite bearing (bushing) and serves as a retainer for the crankshaft front oil seal. Oil seal rings ("O" rings) are used between the engine front cover and the bearing support.

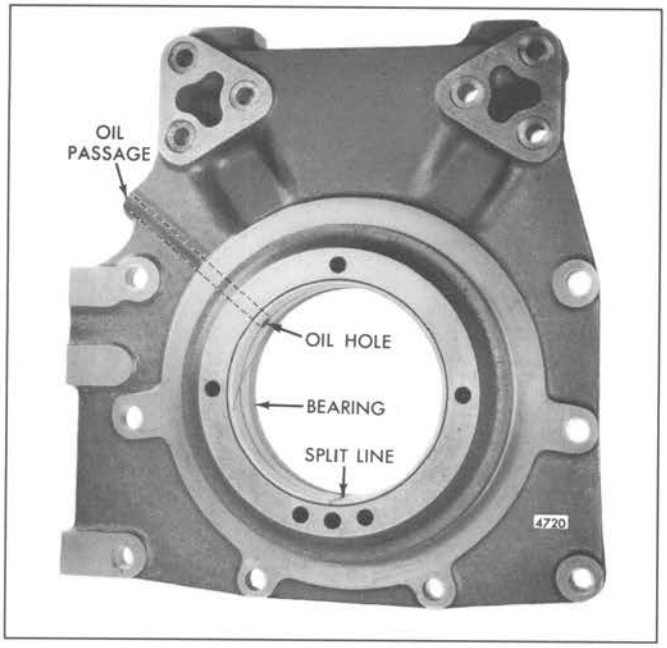


Fig. 1 – Outboard Bearing Support (Trunnion)

Lubrication of the bearing and the crankshaft is provided from the engine front oil gallery through an external oil tube to a drilled and tapped oil passage in the bearing support (Fig. 2).

The bearing support should not require any servicing, except for replacement of the bearing or the oil seal, when such becomes necessary.

It will be necessary to remove the bearing support when replacement of the bearing is required.

Remove Outboard Bearing Support (Trunnion)

1. Remove the trunnion (engine) support (Fig. 2).
2. Remove the outboard bearing to cylinder block oil tube.

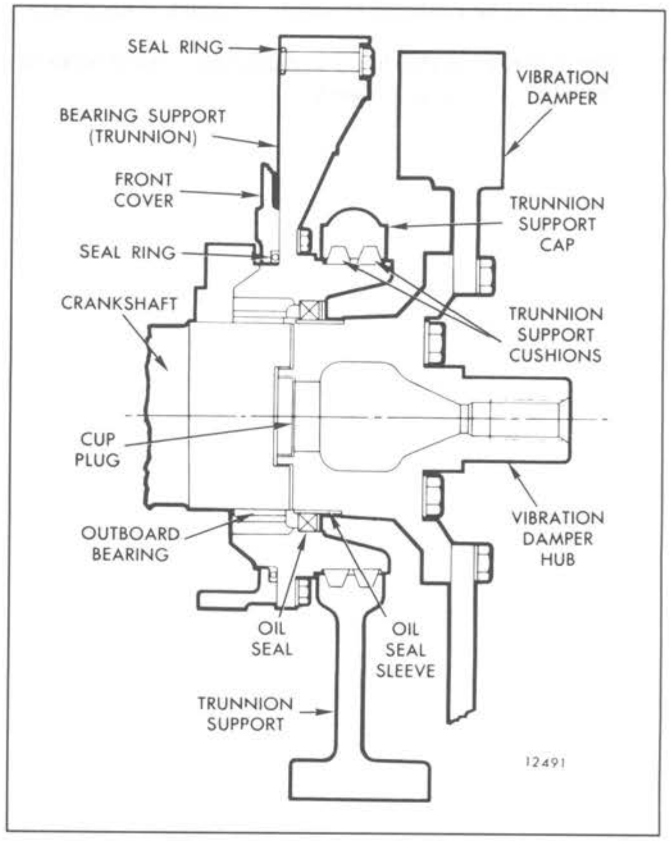


Fig. 2 – Outboard Bearing Support (Trunnion) Details

3. Remove the outboard bearing support (trunnion).
4. Inspect the bearing in the support and replace it, if necessary. When installing a new bearing, press the bearing in flush with the outer surface of the support. Also, be sure the lubricating hole in the bearing lines up with the drilled oil passage, and the split line in the bearing is at the bottom of the support, otherwise oil fed to the bearing and crankshaft will be blocked off (Fig. 1).
5. Replace the oil seal (refer to Section 1.3.2).

Install Outboard Bearing Support (Trunnion)

1. Install a new large seal ("O" ring) and six new small seal rings on the back side of the bearing support (trunnion) – Fig. 2.
2. Lubricate the bearing and oil seal lip with clean engine oil. Guide the bearing support over the crankshaft.

3. Snug the top two (2) middle inboard and bottom two (2) middle bolts. Using a softfaced mallet, strike the trunnion firmly on the top center of the housing driving the trunnion in a downward direction.

4. All vertical crankshaft–to–bearing clearance should be at the bottom of the crankshaft. Clearance from side to side sould be centered virsually. Adjust, if necessary.

5. Snug all bolts with a hand wrench, then torque them to 70–75 lb–ft (95–102 N•m).

6. Install the bearing support–to–cylinder block oil line. Be sure the line is clean and free of obstructions. Fill the drilled feed hole in the support (Fig. 1) with clean engine oil before connecting the line.

7. Install the trunnion support with two 5/8"–11 bolts and lock washers. Tighten the bolts to 137–147 lb–ft (186–200 N•m) torque.

8. Install hub and vibration damper (refer to Section 1.3.6 of the Service Manual). Prelube the oil seal sleeve before installing the hub.

CRANKSHAFT VIBRATION DAMPER

A 12 inch (8V engine), a 13 1/2 inch (12V engine) or an 18 inch, formally 15 inch, (16V engine) 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.

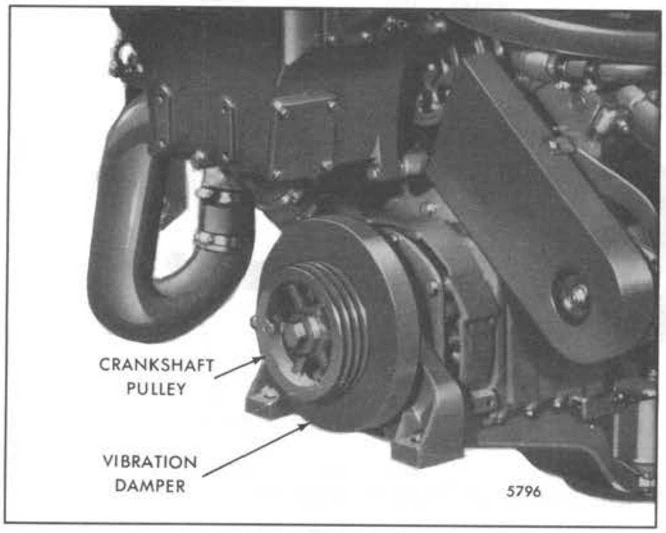


Fig. 1 – Vibration Damper Mounting (8V Engine)

A viscous type vibration damper consists of an inertia mass (flywheel) enclosed in a fluid–tight outer case but separated there from by a thin layer of viscous liquid. 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.

Effective with engine serial number 8VF–2373 the 12 inch (8V engine) vibration damper has a .250" thick flange and utilizes a hub and dowel assembly with ten tapped holes, a scuff plate and a new outer cone with a .120" slot (saw cut) – (Fig. 2). The current inner cone is grooved on the inner diameter and includes a Nitrile seal ring. The former vibration damper has a .150" thick flange and utilizes a hub and dowel assembly with six tapped holes.

A new nylon coated internal flywheel vibration damper is now being used effective with engine serial number 8VF–8259 and 16VF–2333.

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

The new crankshaft bolts are now lubrite coated to prevent possible damage (galling) to the bolt threads and to increase the clamp load to the front end stack up (crankshaft pulley, vibration damper, etc). Also, the new washer (retainer) is now case hardened.

The new bolts and washer can be identified by their black color. The former bolts and washer are a steel (gray) color.

•Vibration Damper Safety Shields

The need for a vibration damper safety shield is mandatory in certain industrial and marine applications in which the engine operates without a hood or in an open or unprotected area. A properly designed and installed safety shield prevents direct physical contact with the damper during engine operation. It also keeps the damper from "walking off" the crankshaft and causing property damage or injury to personnel working near the engine if the crankshaft pulley bolt should loosen and become detached during engine operation.

Detroit Diesel Corporation does not manufacture, sell, or install vibration damper safety shields as it has no control over the great variety of installations in which DDC engines are applied. Space restrictions in these numerous applications make the supply of a properly designed and shaped vibration damper safety shield the responsibility of the OEM (original equipment manufacturer) or distributor designing and/or manufacturing products in which they apply Detroit Diesel engines. However, DDC believes that the following guidelines should be followed when fabricating or installing shields:

1. Shields should be made from 1/8" to 3/16" perforated steel or heavy steel screen.
2. The perforated or open screen area of the shield should be equal to, or greater than, the total area of both sides of the damper and its circumference.
3. Shields should be no closer than 1/2" from the damper when installed.
4. In all cases, safety shields *must* permit the vibration damper to be well ventilated during engine operation to prevent vibration damper overheating.

NOTICE: Shielded vibration dampers are frequently difficult to inspect visually because of the design of the shield and/or *end items* in which the engine is installed. As a result, it is important for OEM's and distributors to supply written instructions to users of their products, cautioning them to periodically inspect the viscous vibration damper for evidence of a split seam, bulged cover, leaks, dents, etc. Any such evidence is sufficient cause for replacement because these conditions can prevent vibration dampers from functioning properly and, as a result, cause serious engine damage. *At time of normal major engine overhaul, the damper must be replaced, regardless of condition.*

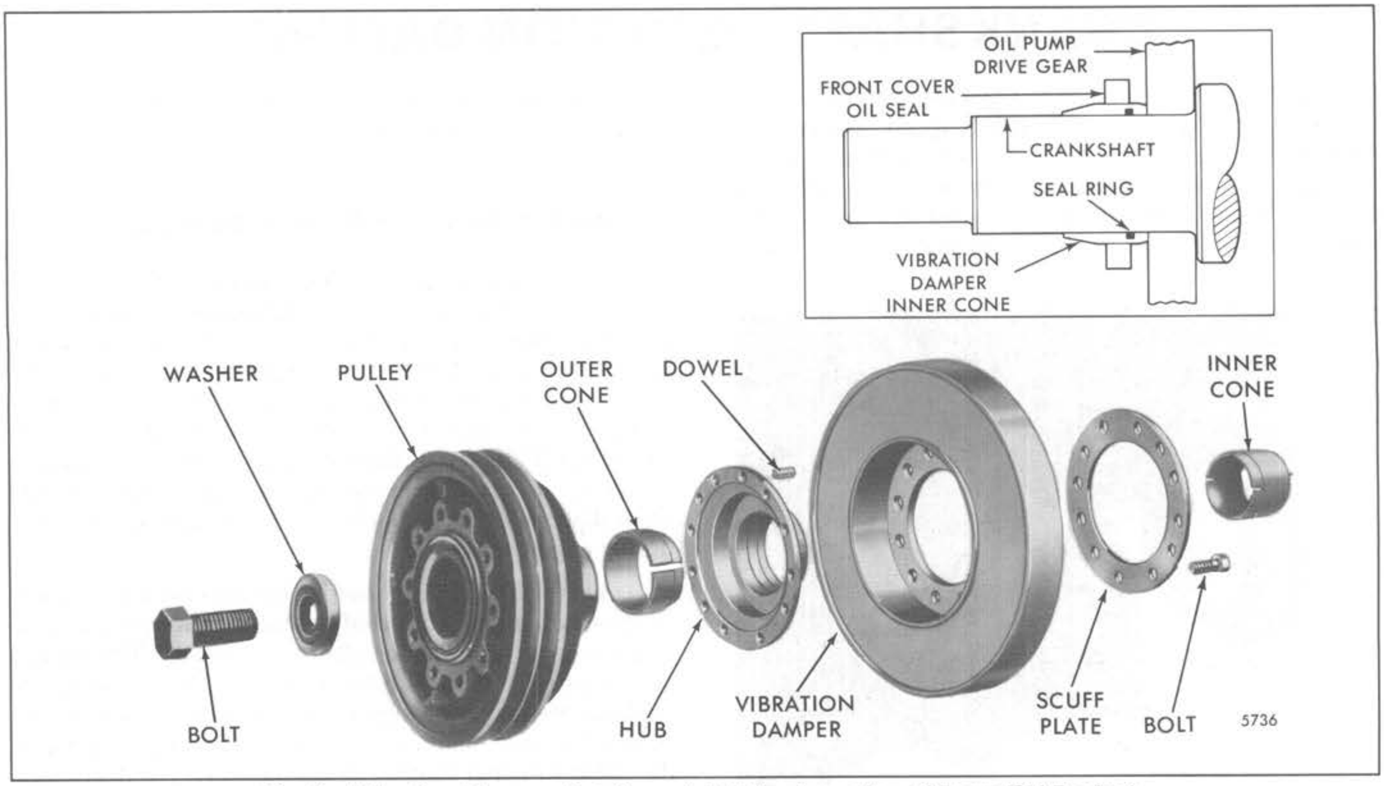


Fig. 2 – Vibration Damper Details and Relative Location of Parts (8V Engine)

Remove Vibration Damper From Crankshaft (8V Engine)

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.

The vibration damper attaching bolt quantity was reduced from 10 to 8. This provides two threaded open bolt holes, located 90° from the dowel pin locations, for puller tool J 24420–A to be used for removing the vibration dampers. Service removal of these same two bolts in the field is permitted on engines built after 8VF–2373.

4. Attach puller J 24420–A to the vibration damper hub with two long bolts threaded into the two 3/8"–24 tapped holes provided in the hub (Fig. 3). Pull the damper and hub assembly together with the outer cone, until the outer cone is loose on the crankshaft. If the puller method does not free the damper, use a punch in the split of the cone to pop the cone out.
5. Remove the puller from the damper hub and pull the outer cone off of the crankshaft.

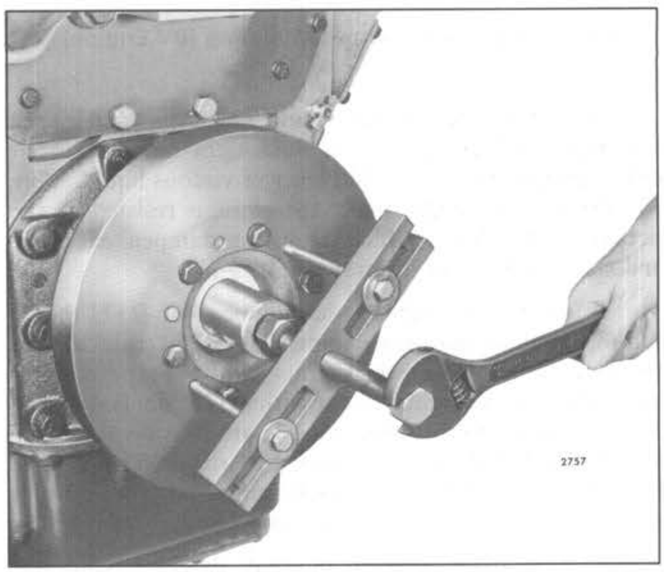


Fig. 3 – Removing Vibration Damper Outer Cone

NOTICE: *Do not pound on the damper with a hammer or pry with other tools 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, damper hub and retainer (current engines) as an assembly off the end of the crankshaft by hand.

7. If necessary, remove the vibration damper inner cone from the crankshaft on the current inner cone, remove and discard the seal ring. The current inner cone is grooved on the inner diameter and includes a Nitrile seal ring. Remove and discard the seal ring.

Remove Vibration Damper From Crankshaft (12V And 16V Engines)

1. Remove the crankshaft pulley retaining bolt and washer.
2. Remove the crankshaft pulley. If required, use a suitable puller to remove the pulley.

NOTICE: *Do not pound on the damper with a hammer or pry with other tools 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.

3. Remove the bolts securing the vibration damper to the hub and lift the damper off the hub.

Inspect Vibration Damper

The viscous type damper should be inspected for dents, nicks, fluid leaks or bulges in the outer casing of the damper. Any indications of the above are sufficient causes for replacement of the damper. Due to the close clearances between the damper internal flywheel and outer casing, dents may render the damper ineffective. Bulges or splits indicate 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 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. Also, inspect the area of the crankshaft adjacent to the oil pump drive keyway.

Inspect the damper inner and outer cones, damper hub and the end of the crankshaft for galling or burrs (Fig. 2). 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. On the current inner cone also check the grooves on the inner diameter for wear. If worn, replace the oil seal and cone (refer to Section 1.3.2).

When replacing the former 12" (8V engine) .150" flange vibration damper or the six bolt hole hub assembly, the current .250" thick flange vibration damper, ten bolt hole hub assembly, scuff plate, ten 7/16"–20 x 1" lock bolts and the new .120" slot outer cone must be used.

A loose engine mount could 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.

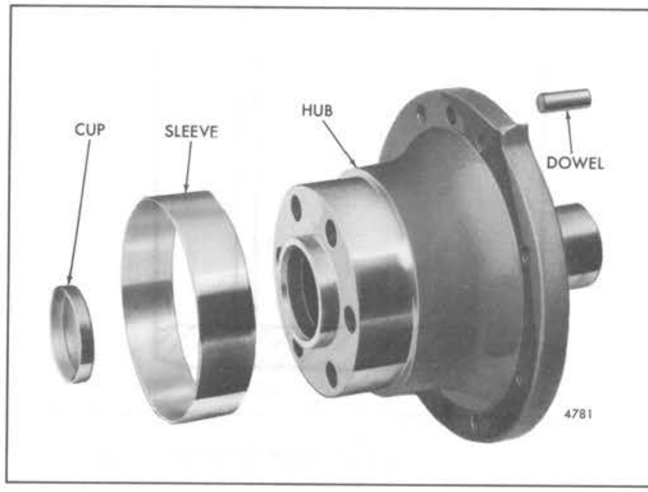


Fig. 4 – 12V and 16V Trunnion Mounted Vibration Damper Hub Details and Relative Location of Parts

Inspect the vibration damper hub sleeve (12V and 16V trunnion mounted engines) for wear at the trunnion oil seal contact surfaces (Fig. 4). If worn, replace the sleeve (refer to Section 1.3.2).

Install Vibration Damper (8V Engine)

All of the parts on the front of the crankshaft must be positioned without any noticalbe interference.

1. If removed, libricate the new seal ring with engine oil and install it in the groove on the inner diameter of the current damper inner cone (Fig. 5). If the engine was built prior to November 1976, install a new inner cone and Nitrile seal ring.
2. Pilot the damper inner cone over the end of the crankshaft, through the oil seal and up against the oil pump drive hub or oil slinger (bearing cap mounted oil pump), with the tapered end of the cone pointing toward the front end of the crankshaft.

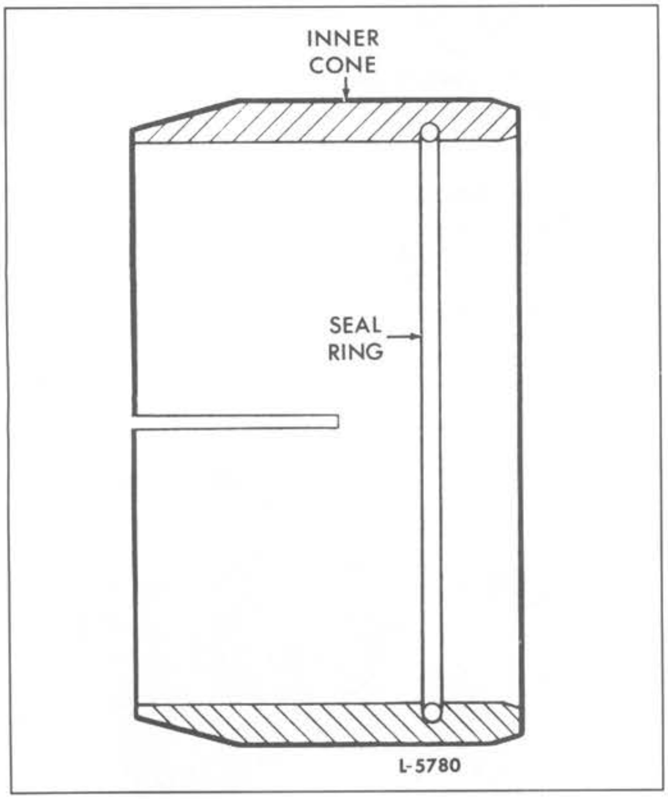


Fig. 5 – Inner Cone with Seal Ring (8V Engine)

3. Assemble the current vibration damper and hub as follows (Fig. 6):
   a. Place the vibration damper on the hub and over the dowel.
   b. Place the scuff plate over the dowels and against the damper and install the eight or ten 7/16"–20 x 1" lock bolts. Tighten the bolts to 75–85 lb–ft (102–115 N•m) torque. When overhauling engines with the former six bolt design vibration damper and hub assembly, the bolts should be tightened to the same torque as the current ten bolt design vibration damper and hub assembly.
4. Slide the vibration damper and hub as an assembly over the end of the crankshaft (long end of hub facing inner cone) and up against the damper inner cone. Do not hit the damper with a hammer to position it on the crankshaft.
5. 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.
6. Install the pulley on the crankshaft.
7. Place the washer on the crankshaft end bolt and thread the bolt into the end of the crankshaft. If the engine was built prior to March 1977, install a new lubrite coated bolt and washer identified by their black color.

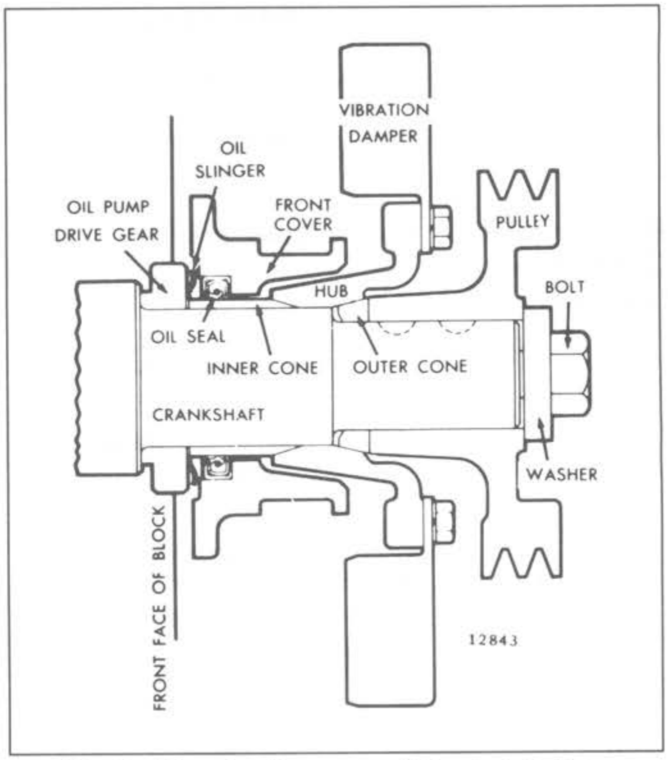


Fig. 6 – Vibration Damper and Crankshaft Pulley Assembly Mounting

8. Tighten the 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. Tighten the bolt to 300 lb–ft (407 N•m) torque and strike the bolt again.
   d. Retighten the bolt to 290–310 lb–ft (393–421 N•m) torque. Do not strike the bolt after final torque has been applied.

The damper assembly must be securely fastened to the crankshaft. When the bolt is drawn up to the specified torque, the cones will hold the damper rigidly in place.

The hex head of the crankshaft bolt may be used to bar, or 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 during the barring operation.* Otherwise, serious engine damage may result if the vibration damper or pulley is not securely fastened to the crankshaft.

CAUTION: To reduce the risk of personal injury when barring over or "bumping" the starter while performing an engine tune–up, personnel should keep their hands and clothing away from the moving parts of the engine, as there is a remote possibility the engine could start.

Install Vibration Damper (12V And 16V Engines)

All of the parts on the front of the crankshaft must be positioned without any noticable interference.

1. Install the hub on the front end of the crankshaft, if it was removed. It is important to properly align the scuff plate and hub assembly with the crankshaft so that all six hub to crankshaft bolts can be installed. Apply International Compound No. 2 (or equivalent) to the bolt threads and the underside of the bolt heads, then tighten the 9/16"-18 hub attaching bolts to 155–165 lb–ft (211–224 N•m) torque.

On 12V and 16V trunnion mounted engines, if the cup plug in the rear of the vibration damper hub was removed, replace it with a new cup plug. It is not necessary to use the cup plug or seal sleeve on engines using stationary type front mounts.

2. Secure the vibration damper to the hub on the front end of the crankshaft with bolts and lock washers. Do not hit the damper with a hammer to position it on the crankshaft. Tighten the bolts to 71–75 lb–ft (96–102 N•m) torque.
3. Drive the crankshaft pulley, if used, straight on the hub with a block of wood and a hammer.
4. Place the washer on the crankshaft end bolt and thread the bolt into the end of the crankshaft.
5. Tighten the 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. Tighten the bolt to 300 lb–ft (407 N•m) torque and strike the bolt again.
   d. Retighten the bolt to 290–310 lb–ft (393–421 N•m) torque. Do not strike the bolt after final torque has been applied.

The damper assembly must be securely fastened to the crankshaft. When the bolt is drawn up to the specified torque, the cones will hold the damper rigidly in place.

The hex head at the crankshaft bolt may be used to bar, or turn, the crankshaft. However, the barring operation should **always** be preformed in a clockwise direction. *It is very important to make certain that the bolt has not been loosened during the barring operation.* Otherwise, serious engine damage may result if the vibration damper or pulley is not securely fastened to the crankshaft.

CAUTION: To reduce the risk of personal injury when barring over or "bumping" the starter while performing an engine tune-up, personnel should keep their hands and clothing away from the moving parts of the engine, as there is a remote possibility the engine could start.

CRANKSHAFT PULLEY

The crankshaft pulley is retained on the crankshaft with keys, cones or a combination of both and secured with a special washer and bolt (Fig. 1).

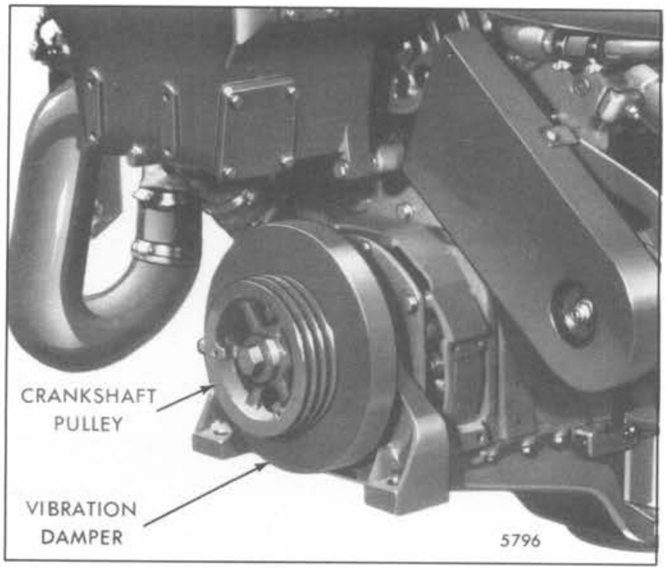


Fig. 1 - Crankshaft Pulley Mounting - 8V Engine

The new crankshaft bolts are now lubrite coated to prevent possible damage (galling) to the bolt threads and to increase the clamp load to the front end stack up (crankshaft pulley, vibration damper, etc). Also, the new washer (retainer) is now case hardened.

The new bolts and washer can be identified by their black color. The former bolts and washer are a steel (gray) color.

The engines are equipped with either rigid type or rubber mounted type pulleys, depending on the engine application. Rubber mounted pulleys incorporate a rubber insulator between the pulley and the pulley hub, for vibration isolation, and a static clip on some engines, between the pulley and the hub, for releasing electrical charges.

The load carrying capability of the front crankshaft pulleys will vary depending upon the pulley used.

Inspection

The appearance of the rubber bushed crankshaft pulley cannot be determined by the appearance of the rubber. The only reliable method of checking for failure of the rubber bushing is to hold the crankshaft stationary and apply pressure to the pulley. If the pulley cannot be rotated, the bushing is in satisfactory condition. If necessary, replace the bushing.

Remove Crankshaft Pulley

1. Remove the pulley retaining bolt and washer and static clip, if used.
2. Remove the pulley using a suitable puller or thread the pulley retaining bolt halfway into the crankshaft and strike the bolt with a 2 to 3 pound lead hammer while prying behind the pulley with two pry bars. Keep the ends of the pry bars as close to the crankshaft as possible.

If tapped holes are provided, install the pulley bolt in the end of the crankshaft then, using puller J 24420-A, remove the pulley from the crankshaft.

Install Crankshaft Pulley

1. Install the keys and/or cones in the front end of the crankshaft as they were removed.
2. Lubricate the end of the crankshaft with engine oil to facilitate pulley installation.
3. Slide the pulley on the end of the crankshaft.
4. Place the washer and static clip, if used, on the bolt and thread the bolt into the end of the crankshaft. If the engine is equipped with a vibration damper, the pulley must be drawn tight against the outer cone (see Section 1.3.6).
5. Tighten the 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. Tighten to 300 lb-ft (407 N•m) torque and strike the bolt again.
   d. Retighten the bolt to 290-310 lb-ft (393-421 N•m) torque. Do not strike the bolt after final torque has been applied.

The hex head of the crankshaft bolt may be used to bar, or 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 during the barring operation. Otherwise, serious engine damage may result if the vibration damper or pulley is not securely fastened to the crankshaft.

NOTICE: Barring a left-hand rotating marine engine equipped with a Jabsco raw water pump may result in damage to the rubber impeller if the impeller vanes are forced to rotate against their normal direction of deflection. To avoid damage, detach the cover and remove the impeller before barring the engine. Mark the front of the impeller for easy reinstallation.

CAUTION: To reduce the risk of personal injury when barring over or "bumping" the starter while performing an engine tune-up, personnel should keep their hands and clothing away from the moving parts of the engine, as there is a remote possibility the engine could start.

FLYWHEEL

Fig. 1 – Typical Flywheel Assembly

The flywheel (Fig. 1) is attached to the rear end of the crankshaft with twelve self–locking bolts on 8V engines only. Six bolts are used on the 6V and 16V engines. 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.

On some engines, a split tube type retainer (Fig. 2) is driven in the end of the crankshaft to prevent the pilot bearing from entering the crankshaft cavity.

On certain applications, a clutch wear plate is bolted to the flywheel.

The flywheel must be removed for service operations such as replacing the starter ring gear, crankshaft or flywheel housing.

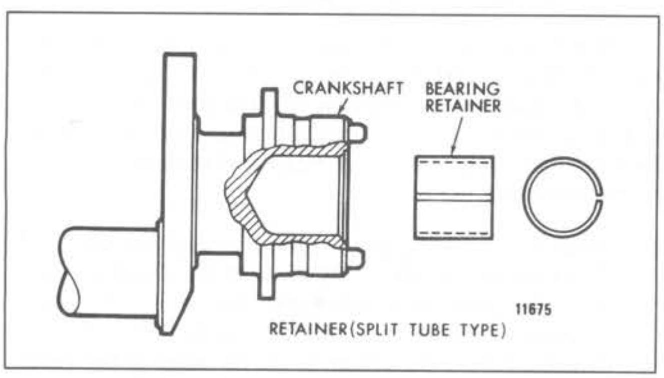


Fig. 2 – Pilot Bearing Retainer

Remove Flywheel (Transmission Removed)

1. Remove two flywheel bolts. Install two suitable guide pins in these holes to support the flywheel.
2. Remove the remaining flywheel attaching bolts and scuff plate.
3. Attach flywheel lifting tool J 25026, or some other suitable safe lifting device, to the flywheel.
4. Attach a chain hoist to the lifting tool to support the flywheel.
5. Remove the flywheel from the crankshaft and the flywheel housing.
6. Remove the clutch pilot bearing, if used, as outlined in Section 1.4.1.
7. If used, it is not necessary to remove the split–tube type bearing retainer from the crankshaft.

Inspection

Check the clutch contact surface of the flywheel or wear plate for cracks or wear. If the flywheel is cracked or worn, it may be refaced. *Do not* remove more than .020" of metal from the flywheel. Maintain all of the radii when refacing the flywheel. If cavities (porosity) of any size appear, fill them so no damage can result to the clutch.

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 brinelling.

On crankshafts with dowels, be sure and check the dowel extension. Dowels must not extend more than 1/2" 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.

The flywheel bolt tap depth in the 8V engine crankshaft has been reduced from 2.620" to 1.620" with approximate engine serial number 8VF–3120. With this change, shorter flywheel attaching bolts are used. The current shorter bolts can be used with the former crankshaft.

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 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.

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.

   NOTICE: Do not, under any circumstances, heat the gear over 400°F (204°C); excessive heat may destroy the original heat treatment.

   Heat indicating "crayons", which are placed on the ring gear and melt at a pre-determined 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. Attach the flywheel lifting tool and, using a chain hoist, position the flywheel in the flywheel housing (use guide studs). Align the flywheel bolt holes with the crankshaft bolt holes.

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

3. 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.

4. Remove the flywheel lifting tool.

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

   NOTICE: International Compound must never be used between two surfaces where maximum friction is desired, as between the crankshaft and the flywheel.

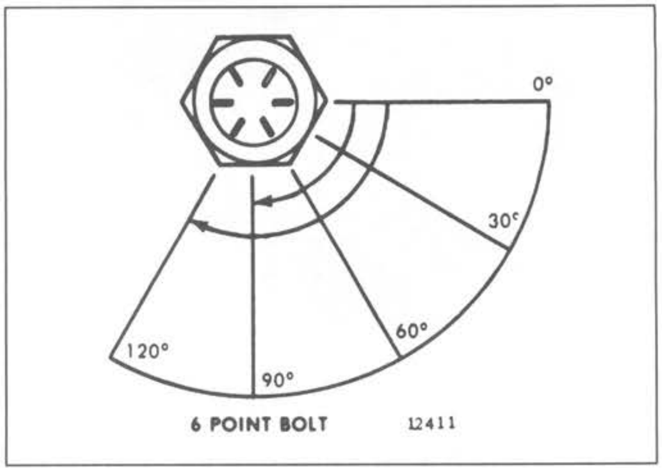


Fig. 3 – Torque–Turn Limits

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

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

8. Use an accurately calibrated torque wrench and tighten the bolts to 50 lb–ft (68 N•m) torque.

9. Turn the bolts an additional 90°–120° (Fig. 3) to obtain the required clamping.

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

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.

10. 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. 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. Also, a split tube type retainer (Section 1.4) is driven in the end of the crankshaft to prevent the pilot bearing from entering the crankshaft cavity.

The clutch pilot bearing is held in place by a scuff plate, or bearing retainer, secured in place by the flywheel attaching bolts.

On some engines, a gasket is used between the bearing retainer and the flywheel to provide an oil tight seal.

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 ball type clutch pilot bearing is prepacked with grease and requires no further lubrication.

Remove Clutch Pilot Bearing (Transmission Removed)

With the flywheel attached to the engine, remove the ball type clutch pilot bearing as follows:

1. Remove the bolts attaching the flywheel to the crankshaft. Remove the bearing retainer and install two 9/16"–18 studs to prevent the flywheel from dropping off the end of the crankshaft.
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 bearing out of the flywheel.
4. Remove the oil seal, if used.

With the flywheel removed from the engine, the clutch pilot bearing may be removed as follows:

1. Place the flywheel on wood supports to provide clearance for the bearing.
2. Use bearing remover J 23907–2 as outlined above, or tool J 3154–04 with suitable adaptor plates, to tap the bearing from the flywheel.
3. Remove the oil seal, if used.

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. Install the oil seal (if used) in the flywheel.
2. Lubricate the outside diameter of the bearing with clean engine oil.
3. Start the bearing in the bore of the flywheel, with the numbered side of the bearing facing away from the engine, and drive the bearing in place with bearing installer J 3154–04 and suitable adaptor plates.
4. Install the flywheel on the crankshaft (refer to Section 1.4).

ENGINE DRIVE SHAFT FLEXIBLE COUPLING

The engine drive shaft flexible coupling (Fig. 1), used on certain vehicle applications, is bolted to the engine flywheel and serves as a drive and also dampens out torque fluctuations between the engine and the Allison HT–700 and CLBT–700 transmissions.

A high capacity spring loaded engine drive shaft flexible coupling (Fig. 2) is used between the engine and Allison remote mounted CLBT–750 transmission. The coupling is bolted to the engine flywheel.

Remove Flexible Coupling (Transmission Removed) – Fig. 1

The flexible coupling assembly is held to the flywheel with the flywheel attaching bolts.

1. Remove two flywheel bolts. Install two suitable guide pins in these holes to support the flywheel.
2. Remove the remaining flywheel bolts and remove the scuff plate and flexible coupling assembly.

Inspect Coupling Assembly

Wash the coupling with clean fuel oil and dry it with compressed air.

CAUTION:To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.

Check for broken, worn or over–heated discs. The discs may be replaced by removing the twelve 1/2"–20 x 3/4" lock bolts holding the coupling assembly together. After replacing the discs, assemble the coupling and tighten the bolts to 96–115 lb–ft (130–156 N•m) torque.

Install Coupling Assembly (Fig. 1)

1. Align the bolt holes in the coupling with the tapped holes in the flywheel.
2. Apply a small quantity of International Compound No. 2, or equivalent, to the threads and contact area of the flywheel attaching bolts. Remove the guide pins and install the scuff plate and the 9/16"–18 x 1 3/4" lock bolts. Tighten the bolts as outlined in Section 1.4 under *Install Flywheel.*

Remove Coupling (Remote Mounted Transmission) – Fig. 2

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

Inspect Coupling Assembly

Wash the coupling in clean fuel oil and dry it with compressed air.

CAUTION:To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.

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 remvoing the

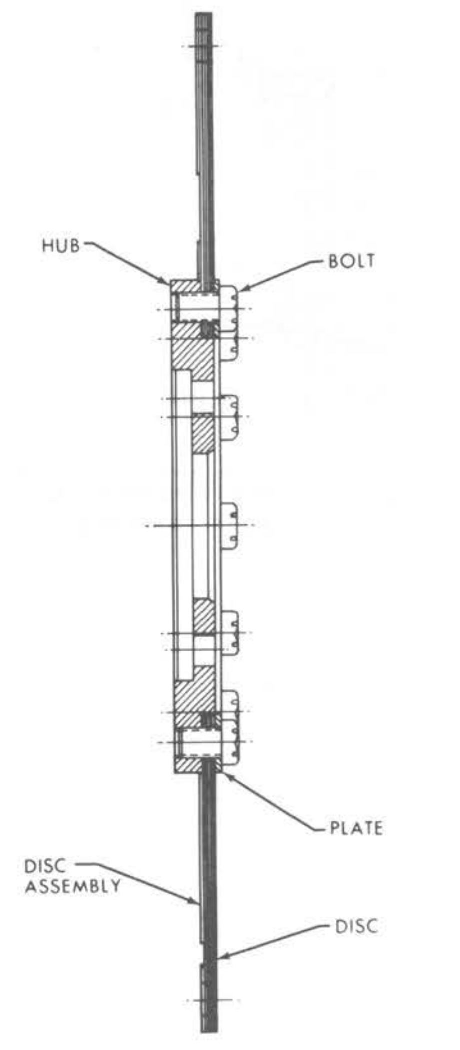


Fig. 1 – Engine Drive Shaft Flexible Coupling

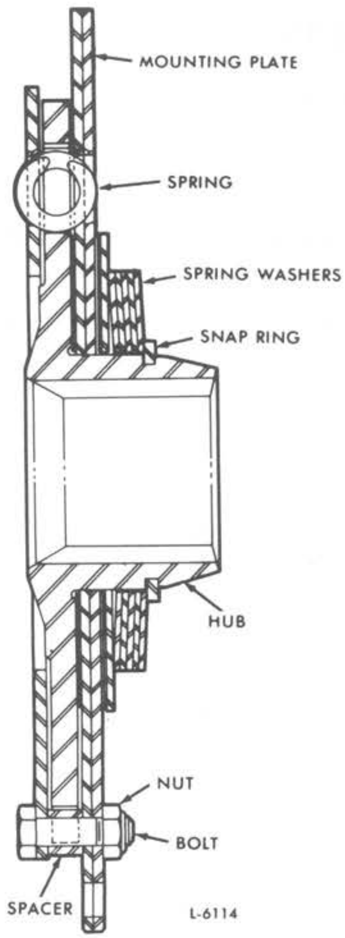


Fig. 2 – Engine Drive Shaft Flexible Coupling (Remote Mounted Transmission)

smaller plate. After replacing the springs, bolt the plates together and tighten the nuts to 25–30 lb–ft (34–41 N•m) torque.

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

Install Coupling Assembly

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 to 45–55 lb–ft (61–75 N•m) torque.

FLYWHEEL HOUSING

The flywheel housing is a one–piece casting mounted against the rear end plate which is attached to the cylinder block. The flywheel housing provides a cover for the gear train and flywheel. It also serves as a support for the starting motor and transmission.

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

Remove Flywheel Housing

1. Mount the engine on an overhaul stand as outlined in Section 1.1.
2. Remove the flywheel housing support brackets attached to the housing and the cylinder heads.
3. Remove the accessories attached to the flywheel housing.
4. Remove the starting motor (Section 7.3).
5. Remove the flywheel (Section 1.4).
6. Remove the oil pan (Section 4.7).
7. Remove the twelve attaching bolts located in the bell of the housing. Remove one attaching bolt located behind the small hole cover on the right–hand side of the flywheel housing. Then remove the remaining bolts around the upper portion of the housing and the two bolts which go through the rear end plate from the front and thread into the housing. Install aligning studs J 1927–01 to guide the housing until it clears the crankshaft during removal (Fig. 1). 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.
8. With the flywheel housing supported by a chain hoist attached to the lifter brackets, strike the front face of the housing alternately on each side of the engine with a soft hammer to work it off the dowels and away from the cylinder block rear end plate.
9. Remove all traces of the old gasket from the cylinder block rear end plate and the flywheel housing.
10. Remove the rear oil seal.

Inspection

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

Inspect the rear end of the crankshaft for wear due to the rubbing action of the oil seal, dirt buildup, or fretting caused by the action of the flywheel. The crankshaft must be clean and smooth, otherwise the oil seal lip will be damaged when the flywheel housing is reinstalled.

To prevent installation of bolts which are too long and bottom out on the blower drive step–up gear (naturally aspirated engines), studs are used at the locations shown in Fig. 2. Studs are installed in the flywheel housing with the teflon coated end threaded into the housing.

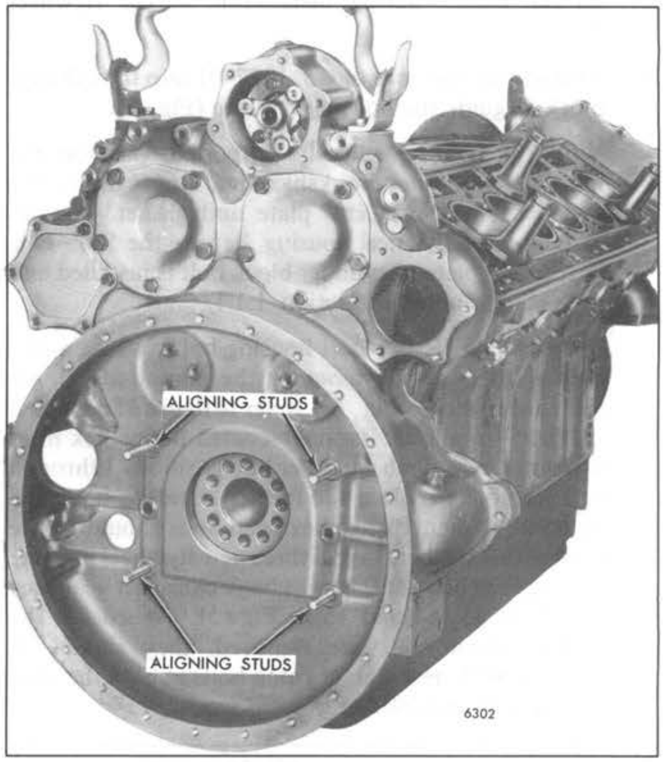


Fig. 1 – Installing Flywheel Housing, Using Oil Seal Expander Aligning Studs

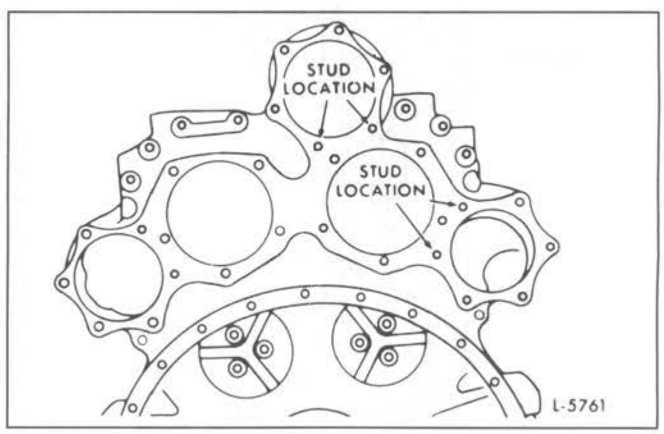


Fig. 2 – Flywheel Housing Cover Attaching Studs (Naturally Aspirated Engines)

Install Flywheel Housing (Except 16V Reinforced Flywheel Housing)

1. Lubricate the gear train teeth with clean engine oil.
2. Affix a new gasket to the flywheel housing. On certain flywheel housings, the idler gear hole spacer is cast integrally in the housing, opposite the idler gear (Fig. 3). As a result of this integral cast design, a shim must be installed between the flywheel housing and the cylinder block end plate. Use grease to hold the shim on the spacer during installation of the flywheel housing.
3. Thread two aligning studs J 1927–01 into the cylinder block to guide the housing in place (Fig. 1).
4. With the housing suitably supported, position the housing over the crankshaft and up against the cylinder block rear end plate and gasket. Before installing the flywheel housing, be sure the 5/8"–11 x 1" rear end plate to cylinder block bolt is installed and tightened as noted in Section 1.1.1.
5. Install all of the flywheel housing bolts, washers and lock washers, while removing the pilot studs, finger tight only (refer to Fig. 4). Refer to figure 4 and install the 3/8"–16 x 1.255" sealant–coated flange hex head bolts in dummy hub and idler hub positions 1 through 6. These bolts replace the former standard hex head bolt and washer. Flange hex head bolts should not be used with a washer. Install three *new* flywheel housing nylon patch bolts at the right bank camshaft gear area (positions 13, 14 and 15 in Fig. 5). Whenever the sealant patch bolts are removed, they should be replaced with *new* sealant patch bolts at both the *idler gear spacer and idler gear* positions.

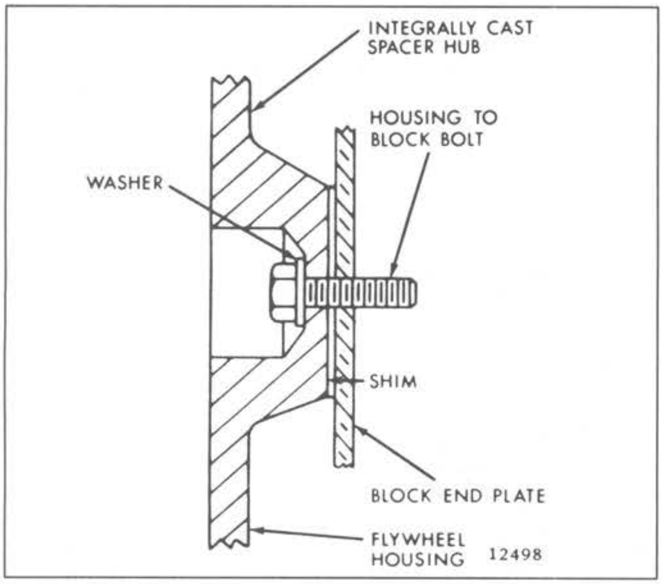


Fig. 3 – Idler Gear Hole Spacer Shim

6. Refer to Fig. 4 for the bolt tightening sequence and, starting at number 4 on a right–hand rotation engine or at number 1 on a left–hand rotation engine, draw the flywheel housing bolts up snug. If the idler gear hole spacer is integrally cast into the housing, be sure the shim is in place. When tightening the flywheel housing bolts, the idler gear hub bolts should always be tightened first. Also, turn the crankshaft by hand while tightening the idler gear hub bolts to prevent any bind or brinelling of the rollers and cups of the tapered roller bearing.
7. Refer to Fig. 5 for the final bolt tightening sequence and, starting at number 1, tighten the flywheel housing bolts to the specified torque. Tighten the 3/8"–24 bolts to 25–30 lb–ft (34–41 N•m) torque, the 3/8"–16 flange hex head idler gear hub and idler gear hole spacer bolts to 30–35 lb–ft (41–47 N•m) torque, the remaining 3/8"–16 bolts (number 30 with nylon patch) to 30–35 lb–ft (41–47 N•m) torque and the 1/2"–13 bolts to 90–100 lb–ft (122–136 N•m) torque. Tighten the two (2) 5/8–11" outboard flywheel housing bolts on the left and right side to 137–147 lb–ft (186–200 N•m) torque. Be sure to rotate the crankshaft when tightening the idler gear hub bolts.

New aluminum flywheel housings are being used on 6V–92TA 43° tilt coach engines effective with engine serial number 6VF–102676 and 6V–92TA 15° tilt coach engines effective with engine serial number 6VF–102867. The new coach flywheel housings have

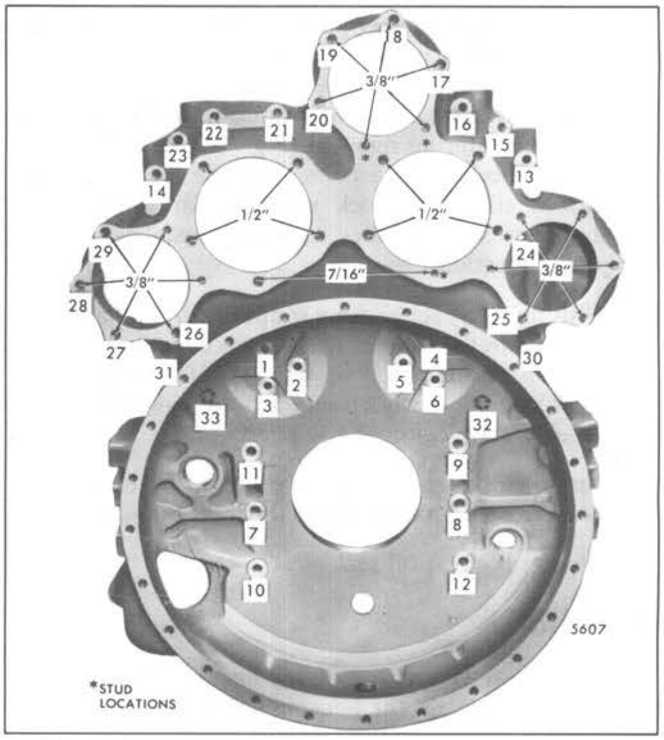
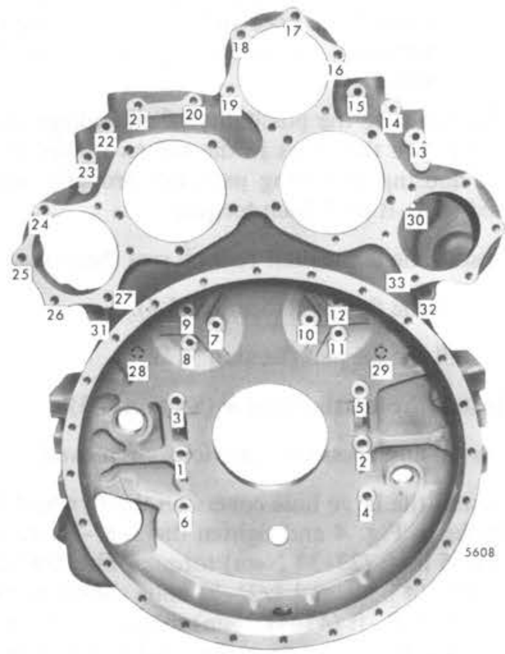


Fig. 4 – Flywheel Housing Bolt Tightening Sequence (Operation 1)



BOLT SIZE	LOCATION	FINAL TORQUE
3/8" — 16 x 1"	7-8-9-10-11-12, 28, 29	40-45 (54-61 Nm)
3/8" — 16" x 1 1/4"	30	30-35 lb-ft (41-47 Nm)
3/8" — 24 x 3 7/8"	13, 14, 15, 20, 21, 22, 23	25-30 lb-ft (34, 41 Nm)
1/2" — 13 x 3 1/4"	1, 2, 3, 4, 5, 6	90-100 lb-ft (122-136 Nm)
5/8" — 11 x 4"	31, 32	137-147 lb-ft (186-200 Nm)

Fig. 5 – Flywheel Housing Bolt Tightening Sequence (Operation 2)

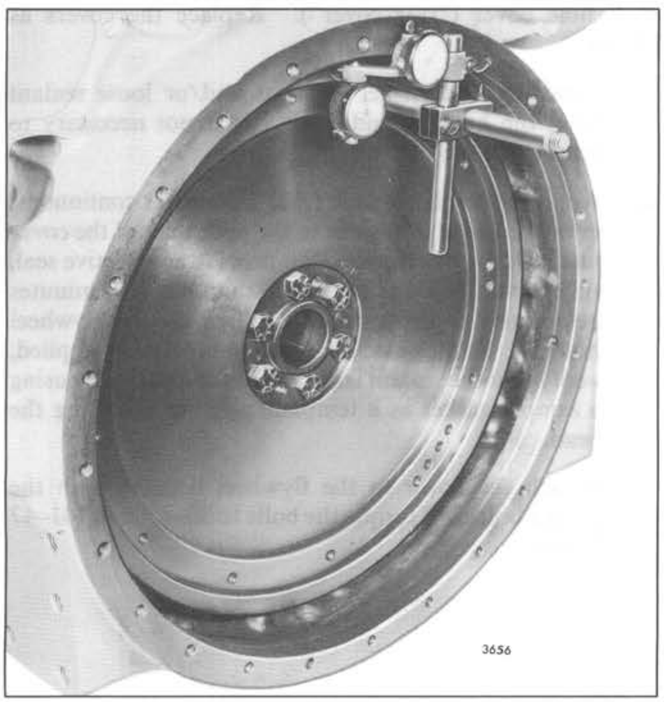


Fig. 6 – Checking Flywheel Housing Concentricity

an additional cast–in drilled boss which provides for a left–side waist bolt.

8. Check the flywheel housing concentricity and bolting flange face runout with tool set J 9737–C, as follows:

   a. Refer to Fig. 6 and thread the base post J 9737–3 tightly into one of the tapped holes in the flywheel. Then, assemble the dial indicators on the base post with the attaching parts provided in the tool set.

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

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.

CAUTION: To reduce the risk of personal injury when barring over or "bumping" the starter, personnel should keep their hands and clothing away from the engine as there is a remote possibility the engine could start.

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

BORE/FACE RUNOUT

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

Check the 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 end plate and flywheel housing or between the end plate and the cylinder block. If the bore diameter still exceeds limits, replace the flywheel housing.

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.

To eliminate the possibility of oil leakage on marine engines, be sure the plugs in the top two holes of the wet flywheel housing mounting pads are properly sealed and tightened (5 lb–ft or 7 N•m torque).

9. Install the crankshaft rear oil seal (Section 1.3.2).
10. Install the flywheel (Section 1.4).
11. Install the oil pan (Section 4.7).
12. Install the starting motor (Section 7.3).
13. Install any acessories previously removed.
14. Install the large hole covers on the flywheel housing. Refer to Fig. 4 and tighten the 3/8"–24 stud nuts to 20–25 lb–ft (27–34 N•m) torque. The 3/8"–24 bolts, 7/16"–14 bolts and 1/2"–13 bolts should be tightened to 30–35 lb–ft (41–47 N•m) torque. Current engines include thread inserts at the small and large hole cover stud hole positions.
15. Remove the engine from the overhaul stand and complete assembly of the engine.

Installing Flywheel Housing Small Hole Covers

An RTV (room temperature vulcanizing) sealant is now being used in place of the gasket to seal flywheel housing small hole cover ("star cover"). Replace the covers as follows:

1. Clean the old gasket material and/or loose sealant from the housing and cover. It is not necessary to remove all the old sealant.
2. Apply a one–eighth inch (.125") diameter continuous, unbroken bead of sealant to the perimeter of the cover just inside the bolt holes. To provide an effective seal, this should be done not more than ten (10) minutes before the cover is to be secured to the flywheel housing. To make sure the sealant is properly applied, verify that the sealant is in the correct location by using a sample gasket as a template prior to installing the bead.
3. Attach the cover to the flywheel housing with the proper bolts and torque the bolts to 30–35 lb–ft (41–47 N•m).

REINFORCED FLYWHEEL HOUSING (16V)

A reinforced flywheel housing with support studs is used on certain 16V engines.

Remove Flywheel Housing

Remove the flywheel housing as previously mentioned.

Inspection

Inspect the flywheel housing for cracks or other damage.

Install Flywheel Housing

Install the flywheel housing, as follows:

1. Thread jam nuts "A" and "C" on the studs (Fig. 7). Thread the longer stud into the left bank side of the cylinder block and the shorter stud into the right bank through the hole in the rear end plate. Tighten the studs.

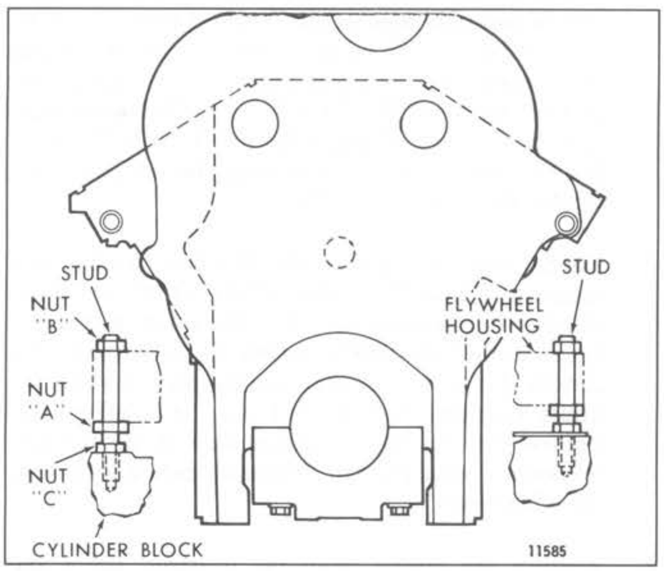


Fig. 7 – Location of Reinforced Flywheel Housing Support Studs

2. Turn nuts "C" on the studs until they contact the cylinder block. Tighten nuts "C".
3. Affix a new gasket to the flywheel housing.
4. Lubricate the gear train teeth with clean engine oil.
5. Thread two aligning studs J 1927-01 into the cylinder block to guide the housing in place (Fig. 1).
6. Install six 3/8"-16 x 1 1/8" self-locking bolts with flat washers in the tapped holes of the idler gear hub and idler gear hole spacer, finger tight only.
7. Remove the aligning studs and install six 1/2"-13 x 3-1/4" housing-to-cylinder block bolts with lock washers, finger tight.
8. Install the remaining flywheel housing attaching bolts with lock washers, finger tight.
9. Refer to Fig. 8 (Operation "1") for the bolt and nut tightening sequence and, starting at number 4 on a right-hand rotation engine or at number 1 on a left-hand rotation engine, draw the flywheel housing bolts and nuts up snug. When tightening the idler gear hub bolts, turn the engine crankshaft to prevent any bind occuring in the idler gear bearing assembly.

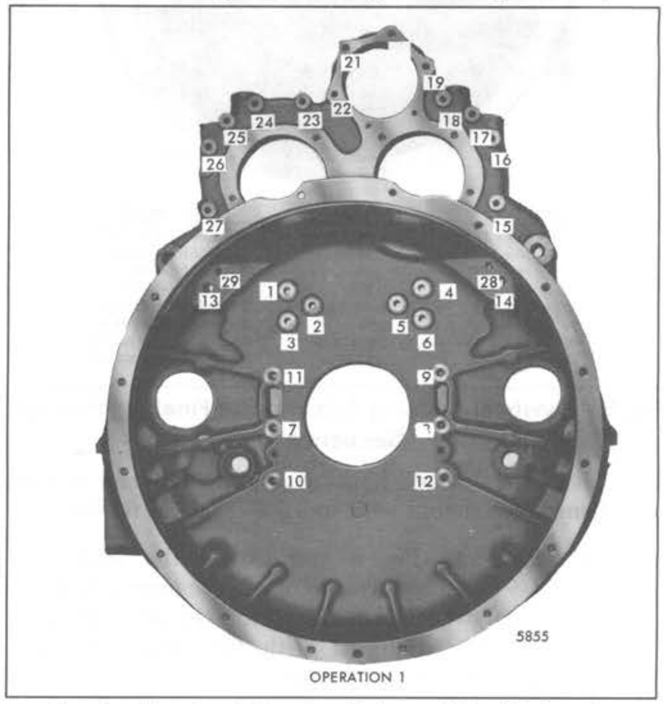
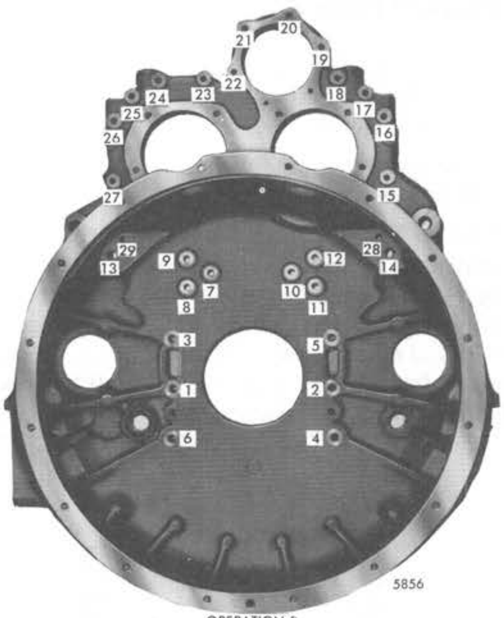


Fig. 8 – Flywheel Housing Bolt and Nut Tightening Sequence

10. Refer to Fig. 9 (Operation "2") for the final bolt and nut tightening sequence and, starting at number 1, tighten the flywheel housing bolts and nuts to the specified torque. Tighten the 3/8"-24 bolts and nuts to 25-30 lb-ft (34-41 N•m) torque, the 3/8"-16 self-locking idler gear hub and idler gear spacer hub bolts to 40-45 lb-ft (54-61 N•m) torque, the remaining 3/8"-16 bolts to 30-35 lb-ft (41-47 N•m) torque and the 1/2"-13 bolts to 90-100 lb-ft (122-136 N•m) torque. Tighten the two (2) 5/8-11" outboard flywheel housing bolts on the left and right side to 137-147 lb-ft (186-200 N•m) torque. Be sure to rotate the crankshaft when tightening the idler gear hub bolts.
11. Replace the crankshaft rear oil seal (Section 1.3.2).
12. Install the flywheel (Section 1.4).



OPERATION 2

BOLT SIZE	LOCATION	FINAL TORQUE
3/8" — 16 x 1"	7, 8, 9, 10, 11, 12	40-45 lb-ft (54-61 Nm)
3/8" — 16 x 3 1/4"	28	30-35 lb-ft (41-47 Nm)
3/8" — 16 x 4 1/4"	15	30-35 lb-ft (41-47 Nm)
3/8" — 24 x 3 1/4"	29	30-35 lb-ft (41-47 Nm)
3/8" — 24 x 3 7/8"	16, 17, 18, 23, 24, 25, 26	25-30 lb-ft (34-41 Nm)
3/8" — 24 x 4 1/4"	27	25-30 lb-ft (34-41 Nm)
1/2" — 13 x 3 1/4"	1, 2, 3, 4, 5, 6	90-100 lb-ft (122-136 Nm)
5/8" — 11 x 4"	13-14	137-147 lb-ft (186-200 Nm)

Fig. 9 – Flywheel Housing Bolt and Nut Final Tightening Sequence

13. Check the flywheel housing concentricity and bolting flange face runout with tool J 9737–C as follows:

    a. Refer to Fig. 6 and thread the base post J 9737–3 tightly into one of the tapped holes in the flywheel. Then, assemble the dial indicators on the base post with the attaching parts provided in the tool set.

    b. Position the dial indicators straight and square with the flywheel housing and make sure each indicator has adequate travel in each direction. If the flywheel extends beyond the flywheel housing bell, the housing bore and face must be checked separately. Use the special adaptor in tool set J 9737–C to check the housing bore.

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

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

CAUTION: To reduce the risk of personal injury when barring over or "bumping" the starter, personnel should keep their hands and clothing away from the engine as there is a remote possibility the engine could start.

    e. If the runout exceeds the maximum limits, remove the flywheel and the flywheel housing and check for dirt or foreign material, such as old gasket material, between the end plate, flywheel housing and new gasket (and between the end plate and the cylinder block), which may result in warpage. Reinstall the flywheel housing and secure the attaching bolts in the proper sequence and to the specified torque. Then, recheck the runout. If necessary, replace the flywheel housing.

14. If removed, place the upper oil pan in position against the cylinder block and flywheel housing and install all of the 3/8"–16 oil pan attaching bolts and lock washers finger tight only. Then, install the two (2) 3/4"–10 oil pan to flywheel housing bolts and lock washers to draw the oil pan tight against the flywheel housing. Next, tighten the 3/8"–16 oil pan bolts to draw the oil pan tight against the cylinder block. Now tighten the 3/4"–10 bolts to 240–250 lb–ft (325–339 N•m) torque and the 3/8"–16 oil pan bolts to 10–20 lb–ft (14–27 N•m) torque. When tightening the oil pan bolts, tighten the center bolts first.

15. Thread nut "A" against the flywheel housing and tighten stud nuts "B" to 160–170 lb–ft (217–231 N•m) torque while holding nut "A" from rotating (Fig. 6). Then, recheck the flywheel housing concentricity and runout. If the dial indicator readings are not within the limits specified, loosen stud nut "B" slightly and tighten jam nut "A" on either side of the flywheel housing to bring the dial indicator reading within the specified limits.

16. Remove the engine from the overhaul stand and complete assembly of the engine.

Installing Flywheel Housing Small Hole Covers

An RTV (room temperature vulcanizing) sealant is now being used in place of the gasket to seal flywheel housing small hole cover ("star cover"). Replace the covers as follows:

1. Clean the old gasket material and/or loose sealant from the housing and cover. It is not necessary to remove all the old sealant.

2. Apply a one–eighth inch (.125") diameter continuous, unbroken bead of sealant to the perimeter of the cover just inside the bolt holes. To provide an effective seal, this should be done not more than ten (10) minutes before the cover is to be secured to the flywheel housing. To make sure the sealant is properly applied, verify that the sealant is in the correct location by using a sample gasket as a template prior to installing the bead.

3. Attach the cover to the flywheel housing with the proper bolts and torque the bolts to 30–35 lb–ft (41–47 N•m).

PISTON AND PISTON RINGS

The cross–head piston is a two–piece piston consisting of a crown and a skirt (Figs. 1 and 2). A metal 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.

Two bolts and spacers are used to attach the connecting rod to the piston pin. The piston pin in the non–turbocharged (naturally aspirated) engines and former turbocharged engines has a lubricating oil tube which retains a floating nut inside of the piston pin. The solid core piston pin, used in the current turbocharged engines, has a radial drilled hole through the center. A threaded hole on each side of the oil hole receives the connecting rod attaching bolts.

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.

The non–turbocharged (naturally aspirated) engines use 19:1 compression ratio piston and the turbocharged engines use a 17:1 compression ratio piston. To aid identification of a piston, refer to Fig. 3. Fit the proper side of the gage in the bowl of the piston crown. When the gage rests on the rim of the crown, it is a "GO" check for a piston used in a turbocharged engine. When there is a space of approximately .040", it identifies a piston used in a naturally aspirated engine.

Detroit Diesel engines are designed to operate on diesel fuels containing less than 0.5% sulfur. Plasma–faced fire rings (Fig. 4) may be used in areas where approved fuel is not commercially available or economically feasible to obtain. It should be recognized that even with the use of the high sulfur fuel modification and maintenance procedures (see Section 15.1), engine life may still not equal that with our recommended fuels.

NOTICE: Recommended engine modifications do not apply to U.S. certified automotive engines.

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.

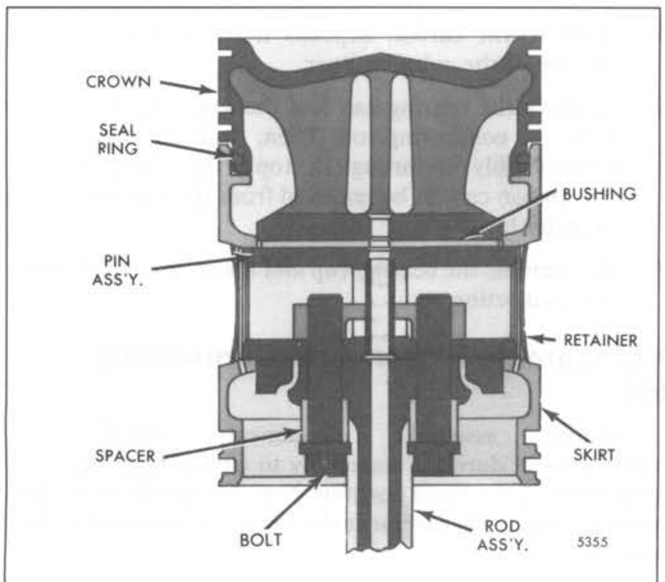


Fig. 1 – Cross–Head Piston and Connecting Rod Assembly

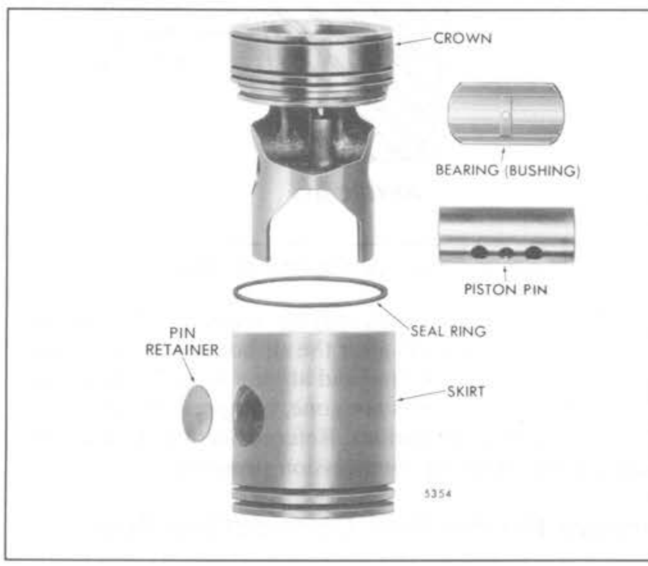


Fig. 2 – Cross–Head Piston and Connecting Rod Components

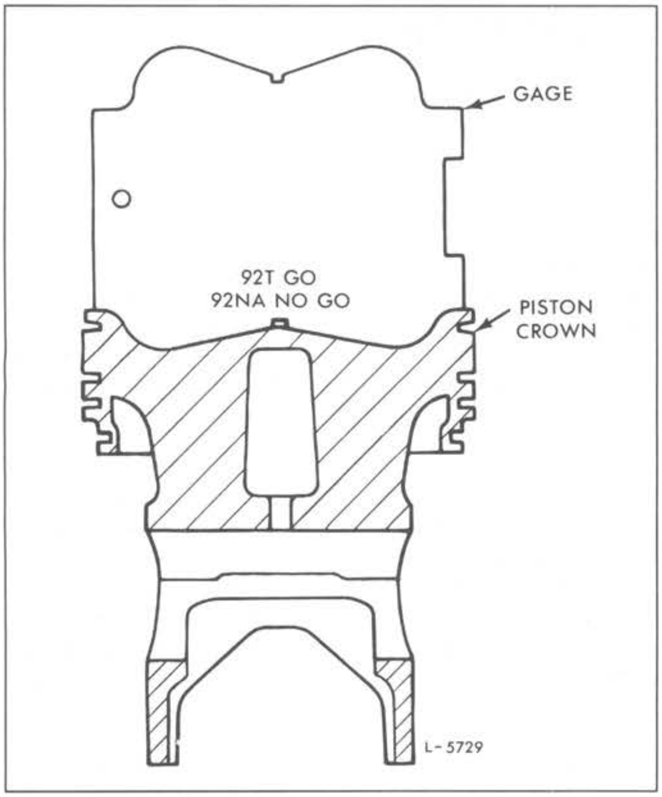


Fig. 3 – Identification of Piston using Gage J 25397

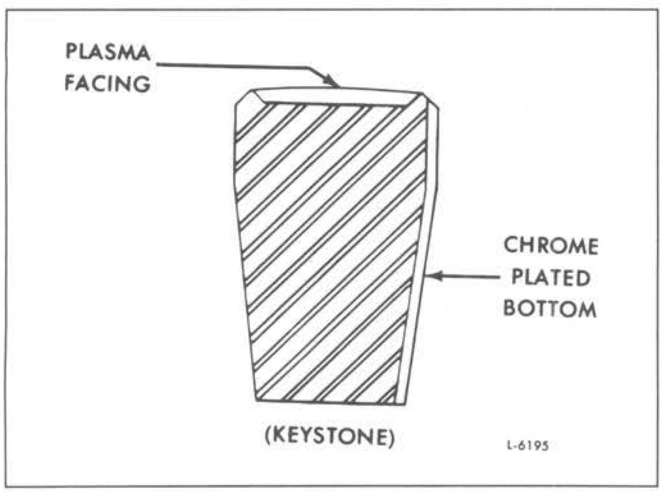


Fig. 4 – Plasma-Faced Fire Ring

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.

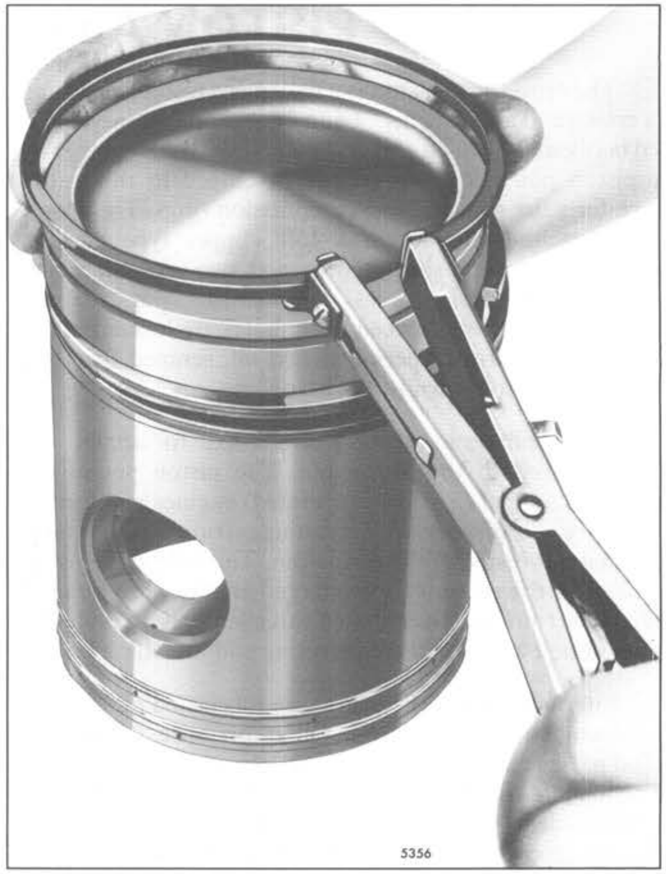


Fig. 5 – Removing or Installing Piston Rings using Tool J 8128

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

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. 5).

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 steel–toed 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.

> **CAUTION:To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.**

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 (no wear step on the lower groove land), 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 tapered fire ring groove width in the current piston crown with tool J 24599 (Fig. 6). Slide the "NO–GO" wire (.106" diameter) of the tool completely around the fire ring groove. Should the wire be below flush at any one area, the piston crown must be replaced. The "GO" wire (.100" diameter) should be flush or protrude slightly from the fire ring groove.

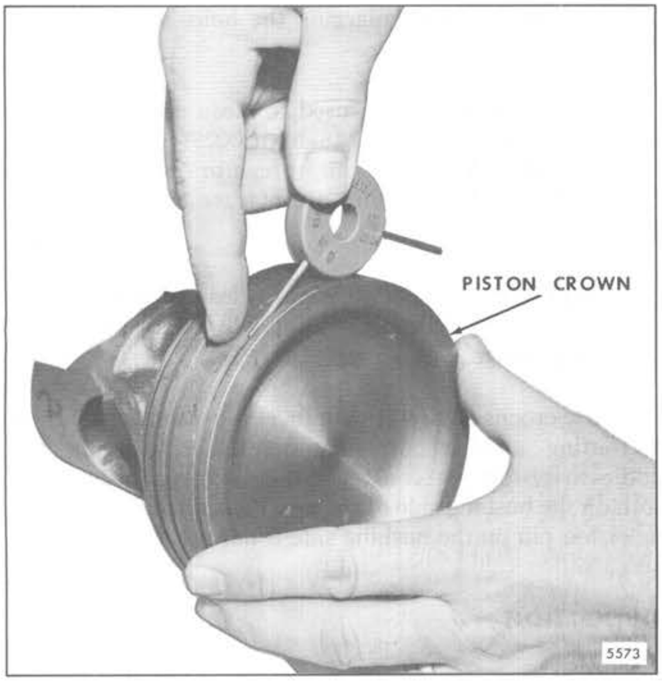


Fig. 6 – Checking Fire Ring Groove in Piston Crown with Tool J 24599

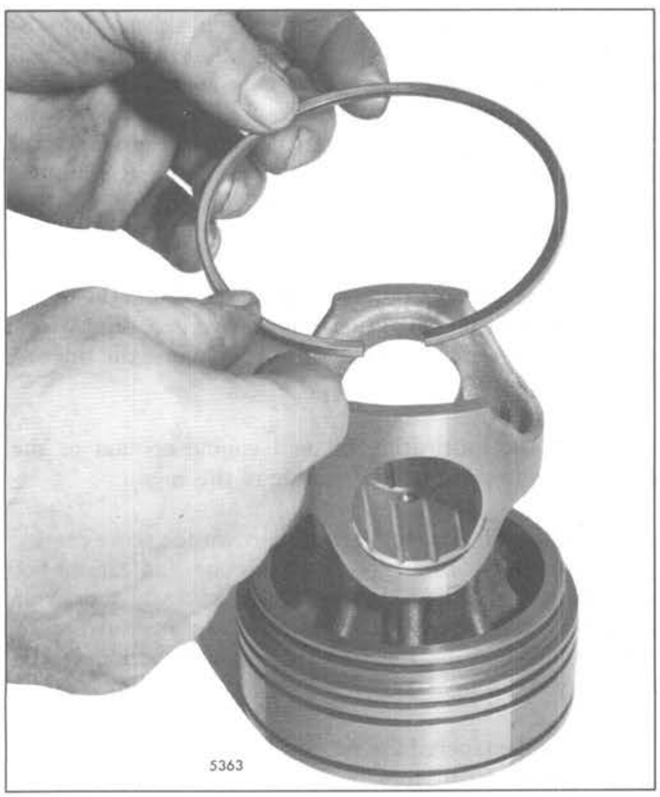


Fig. 7 – Installing Seal Ring

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).

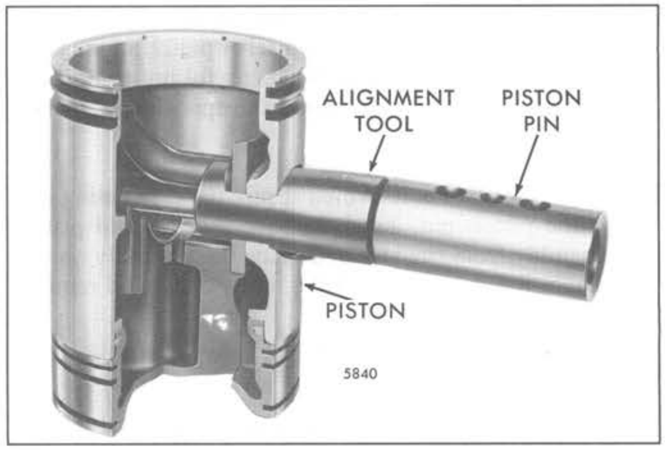


Fig. 8 – Installing Piston Pin

The current piston skirt has only one row of oil drain holes (Fig. 17). The piston skirt with two rows of oil drain holes and the "J" relief is used in non–turbocharged engines built before July, 1978. However, the two types of piston skirts can be mixed in early turbocharged engines.

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).

•Crosshead Piston Dome Inspection

Before reusing a crosshead piston dome, inspect the dome for serviceability, using the magnetic particle or fluorescent magnetic particle inspection method. In both cases, the direction of magnetism must be proper to assure finding the cracks of concern.

Magnetic Particle Method — Magnetize the dome, then cover with a fine magnetic powder (dry) or solution (wet). Flaws such as cracks will form small local magnets which will attract the metallic particles, effectively marking the crack. Demagnetize the dome and clean thoroughly after completing 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".

If magnetic particle inspection reveals a crack in any strut of a corsshead piston dome, the dome must be discarded and replaced.

NOTICE: Reusing a crosshead piston dome with a cracked strut can result in dome separation and serious engine damage.

When conducting a magnetic particle inspection, make sure that a casting joint is not mistaken for a crack.

•Lubrication

Use a mixture of clean engine oil and *STP* (or equivalent) on all moving parts of the cylinder kit during assembly. This mixture adheres to the parts for a longer period of time than plain engine oil, thus helping prevent scuffing of parts at engine start-up. The suggested mix ratio is 8:1 (8 parts engine oil to 1 part *STP*, or equivalent).

Assemble Piston And Connecting Rod

1. Refer to Section 1.0 for 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.

   NOTICE: The bearing must be installed before assembling the piston skirt and crown.

3. Lubricate the fluoroelastomer seal ring liberally with the *STP*/oil mix and install it on the piston.

   NOTICE: Unlike the former cast iron ring, the new fluoroelastomer ring is compressed when the skirt is pushed into position on the piston crown, so no ring compressor tool is required.

   NOTICE: Before completely assembling the piston, check to make sure the seal ring does not stick in the ring groove. It is imperative for satisfactory engine operation that the seal ring is free in the piston crown groove. Check the full 360° circumference of the groove to be sure there are no tight spots. When the piston crown, seal ring and piston skirt are assembled, the skirt should spin freely on the crown (crown top down on the bench). If the seal ring sticks, remove high spots or nicks in the groove with a flat file. If this does not relieve sticking, replace the piston crown.

4. Lubricate the piston pin with the *STP*/oil mix and install it as shown in Fig. 8.

   NOTICE: Line up the piston pin opening in the piston skirt with the bearing (bushing) opening in the piston crown with tool J 24285 to prevent damage to the pin or bushing.

   •NOTICE: Do not use Series 92 piston pins in Series 71 engines and visa–versa. The one–piece Series 92 piston pin is slightly heavier that the unitized Series 71 pin. Engine balance may be affected if piston pins are used in engines for which they are not designed.

5. Install the spacers on the two 7/16"–20 x 2" connecting rod to piston pin attaching bolts.
6. Apply a small amount of International Compound No. 2, or equivalent, to the bolt threads and bolt head contact surfaces.
7. Install and tighten the bolts finger tight. Then, clamp the connecting rod in a vise and tighten the bolts to 55–60 lb–ft (75–81 N•m) torque (Fig. 9). Do not exceed this torque.

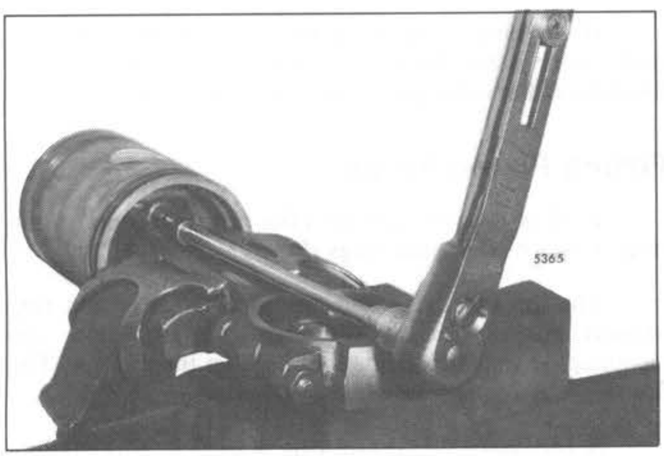


Fig. 9 – Tightening Connecting Rod to Piston Pin Bolts

Fig. 10 – Installing Piston Pin Retainer with Tool J 23762–A

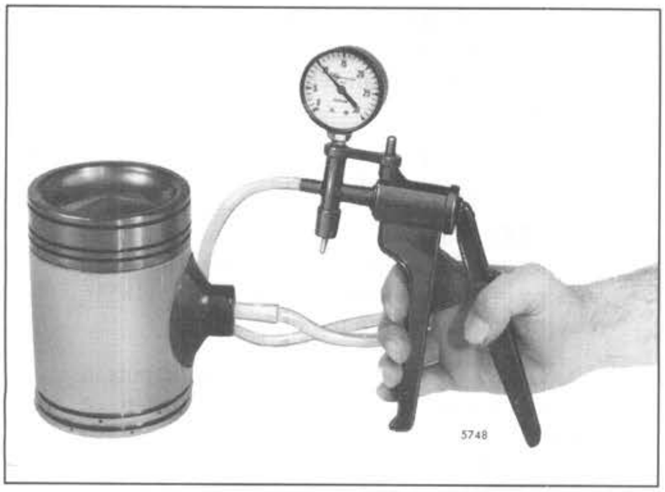


Fig. 11 – Checking Piston Pin Retainer for Proper Sealing with Tool J 23987-01

8. 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. 10).

9. Install the second piston pin retainer in the same manner.

NOTICE: 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.

10. 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, from reaching the cylinder walls. Check each retainer for proper sealing with leak detector J 23987-01 (Fig. 11). 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.

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 diameter (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 and check the clearance in four places 90° apart (Fig. 12).

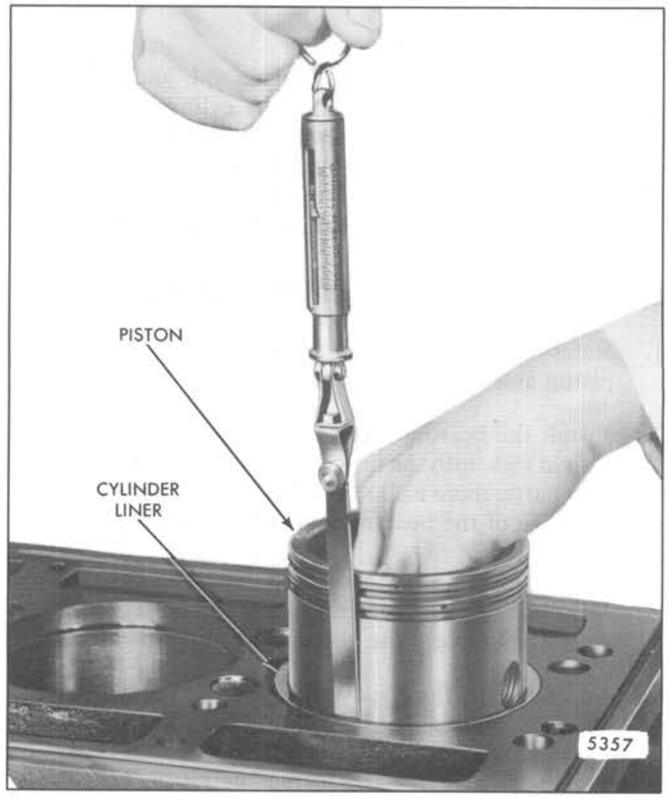


Fig. 12 – Measuring Piston-to-Liner Clearance with Gage J 5438-01

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. 13).

The top (fire) ring and the upper compression ring (second groove) are pre-stressed (Fig. 14). Both are identified by a small indentation mark on the top side. The fire ring is chrome-plated on the lower side.

A two-piece oil control ring is used in both oil ring grooves in the pistons for all current engines.

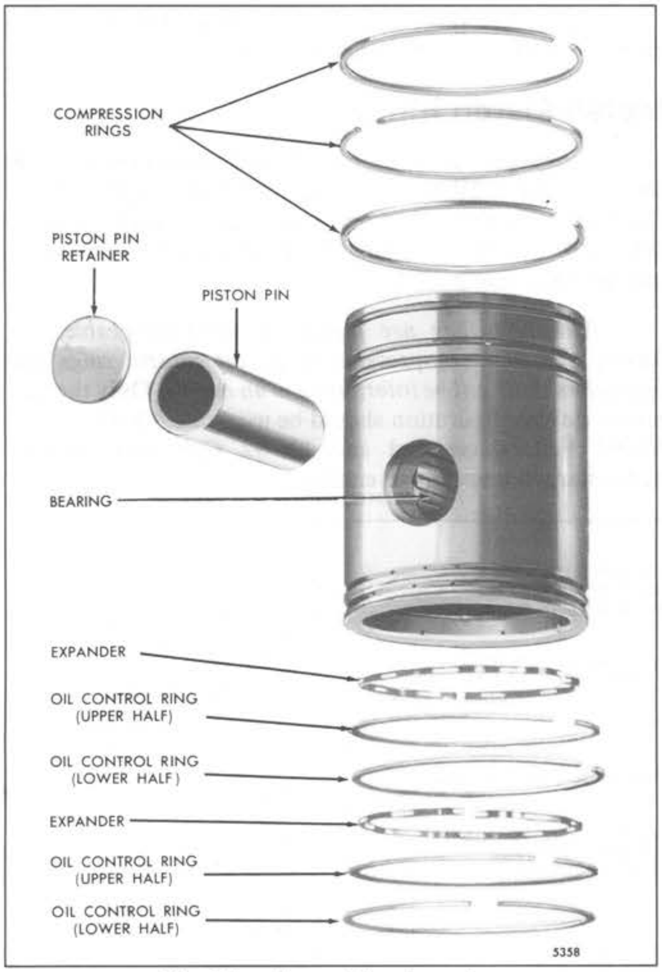


Fig. 13 – Piston Ring Location

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 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. 15). Refer to Section 1.0 for ring gap specifications.

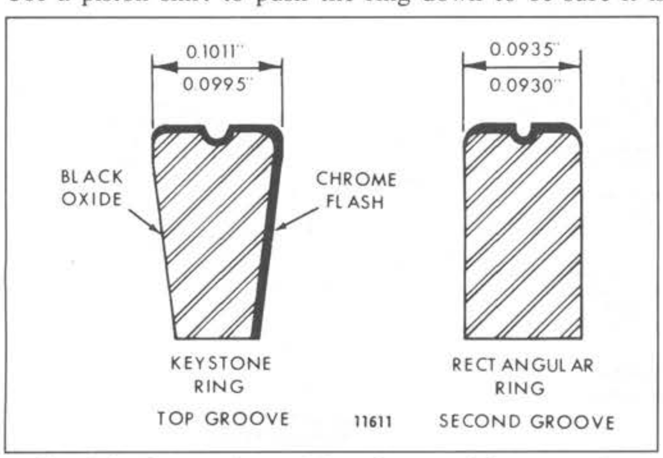


Fig. 14 – Comparison of Pre-Stressed Compression Rings

Fig. 15 – 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".

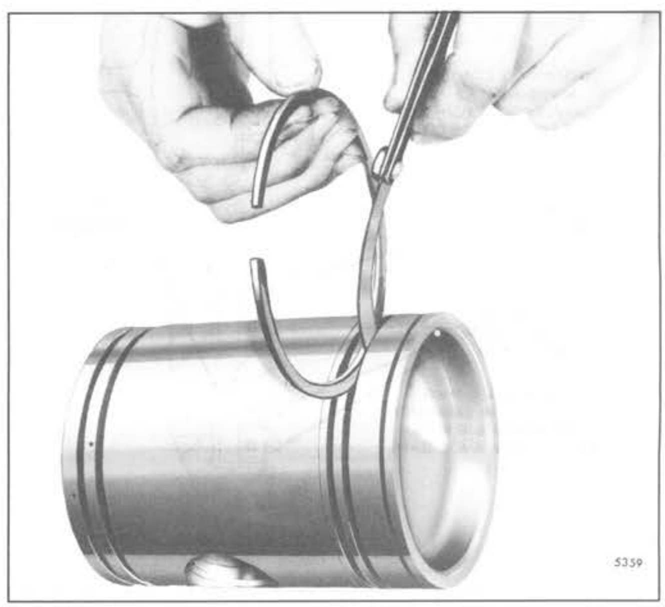


Fig. 16 – Measuring Piston Ring Side Clearance

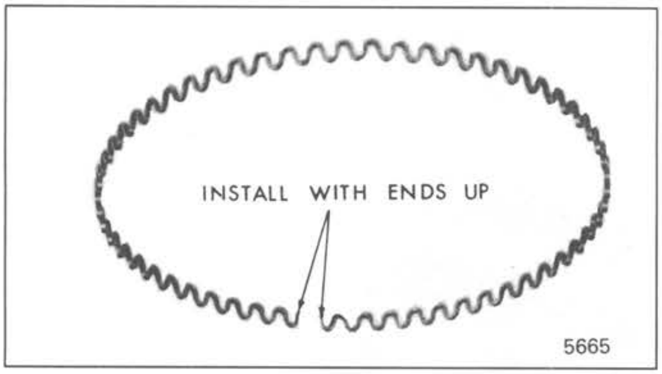


Fig. 17 – Peripheral Abutment Type Oil Control Ring Expander

Check the ring side clearance (Fig. 16). Ring side clearances are specified in Section 1.0.

Install Piston Rings

A new piston ring set has been released for all 1983 6V–92 and 8V–92 Federal–certified and 8V–92 California–certified turbocharged automotive engines (Fig. 20). 6V–92 California–certified engines continue to use the 1982 ring package (Fig. 19).

Although they are physically interchangeable, the former and new compression rings, oil control rings and expanders must not be intermixed in an engine. Only the new piston ring configuration should be used in 1983 6V–92 and 8V–92 Federal–certified and 8V–92 California–certified turbocharged automotive engines.

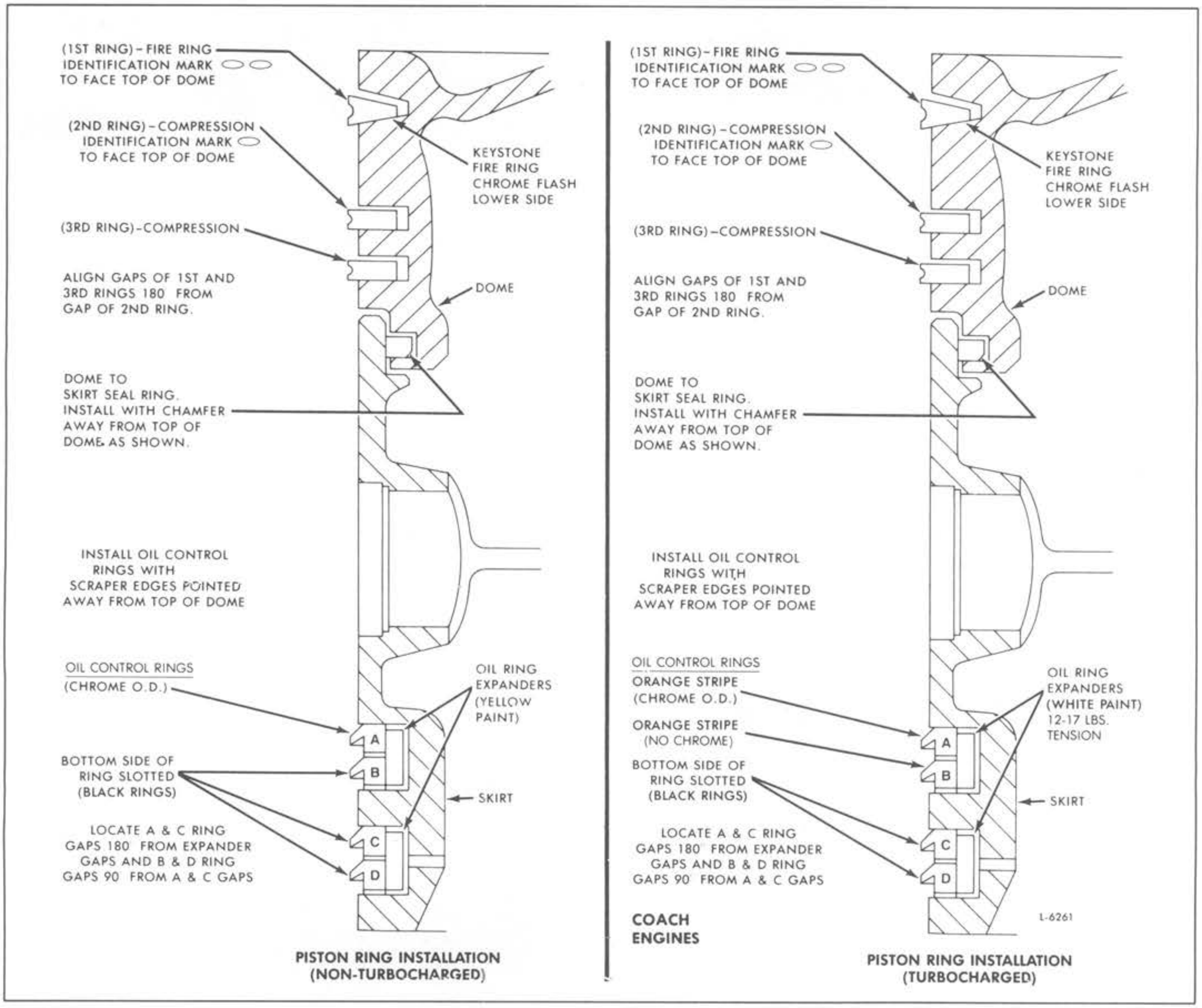


Fig. 18 – Piston Ring Installation Instructions

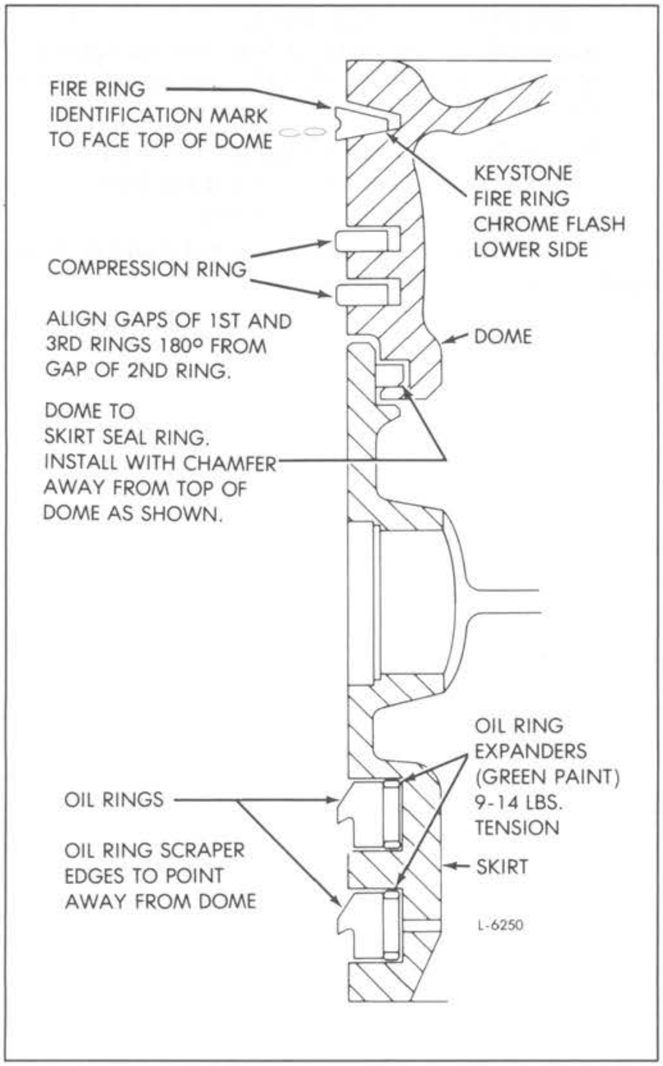


Fig. 19 – Piston Ring Installation – 1982 and 1983 6V–92 California Engines (Turbocharged)

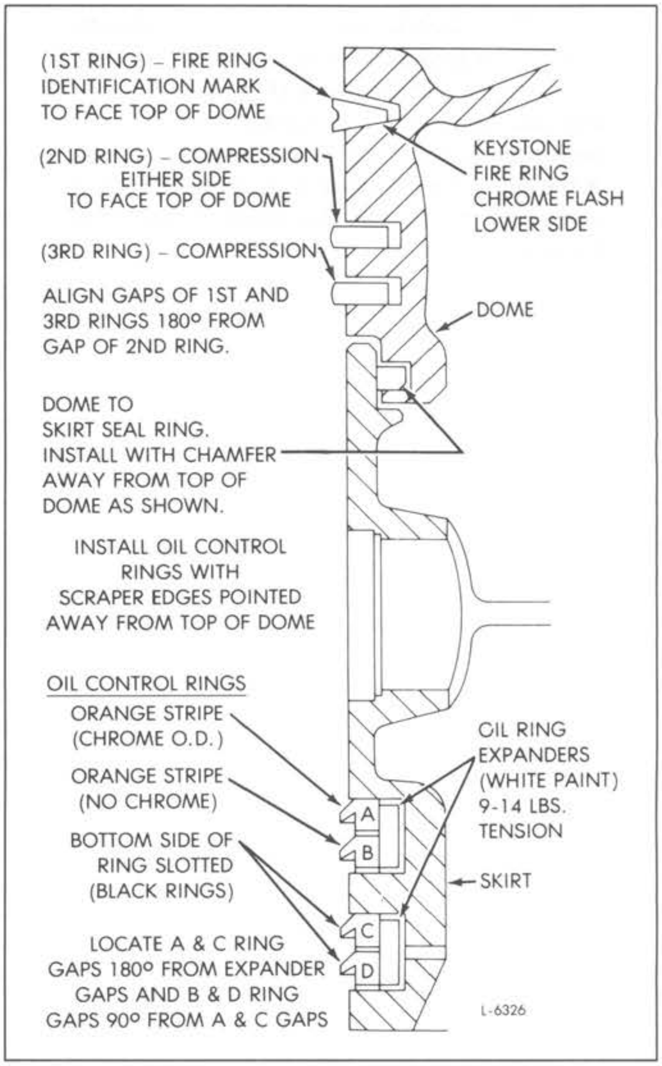


Fig. 20 – Piston Ring Installation – 1983 Fed., 1983 8V–92 Cal. and Prior Engines (Turbocharged)

The new piston ring configuration may also be used to service all prior 6V–92 and 8V–92 Federal and California automotive engines, except the 1982 6V–92 California, the 1983 6V–92 California and all intercity transit and parlor coach engines.

NOTICE: Lubricate the piston rings and piston with *STP* or equivalent, 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. Refer to Fig. 13, 18, 19 or 20 for ring identification and location.
2. Stagger the ring gaps around the piston.

OIL CONTROL RINGS

Refer to Fig. 18, 19 or 20 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.

NOTICE: Install the peripheral abutment type ring expanders with the legs of the free ends toward the top of the piston (Fig. 17). With the free ends pointing up, noticeable resistance will be encountered during installation of the piston if the ends of the expander are overlapped and corrective action can be taken before ring breakage occurs.

2. Lubricate the oil control rings with *STP*, or equivalent and install the rings by hand. Start with the upper half of the top oil ring and align the gaps as indicated in Fig. 18, 19 or 20.

   NOTICE: The scraper edges of all oil control rings must face downward (toward the bottom of the piston) for proper oil control.

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

CONNECTING ROD

The connecting rod (Fig. 1) 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. The bearing cap and connecting rod are forged in one piece and bored prior to separation.

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 self–locking bolts and spacers. The lower bearing cap is secured to the connecting rod by two specially machined bolts and nuts.

Lubricating oil is forced through a "Y" 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 fuel oil and dry them with compressed air.

CAUTION:To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.

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 before reassembly.

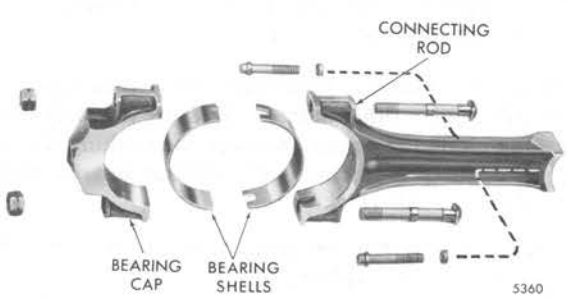


Fig. 1 – Connecting Rod Details

NOTICE: 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. Is the connecting rod 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. 2) by the magnetic particle method outlined in Section 1.3 under *Crankshaft Inspection.*
2. Determine the average bore diameter of the rod, using a dial bore gage and master ring as follows (Fig. 5).
   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 as shown in Fig. 5.
   c. Obtain 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 the average bore out–of–round and can be .0005" maximum.
   e. Add C with X and average to obtain average bore size.

   $\frac{C + X}{2} =$ Average diameter of bore which must be within 3.0615" to 3.0635".

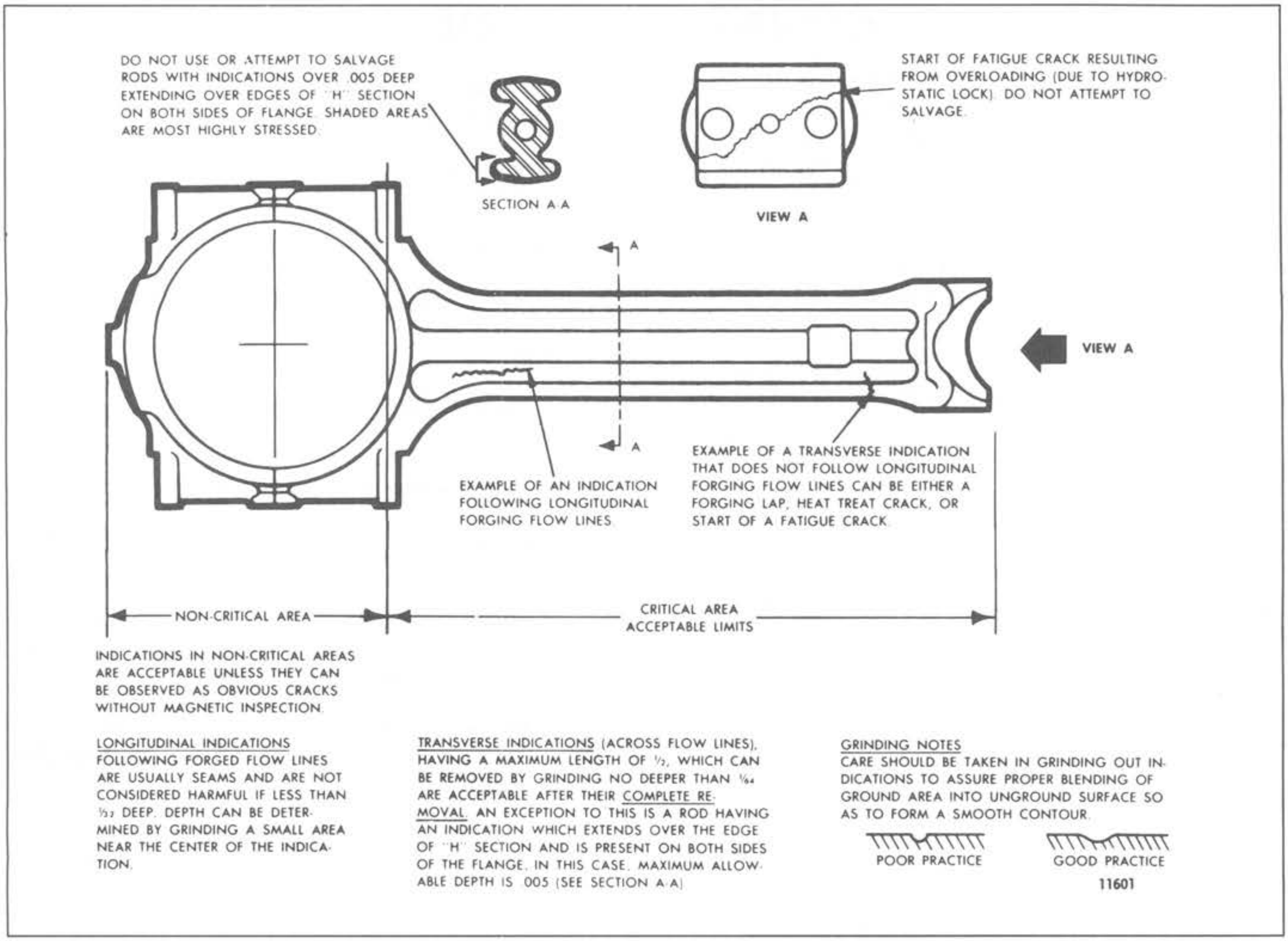


Fig. 2 – Magnetic Particle Inspection Limits for Connecting Rod

NOTICE: 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. 5):

   a. Subtract 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. 5).

   Specifications: 10.121" to 10.126".

   NOTICE: 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.

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

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 .086" or less. A new bushing is .087" to .088" thick.

A new piston pin bushing with a shorter oil distribution slot (fig. 4) replaced the long slot bushing in 1986. The short slot bushing provides optimum piston pin and bushing lubrication, even at maximum loads, and only this bushing should be used in Series 92 engines.

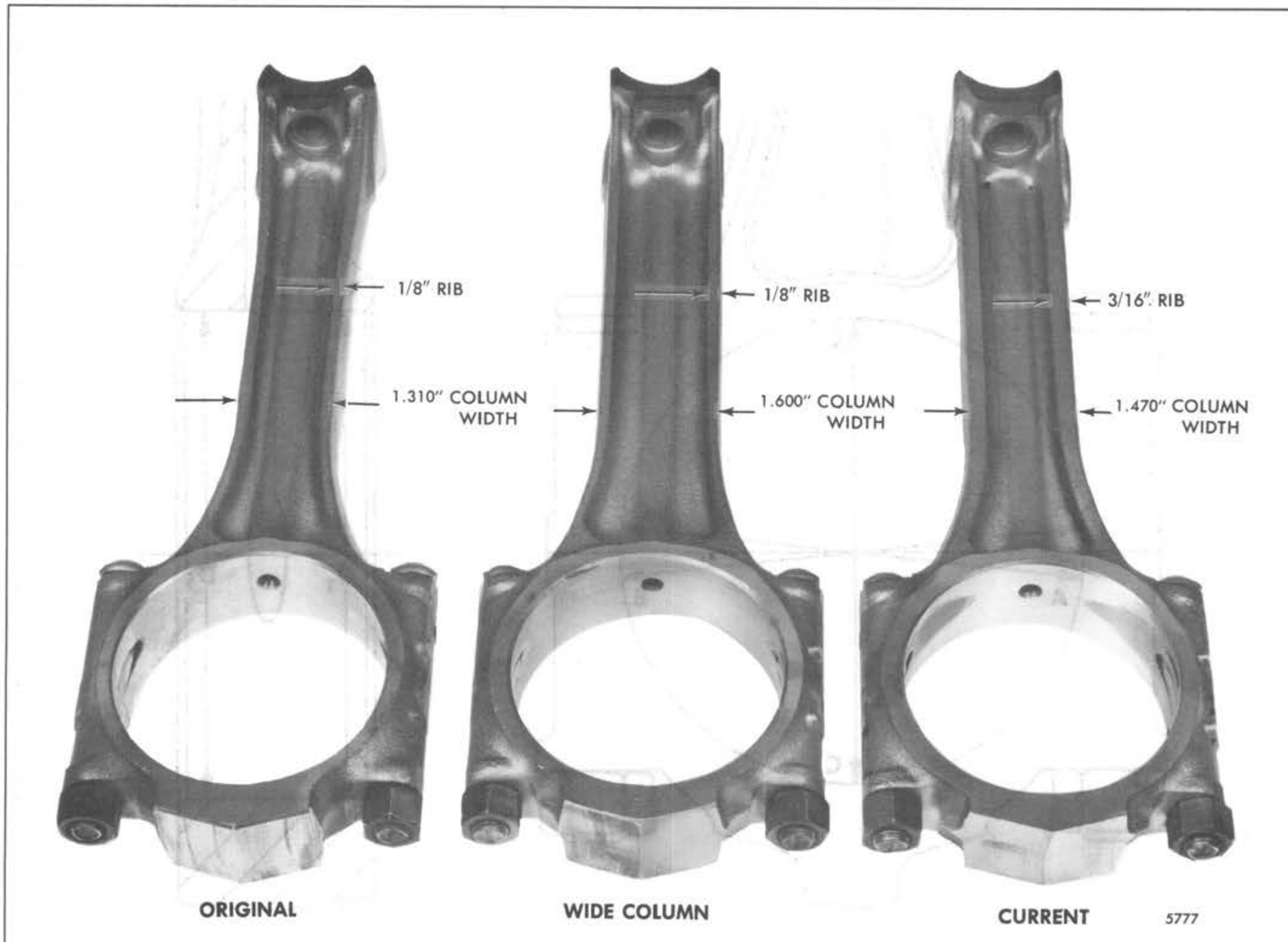


Fig. 3 – Comparison of Connecting Rods

Inspect the piston pin for signs of fretting. When re–using a piston pin, the highly polished and lapped surface of the pin must not in any way be refinished. Polishing or refinishing the piston pin is not recommended as it could result in very rapid bushing wear. A new piston pin has a diameter of 1.4996" to 1.5000". Replace the piston pin if it is worn to a diameter of 1.4980" or less.

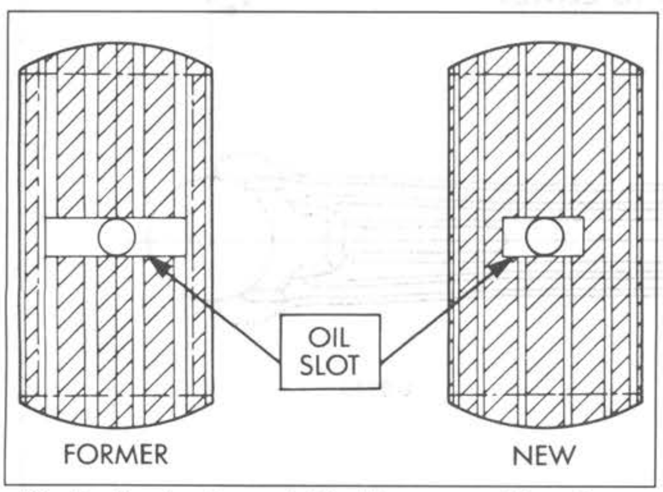


Fig. 4 – Bearing Faces (I.D.) of Former and New Piston Pin Bushings

Effective with approximate engine serial numbers 6VF–634, 8VF–1243 and 16VF–1004, a solid core piston pin is used in the *turbocharged engines (Fig. 6)*. The piston pin has a drilled oil hole at the center and a tapped hole on each side of the oil hole is provided to receive the connecting rod attaching bolts. The current connecting rod has a 1.470" wide column and provides greater strength under severe operating conditions and can be identified by white paint on the bottom of the bearing cap. The former connecting rods (1.310" and 1.600" wide column) (Fig. 3) have been superseded and will not be serviced. The former and current rod assemblies can be mixed in an engine. However, for maximum benefit, a complete set of the current connecting rods should be installed.

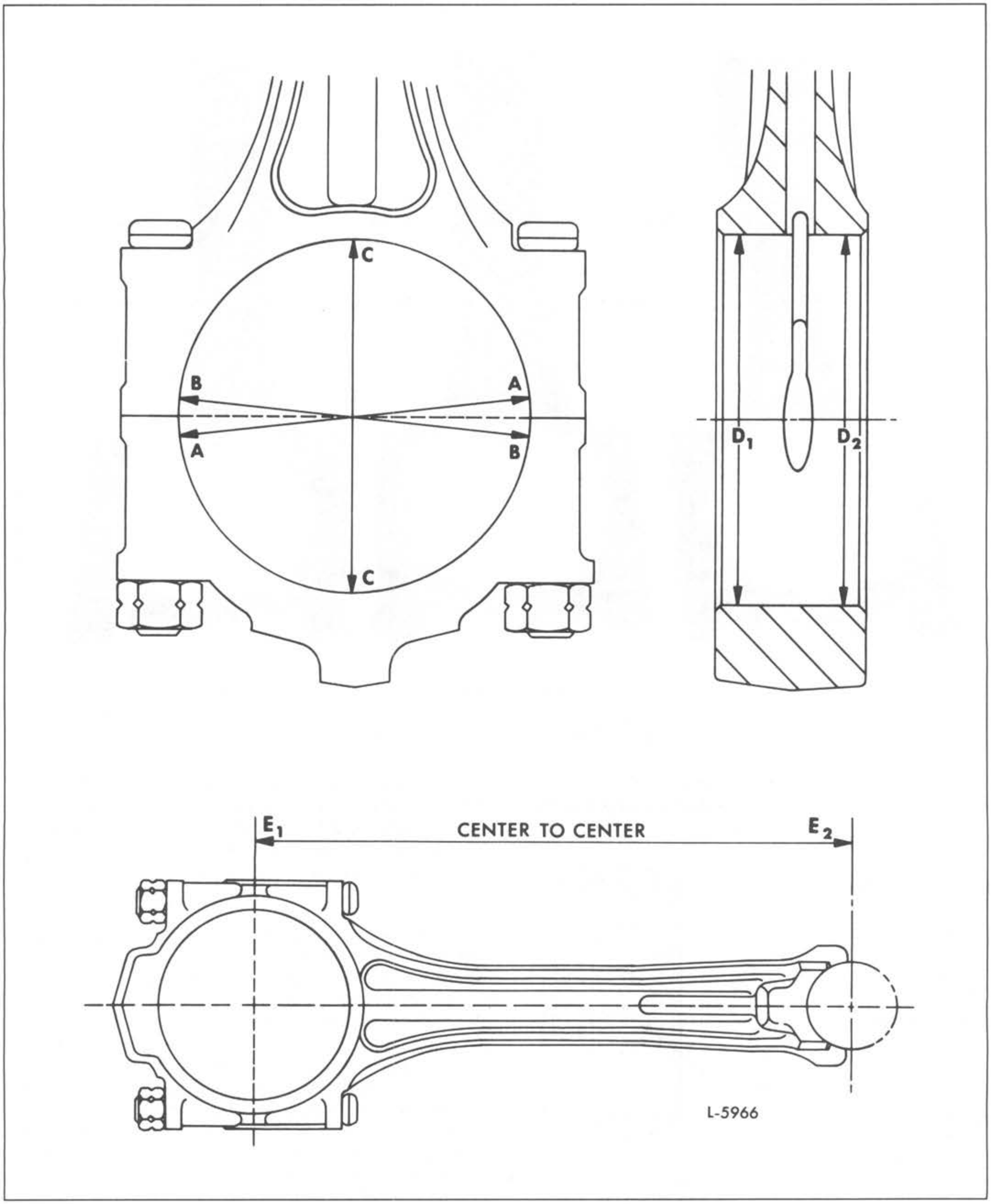


Fig. 5 – Dimensional Inspection of Cross-Head Piston Connecting Rods

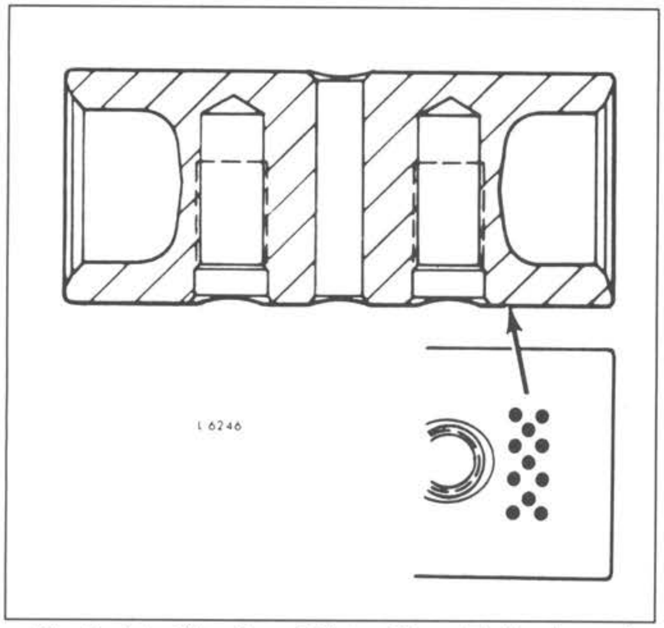


Fig. 6 – Identification of Piston Pins – Turbocharged Engines

Assemble Connecting Rod To Piston

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

CONNECTING ROD BEARINGS

The connecting rod bearing shells (Fig. 1) are precision made and are of the replaceable type 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 multiple layer copper–lead coplated bearings have an inner surface, called the matrix, of copper–lead. A thin deposit of lead–tin is then plated onto the matrix. The lead–tin overlay has excellent resistance to friction, corrosion and scoring tendencies which, combined with the material of the matrix, provides improved load carrying characteristics. These bearings are identified by the satin silver sheen of the overlay when new and a dull gray after being in service.

The upper and lower connecting rod bearing shells are different and are not interchangeable. Both shells are notched midway between the bearing edges for approximately 3/4 of an inch in from each parting line for bolt clearance and oil flow. In addition, the lower bearing shell has a circumferential oil groove that terminates at the notched ends. These notches 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 and piston pin bushing through the oil passage in the connecting rod.

Remove Bearing Shells

The connecting rod bearing caps are numbered 1L, 1R, 2L, 2R, etc., with matching numbers and letters stamped on the connecting rod. When removed, the bearing cap and the bearing shell should always be reinstalled on the original connecting rod.

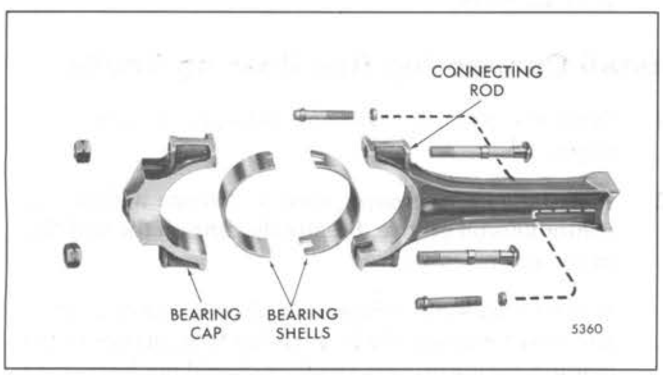


Fig. 1 – Connecting Rod and Bearing Shells

Remove the connecting rod bearings as follows:

1. Drain the oil and remove the oil pan.
2. Disconnect and remove the lubricating oil pump inlet pipe and screen assembly. If the engine is equipped with an oil pump which is mounted on the main bearing caps, remove the oil pump as outlined in Section 4.1.
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 lubricating oil.

After removal, clean the bearings and inspect them for scoring, pitting, flaking, chipping, cracking, loss of overlay or signs of overheating. If any of these defects are present, the bearings must be discarded. However, overlay plated bearings may develop minute cracks or small isolated cavities on the bearing surface during engine operation.

These are characteristics of and are NOT detrimental to this type of bearing. The bearings should not be replaced for these minor surface imperfections (Fig. 2). 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.

Examine the backs of the bearing shells for areas of no contact. Determine the amount of wear and replace, if necessary, the bearings and/or the connecting rod.

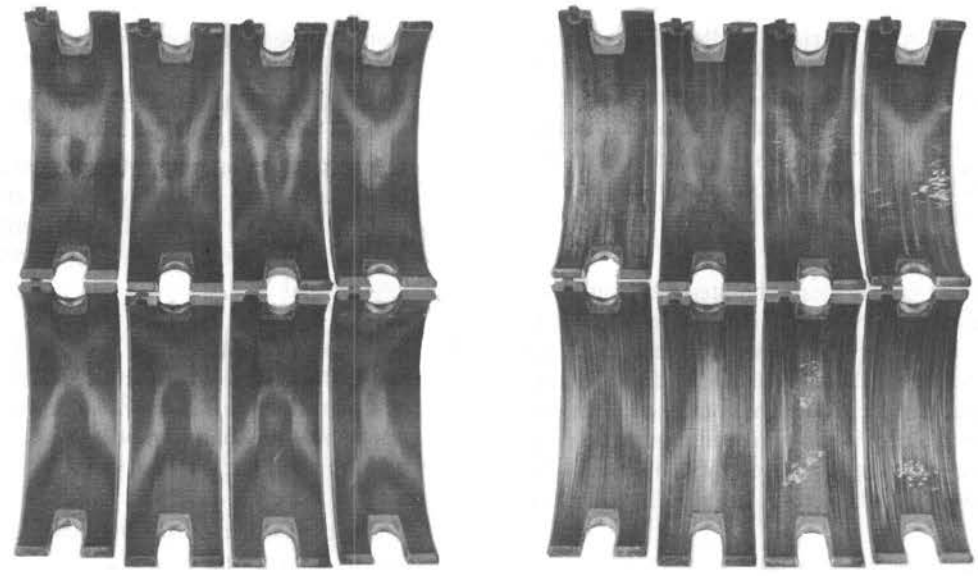


Fig. 2 – Comparison of Connecting Rod Bearing Shells

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 .1240" to .1245". Refer to Table 1.

Bearing Size	*New Bearing Thickness	Minimum Worn Thickness
Standard	.1240"/.1245"	.1230"
.002" Undersize	.1250"/.1255"	.1240"
.010" Undersize	.1290"/.1295"	.1280"
.020" Undersize	.1340"/.1345"	.1330"
.030" Undersize	.1390"/.1395"	.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 .0056".

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. Undersize bearings (.002") are available to compensate for slight journal wear where only slight grinding is required.

> **NOTICE:** Bearing shells are NOT reworkable from one undersize to another under any circumstances.

Install Connecting Rod Bearing Shells

1. Wipe the journal clean and lubricate it with clean engine oil.

2. Install the upper bearing shell — the one *without* the continuous oil groove. Be sure the tang on the shell fits in the groove in the rod.

   If there is a visible difference in the color of new upper and lower bearing shells, it is due to a change in the manufacturing process and they should not be rejected on the basis of the dissimilar appearance.

Bearing shell *sets* from individual suppliers are completely interchangeable and can be mixed in an engine.

NOTICE: Upper and lower bearing shells are serviced only in sets. 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.

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

4. Note the number and letter stamped on the bearing cap and install the lower bearing shell — the one with the continuous oil groove — into the bearing cap. Install the cap and shell in place.

5. Lock the bearing caps securely in place with bolts and nuts. Tighten the connecting rod bolt nuts to 60–70 lb–ft (81–95 N•m) torque (lubrite nut).

NOTICE: 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 pipe and screen assembly. If the engine is equipped with an oil pump which is mounted on the main bearing caps, install the oil pump as outlined in Section 4.1.

7. Install the oil pan.

8. Refer to *Lubrication Specifications* in Section 13.3 and refill the crankcase to the proper level on the dipstick.

9. If new bearings were installed, operate the engine on the *run–in* schedule as outlined in Section 13.2.1.

CYLINDER LINER

The cylinder liner (Fig. 1) is of the replaceable wet type (water above ports), 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 fits into a counterbore in the cylinder block and rests on a replaceable cast iron insert which permits accurate alignment of the cylinder liner.

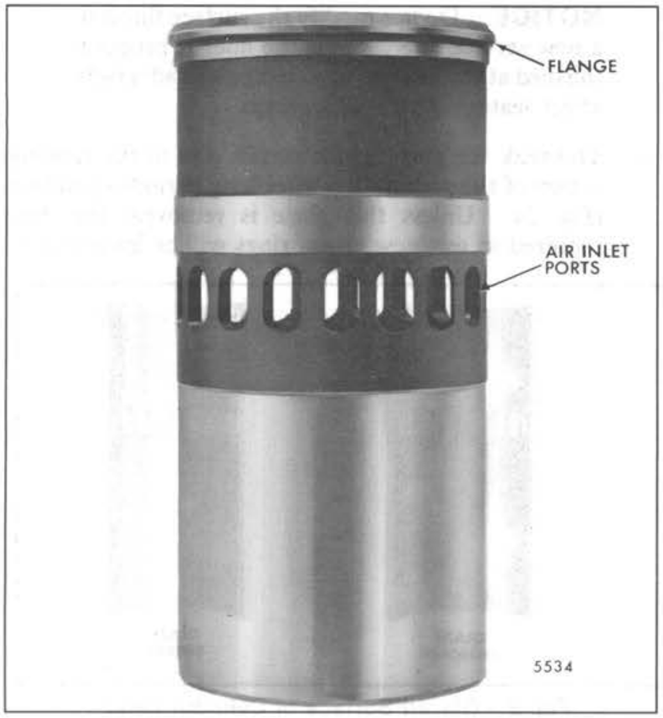


Fig. 1 – Typical Cylinder Liner

Two Teflon® coated seal rings, recessed in the cylinder bore, are used between the liner and the block to prevent water leakage.

The upper half of the liner is directly cooled by water surrounding the liner. At the air inlet ports, the liner is cooled by the air introduced into the cylinder through equally spaced ports around the liner. The lower half of the liner is cooled by water inside the cylinder block water jacket surrounding the liner.

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.

Refer to Fig. 2 and remove a cylinder liner as follows:

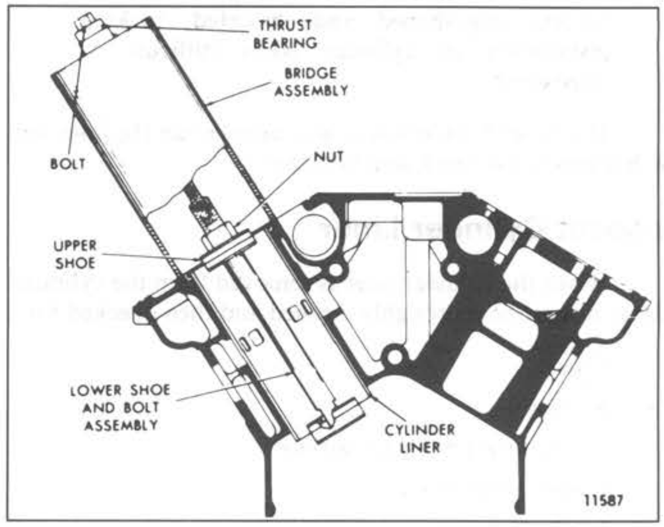


Fig. 2 – Removing Cylinder Liner

1. Remove the piston and connecting rod assembly as outlined in Section 1.6.

2. Remove the cylinder liner with tool set J 24563–A as follows:

   a. Ease the lower shoe and bolt assembly down into the liner. Place the shoe on the bottom edge of the liner with the flat on the shoe parallel with the crankshaft bore.

   b. Hold the lower shoe and bolt assembly in the *pulling* position. Place the upper shoe with the flat in the same position as the lower shoe over the threaded end of the bolt. Thread the nut down on the bolt assembly and be sure that the pilots on both of the shoes are seated properly.

   c. Place the bridge assembly (open end down) over the upper shoe and down against the block.

   d. With the thrust bearing on the bolt, install the bolt through the bridge assembly strap hole.

   e. Thread the bolt into the female threaded portion of the bolt assembly.

f. Turn the bolt in a clockwise direction and withdraw the liner from the block. Then, remove the tool from the liner.

g. Remove and tag the liner insert from the counterbore in the block.

h. Remove and discard both cylinder liner seal rings from the grooves 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 set J 24563–A 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 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 side for cleaning can lead to liner distortion.

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. Also, examine the liner for cavitation erosion above the ports.

The liner flange must be smooth and flat on both the top and bottom surfaces. Check for cracks at the flange. The liner insert must also be smooth and flat on the top and bottom surfaces as it also acts as a water seal. Replace the insert if there is evidence of brinelling.

Measure the block bore and the outside diameter of the liner. Refer to Section 1.0 for the liner–to–block specifications.

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

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

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

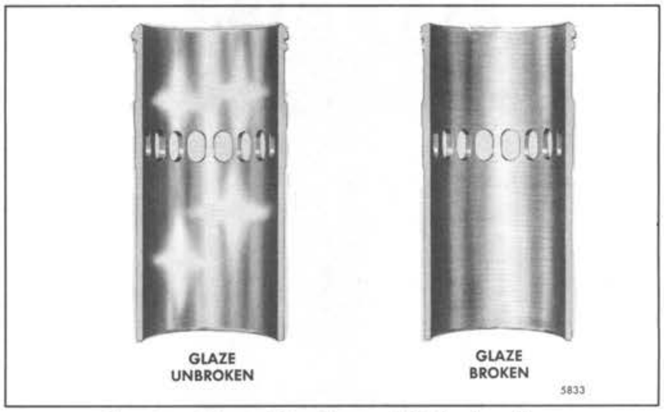


Fig. 3 – Glazed Surface of Cylinder Liner

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. 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.

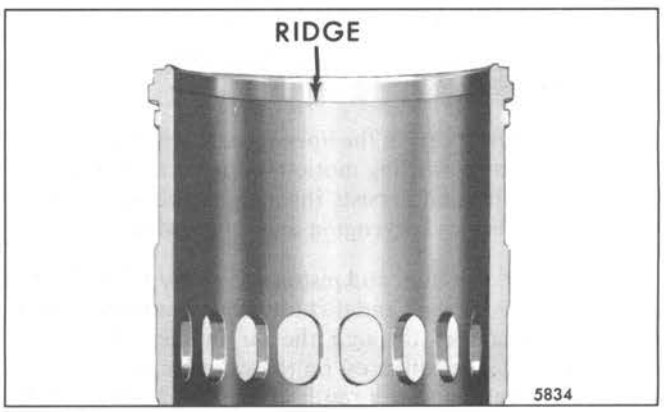


Fig. 4 – Cylinder Liner Ridge Due to Wear

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 5902–1, 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 a 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 (Specifications – Section 1.0).

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. New service liners have an *inside* diameter of 4.8390" to 4.8415". Use cylinder bore gage J 5347–B, which has a dial indicator calibrated in .0001" increments. Dial bore gage master setting fixture J 23059–01 may be used in place of the master ring gage. Set the cylinder bore gage on zero in master ring gage J 24564. Also, check the liner for taper and out–of–round.

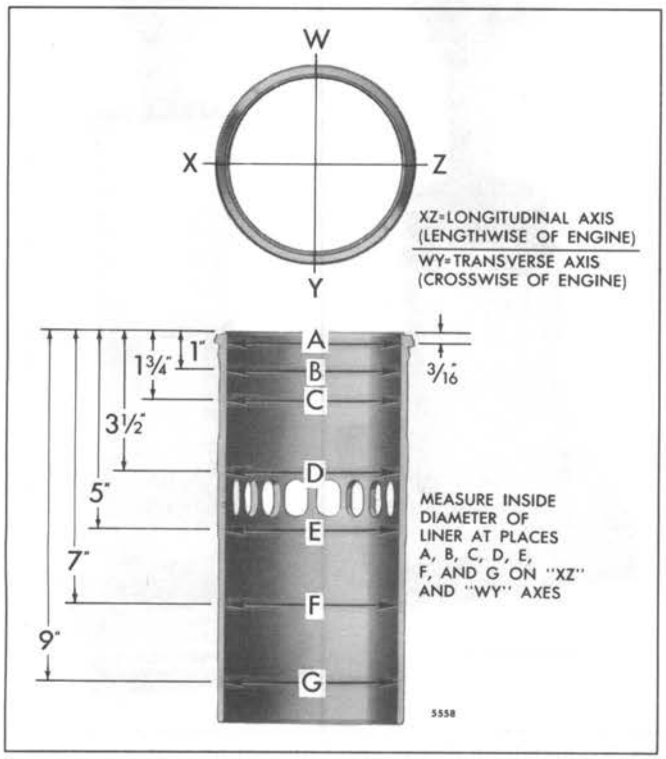


Fig. 5 – Cylinder Liner Measurement Diagram

The piston–liner clearance must be within the specified limits (Specifications – Section 1.0). Also, the taper and the out–of–round must not exceed .0025" on a used liner. The taper must not exceed .0015" or the out–of–round must not exceed .002" on a new liner.

Fitting Cylinder Liner In Block Bore

Smoke and fuel economy improvements were developed by changing the cylinder liner port configurations. The port height was reduced from 1.05" to .95" resulting in increased expansion stroke and the port angle was changed from 30° to 25° to optimize cylinder swirl conditions. These changes reduced engine smoke levels while meeting required emission levels. It is important to ensure that an engine is fitted with the appropriate cylinder liners for which it was designed.

1. Wipe the inside and outside of the liner clean and make sure the block bore and counterbore are clean, so the liner insert will seat properly. The block counterbore depth must be from .4755" to .4770" and must not vary more than .0015" in depth around the circumference. Also, no two adjacent block counterbores may range in depth more than .001" when gaged along the longitudinal cylinder block centerline.

   The cylinder liner is classified according to the flange thickness to help control the distance from the top of the liner to the top of the cylinder block. A cylinder liner with a flange thickness of .3109"–.3100" (C1) has the part number etched on the lower portion of the bottom half of the liner. A liner with a flange thickness of .3120"–.3110" (C2) has the part number etched on the upper portion of the bottom half of the liner (below

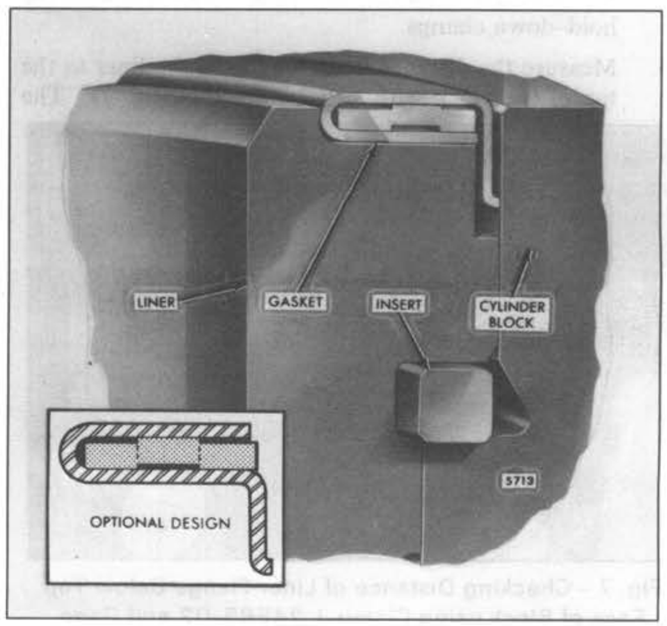


Fig. 6 – Cylinder Liner Mounting in Block

Size	Thickness	Identification (New Inserts)
std.	.1188"-.1193"	Black oxide or 2 purple stripes
std.	.1200"-.1205"	No color
std.	.1212"-.1217"	Copper or 2 orange stripes
+.015"	.1338"-.1343"	White and purple stripe
+.015"	.1350"-.1355"	White stripe
+.015"	.1362"-.1367"	White and orange stripe

TABLE 1

the air inlet ports). Effective December of 1987, liners also have an "L" or "H" etched next to the part number in these locations. The "L" denotes the thinner range (.3109" - .3100"), while the "H" denotes the thicker range (.3120" - .3110").

2. Place the liner insert (previously tagged) in the counterbore of the block (Fig. 6). Refer to Table 1 for the dimensions and identification of the liner inserts available, if a new liner insert is required.
3. Push the cylinder liner into the cylinder block until the liner flange rests on the insert. Do not use excessive force to install the liner. The liner should slide smoothly in place with hand pressure.
4. Clamp the liner in place with hold–down clamp J 24565–02 as illustrated in Fig. 7 and tighten the two (2) bolts to 50 lb–ft (68 N•m) torque.

   The cylinder head bolt hole counterbore has been increased in depth to .800" on current cylinder blocks. The depth was formerly .500". This necessitates the use of longer bolts (11/16"–11 x 3") for use with the hold–down clamps.
5. Measure the distance from the top of the liner to the top of the block with a dial indicator (Fig. 7). The liner flange must be .0418" to .0482" below the surface of the block. However, even though all of the liners are within these specifications, there must not be over .0015" difference between any two adjacent liners when measured along the cylinder longitudinal centerline. If the above limits are not met, install a different thickness insert (Table 1), install the liner in another cylinder bore and recheck, or use a new cylinder liner.

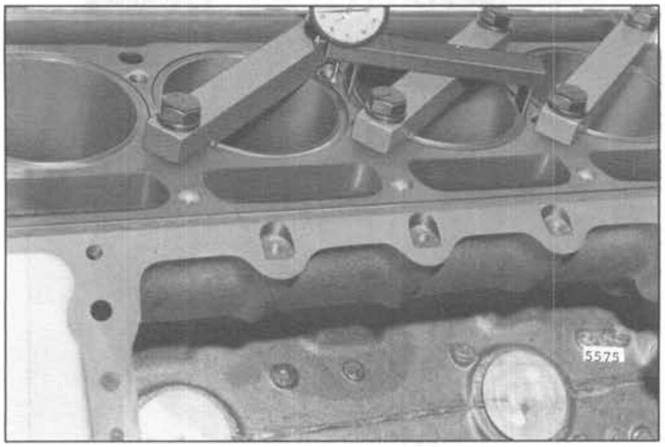


Fig. 7 – Checking Distance of Liner Flange Below Top Face of Block using Clamp J 24565–02 and Gage J 24898

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 side opposite the camshaft.
7. Remove the hold–down clamp and the cylinder liner. Do not remove the liner insert.

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, lubricate the piston, rings and the inside surface of the piston ring compressor J 24227. Use an 8:1 mixture of clean engine oil and *STP*, or equivalent.

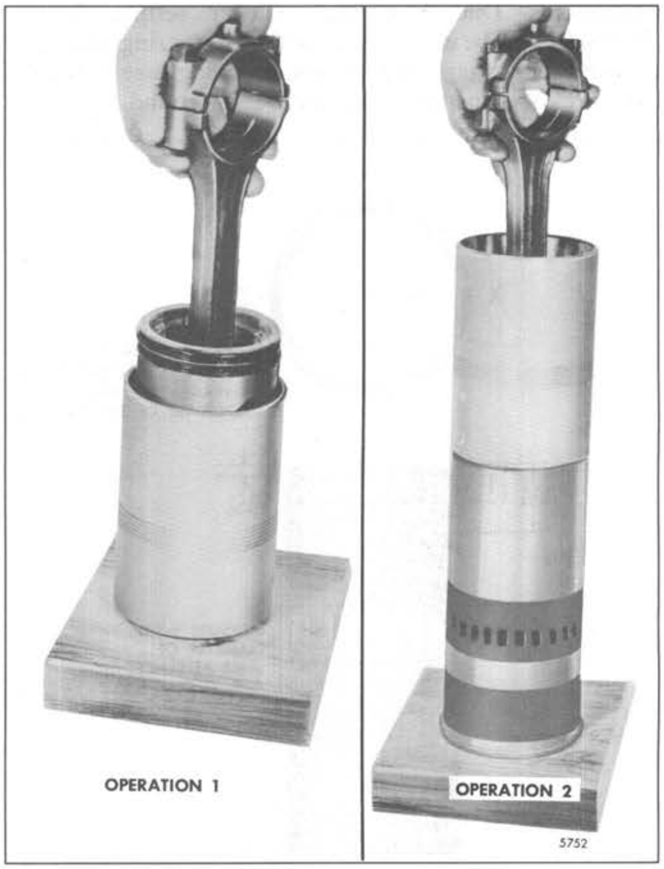


Fig. 8 – Installing Piston and Connecting Rod Assembly in Ring Compressor and Cylinder Liner

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 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 must be stamped in the same location as on the connecting rod that was replaced.

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 considerable force on the oil ring. 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 And Connecting 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:

1. Make sure the seal ring grooves in the cylinder block bore are clean. Then, install a new seal ring in each groove.

2. Clean engine oil may be used to supplement lubrication when installing liner–to–block seal rings. *Do not* use hydrogenated vegetable type shortening. During liner installation always check to make sure that the seal rings remain in the seal ring grooves of the block.

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 *without* the continuous oil groove — in the connecting rod. Lubricate the bearing shell with clean engine oil.

6. Position the piston, rod and liner assembly in front of the cylinder block bore so that the identification number and letter on the connecting rod face the outer edge of the cylinder block and the matchmarks on the liner and the block are in alignment. Guide the end of the connecting rod through the block bore carefully to avoid damaging or dislodging the bearing shell. Then, slide the piston, rod and liner assembly straight into the block bore until the liner flange rests against the insert in the counterbore in the block (Fig. 9).

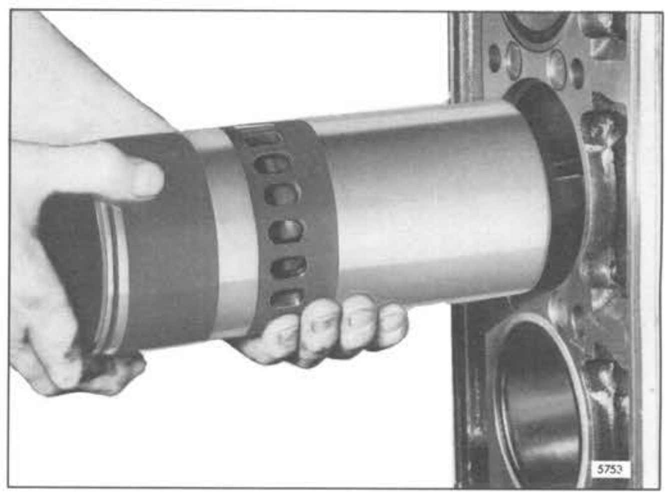


Fig. 9 – Installing Piston, Connecting Rod and Liner Assembly in Cylinder Block

7. Push or pull the piston and connecting rod into the liner until the upper bearing shell is firmly seated on the crankshaft journal. Be sure the marks on the end of the connecting rod cap bolts are parallel with each other. This indicates proper alignment of the bolts in the connecting rod.

NOTICE: The distance from the vertical center line of the connecting rod bolts to the edges of the rod are not equal. Therefore, when installing the piston and connecting rod assembly, be sure that the narrow side of the two connecting rods on the crankshaft journal are together to avoid cocking of the rod.

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. 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. Tighten the connecting rod bolt nuts to 60–70 lb–ft (81–95 N•m) torque.

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

10. Check the connecting rod side clearance. The clearance between each pair of connecting rods should be .008" to .016" with new parts.

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 – *Install Cylinder Head*. 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

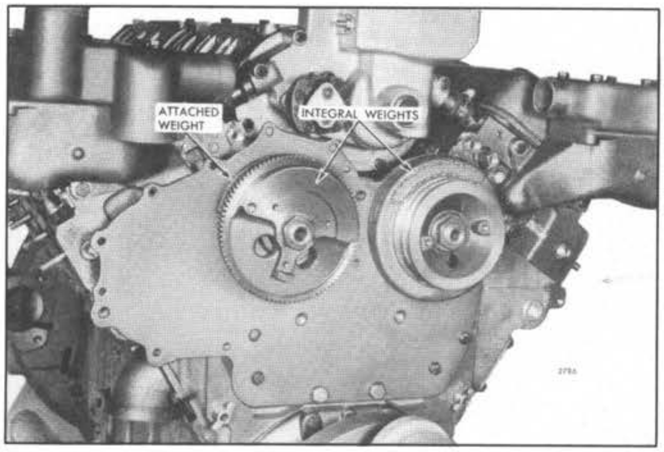


Fig. 1 – Typical Front Balance Weight Mounting

In the balance of the two–cycle engine, 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. This unbalanced couple tends to move the ends of the engine in an elliptical path. This couple is cancelled by incorporating an integral crankshaft balance component and by placing balance weights at the outer ends of the camshafts. These camshaft balance weights are integral with the camshaft gears and the camshaft front pulley. An additional balance weight is bolted to the water pump drive gear used on the 6V and 8V engines. This balance arrangement produces a couple that is equal and opposite in magnitude and direction to the primary couple.

On the camshafts, each set of weights (weights on the outer ends of one cylinder bank comprise a set) rotate in an opposite direction with respect to the other. When the weights on either end of the engine are in a vertical plane, their centrifugal forces are in the same direction and oppose the primary couple. When they are in a horizontal plane, the centrifugal forces of these balance weights oppose each other and are, therefore, cancelled. The front balance weights act in a direction opposite to the rear balance weights, therefore, rotation will result in a couple effective only in a vertical plane. This couple, along with that built into the crankshaft, forms an elliptical couple which completely balances the primary couple.

Both the rotating and primary reciprocating forces and couples are completely balanced in the V–92 engine. There are no secondary forces present in the V–92 engine. Consequently, the engine will operate smoothly and in balance throughout its entire speed range.

A camshaft torsion vibration damper is mounted to an adaptor hub attached to the water pump drive gear used on the 8V engines.

GEAR TRAIN AND ENGINE TIMING

GEAR TRAIN (6V AND 8V ENGINES)

A train of helical gears, completely enclosed between the engine end plate and the flywheel housing, is located at the rear of the engine. The gear train consists of a crankshaft gear, an idler gear, two camshaft gears and a blower drive gear. For non–turbocharged engines, a step–up gear is attached to the right bank camshaft gear which meshes with and drives the blower drive gear (Fig. 1).

The crankshaft gear, bolted to the flange at the rear of the crankshaft, drives the camshaft gears as well as the blower drive gear through an idler gear mounted on a stationary hub on either the right–hand or left–hand side of the engine (viewed from the flywheel end), depending upon the engine rotation.

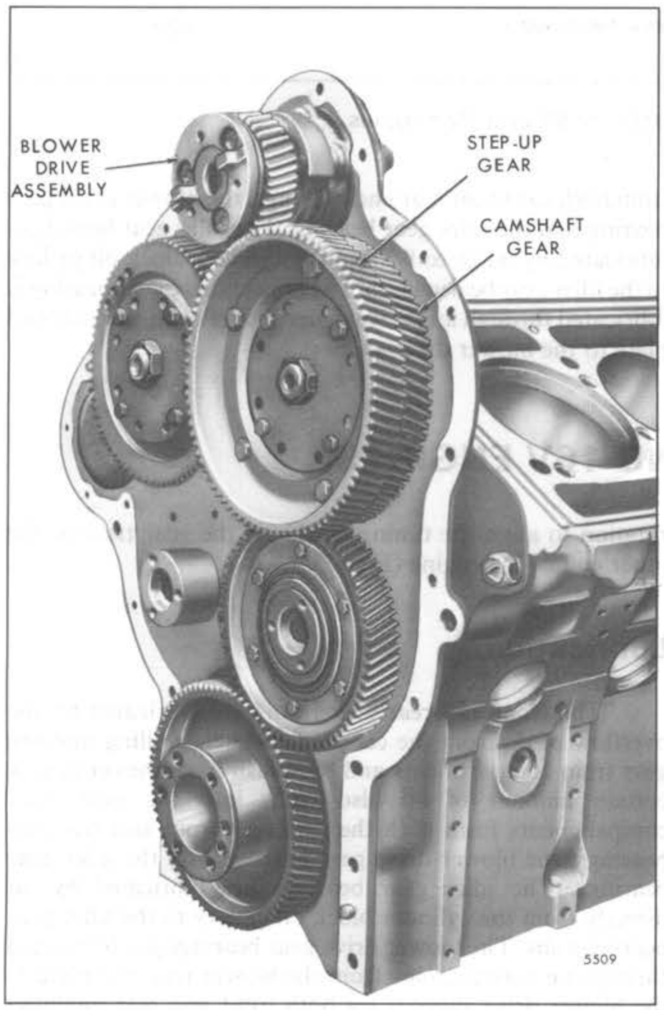


Fig. 1 – Gear Train

The camshaft gears are pressed on and keyed to their respective shafts and each is secured by a nut and gear nut retainer.

The two camshaft gears 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 (Fig. 2). The symbol system of marking the gears makes gear train timing a comparatively easy operation. When assembling the engine, it is important to remember the engine rotation. Then, working from the crankshaft gear to the idler gear and to the camshaft gear in that order, line up the appropriate symbols on the gears as each gear assembly is installed on the engine.

> **NOTICE:** It is advisable to line up and make a sketch indicating the position of the timing marks *before* removing or replacing any of the gears in the gear train.

There are no timing marks on the accessory drive gear, if used, or the blower drive gear. Therefore, it is not necessary to align these gears in any particular position during their installation.

However, as the blower drive gear and the accessory drive gear have only about half as many teeth as the camshaft gears, they turn at approximately twice the speed of the crankshaft.

The backlash between the various mating gears in the gear train should be .002" to .008", and should not exceed .010" backlash between worn 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, the flywheel housing should be removed and the gear train and its bearings inspected. A rattling noise usually indicates excessive gear lash whereas a whining noise indicates too little gear lash.

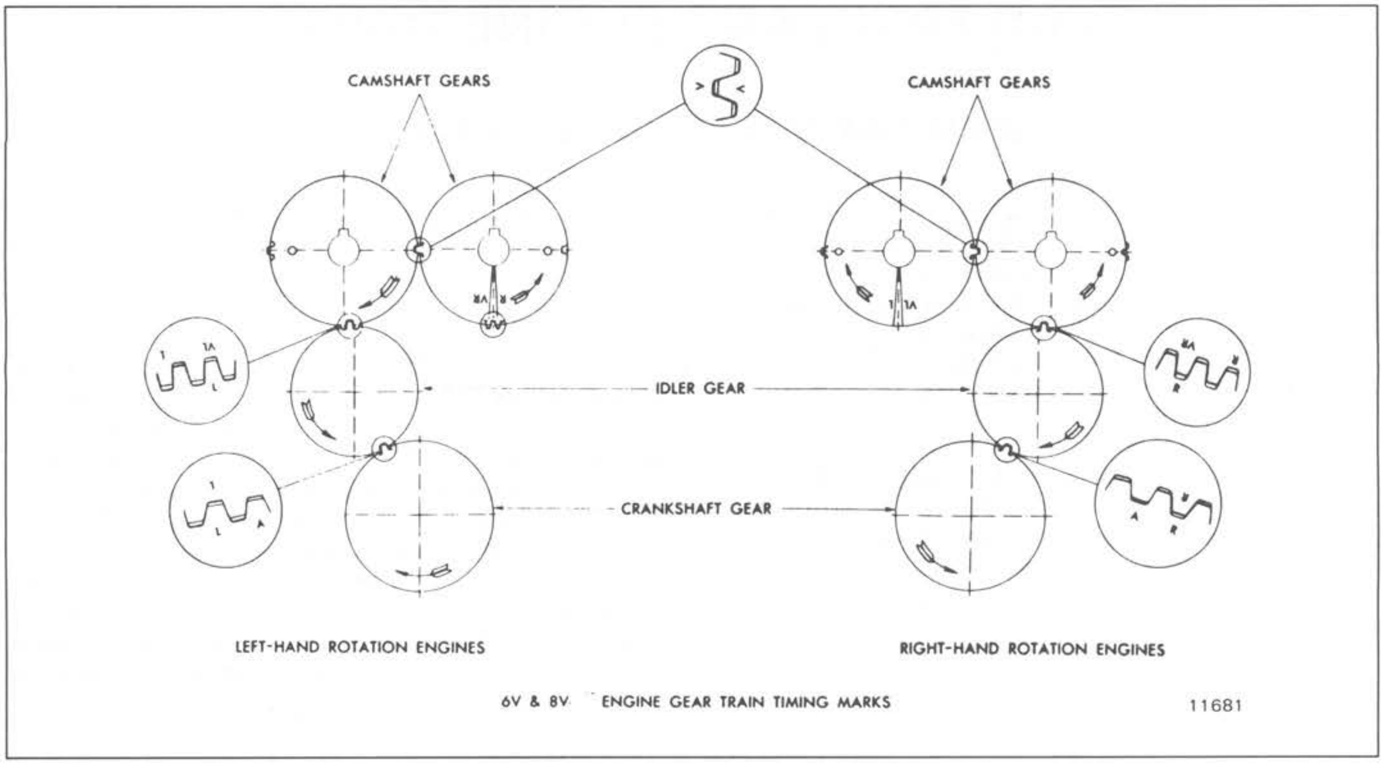


Fig. 2 – Gear Train and Timing Marks for 6V and 8V Engines

Lubrication

The gear train is lubricated by the overflow of oil from the camshaft pockets spilling into the gear train compartment and by splash from the oil pan. A certain amount of oil also spills into the gear train compartment from both camshaft rear end bearings, the blower drive gear bearing and the idler gear bearing. The idler gear bearing is lubricated by oil directly from the cylinder block oil gallery to the idler gear bearing hub. The blower drive gear bearing is lubricated through an external pipe from the blower rear end plate to the blower drive support.

GEAR TRAIN (12V AND 16V ENGINES)

A train of helical gears is located at each end of a 12V or 16V engine. Each gear train consists of two camshaft gears, an idler gear and a crankshaft timing gear. Standard gear train timing is illustrated in Fig. 3.

Before removing or replacing any of the gears, rotate the crankshaft in the direction of engine rotation until the diamond timing marks are aligned on the front camshaft gears or the triangle timing marks are aligned on the rear camshaft gears (Fig. 3). Then check whether the "L" or "R" timing mark on the crankshaft gear is aligned with the "L" or "R" on the idler gear and record this information for reassembly purposes.

Note that when the gear train is installed (and the timing marks properly aligned) at one end of the engine, the crankshaft must be rotated 180° in the direction of engine rotation to align the timing marks on the gear train at the other end of the engine (Fig. 3).

Lubrication

The front and rear gear trains are lubricated by the overflow of oil from the camshaft pockets spilling into the gear train compartments and by splash from the oil pan. A certain amount of oil also spills into the gear train compartments from both the camshaft front and rear end bearings, the blower drive gear bearings and the idler gear bearings. The idler gear bearings are lubricated by oil directly from the cylinder block oil gallery to the idler gear bearing hubs. The blower drive gear bearings are lubricated through an external pipe from the blower rear end plate to the blower drive support for both front and rear mounted blowers.

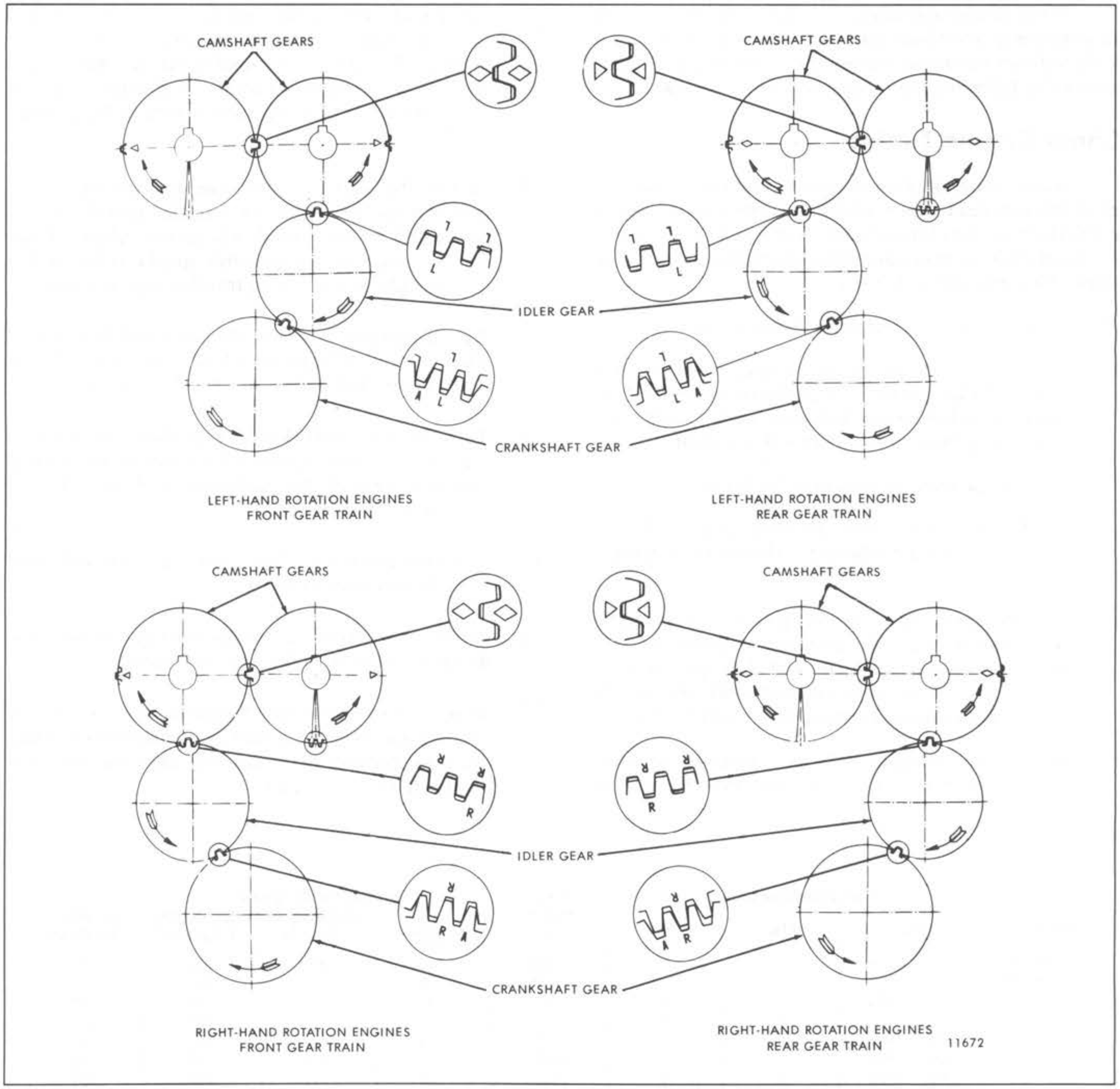


Fig. 3 – Gear Train and Timing Marks for 12V and 16V Engines

ENGINE TIMING

The correct relationship between the crankshaft and the two camshafts must be maintained to properly control fuel injection, the opening and closing of the exhaust valves and engine balance.

The crankshaft timing gear can be mounted in only one position since one attaching bolt hole is offset. The two camshaft gears can also be mounted in only one position due to the location of the keyway in each camshaft relative to the cams. Therefore, when the engine is properly timed, the timing marks on the various gears will match as shown in Figs. 2 and 3.

An engine which is "out of time" may result in preignition, uneven running and a loss of power.

When an engine is suspected of being out of time due to an improperly assembled gear train, a quick check can be made without having to remove the flywheel and flywheel housing by following the procedure outlined below.

Check Engine Timing

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

1. Clean and remove one valve rocker cover.
2. Select any cylinder for the timing check — it is suggested that a cylinder adjacent to one of the valve rocker cover bolt or stud holes be chosen since the stud or bolt may be used to mount a dial indicator.
3. Remove the injector as outlined in Section 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.
5. 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.
6. 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.
7. Mount the indicator over the injector tube. The indicator mounting may be threaded into the rocker cover stud or the tapped hole in the cylinder head. Check to be sure the indicator spindle is free in the injector tube and is free to travel at least one inch.
8. Attach a suitable pointer to the crankshaft front cover. The outer end of the pointer should extend over the top of the crankshaft pulley (or vibration damper).
9. Turn the crankshaft slowly in the direction of engine rotation until the indicator hand just stops moving. Continue turning the crankshaft until the indicator hand starts to move again.
10. Reset the dial to zero. Then turn the crankshaft until the indicator reading is .010".
11. Scribe a line on the crankshaft pulley (or vibration damper) in line with the end of the pointer.
12. Slowly turn the crankshaft opposite the direction of engine rotation until the indicator hand stops moving. Continue turning the crankshaft until the indicator hand starts to move again.

ENGINE	CERTIFICATION LABEL			CAM IDENT +	INDICATOR READING*			CORRECT (AT CAM)
	YEAR	FED	CALIF		CORRECT	RETARDED 1 TOOTH	ADVANCED 1 TOOTH	
ALL 6V-92	1974 - 1976	X	X	3J28	.230	.197	.262	.187
AND **8V-92**	1977 - 1978	X		3J28	.230	.197	.262	.187
	1977 - 1978		X	3J33	.197	.165	.230	.160
	1979	X	X	3J32	.204	.171	.237	.166
	1980 - 1981	X		3J32	.204	.171	.237	.166
	1980 - 1981		X	3J41	.139	.106	.172	.113
	1982 - 1983	X	X	3J32	.204	.171	.237	.166
	1984	X		3J28	.230	.197	.262	.187
	1984		X	3J32	.204	.171	.237	.166
ALL 12V-92								
REAR CAM	1980 - 1984			3J32	.204	.171	.237	.166
FRONT CAM	1980 - 1984			3J32	.215	.182	.248	.175
ALL 16V-92								
REAR CAM	1974 - 1984			3J28	.230	.197	.262	.187
FRONT CAM	1974 - 1984			3J28	.241	.208	.271	.196

+Camshaft Identification stamped on rear end of camshaft.
* Indicator Readings shown are nominal values. The allowable tolerance is ±.005"

Table 1

13. Reset the dial to zero. Then turn the crankshaft until the indicator reading is .010".

14. Scribe a second line on the crankshaft pulley (or vibration damper) in line with the end of the pointer.

15. Scribe a third line half way between the first two lines. This is top dead center. Remove the indicator and rod from the engine.

    NOTICE: If the crankshaft pulley retaining bolt has loosened, tighten it to the specified torque (Section 1.3.7).

16. Install the injector as outlined in Section 2.1.1. Then refer to Section 14 and adjust the valve clearance and time the injector.

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

18. Note the indicator reading and compare it with the dimensions listed in Table 1.

19. After completing the timing check, remove the dial indicator. Also remove the pointer from the crankshaft front cover.

20. Install the valve rocker cover.

CAMSHAFTS AND BEARINGS

(6V AND 8V ENGINES)

The contrarotating camshafts are located just below the top of the cylinder block. A left cylinder bank and a right cylinder bank camshaft is provided to actuate the exhaust valve and injector operating mechanism.

Both ends of each camshaft are supported by a bearing assembly which consists of a flanged housing and two (2) bushings. In addition, intermediate two–piece bearings support the camshafts at uniform intervals throughout their length. The intermediate bearings are secured to the camshaft by lock rings, thus permitting them to be inserted in the cylinder block with the shafts. Each intermediate bearing is secured in place, after the camshafts are installed, with a lock screw threaded into a counterbored hole in the top of the cylinder block.

The camshaft gear thrust load is absorbed by two (2) thrust washers, one on each end of the rear camshaft end bearing, on each shaft.

A camshaft front pulley (integral weight) is attached to the front end of the left bank camshaft and a water pump drive gear (bolt–on weight) is attached to the front end of the right bank camshaft. A camshaft gear is attached to the rear end of each camshaft. The pulley and the gears are retained on the camshafts with a retaining nut or a lock bolt and washer.

The 8V engines are equipped with a rubber bushed camshaft torsional vibration damper that is keyed and bolted to a hub attached to the water pump drive gear with three (3) bolts, plain washers and lock washers.

Lubrication

Lubricating oil is supplied under pressure to the bearings via drilled passages in the rear of the cylinder block, which lead from the main oil gallery to each rear end bearing. From the rear end bearings, the oil passes through the drilled oil passages in the camshafts to the intermediate bearings and to the front end bearings.

The lower halves of the camshaft intermediate bearings are grooved along the horizontal surface that mates with the upper halves of the bearings (Fig. 1). Oil from the passage in the camshaft is forced through the milled slots in the bearing and then out the grooves to furnish additional oil to the cam follower rollers. This permits the cam pocket to be filled rapidly to the operating oil level immediately after starting the engine.

Remove Camshafts

Whenever an engine is to be completely reconditioned or the bearings, thrust washers or gears need replacing, remove the camshafts from the engine as follows:

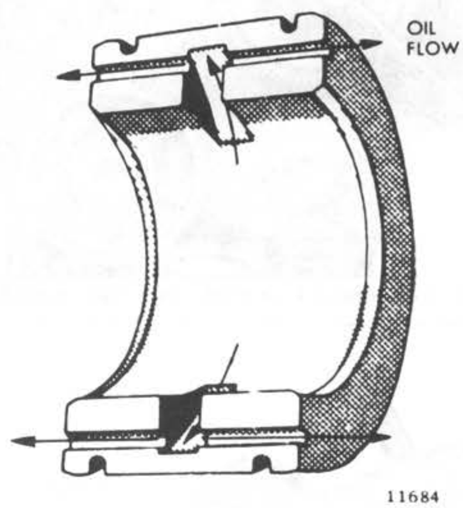


Fig. 1 – Camshaft Intermediate Bearing (Lower Half)

1. Drain the engine cooling system.
2. Remove all of the accessories and assemblies necessary so the engine may be mounted on an overhaul stand (see Section 1.1).
3. Mount the engine on the overhaul stand. Be sure the engine is securely mounted on the overhaul stand before releasing the lifting sling.
4. Remove the cylinder heads as outlined in Section 1.2.
5. Remove the flywheel and flywheel housing as outlined in Sections 1.4 and 1.5.
6. Remove the water pump.
7. Remove the front balance weight cover.
8. Remove the bolts and step–up gear, if used, from the rear right bank camshaft gear (see Section 1.7.1).
9. Remove the bolts which secure the nut retaining plates to the camshaft gears. Then, remove the nut retaining plates.
10. Wedge a clean rag between the gears (Fig. 2) and remove the gear retaining nut from both ends of each camshaft. On left hand rotation engines remove the lock bolt and washer from the right bank camshaft.
11. Attach puller J 24420–A to the camshaft pulley. Use adaptor J 7932 between the end of the camshaft and the pulley screw to protect the end of the camshaft (Fig. 3).
12. Remove the camshaft vibration damper and hub from the water pump drive gear, if used.

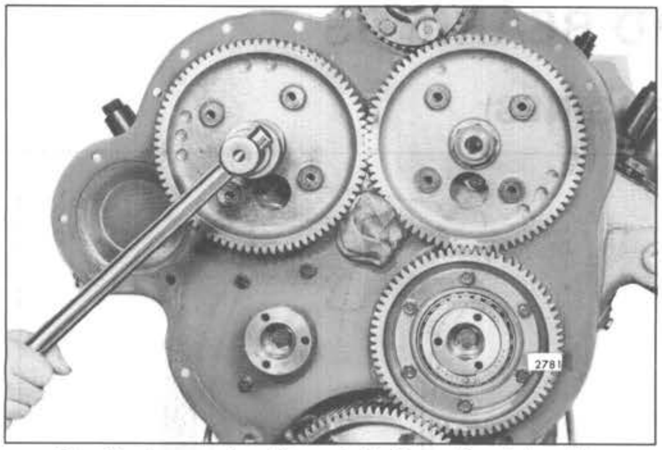


Fig. 2 – Loosening Camshaft Gear Retaining Nut

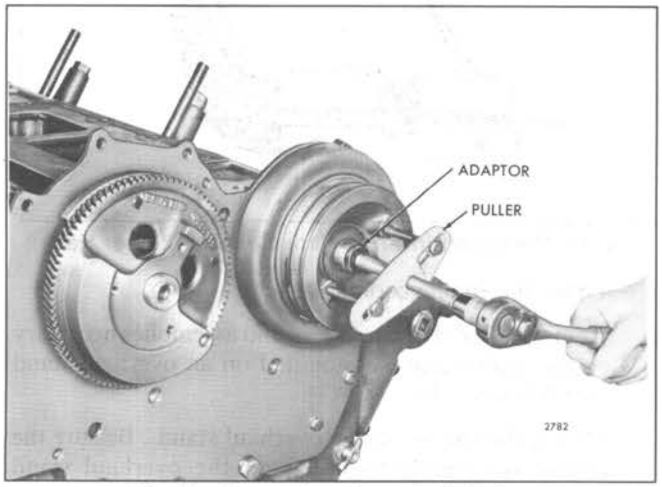


Fig. 3 – Removing Camshaft Pulley

13. Remove the water pump drive gear from the front end of the right bank camshaft, using puller J 24420–A and adaptor J 7932.
14. Remove the Woodruff key and the spacer from the front end of each camshaft.
15. Remove all of the camshaft intermediate bearing lock screws from the top of the cylinder block.

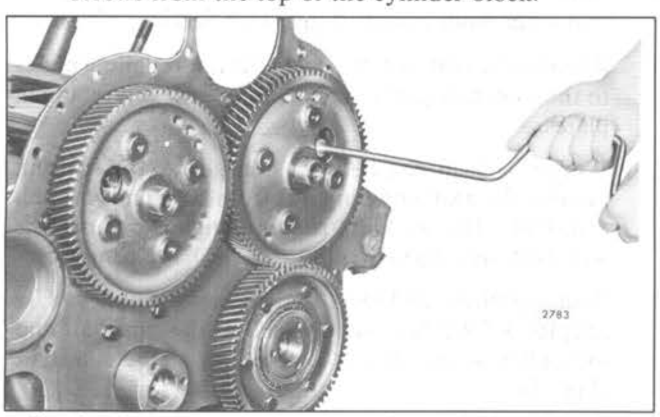


Fig. 4 – Removing or Installing Camshaft End Bearing Retaining Bolts

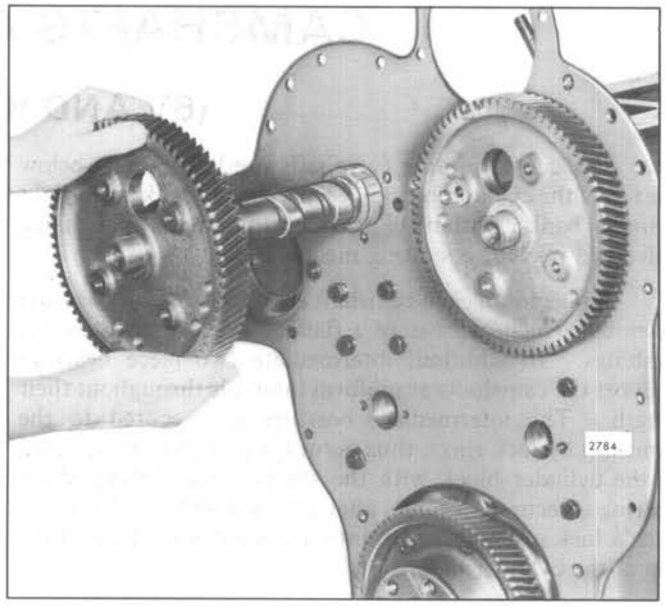


Fig. 5 – Removing or Installing Camshaft Assembly

16. Rotate the camshaft gears as required to reveal the camshaft end bearing retaining bolts. Then, remove the bolts (Fig. 4).
17. Withdraw each camshaft, bearing and gear assembly from the cylinder block (Fig. 5).
18. Remove the camshaft front end bearing retaining bolts. Then, withdraw the bearings from the cylinder block. If necessary, use a pry bar under the bearing flange.

Remove Camshaft (Flywheel Housing And Transmission In Place)

The 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 and attach the camshaft gear puller tool J 1902–01 to the flywheel housing.*

1. Drain the engine cooling system and remove the radiator or heat exchanger and all attaching parts.
2. Remove the parts, accessories and assemblies that are necessary to facilitate the removal of the flywheel housing hole cover over the camshaft and the front balance weight cover.
3. Remove the cylinder head (Section 1.2).
4. Remove the front balance weight cover.
5. Remove the camshaft gear nut retaining plate.
6. Block the crankshaft, between the crankshaft throw and the cylinder block, and remove the gear retaining nut or lock bolt and washer from both ends of the camshaft.

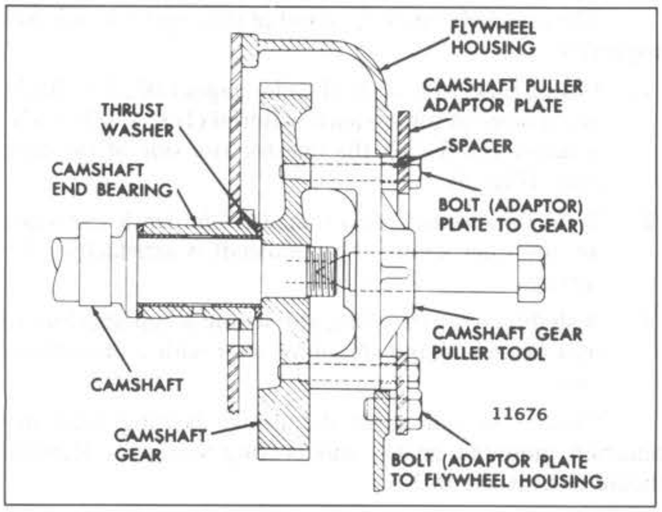


Fig. 6 – Removing Camshaft with Camshaft Gear Puller J 1902–01 and Adaptor Plate Set J 6202

7. If a left bank camshaft is to be removed, attach puller J 24420–A to the camshaft pulley. Use adaptor J 7932 between the end of the camshaft and the pulley screw to protect the end of the camshaft (Fig. 3).
8. If a right bank camshaft is to be removed, remove the camshaft vibration damper and hub from the water pump drive gear, if used.
9. Remove the water pump drive gear and spacer from the front end of the camshaft, using puller J 24420–A and adaptor J 7932.
10. Remove the Woodruff key and the spacer from the front end of the camshaft.
11. Remove all of the camshaft intermediate bearing lock screws from the top of the cylinder block.
12. Remove the three bolts that secure the camshaft bearing to the front end plate.
13. 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 (Figs. 6 and 7).
14. 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, also the thrust washers securely in place and in alignment which will aid in the reinstallation of the camshaft.
15. Remove the front bearing from the camshaft. Then, pull the camshaft and intermediate bearings from the cylinder block.

Disassemble Camshafts

1. Remove the gear from each camshaft (refer to Section 1.7.3).
2. Slide the camshaft rear end bearing and thrust washers off of each camshaft.

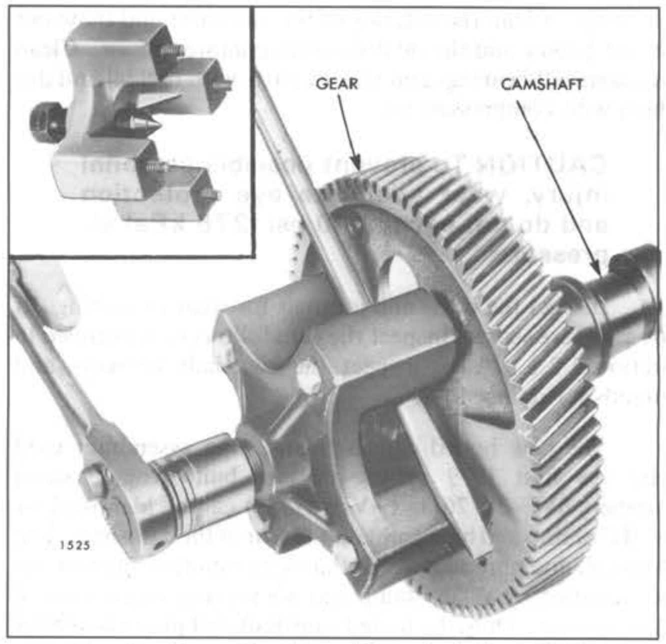


Fig. 7 – Removing Gear (Camshaft Gear Puller J 1902–01)

3. Remove the lock rings from the camshaft intermediate bearings, thus freeing the two halves of each bearing.
4. Remove the end plugs from each 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 camshaft bearings and related parts with fuel oil and dry them with compressed air.

CAUTION:To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.

Inspect the cams and journals for wear or scoring. If the cams are scored, inspect the cam followers as outlined in Section 1.2.1. Also, inspect the camshaft keyways and threads for damage.

The new honed camshaft and plug assemblies used with the first 1979 vehicle engines built (engine serial numbers 6VF–38776 and 8VF–33332) can be identified by an "H" stamp and blue paint on the rear of the camshaft. The camshaft and plug assemblies that were tumbled finished can be identified by a "T" stamp and white paint on the rear of the camshaft. Only the honed camshaft and plug assemblies will be serviced.

NOTICE: The 1979 "H" stamped, camshaft and plug assemblies should not be used in earlier model engines, as this may cause low horsepower and affect the Smoke and Emissions Standards because of changes in injector lobe timing. Nor should 1978 "H" stamped camshaft and plug assemblies be used in 1979 automotive engines for the same reason.

If there is a doubt as to the acceptability of the camshaft for further service, determine the extent of cam lobe wear as follows:

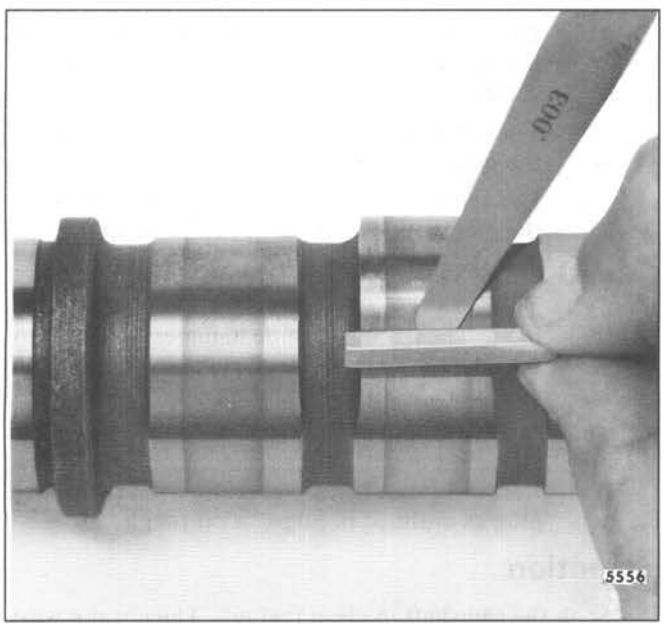


Fig. 8 – Checking Cam Lobe Wear

The camshaft can be in or out of the engine during this inspection.

1. With a tapered leaf set of feeler gages (.0015" – .010") 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. 8).
2. If the flats measure less than .003" in depth and there are no other defects, the camshaft is satisfactory for service.
3. A slightly worn cam 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 each camshaft rear end bearing and thrust washer. Also, examine the surfaces of each camshaft and camshaft gear which contact the thrust washers. Replace excessively worn or scored parts. Camshaft or camshaft gear thrust surfaces that are not scratched too severely may be smoothed down with an oil stone.

If a new camshaft is to be installed, steam clean it to remove the rust preventive and blow out the oil passages with compressed air.

New standard size thrust washers are .119" to .122" thick. The clearance between the thrust washer and the thrust shoulder of the camshaft is .003" to .015" with new parts, or a maximum of .018" with used parts. Excessive clearance may be reduced by using thrust washers which are .005" or .010" oversize.

When the thrust surfaces of a camshaft are ground undersize, a radius of 1/32" to 3/32" must be maintained between the bearing surface of the thrust collar shoulder and the bearing surface of the camshaft (Fig. 9). A fillet radius gage may be used to measure the specified radii.

Inspect the bushings in the front and rear camshaft end bearings. Replace the bushings if they are worn excessively (maximum of .006" bushing to shaft clearance) or if the

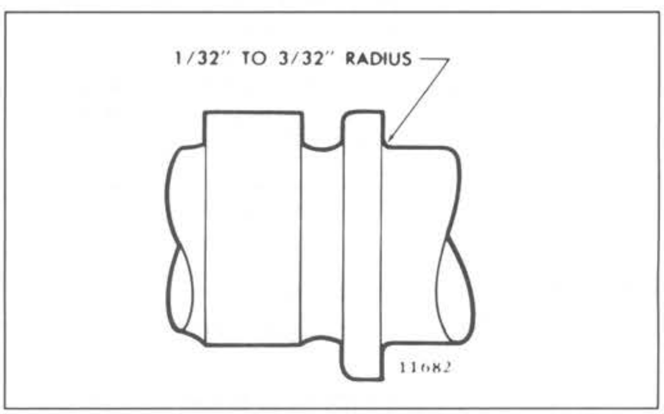


Fig. 9 – Camshaft Journal Fillet

bushings have turned in the bearing. Rear camshaft end bearings are available in .010" or .020" undersize for use with shafts which have worn or been reground and the clearances exceed the specified limits.

New bushings must be finish bored to a 20 rms finish after installation and checked for the proper press fit, which is indicated if the bushings will not move when a 2000 pound end load is applied. Also, the inside diameter of the bushings must be square with the rear face of the bearing within .0015" total indicator reading, and concentric with the outside diameter of the bearing housing within .002" total indicator reading. The bushings must project .045" to .055" from each end of the rear camshaft end bearings. The bushings in the front camshaft end bearings must be flush with the ends of the bushing bore.

The clearance between the camshaft end journals and the camshaft end bearing bushings for 6V engines is .0025" to .004" and for 8V engine is .0035" to .005" with new parts, or a maximum of .006" with used parts. Undersize and oversize camshaft end bearings are available for service.

Inspect the oil seal in the left bank camshaft front end bearing for wear or damage. Replace the seal if necessary. Also, examine the spacer used at the front end of each camshaft. The outside diameter of the spacer used in the left bank front end bearing must provide a smooth oil seal contact surface. The outside diameter is not ground and polished on the original spacer used on the right bank camshaft. Only the polished spacer is available for service and may be used in either position.

Replace excessively scored or worn camshaft intermediate bearings. The clearance between the camshaft journals and the intermediate bearings is .0025" to .005" with new parts, or a maximum of .009" with worn parts. Undersize and oversize camshaft intermediate bearings are available for service. Also, examine the intermediate bearing lock screws and the tapped holes in the cylinder block for damaged threads.

Examine the teeth on the water pump drive gear and the camshaft gears for scoring, pitting or wear. Replace the gears, if necessary. Also, examine the keyways and tapped holes in the gears and the camshaft pulley for damage.

Inspect the rubber bushed torsion vibration damper, if used, for deterioration of rubber, slippage of the outer ring and alignment of the hub face to the rubber and outer ring.

Assemble Camshafts

Refer to Fig. 10 and assemble the camshafts.

1. Coat the sides of the camshaft plugs with a light coating of Permatex Hi–Tack® or equivalent.
2. Install new end plugs in each camshaft. Press the plugs in to a depth of 1.940" to 2.060" (Fig. 11).
3. Apply grease to the steel face of each thrust washer. Then, place a thrust washer against each end of the two camshaft rear end bearings. Be sure the steel face of each thrust washer is next to the bearing.
4. Lubricate the rear camshaft bearing journal and slide a rear end bearing on each camshaft, with the bolting flange of the bearing toward the outer (camshaft gear) end of the shaft.
5. Install the camshaft gear on each shaft as outlined in Section 1.7.3.
6. Lubricate the camshaft intermediate bearing journals. Then, place the two halves of each intermediate bearing on a camshaft journal and lock the halves together with two lock rings. Assemble each lock ring with the gap over the upper bearing and the ends an equal distance above the split line of the bearing.

Install Camshafts

1. Insert the front end of the camshaft with the right–hand helix gear through the opening on the right bank side in the rear end plate until the first intermediate bearing enters the bore. Continue to work the camshaft and bearings into the cylinder block until the camshaft gear teeth are about to engage the teeth of the mating gear (Fig. 5). Use care not to damage the cam lobes when installing the camshaft.

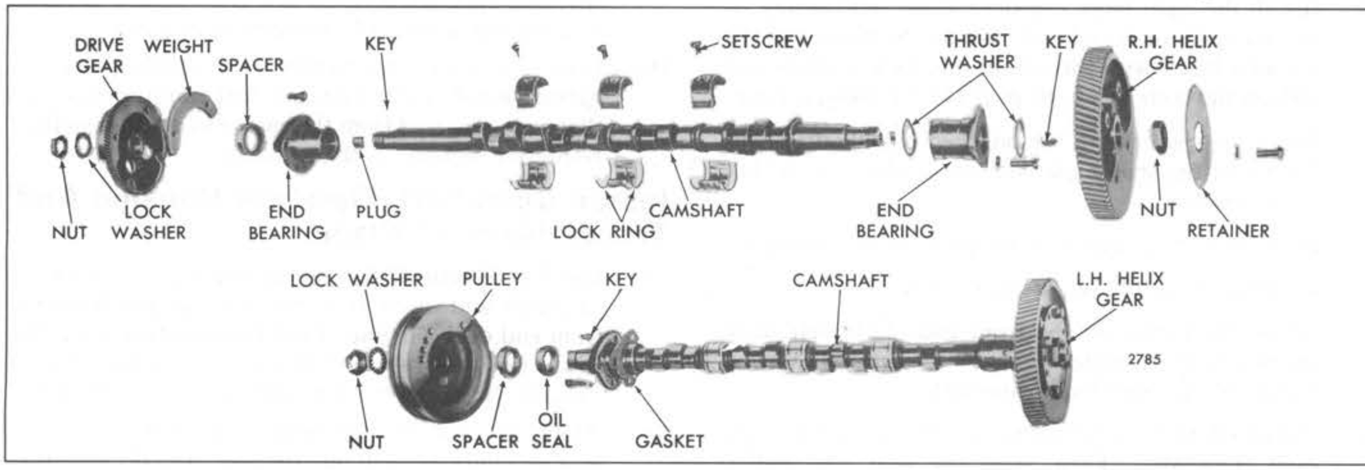


Fig. 10 – Camshaft Details and Relative Location of Parts

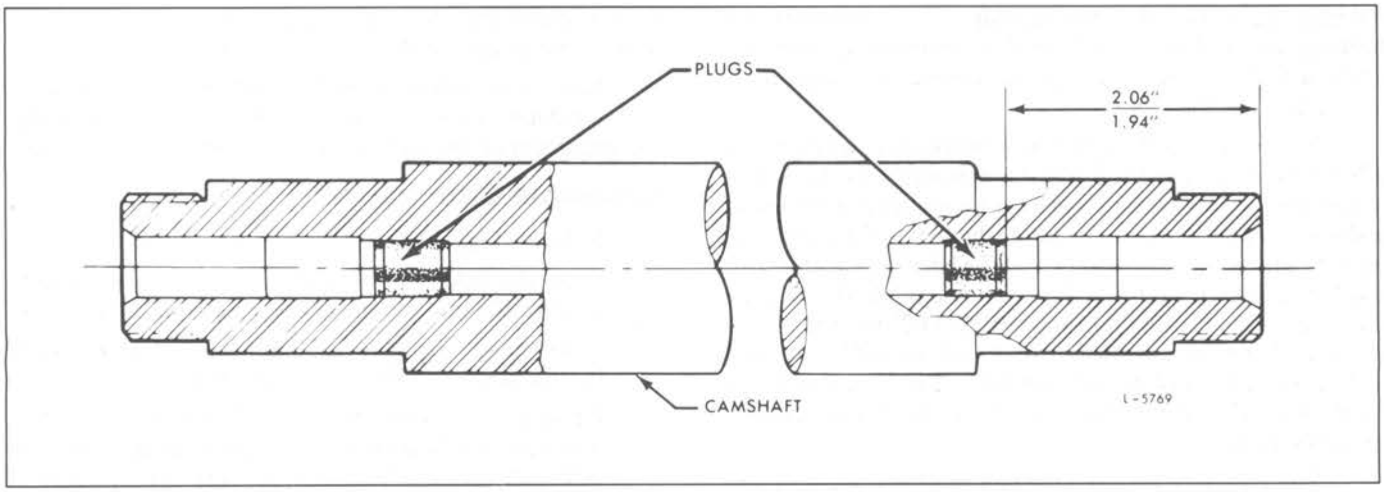


Fig. 11 – Camshaft Plug Installation

2. Align the timing marks on the mating gears (see Section 1.7.1) and slide the camshaft gear in place.
3. Secure the camshaft rear end bearing to the cylinder block with three lock washers and bolts. Rotate the camshaft gear as required to install the bolts through the hole in the web of the gear (Fig. 4). Tighten the bolts to 35–40 lb–ft (47–54 N•m) torque.
4. Turn the camshaft intermediate bearings until the holes in the bearings are in alignment with the tapped holes in the top of the cylinder block. Install the lock screws and tighten them to 15–20 lb–ft (20–27 N•m) torque.
5. Install the other camshaft in the same manner.
6. Attach a new gasket to the camshaft front end bearing that includes the oil seal. Lubricate the bearing journal and slide the bearing on the left bank camshaft, with the bolting flange of the bearing toward the outer end of the shaft. Secure the bearing to the cylinder block with three bolts and lock washers. Tighten the bolts to 35–40 lb–ft (47–54 N•m) torque.
7. Install the right bank camshaft front end bearing — the one without the oil seal. Secure the bearing to the cylinder block with three bolts and lock washers and tighten the bolts to 35–40 lb–ft (47–54 N•m) torque.
8. Select the spacer with the polished outside diameter. Lubricate the spacer and slide it in place on the left bank camshaft.
9. Install the other spacer on the right bank camshaft.
10. Install a Woodruff key in each camshaft.
11. Install the pulley on the front end of the left bank camshaft and the water pump drive gear and external weight on the right bank camshaft.
12. Slip an internal tooth lock washer over the front end of each camshaft. Then, start the gear and pulley retaining nuts on the camshafts.
13. Wedge a clean rag between the camshaft gears to prevent their turning. Then, tighten the nut on each end of both camshafts to 300–325 lb–ft (407–441 N•m) torque.
14. Attach the hub to water pump drive gear with three (3) bolts, plain washers and lock washer, if used. Tighten the bolts to 30–35 lb–ft (41–47 N•m) torque.
15. Install the camshaft gear nut retainers with bolts and lock washers. Tighten the bolts to 35–39 lb–ft (47–53 N•m) torque.
16. Check the clearance between the thrust washer and the thrust shoulder of each camshaft. The specified clearance is .003" to .015" with new parts, or a maximum of .018" with used parts.
17. Install the step–up gear, if used (see Section 1.7.1), over the pilot on the right bank camshaft gear with five (5) 3/8"–24 lock bolts. Be sure the lip on the step–up gear is seated squarely in the pilot diameter ring groove in the camshaft gear before tightening the bolts. Tighten the bolts to 50–60 lb–ft (68–81 N•m) torque.
18. Check the backlash between the mating gears. The specified backlash between new gears is .002" to .008", or a maximum of .010" between worn gears.
19. Install the parts, accessories or assemblies (such as balance weight cover and camshaft vibration damper) that were removed from the engine as outlined in their respective sections in this manual.

Install Camshaft (Flywheel Housing And Transmission In Place)

1. Install a Woodruff Key in the drive gear end of the camshaft and insert this end into position from the front end of the engine. Push the camshaft in until it slides into the rear end bearing. Use care not to damage the cam lobes when installing the camshaft.
2. Align the key in the shaft with the keyway in the drive 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. Attach a new gasket to the front end bearing that includes an oil seal and install the front end bearing (and spacer or spacer and oil seal) with the bolts and lock washers. Lubricate the spacer with the polished outside diameter and slide it in place on the left bank camshaft. Tighten the bolts to 35–40 lb-ft (47–54 N•m) torque.
5. Install a Woodruff key in the front end of the camshaft and install either the pulley on the left bank camshaft or the water pump drive gear and external weight on the right bank camshaft.
6. Slip an internal tooth lock washer over the front end of the camshaft and start the gear retaining nut on the camshaft. On certain 6V and 8V left hand rotation engines, install a 9/16"–18 lock bolt and washer in the right bank camshaft.
7. Block the crankshaft, between the crankshaft throw and the cylinder block to prevent rotation of the engine, and tighten the retaining nuts at both ends of the camshaft to 300–325 lb-ft (407–441 N•m) torque. Tighten the lock bolt to 180–190 lb-ft (244–258 N•m) torque.
8. Attach the hub, if used, to the water pump drive gear with three bolts, washers and lock washers. Tighten the bolts to 30–35 lb-ft (41–47 N•m) torque.
9. Revolve the camshaft intermediate bearings to align the locking holes in the bearing with the tapped holes in the top of the cylinder block. Install the lock screws and tighten them to 15–20 lb-ft (20–27 N•m) torque.
10. Install the camshaft gear nut retainers with bolts and lock washers. Tighten the bolts to 35–39 lb-ft (47–53 N•m) torque (retainers not used with lock bolts).
11. Reinstall the parts, accessories and assemblies (such as balance weight cover and camshaft vibration damper) that were removed from the engine as outlined in their respective sections in this manual. Refill the cooling system.

12V AND 16V ENGINES

The counter–rotating camshafts are located near the top of the cylinder block. There are two camshafts in each cylinder bank. Each camshaft actuates the valve and injector operating mechanism in one of the cylinder heads.

The end of each camshaft is supported by a three–piece bearing. In addition, intermediate two–piece bearings support the camshafts at uniform intervals throughout their length. These intermediate bearings are held around the camshaft bearing surfaces by lock rings, thus permitting them to be inserted into the block with the shaft. Each intermediate bearing and inner end bearing is secured in place by a lock screw sunk into a counterbore at the top of the block. A 3/8" x 1/2" split copper washer is used under the lock screws at the inner end bearings on current engines (Fig. 12).

Lubrication is supplied under pressure, via angular drilled passages in the ends of the cylinder block, which lead from the main oil gallery, to each camshaft rear end bearing. From the rear end bearings, oil flows through the drilled camshafts to the intermeditate bearings and the inner end bearings.

The current inner camshaft end bearings have one 1/2" chamfered hole and two 1/4" chamfered holes to ensure alignment with the oil supply hole to the overhead mechanism. At engine overhaul, be sure to install the current bearings on early engines (prior to approximate engine serial No. 16VF–1260).

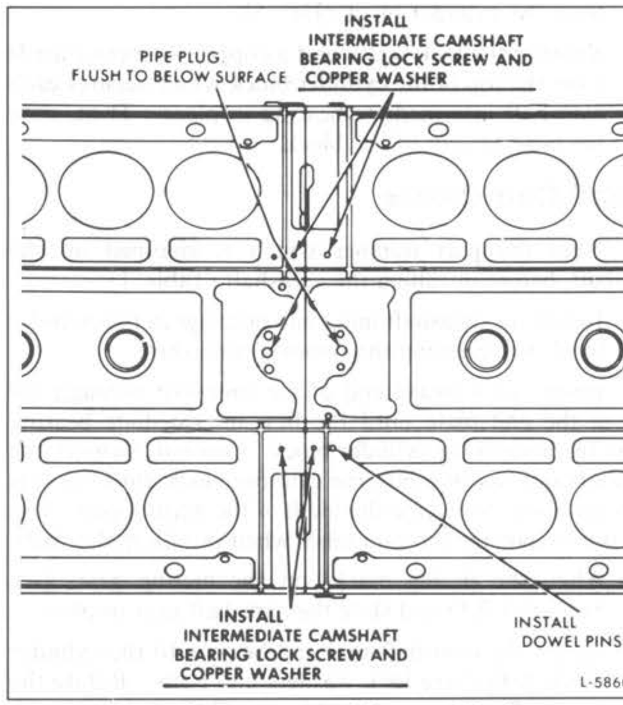


Fig. 12 – Location of Copper Washers

Remove Camshafts

Whenever an engine is to be completely reconditioned or the bearings, thrust washers or gears need replacing, remove the camshafts from the engine as follows:

1. Drain the engine cooling system.
2. Remove all of the accessories and assemblies necessary so the engine may be mounted on an overhaul stand (see Section 1.1).
3. Mount the engine on the overhaul stand. Be sure the engine is securely mounted on the overhaul stand before releasing the lifting sling.

4. Remove the cylinder heads as outlined in Section 1.2.
5. Remove the flywheel, flywheel housing, crankshaft pulley, vibration damper and the front cover as outlined in their respective sections of this manual.
6. Remove the bolts and step-up gear, if used, from the rear right bank camshaft gear (see Section 1.7.1).
7. Remove the bolts which secure the nut retaining plates to the camshaft gears. Then, remove the nut retaining plates.
8. Wedge a clean rag between the gears (Fig. 2) and remove the gear retaining nut from both ends of each camshaft. On left hand rotation engines remove the lock bolt and washer from the right bank camshaft.
9. Remove the water pump drive gear from the front end of the right bank camshaft, using puller J 24420-A and adaptor J 7932.
10. Remove camshaft end bearing to cylinder block bolts by inserting a socket wrench through hole in web of camshaft gear. Rotate the camshaft gear as required to reveal the bearing bolts through the hole in the web of the gear (Fig. 4).
11. Withdraw camshaft, bearings and gear as an asembly from the cylinder block (Fig. 5).
12. Remove the lock screw and a copper washer (if used) from the top of the cylinder block which secures each camshaft intermediate bearing in place. Then, slide the bearings out of the block.

Install Camshafts

Note the part number which is stamped on the camshaft, before installing the camshaft (Table 1).

1. Install the camshaft inner end bearings in the cylinder block by reversing the removal procedure.

Insert the forward end of the camshaft through the hole in the end plate until the first intermediate bearing enters the bore in the cylinder block. Continue to work the camshaft and bearings into the cylinder block until the gear teeth are about to engage the teeth of the mating gear. Use care not to damage the cam lobes when installing the shaft.

2. Align the timing marks on the mating gears (see Section 1.7.1) and slide the camshaft gear in place.
3. Secure the camshaft rear end bearing to the cylinder block with three lock washers and bolts. Rotate the camshaft gear as required to install the bolts through the hole in the web of the gear (Fig. 4). Tighten the bolts to 35–40 lb-ft (47–54 N•m) torque.
4. Turn the camshaft intermediate bearings until the holes in the bearings are in alignment with the tapped holes in the top of the cylinder block. Install the lock screws and tighten them to 15–20 lb-ft (20–27 N•m) torque.
5. Install the other camshafts in the same manner.
6. Wedge a clean rag between the camshaft gears to prevent their rotation; then, using a 1-1/2" socket wrench, tighten the nut on the outer end of each camshaft to 300–325 lb-ft (407–441 N•m) torque. Tighten the lock bolt (used on certain engines) to 180–190 lb-ft (244–258 N•m) torque.
7. Install the camshaft gear nut retainers with bolts and lock washers. Tighten the bolts to 35–39 lb-ft (47–53 N•m) torque.
8. Check the clearance between the thrust washer and the thrust shoulder of each camshaft. The specified clearance is .003" to .015" with new parts, or a maximum of .018" with used parts.
9. Check the backlash between the mating gears. The specified backlash between new gears is .002" to .008", or a maximum of .010" between worn gears.
10. Install the parts, accessories or assemblies (such as balance weight cover and camshaft vibration damper) that were removed from the engine as outlined in their respective sections in this manual.

CAMSHAFT IDENTIFICATION CHART

16V-92 (TUMBLED)

Part Number on Camshaft	Location of Camshaft In Cylinder Block (R.H. Engine)	Location of Camshaft In Cylinder Block (L.H. Engine)
5148795	Left Bank Rear	Right Bank Front
5148746	Right Bank Rear	Left Bank Front
5148747	Left Bank Front	Right Bank Rear
5148748	Right Bank Front	Left Bank Rear

12V-92 (HONED)

Part Number on Camshaft	Location of Camshaft In Cylinder Block (R.H. Engine)	Location of Camshaft In Cylinder Block (L.H. Engine)
5107758	Left Bank Rear	Right Bank Front
5107759	Right Bank Rear	Left Bank Front
5107760	Left Bank Front	Right Bank Rear
5107761	Right Bank Front	Left Bank Rear

16V-92 (HONED)

Part Number on Camshaft	Location of Camshaft In Cylinder Block (R.H. Engine)	Location of Camshaft In Cylinder Block (L.H. Engine)
5107306	Left Bank Rear	Right Bank Front
5107307	Right Bank Rear	Left Bank Front
5107308	Left Bank Front	Right Bank Rear
5107309	Right Bank Front	Left Bank Rear

TABLE 1

CAMSHAFT GEARS

The camshaft gears (Fig. 1), located at the flywheel end of the engine, mesh with each other and run at the same speed as the crankshaft. Either one of the gears may be driven by the crankshaft timing gear through an idler gear, depending upon engine rotation. Viewing the engine from the gear train end, the right–hand camshaft gear has right–hand helical teeth, and the left–hand camshaft gear has left–hand helical teeth. The idler gear mates with the right–hand camshaft gear on right–hand rotation engines, and the left–hand camshaft gear on left–hand rotation engines as shown in Figs. 2 and 3, Section 1.7.1.

Since the two camshaft gears must be in time with each other, timing marks are stamped on the rim of both gears. Also, since these two gears as a unit must be in time with the crankshaft, timing marks are located on the idler gear and the crankshaft gear.

The rear camshaft gears for the 6V and 8V–92 engines are not interchangeable. The 8V–92 gears are heavier (the added weight is on the inside) than the 6V–92 gears and, if installed on a 6V engine, will cause vibration in excess of the specified limits.

The 6V camshaft gears can be identified by cast markings "6V" and "92" opposite the center hole and two large round cast web holes through the gears (Fig. 3).

The 8V camshaft gears can be identified by cast markings "8V" and "92" opposite web holes through the gear (Fig. 3).

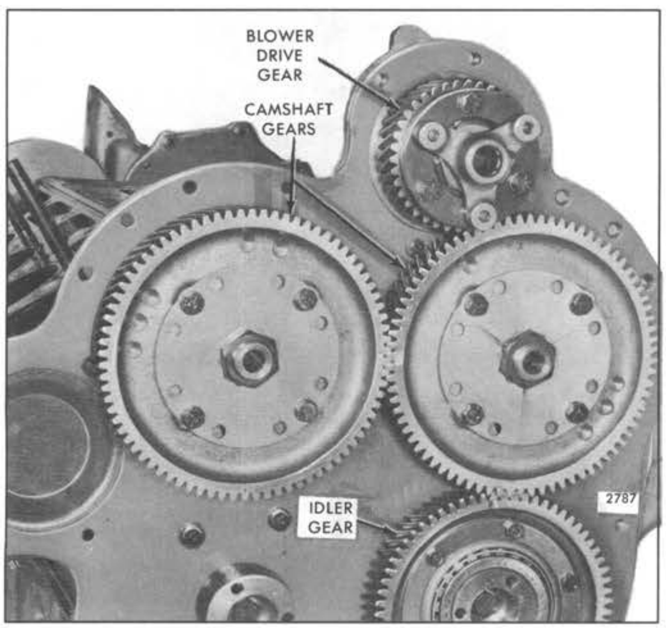


Fig. 1 – Camshaft Gears Mounted on Engine

Remove Camshaft Gears

1. Remove the camshafts from the engine as outlined in Section 1.7.2.

2. Place one of the camshaft and gear assemblies in an arbor press as shown in Fig. 4.

3. Place a wooden block under the lower end of the camshaft to protect the threads when the shaft is pressed from the gear.

4. Place a short one–inch diameter brass rod on the end of the camshaft and press the shaft out of the gear.

   NOTICE: If an arbor press is not available, tool J 1902–01 may be used to remove the gear from the camshaft.

5. If necessary, remove the Woodruff key from the camshaft.

6. Remove the gear from the other camshaft in a similar manner.

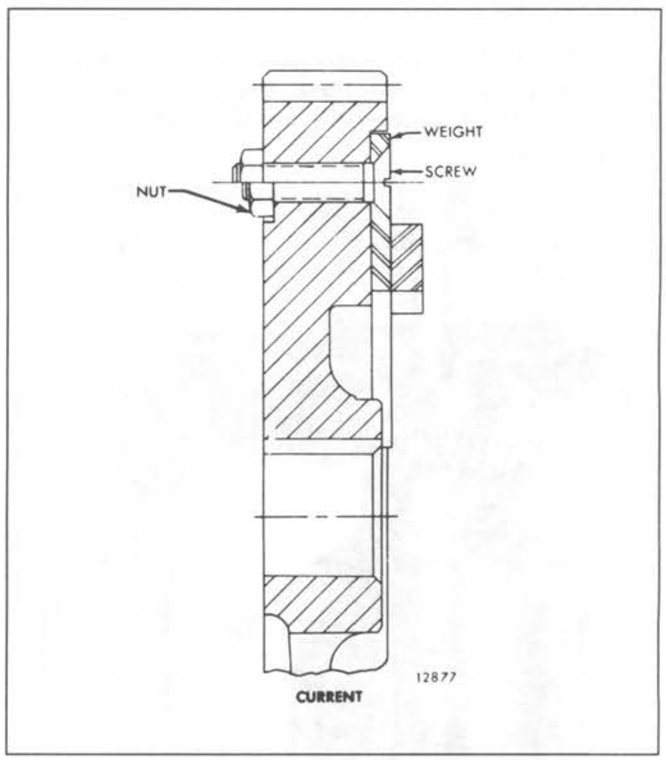


Fig. 2 – Camshaft Gear Weight

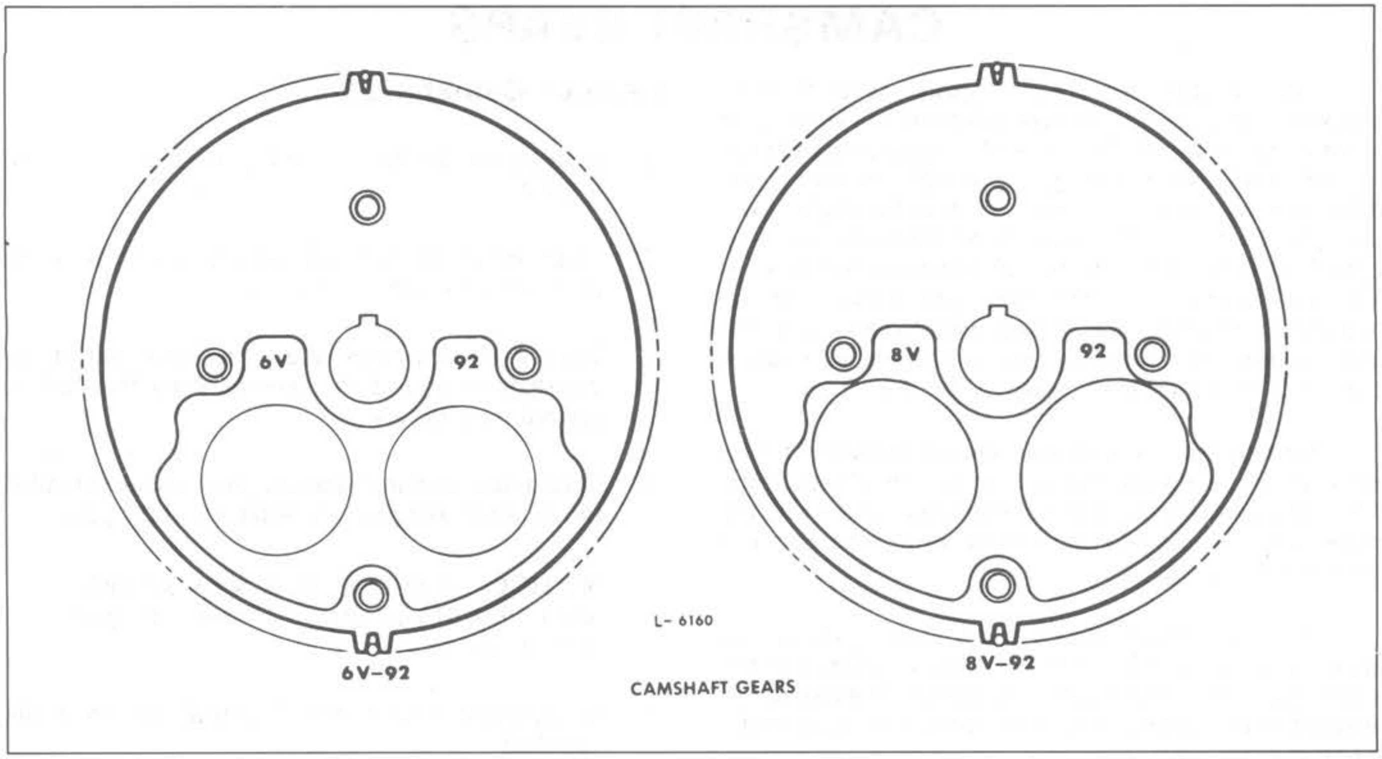


Fig. 3 – Identification of Camshaft Gears

Inspection

Clean the gears with fuel oil and dry them with compressed air.

CAUTION: To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.

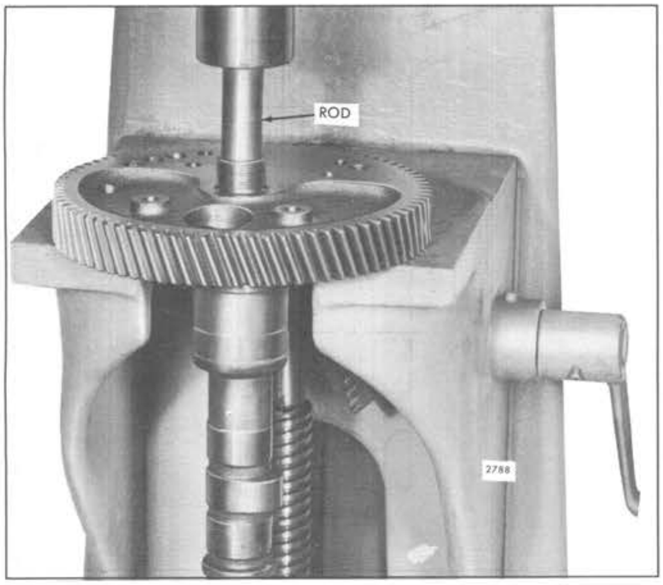


Fig. 4 – Removing Camshaft Gear

Examine the gear teeth for scoring, pitting or wear. Replace the gears if necessary. Also check the other gears in the gear train.

Install Camshaft Gears

1. If previously removed, install the camshaft rear end bearing and thrust washers on the camshaft as follows:

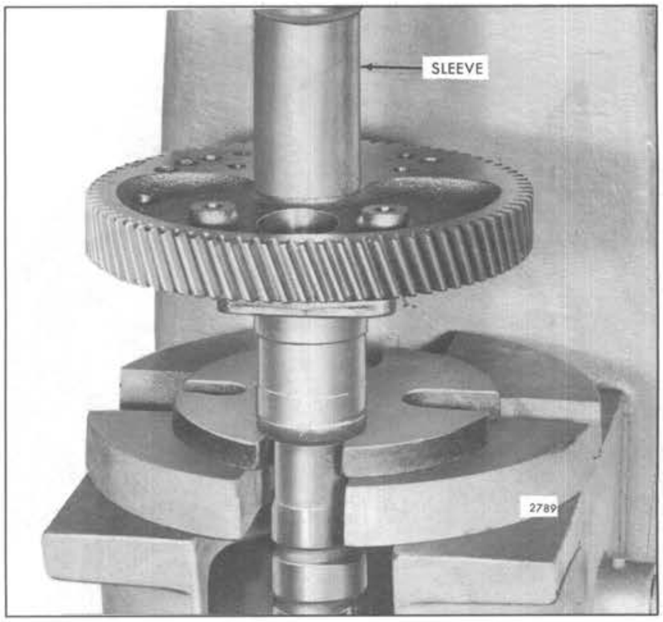


Fig. 5 – Installing Camshaft Gear

a. Apply grease to the steel face of each thrust washer and place one washer at each end of the bearing. Be sure the steel face of each washer is next to the bearing.

b. Lubricate the bearing journal and slide the bearing and thrust washers on the camshaft, with the bolting flange of the bearing toward the outer (gear) end of the shaft.

2. Install a Woodruff key in the camshaft.

NOTICE: Before installing a rear camshaft gear, observe the cast web holes identification and, in addition, look for the "6V" or "8V" cast identification marks for proper gear installation.

3. Start the gear over the end of the camshaft, with the key in the shaft aligned with the keyway in the gear.

4. Then, with the camshaft supported in an arbor press, place a sleeve on top of the gear and press the gear tight against the shoulder on the shaft (Fig. 5).

NOTICE: If an arbor press is not available, use tool J 1903 to install the gear on the camshaft.

5. Thread the camshaft gear retaining nut on the camshaft. Tighten the nut after the camshaft is installed in the engine.

6. Install the gear on the other camshaft in a similar manner.

7. Install the camshaft and gear assemblies in the engine as outlined in Section 1.7.2.

CAMSHAFT GEARS (12V and 16V ENGINES)

A pair of camshaft gears, which mesh with each other and rotate at engine speed, is located at both the front and rear end of the engine.

Since the camshaft gears, idler gear and crankshaft gear, in each gear train, must be in time with the crankshaft, timing marks are located on the gears. Refer to Fig. 3 in Section 1.7.1.

The camshaft gears used on 16V engines are not interchangeable with those used on 6V or 8V engines due to the difference in the size of the integral balance weights.

Follow the removal, inspection and assembly procedures outlined above for all V–92 engines.

IDLER GEAR AND BEARING ASSEMBLY

The idler gear (Fig. 1) 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. A dowel in the hub correctly positions the hub and prevents it from rotating.

The idler gear is pressure lubricated by oil from the cylinder block rear cross oil gallery. Oil enters an opening between the cylinder block and the idler gear hub and circulates around the idler gear hub bolt which has a smaller outside diameter than the inside diameter of the gear hub bolt hole. The oil is forced through a drilled passage in the gear hub to the roller bearing.

The idler gear bearing consists of two cups, two cones and an outer and an inner spacer ring.

The cones of the idler gear bearing are pressed onto the gear hub and, therefore, do not rotate. Spacer rings separate the bearing cups and cones. The bearing cups are a light press fit in the idler gear and are held against a flanged lip inside the idler gear on one side and by a bearing retainer secured with six lock bolts on the other side.

A left-hand helix gear is provided for right-hand rotation engines and a right-hand helix gear is provided for left-hand rotation engines (see Section 1.7.1).

An idler gear hole spacer (dummy hub) is used on the side opposite the idler gear (Fig. 9).

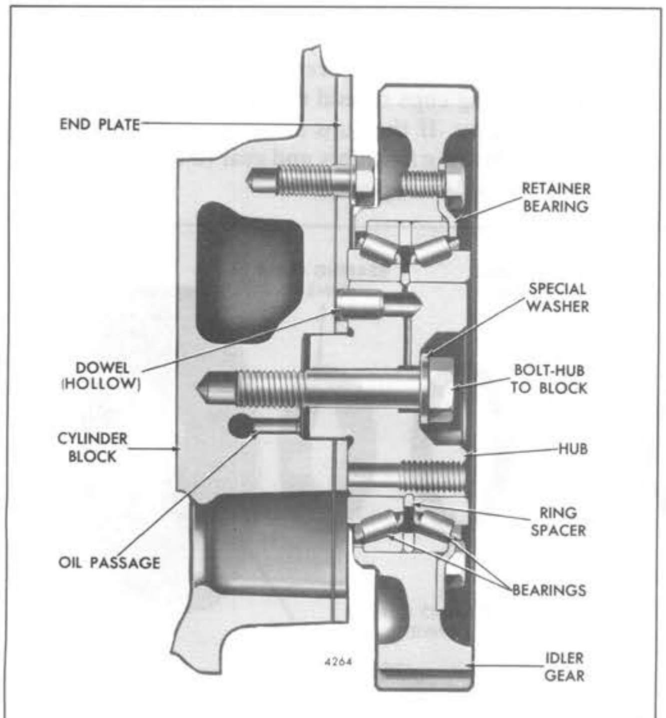


Fig. 1 – Idler Gear Mounting

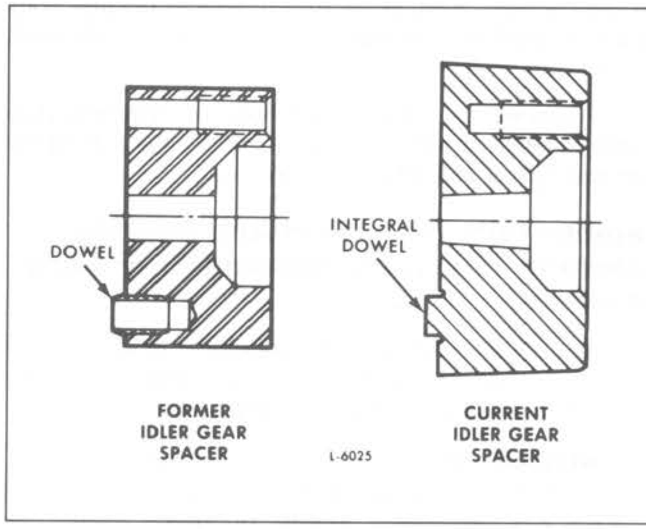


Fig. 2 – Idler Gear Spacer

NOTICE: On certain engines, the idler gear hole spacer is cast integral in the flywheel housing, on the side opposite the idler gear.

To minimize oil leakage into the flywheel housing, a new idler gear spacer (dummy hub) is now being used in those engines not equipped with an integral idler gear spacer type flywheel housing (Fig. 3).

The former and new spacers are interchangeable. Only the new spacer will be serviced. The new flanged hex head bolts with a self locking sealing patch should be used with the new spacer. They can be used with the former spacer or at the idler gear position, however, do not use a flat washer under the new flanged head bolts.

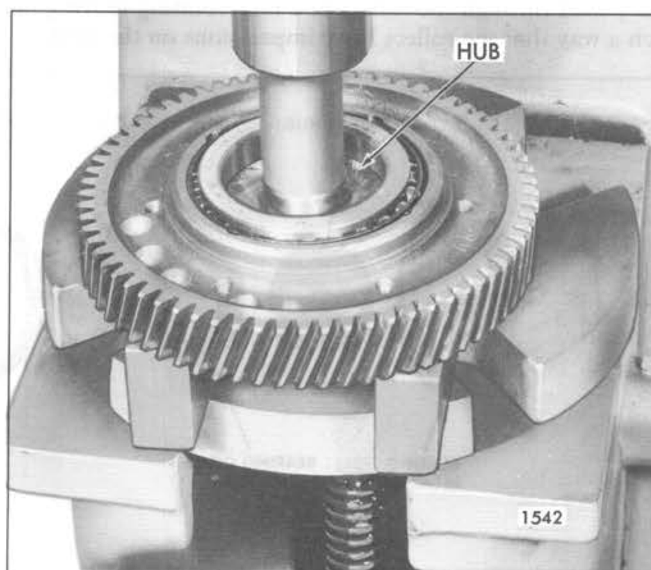


Fig. 3 – Pressing Hub Out of Idler Gear Bearing

SERVICE NOTE: The service idler gear assemblies will not include the new "seal patch" bolts. The flat washer has been deleted. Also, at the time of rebuild the new bolts should be used to minimize oil leakage into the flywheel housing.

Whenever the sealant patch bolts are removed, they should be replaced with *new* sealant patch bolts at both the idler gear spacer and idler gear positions.

Remove Idler Gear, Hub And Bearing Assembly (Flywheel Housing Previously Removed)

1. Remove the idler gear hub to cylinder block bolt and special washer and withdraw the assembly from the cylinder block rear end plate (Fig. 1).

   NOTICE: 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.

2. If necessary, remove the idler gear hole spacer (dummy hub) in the same manner.

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 and three bolt locks, if used, which secure the bearing retainer to the idler gear and remove the bearing retainer.

   NOTICE: The component parts of the idler gear bearing are matched; therefore, matchmark the parts during disassembly to ensure reassembly of the parts in their original positions.

2. Clean the idler gear assembly with fuel oil and dry it with compressed air.

3. Place the idler gear assembly in an arbor press, with the inner bearing cone supported on steel blocks as shown in Fig. 3. While rotating the idler gear assembly, press the hub out of the bearing. Remove the gear assembly from the arbor press and remove the bearing cones and spacer rings. Tap the bearing cups from the idler gear by using a brass drift alternately at the four notches provided around the shoulder of the gear.

   NOTICE: Unless it is determined that the bearing assembly is to be replaced, the inner and outer bearing cups should not be removed from the idler gear. If the cups are loose in the gear bore, the bearing assembly and gear (if the bore is worn) should be replaced.

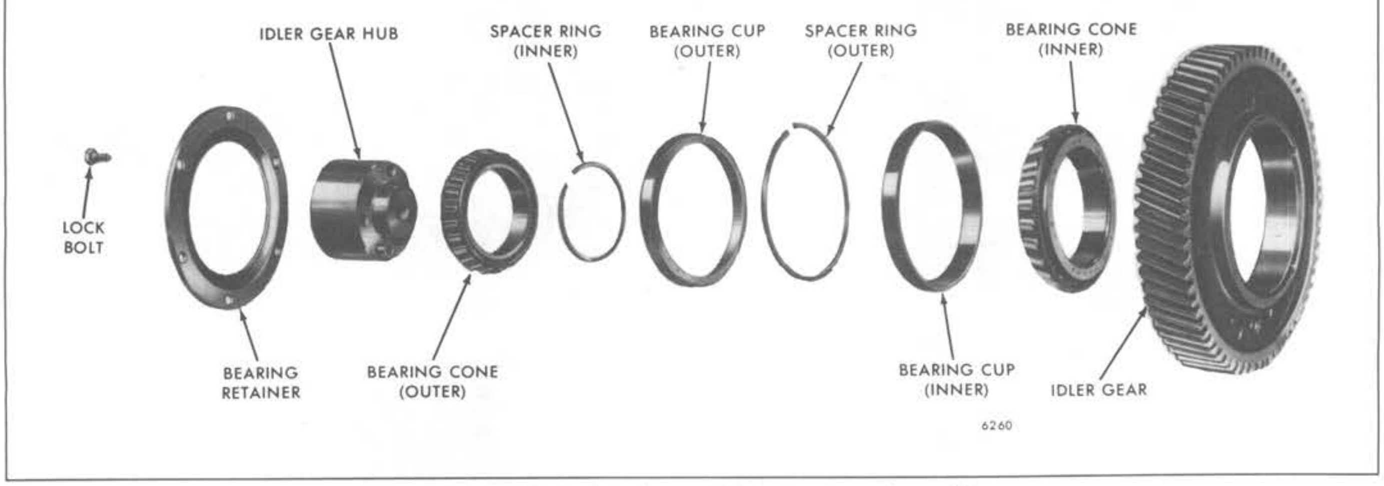


Fig. 4 – Idler Gear Details and Relative Location of Parts

Inspection

Wash the idler gear, hub and bearing components thoroughly in clean fuel oil and dry them with compressed air.

CAUTION:To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.

Check the idler gear hub to ensure that no chips or foreign material is deposited in the holes so as to cause interference with the flywheel housing attaching bolts.

Inspect the bearing carefully for wear, pitting, scoring or flat spots on the rollers or cones. Replace the bearing if it is defective.

Examine the gear teeth for evidence of scoring, pitting and wear. If severely damaged or worn, replace the gear. Also inspect the other gears in the gear train.

Assemble Idler Gear, Hub And Bearing

Refer to Fig. 4 and assemble the bearing components in their *original positions* (refer to identification marks made during disassembly) as outlined below:

NOTICE: The idler gear bearing is a matched assembly. *Do not* mix the components with another bearing assembly.

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 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.

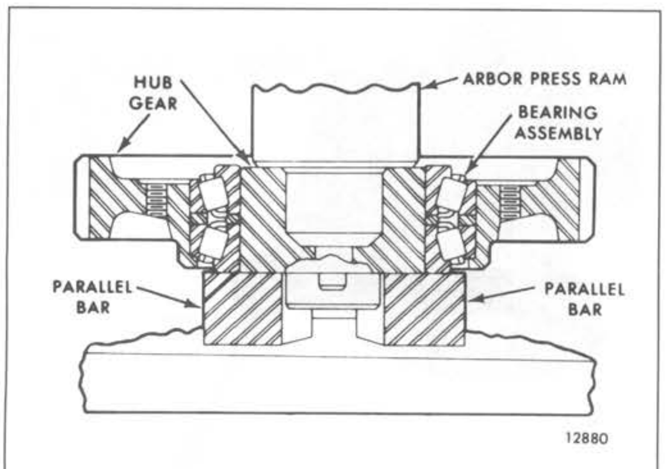


Fig. 5 – Pressing Hub into Idler Gear Bearing

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 steel plate (pre–load test plate) between the ram of the press and the bearing cup.
4. Press the inner bearing cone (numbered side up) on the idler gear hub, flush with the inner hub mounting face. Use the pre–load test plate (with the large center hole) between the ram of the press and the bearing.
5. Install the inner spacer ring on the idler gear hub so that the oil hole in the hub is 180° from the gap in the inner spacer ring.
6. Position the gear with both cups over the hub and the inner bearing cone.
7. Press the outer idler gear bearing cone over the hub while rotating the gear to seat the rollers properly between the cones. The bearing cones must be supported so as not to load the bearing rollers during this operation (Fig. 5).
8. Before installing the gear and bearing assembly, check the pre–load.

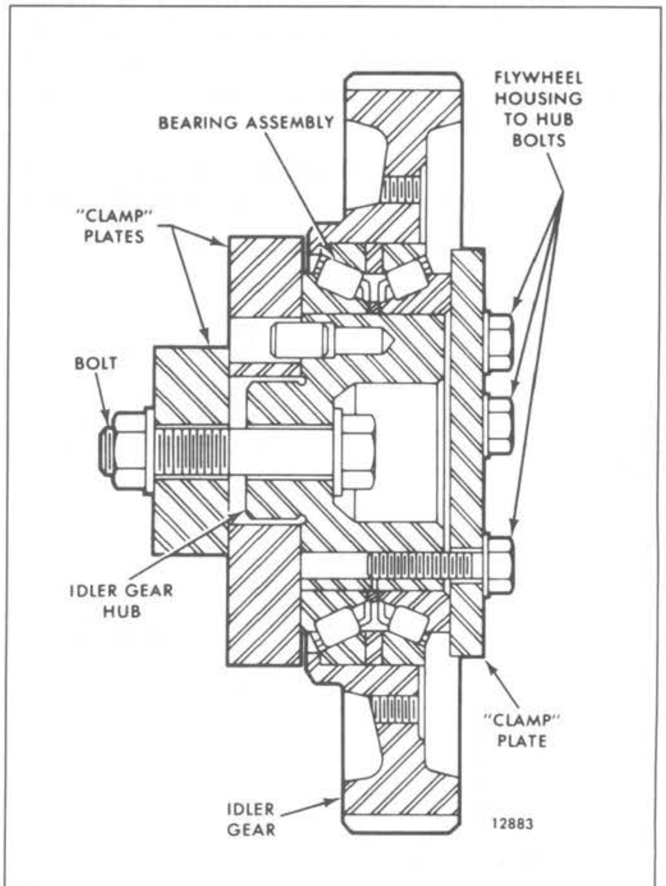


Fig. 6 – Fixture for Testing Bearing Pre–Load

Check Idler Gear Bearing Pre–Load

The rollers in the bearing are loaded between the bearing cup and the 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. 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 must 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 steel plate 4" square (pre–load test plate) against the hub and cone, as outlined below.

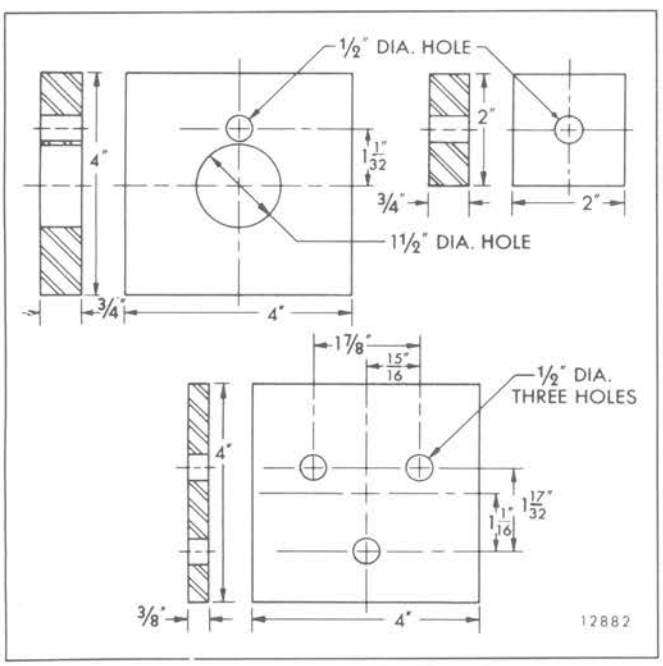


Fig. 7 – Plates for Bearing Test Fixture

1. Mount the idler gear assembly on the engine.
2. Install the center bolt and washer through the gear hub and thread it into the cylinder block. Tighten the bolt to 80–90 lb–ft (108–122 N•m) torque.
3. Place the steel plate (lower plate shown in Fig. 7) against the hub and bearing. Insert three 3/8"–16 bolts through the plate and thread them into the hub. Tighten the bolts to 25–40 lb–ft (34–54 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 two of the gear teeth and 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. 8). Maintain a straight steady pull on the cord and 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 1/2 lb. minimum to 4 lbs. maximum, and does not fluctuate more than 2 lbs 11 oz., the idler gear and bearing assembly is satisfactory for use.

If the crankshaft and camshaft gears are mounted on the engine, a suitable fixture, which may be held in a vise, can be made as shown in Fig. 6. Three plates (shown in Fig. 7), a 1/2"–13 x 2–3/4" bolt and a plain washer are used with a 1/2"–13 nut and plain washer for mounting. One of the plates is used to take the place of the flywheel housing, and the other two plates, the cylinder block. "Engine–mounted" conditions are simulated by tightening the nut to 80–90 lb–ft (108–122 N•m) torque and tightening the three plate–to–hub attaching bolts to 25–40 lb–ft (34–54 N•m) torque.

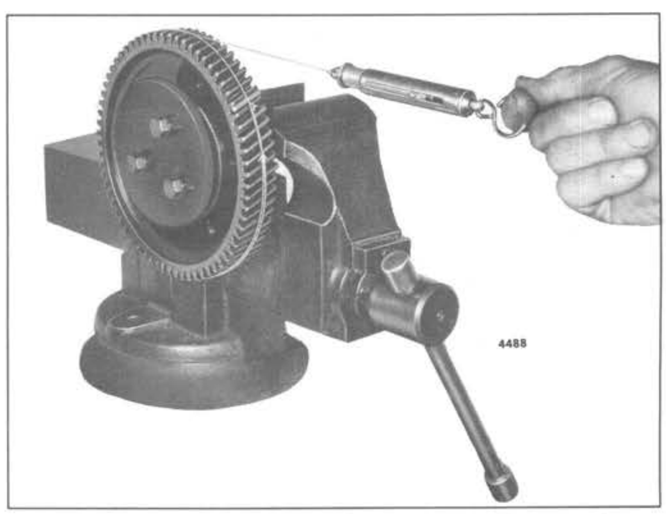


Fig. 8 – Checking Idler Gear Bearing Pre–Load

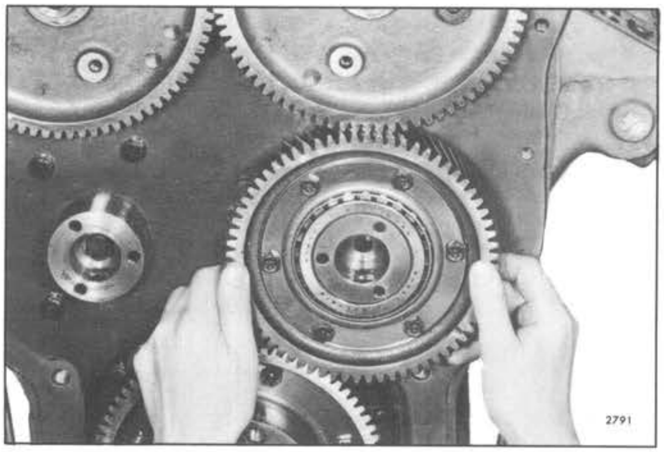


Fig. 9 – Installing Idler Gear, Hub and Bearing Assembly

Check the pre–load on the bearings, as follows:

1. Attach two of the plates (two upper plates shown in Fig. 7) to the idler gear hub with the 1/2"–13 bolt, washers and nut as shown in Fig. 6. Tighten the bolt to 80–90 lb–ft (108–122 N•m) torque.
2. Attach the third plate to the idler gear hub with three 3/8"–16 bolts. Tighten the bolts to 25–40 lb–ft (34–54 N•m) torque.
3. Clamp the idler gear assembly and fixture in a vise (Fig. 8).
4. Attach a cord to the idler gear and spring scale and check the bearing pre–load as outlined in Step 4 of the previous method.

If the scale reading is within the 1/2 to 4 lbs. specified, but fluctuates more than 2 lbs. 11 ounces, the idler gear and bearing assembly must NOT be installed on the engine. Fluctuations in scale reading may be caused by the cones not being concentric to each other, damaged cones or rollers, or dirt or foreign material within the bearings. In these cases, the bearing should be inspected for the cause of fluctuation in the scale readings and corrected or a new bearing installed. A scale reading which exceeds the specified maximum indicates binding of the bearing rollers, or rollers improperly installed. When the scale reading is less than the specified minimum, the bearing is more likely worn and the bearing should be replaced.

After the pre–load check is completed, remove the steel plates and install the bearing retainer.

Attach the bearing retainer to the idler gear with six new lock bolts. Because the lock bolts are coated with a locking compound, always use new lock bolts when assembling the idler gear. Tighten the bolts to 24–29 lb–ft (33–39 N•m) torque.

NOTICE: Do not use standard bolts and do not use the former bolt locks.

Install Idler Gear, Hub And Bearing Assembly

1. Position the crankshaft gear and camshaft gear so 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 camshaft gear, and simultaneously rotate the gear hub so the dowel in the hub registers with the hole in the end plate.
3. Roll the idler gear into position and align the hollow dowel with the oil hole in the end plate. Then gently tap the hub until it seats against the end plate.
4. After making sure the hub is tight against the end plate, secure the idler gear assembly with the 1/2"–13 bolt and special washer. Tighten the bolt to 80–90 lb–ft (108–122 N•m) torque.
5. If previously removed, install the idler gear hole spacer (dummy hub) (Fig. 9). Secure the spacer to the cylinder block end plate and cylinder block with a 1/2"–13 bolt and special washer. Tighten the bolt to 80–90 lb–ft (108–122 N•m) torque.
6. Lubricate the idler gear bearing and gear teeth liberally with clean engine oil.
7. Check the backlash between the mating gears. The backlash must be .002" to .008" between new gears and must not exceed .010" between worn gears.

CRANKSHAFT TIMING GEAR

6V and 8V Engines

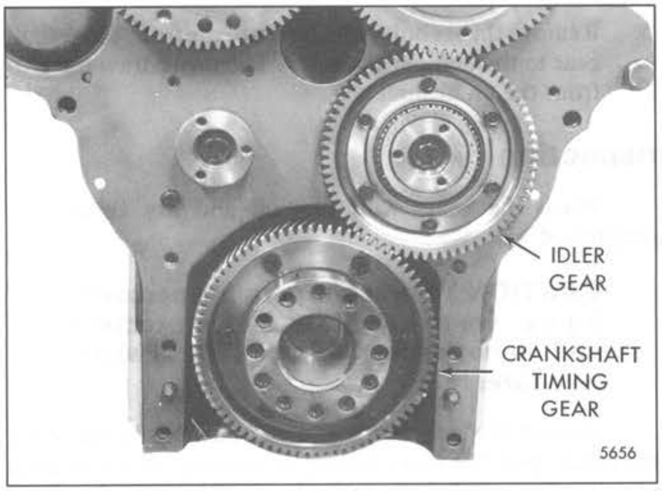


Fig. 1 – Crankshaft Timing Gear Mounting
(R.H. Rotation Engine Shown)

The crankshaft timing gear (Fig. 1) is bolted to the flange at the rear end of the crankshaft and drives the camshaft gears, as well as the blower drive gear, through an idler gear.

Since the two 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).

• New crankshafts and crankshaft timing gears replaced the former crankshafts and timing gears effective with engine serial numbers 6VF0123940 and 8VF098671. The new timing gears have a hole drilled in their bolt flanges. This hole provides clearance for a new 1/4" x 3/4" L. roll pin installed in the timing gear end of the new crankshafts (refer to section 1.3). The pin permits only right-hand crankshaft timing gears to be installed on right-hand engine crankshafts, and only left-hand timing gears to be installed on left-hand engine crankshafts.

The new crankshafts with their new respective crankshaft timing gears are completely interchangeable with the former crankshafts and timing gears for the same engine rotation, and only the new parts will be serviced.

NOTICE: The roll pins can be removed from the new crankshafts to allow reuse of the former crankshaft timing gears. When reusing the former gears without the clearance hole, *the proper rotation gear must be matched with the proper rotation crankshaft.*

Remove Crankshaft Timing Gear (Flywheel Housing Removed)

The crankshaft gear is a press fit on the crankshaft. Remove the gear as follows:

1. Remove the crankshaft rear oil seal sleeve, if used. To remove the sleeve, peen the outside diameter of the sleeve until it stretches sufficiently so it can be slipped off of the crankshaft.
2. Before removing the crankshaft gear, align the timing marks of the gear train and note their location so the gear can be reinstalled in its original position.
3. Remove the six bolts which secure 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 gear puller.

Inspection

Clean the gear with fuel oil and dry it with compressed air.

CAUTION:To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.

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. Position the gear on the rear end of the crankshaft with the bolt holes in the gear aligned with the tapped holes in the crankshaft. One bolt hole is offset so the gear can be attached in only one position.
2. Align the proper timing mark on the crankshaft gear with the corresponding mark on the idler gear (refer to Section 1.7.1).
3. Start the six 3/8" –24 bolts through the gear and into the crankshaft. Then draw the gear tight against the shoulder on the crankshaft. Tighten the bolts to 35–39 lb–ft (47–53 Nm) torque.
4. Check the backlash with the mating gear. The backlash should be .002" to .008" with new gears or .010" maximum with used gears.
5. Install a new crankshaft rear oil seal sleeve, if required, as outlined in Section 1.3.2.

CRANKSHAFT TIMING GEAR

12V AND 16V ENGINES

Two crankshaft timing gears are located on the crankshaft. The rear crankshaft gear is attached to the flange at the rear of the crankshaft. The lubricating oil pump drive gear is attached to the rear crankshaft gear. The front crankshaft gear assembly (gear and bushing) is attached to a damper assembly which is mounted on the flange at the front of the crankshaft.

• New crankshafts and crankshaft timing gears replaced the former crankshafts and timing gears effective with engine serial numbers 12VF002032 and 16VF006468. The new timing gears have a hole drilled in their bolt flanges. This hole provides clearance for a new 1/4" x 3/4" L. roll pin installed in the timing gear end of the new crankshafts (refer to section 1.3). The pin permits only right-hand crankshaft timing gears to be installed on right-hand engine crankshafts, and only left-hand timing gears to be installed on left-hand engine crankshafts.

The new crankshafts with their new respective crankshaft timing gears are completely interchangeable with the former crankshafts and timing gears for the same engine rotation, and only the new parts will be serviced.

> **NOTICE:** The roll pins can be removed from the new crankshafts to allow reuse of the former crankshaft timing gears. When reusing the former gears without the clearance hole, *the proper rotation gear must be matched with the proper rotation crankshaft.*

Remove Crankshaft Timing Gear (Flywheel Housing Removed)

1. Remove the crankshaft 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 six bolts which secure the rear timing gear to the crankshaft Then remove the rear timing gear and oil pump drive gear as an assembly. If necessary, use a gear puller. Provide a base for the puller screw by placing a steel plate across the cavity in the end of the crankshaft.

4. Separate the crankshaft and oil pump drive gears by removing the six attaching bolts.

5. Remove the six bolts which secure the front crankshaft gear to the damper assembly. Then withdraw the gear from the crankshaft.

Inspection

Wash the gears with fuel oil and dry them with compressed air.

> **CAUTION: To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.**

Inspect the gear teeth and the bushing in the front crankshaft gear for wear, pitting or scoring. The clearance between the crankshaft and the bushing in the front crankshaft gear is .001" to .003" with new parts and should not exceed .005" with used parts. If the crankshaft gear or bushing is excessively worn, install a new gear and bushing assembly.

Clean and disassemble the damper. Then examine the damper springs for pitted or fractured coils. Replace defective springs.

Assemble Damper

1. Lay the inner plate (flat side up) on a bench.

2. Place a spring in each slot of the damper.

3. Place the hub on the inner plate with the notches in the hub and the inner plate located as shown in Fig. 2.

4. Align the spring slots in the outer plate with the springs in the hub. Then lay the outer plate on the hub.

5. Slide the spacers in between the inner an outer plates and align the spacers with the bolt holes in the plates.

6. Push the bolts through the inner plate, spacers and the outer plate. Then install the nuts on the bolts. Tighten the nuts to 30–35 lb–ft (41–47 Nm) torque.

Install Crankshaft Timing Gear

Refer to Section 1.7.1 for the position of the gear train timing marks and proceed as follows:

1. Lay the rear crankshaft timing gear (timing mark side down) on a bench. Place the oil pump drive gear (narrow side down) on the crankshaft gear. Install the oil pump drive gear bolts. Tighten the bolts to 15–19 lb–ft (20–26 Nm) torque.

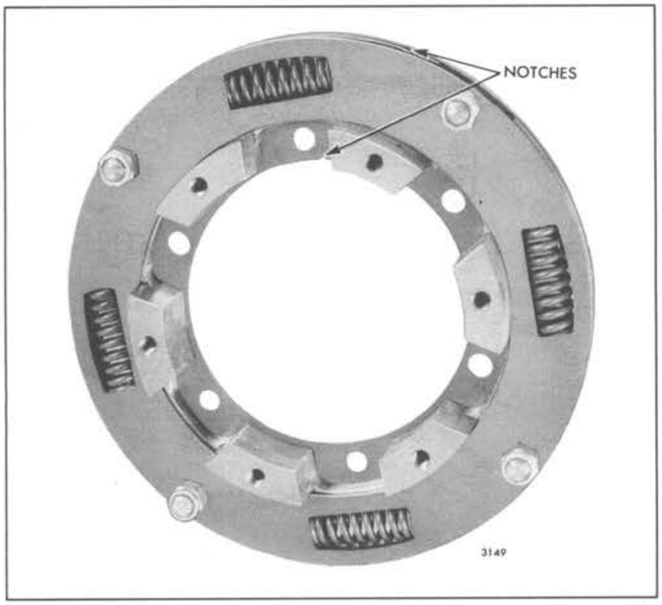


Fig. 2 – Proper Location of Notches in Damper Assembly

2. Slide the gear (oil pump gear first) on the rear end of the crankshaft. Align the bolt holes in the crankshaft gear with the tapped holes in the crankshaft. Then install and tighten the crankshaft gear bolts to 35–39 lb–ft (47–53 Nm) torque.

3. Align the proper timing mark on the crankshaft gear with the corresponding mark on the idler gear.

4. Position the damper on the front end of the crankshaft, if it was removed. Install and tighten the damper-to-crankshaft bolts to 35–39 lb–ft (47–53 Nm) torque.

5. Align the timing marks and attach the front crankshaft gear to the damper with six bolts. Tighten the bolts to 15–19 lb–ft (20–26 Nm) torque.

6. Check the backlash of the gears. The backlash should be .002" to .008" with new gears or .010" maximum with used gears.

7. Install a new crankshaft oil seal sleeve, if used, on the crankshaft as outlined on Section 1.3.2.

BLOWER DRIVE GEAR AND SUPPORT ASSEMBLY

For non–turbocharged engines, the blower drive gear is driven by a step–up gear (86 teeth) attached to the right cylinder bank camshaft gear (Fig. 1). For turbocharged engines, the blower drive gear is driven directly by the right cylinder bank camshaft gear (Fig. 2).

Two blower drive gear and support assemblies are used on the 12V and 16V engines. Both the front and the rear blower drive gears on the non–turbocharged 12V and 16V engines are the same and are driven by the step–up gear (86 teeth), attached to the front and rear camshaft gears. However, on the 12V and 16V turbocharged engine, each blower drive gear is driven directly by the camshaft gear. Therefore, the blower drive gear and support assembly on the front of the engine which incorporates a right–hand helix gear, and the blower drive gear and support assembly on the rear of the engine which incorporates a left–hand helix gear are not completely interchangeable.

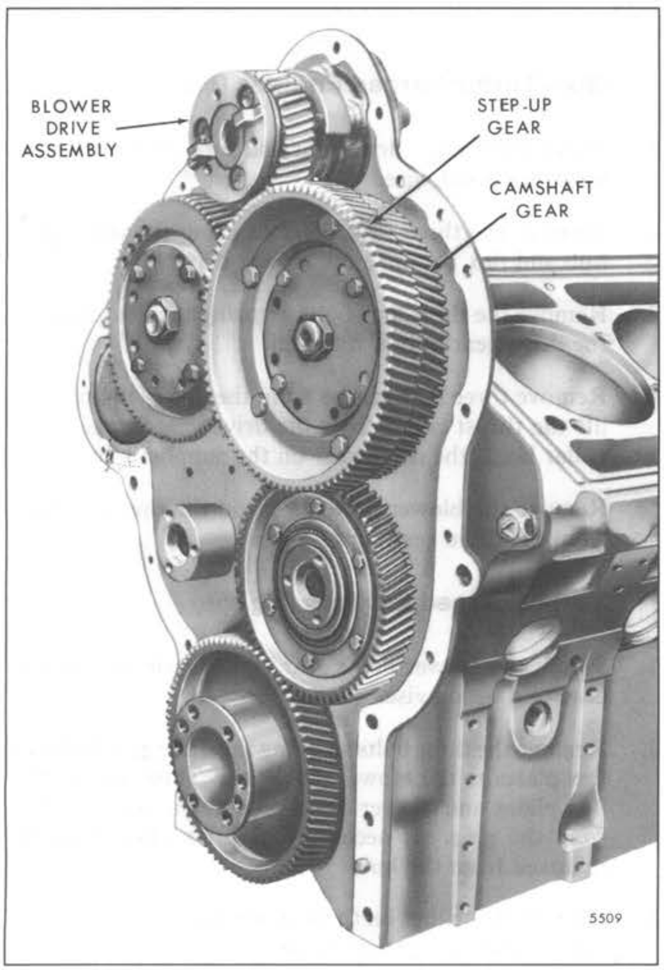


Fig. 1 – Blower Drive Gear Mounting (Non–Turbocharged Engine)

Since the camshaft gear runs at engine speed, the blower drive gear, which has about half as many teeth as the camshaft gear, runs approximately twice engine speed.

The blower to engine speed ratio for the 6V, 8V and 16V non–turbocharged engines is 2.60:1 (blower drive gear has 33 teeth). The blower to engine speed ratio for the turbocharged engines is 2.05:1 (blower drive gear has 38 teeth). The blower to engine speed ratio for the 1976 California 6V–92TA, 12V–92T and 16V–92TA engines is 1.95:1.

The blower drive gear is mounted on a support which is attached to the cylinder block rear end plate. The blower drive gear bearings are pressure lubricated through an external line from the blower rear end plate to the blower drive support.

Remove Blower Drive Gear And Support Assembly (Flywheel Housing Removed)

Removal of the flywheel housing is not necessary when removing the blower drive gear. However, an inspection of the gear train is advisable when any one of the gears require service. The procedures for removal of the flywheel and flywheel housing are found in Sections 1.4 and 1.5.

1. Remove the blower(s) and blower drive support lubrication tube as outlined in Section 3.4.1.
2. Remove the two blower drive support–to–cylinder block rear end plate attaching bolts with copper washers.
3. Tap the blower drive support to loosen it, then carefully withdraw the support from the cylinder block rear end plate so the blower drive gear teeth will not be damaged. Discard the gasket.

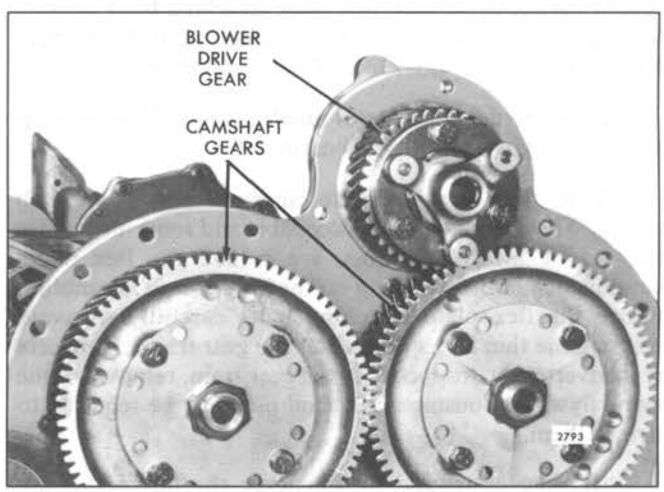


Fig. 2 – Blower Drive Gear Mounting (Turbocharged Engine)

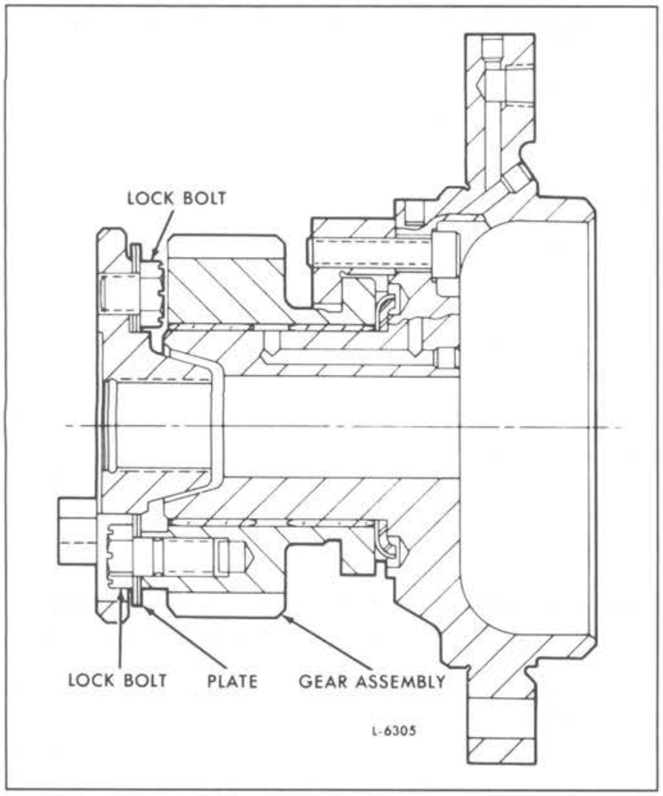


Fig. 3 – Rear Hub Assembly – Non-Turbocharged Engines

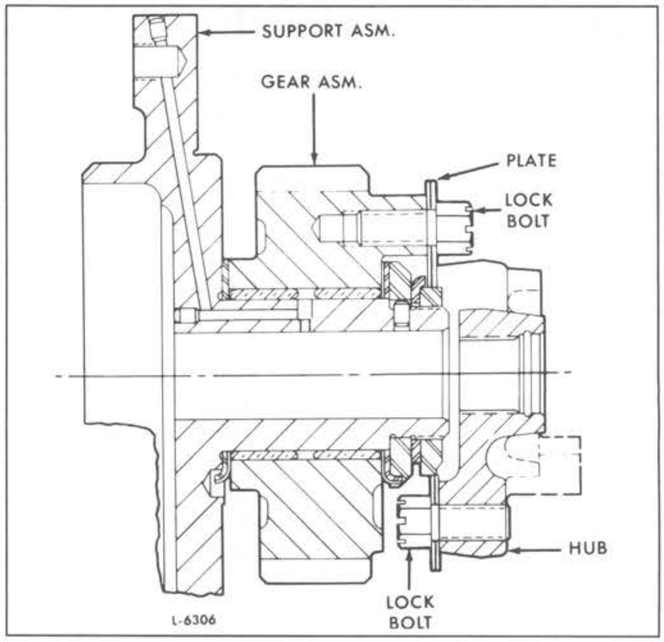


Fig. 4 – Rear Hub Assembly – Turbocharged Engines

Disassemble Blower Drive Gear And Support Assembly

New blower drive shaft flex plates and type B hex lock bolts are now being used on engines that incorporate the large bearing blower (Figs. 3 and 4). The tumbled flex plates will continue to be used, as required. However, the thin hub spacers formerly used to protect the tumbled flex plates are no longer required and will not be serviced. The change to the new blower drive shaft flex plate attaching bolts became effective with engine serial numbers 6VF–092516, 8VF–077675, 12VF–001216 and 16VF–005875.

Only the new flex plates and bolts should be used to service 92 engines with large bearing blowers.

Some former engines are equipped with thin hub spacers. They are not readily accessible and some mechanics may not be aware that they are behind the flex plate. Consequently, when working on the blower hub assemblies, remove the flex plate attaching bolts carefully to avoid dropping the thin hub spacers into the gear train. If spacers are inadvertently dropped into the gear train, removal of the engine flywheel housing and/or oil pan may be required to retrieve them.

At time of rebuild or whenever the flex plates are removed, new type B lock bolts must be used. *Do not attempt to reuse patch bolts.*

Non-Turbocharged Engines (Fig. 5)

1. Secure the blower drive gear and support it in the soft jaws of a bench vise.
2. Remove the three lock bolts securing the drive gear hub and flex plates to the blower drive gear.
3. Remove the three lock bolts securing the flex plates to the drive gear hub, if required.
4. Remove three lock screws from the drive support and lift the thrust collar from the drive gear flange. The collar holds the drive gear on the support hub.
5. Remove the blower drive gear and the thrust washer from the drive gear support hub.

Turbocharged Engines (Fig. 6)

1. Secure the blower drive gear and support in the soft jaws of a bench vise.
2. Remove the three bolts securing the drive gear hub and flex plates to the blower drive gear. Then remove the flex plates and blower drive gear hub as an assembly from the gear. If necessary, the flex plates may be removed from the hub.
3. Straighten the lugs on the lock washer and remove the blower drive gear support nut.
4. Withdraw the lock washer, blower drive gear thrust washer, thrust bearings and gear from the support.

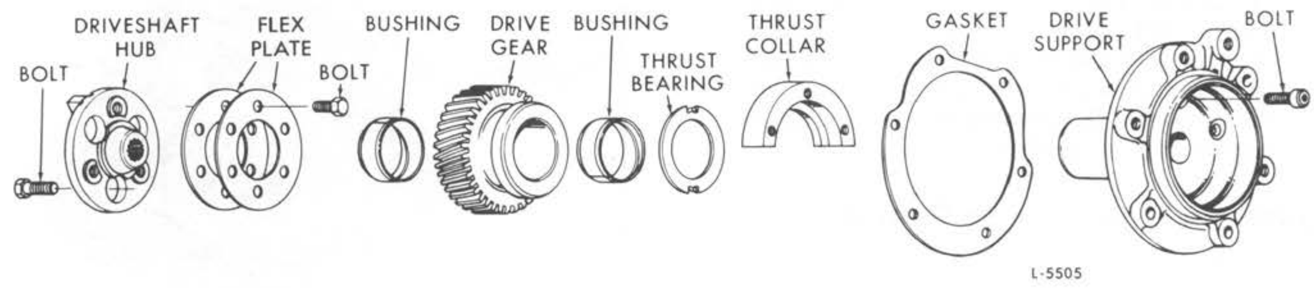


Fig. 5 – Rear Hub, Blower Drive Gear, Support Assembly and Relative Location of Parts

Inspection

Clean the parts with fuel oil and dry them with compressed air.

CAUTION:To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.

Make sure the oil passage in the blower drive gear support is clean. Check the inside diameter of the blower drive gear bushings and the outside diameter of the support hub for wear or excessive heat. Also, check the clearance between the bushings and the support hub. Refer to the wear specifications in Section 1.0. Install new parts whenever the clearance exceeds the limit.

If new bearings are installed, the outer end of each bearing must be pressed in flush to .010" below the face of the gear. The bearings must be reamed to size (1.6260" to 1.6265" inside diameter) and to a finish of 20 microinches after installation. The bearing bores must also be square with the machined faces of the bolt bosses on the gear within .003" total indicator reading and concentric with the pitch diameter of the gear teeth.

The thrust washer retaining pin must extend approximately .080" above the threaded end of the hub.

Examine the blower drive support thrust washer and thrust bearing for scoring and wear. Replace them, if necessary. Refer to Section 1.0 for the thickness of a new blower drive support thrust washer and thrust bearing.

Inspect the gear teeth for evidence of scoring, pitting, burning and wear. If necessary, install a new gear.

Inspect the flex plates for cracks or other damage. Replace the plates, if necessary.

Check the serrations in the blower drive shaft hub for wear or other damage. Replace the hub, if necessary.

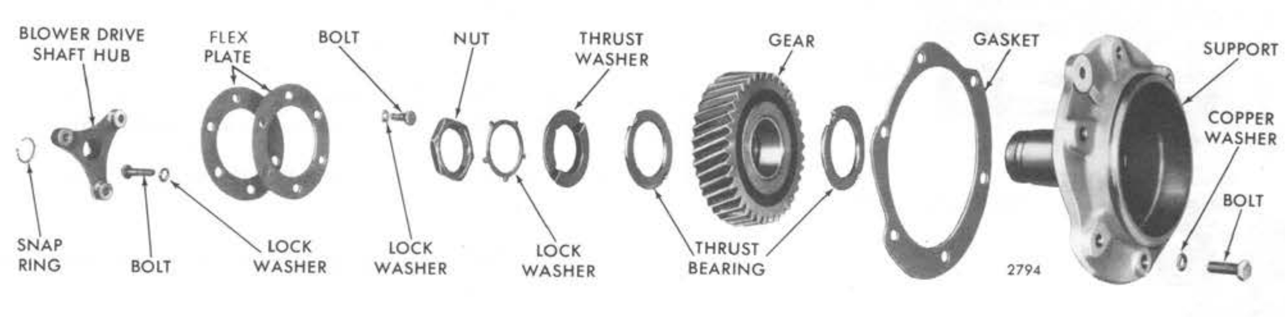


Fig. 6 – Rear Hub, Blower Drive Gear, Support Assembly and Relative Location of Parts

NOTICE: To reduce spline wear, the blower drive shafts, blower drive couplings and accessory drive hubs (Fig. 7) have been replaced by specially heat treated parts, effective with engines 6VF–21492 and 8VF–19187. It is recommended that all of the subject components be replaced (including the flex plates) when any one or more of the parts require replacement on engines prior to the above serial numbers.

Assemble Blower Drive Gear And Support Assembly

Non–Turbocharged Engine (Fig. 5)

1. With the blower drive support clamped in the soft jaws of a bench vise, position the blower drive gear thrust washer on the drive support hub so that the tangs on the washer register with the holes in the support.

NOTICE: The new thrust washer with two I.D. keyways and the new locking washer with a longer tang must be used together for optimum nut locking performance.

2. Lubricate the hub of the drive support, the bushings in the drive gear and the face of the thrust washer and thrust collar with clean engine oil.

3. Slide the drive gear on the support hub with the flange end of the gear against the thrust washer.

4. Install the thrust collar over the flange end of the drive gear and against the drive support. Secure the collar with three 5/16"–18 x 1–1/4" socket head lock bolts. Tighten the bolts to 16–21 lb–ft (22–28 Nm) torque.

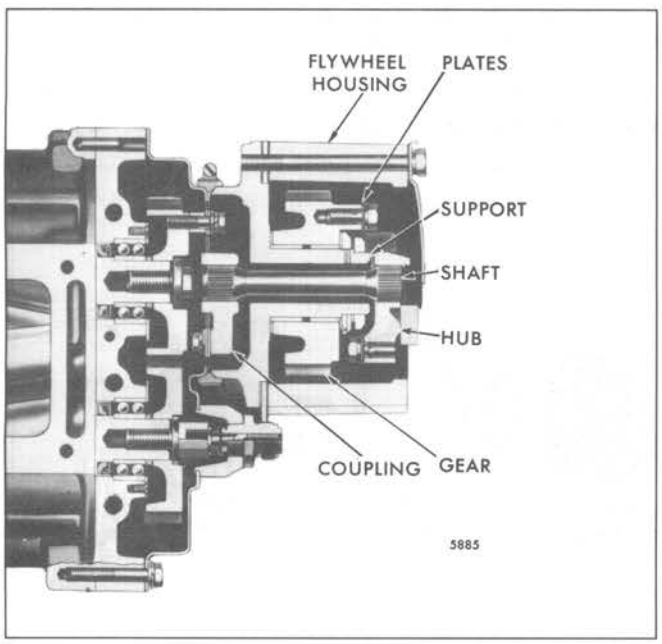


Fig. 7 – Blower Drive Components

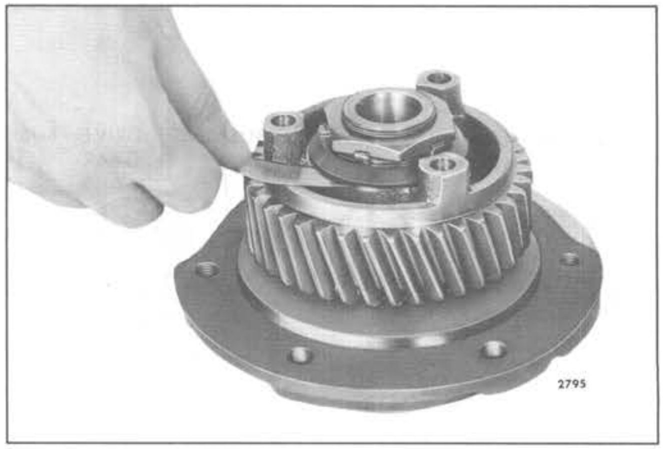


Fig. 8 – Checking Clearance Between Blower Drive Gear Support Thrust Washer and Thrust Bearing

NOTICE: The thrust collar holds the drive gear on the support hub.

5. If the two flex plates were removed or replaced, secure them to the drive gear hub with the three special 3/8"–24 x .345" lock bolts. Tighten the bolts to 40–45 lb–ft (54–61 Nm) torque.

6. Secure the drive hub and flex plate assembly to the drive gear with three special 3/8"–24 x .925" lock bolts. Tighten the bolts to 35–39 lb–ft (47–53 Nm) torque.

7. Check the clearance between the blower drive gear support thrust washer and the blower drive gear thrust bearing (Fig. 8). The clearance should be .003" to .017" with new parts and should not exceed .019" between worn parts.

Turbocharged Engines (Fig. 6)

1. With the blower drive support clamped in the soft jaws of a bench vise, position one of the blower drive thrust bearings on the support so that the tangs on the bearing register with the holes in the support.

2. Lubricate the hub of the support, the bushings in the gear, both thrust bearings and the blower drive gear support thrust washer with clean engine oil.

3. Slide the gear on the hub with the flat side of the gear down.

4. Install the second thrust bearing on the support with the tangs on the bearing facing up.

5. Position the blower drive support thrust washer on the support so that the slots in the thrust washer register with the tangs on the bearing.

6. Secure the gear on the support with a lock washer and nut. Tighten the nut to 50–60 lb–ft (68–81 Nm) torque and bend the lugs on the lock washer against the flats on the nut to secure the nut.

7. Check the clearance between the blower drive gear support thrust washer and the blower drive gear thrust bearing (Fig. 8). The clearance should be .005" to .010" with new parts and should not exceed .012" between worn parts.

8. If the flex plates were removed from the blower drive gear hub, attach the spring plates to the hub with three special 3/8"–24 x .925" lock bolts. Tighten the bolts to 35–39 lb–ft (47–53 Nm) torque.

   NOTICE: Do not install the lock washers against the steel plates.

9. Then, assemble the flex plates and the hub to the gear with three special 3/8"–24 x .925" lock bolts. Tighten the bolts to 35–39 lb–ft (47–53 Nm) torque.

Install Blower Drive Gear And Support Assembly

1. Affix a new gasket to the blower drive gear support and attach the gear and support assembly to the cylinder block rear end plate with two bolts and copper washers. Tighten the bolts to 25–30 lb–ft (34–41 Nm) torque.

2. Check the gear backlash between the blower drive gear and the step–up gear attached to the camshaft (non–turbocharged engine) or the camshaft gear (turbocharged engine). To accurately check the backlash, all of the flywheel housing attaching bolts must be tightened to their proper torque as outlined in Section 1.5. Backlash should be .002" to .008", and should not exceed .010" with worn parts.

3. Remove the four flywheel housing–to–blower drive support bolts. Then, install the blower(s) as outlined in Section 3.4.1.

ACCESSORY DRIVES

ACCESSORY DRIVE POSITIONS	DRIVE RATIO
1	1:1
2	1:1
*3	2.60:1 or 2.05
4	2.05:1
5	NOT A DRIVE POSITION

*Depends upon engine application

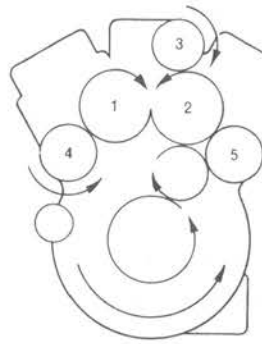


Fig. 1 – Accessory Drive Locations

Accessories such as an air compressor, hydraulic pump or battery–charging alternator may be direct–driven or belt–driven from various locations on the engine.

For the possible accessory drive location and rotation of the drive at a particular position, refer to Fig. 1.

At the front of the engine, the left–bank camshaft pulley (Fig. 2) and the crankshaft pulley may be used to drive accessories. On certain applications, an accessory drive pulley (Fig. 2), which mounts on a shaft attached to the water pump drive gear, provides a drive for a high mounted battery–charging alternator.

Accessories may also be driven by the blower drive gear, left–bank accessory drive gear or either camshaft gear at the rear of the engine.

FRONT ACCESSORY DRIVE

The front accessory drive (Fig. 2) consists of a short drive hub which is bolted to the water pump drive gear and a pulley keyed to the hub and secured with a bolt, lock washer and plain washer. An oil seal, pressed in the balance weight cover, prevents oil from seeping out where the shaft extends through the cover.

Remove Front Accessory Drive

1. Loosen the alternator adjusting strap and alternator mounting bolts and remove the drive belt.
2. Remove any accessories necessary to provide access to the accessory drive pulley.
3. Remove the water pump (refer to Section 5.1).
4. Remove the pulley retaining bolt, lock washer and plain washer. Then remove the pulley and the key.
5. Remove the balance weight cover (refer to Section 1.7.8).
6. Replace the oil seal in the balance weight cover, if necessary.
7. Remove the three bolts and lock washers and withdraw the drive shaft from the water pump drive gear.

Install Front Accessory Drive

1. Attach the accessory drive shaft to the water pump drive gear with three 5/16"–24 x 7/8" bolts and lock washers. Tighten the bolts to 15–19 lb–ft (20–26 Nm) torque.
2. Install the balance weight cover as outlined in Section 1.7.8.
3. Install the key in the shaft. Then install the pulley on the shaft and secure it in place with a 3/8"–16 x 7/8" bolt, lock washer and plain washer. Tighten the bolt to 25 lb–ft (34 Nm) torque.
4. Install the water pump as outlined in Section 5.1.
5. Install any accessories which were removed to provide access to the accessory drive pulley.

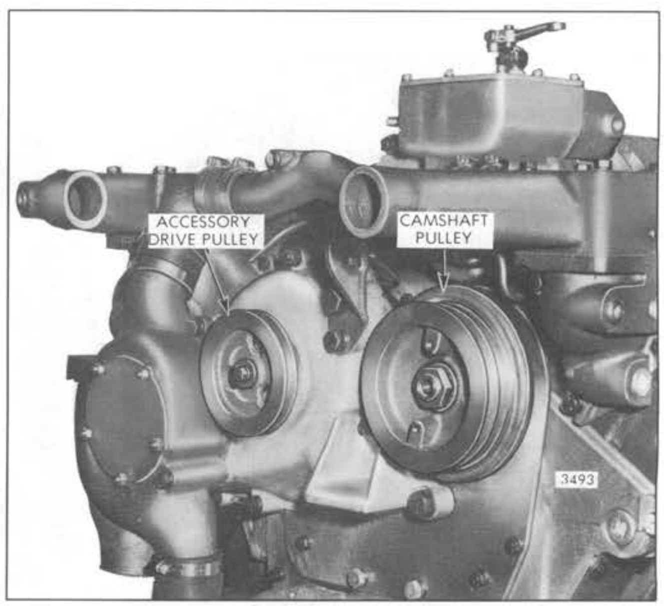


Fig. 2 – Front Mounted Accessory Drive Pulleys (6V and 16V)

6. Install the drive belt and adjust the alternator to provide the proper tension on the belt. Then tighten the alternator adjusting strap bolt and alternator mounting bolts.

NOTICE: When installing or adjusting accessory drive belts, be sure the bolt at the accessory adjusting pivot point is properly tightened, as well as the bolt in the adjusting slot (refer to Section 1.5.1).

REAR ACCESSORY DRIVE (Camshaft Driven)

The camshaft driven acxcessory drive consists of a drive plate bolted to either one of the camshaft gears.

A direct–driven accessory is flange–mounted on the flywheel housing and is driven by a coupling which is splined to both the accessory drive plate and a drive hub on the accessory shaft (Fig. 3).

For a belt–driven accessory, a drive shaft is used in place of the drive coupling. One end of the drive shaft is splined to the drive plate and the other end is supported by a bearing in the accessory drive retainer which is attached to the flywheel housing (Fig. 4). A drive pulley, attached to the outer end of the drive shaft, is connected by belts to the pulley on the accessory which is mounted above the flywheel housing.

On some engines, an accessory drive hub is bolted directly to the camshaft gear (Fig. 5). An oil seal retainer is bolted to the flywheel housing and the pulley is keyed and secured to the hub with a bolt, lock washer and plain washer.

Remove Accessory Drive

Refer to Fig. 3 and remove the accessory drive used with a direct–drive accessory as follows:

1. Disconnect any external piping or hoses at the accessory.
2. Remove the bolts and lock washers securing the accessory to the flywheel housing. Pull the accessory straight out from the flywheel housing. Remove the gasket.
3. Remove the drive coupling.
4. Place a clean, lintless cloth in the flywheel housing opening (under the accessory drive plate) to prevent bolts from accidentally falling into the gear train. Then remove the four shoulder bolts (and lock washers, if used) and withdraw the accessory drive plate.

Refer to Figs. 4 and 5 and remove the accessory drive used with a belt–driven accessory as follows:

1. Loosen the accessory mounting or adjusting bolts and remove the drive belts.
2. Remove the nut which retains the drive pulley on the accessory drive shaft.
3. Use a suitable gear puller and withdraw the pulley from the shaft. Remove the key from the shaft.

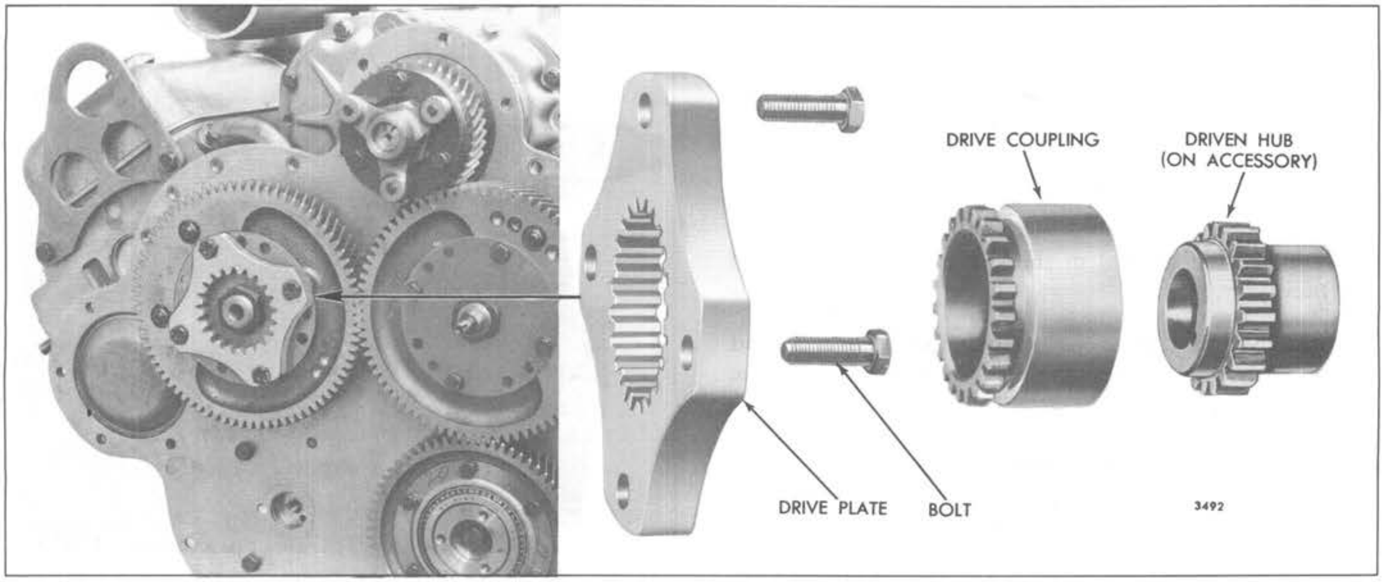


Fig. 3 – Components of Accessory Drive for Direct–Driven Accessories

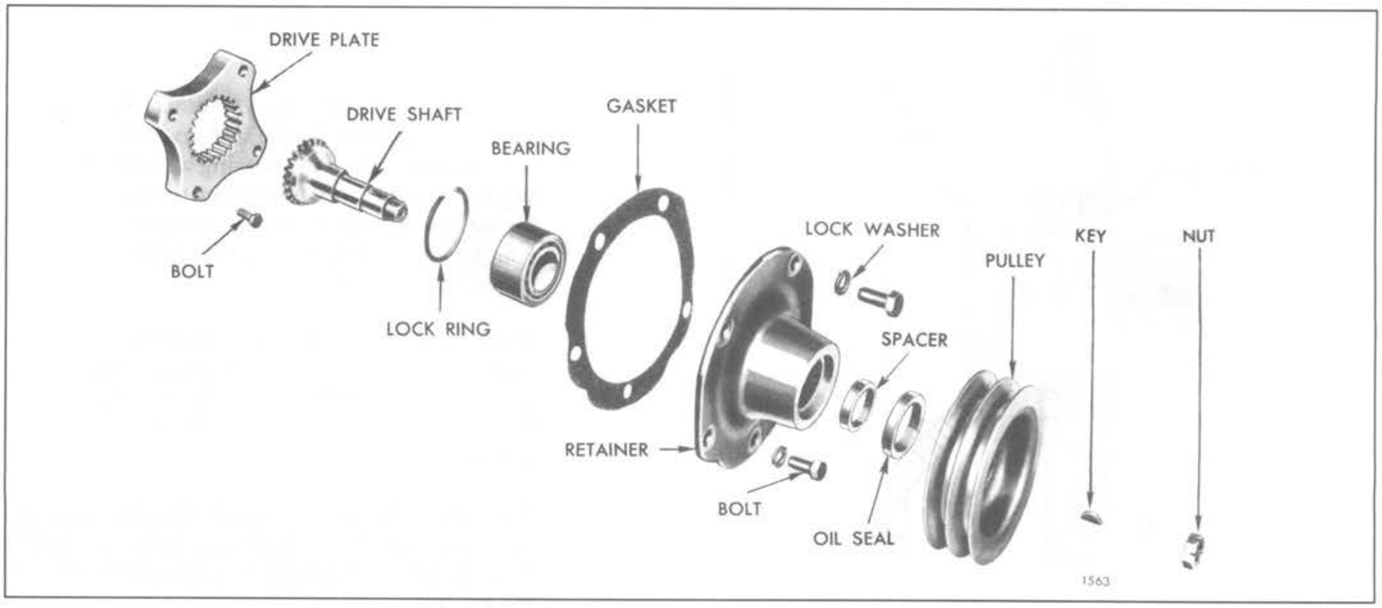


Fig. 4 – Components of Accessory Drive for Belt–Driven Accessory (Drive Plate Type)

4. Remove the bolts and washers and withdraw the accessory drive retainer assembly from the flywheel housing. Remove the gasket.

5. Place a clean, lintless cloth in the flywheel housing opening (under the accessory drive plate or drive hub) to prevent bolts from accidentally falling into the gear train. Then remove the four shoulder bolts and withdraw the accessory drive plate or drive hub.

6. Remove the accessory drive shaft from the retainer (Fig. 4).

7. Remove the snap ring and ball bearing from the accessory drive retainer (Fig. 4).

Inspection

Clean all of the parts with fuel oil and dry them with compressed air.

CAUTION:To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.

Check the teeth on the drive plate and the drive coupling or drive shaft for wear. Replace any parts which are worn excessively.

Inspect the ball bearing used to support the accessory drive shaft shown in Fig. 3. *Shielded bearings must not be washed;* dirt may be washed in and the cleaning fluid could

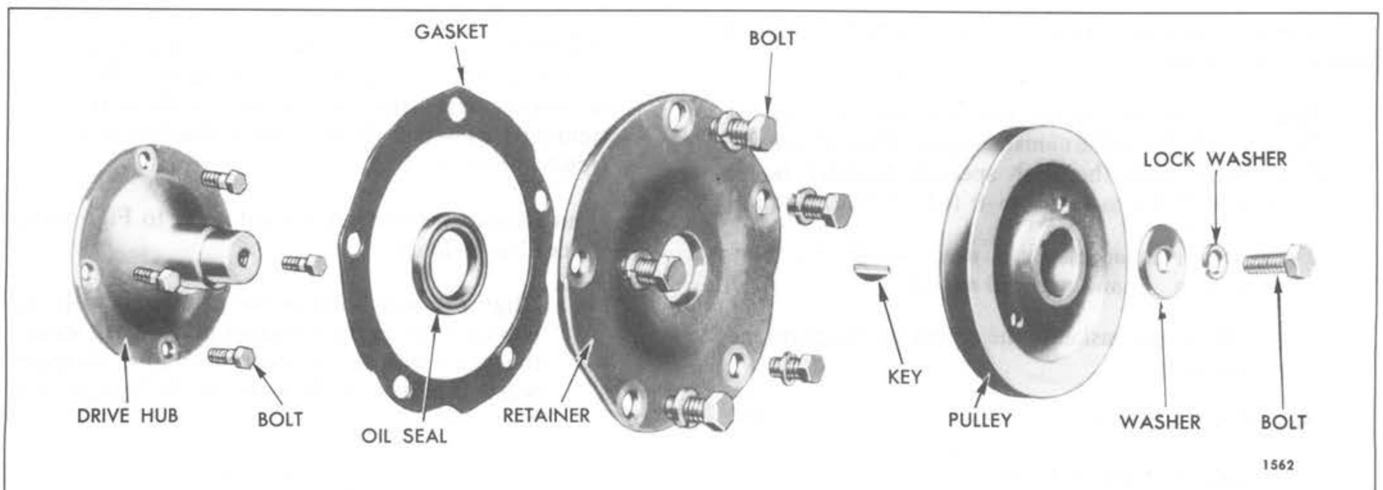


Fig. 5 – Components of Accessory Drive for Belt–Driven Accessory (Drive Hub Type)

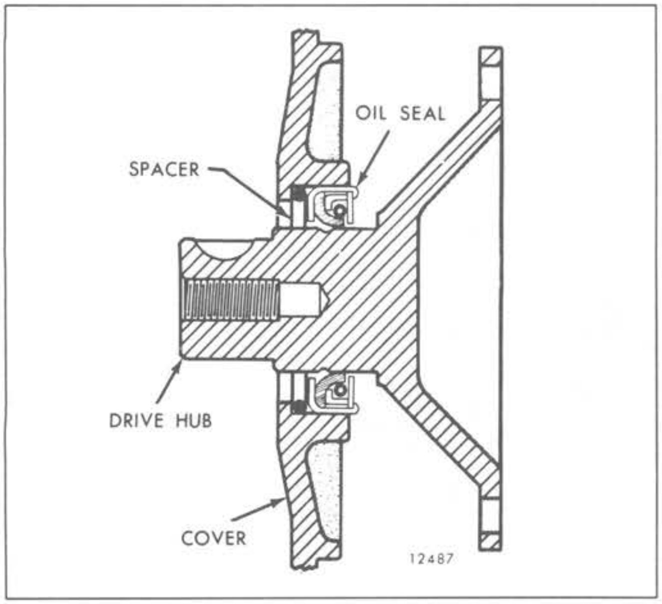


Fig. 6 – Location of Oil Seal Spacer

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.

Remove and discard the oil seal. Also inspect the oil seal contact surface of the drive shaft (Fig. 4) or drive hub (Fig. 5) for grooving. If the shaft is grooved and cannot be "cleaned–up", replace it.

If the drive hub (Fig. 5) 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 and provide a new sealing surface for the lip of the oil seal (Fig. 6).

Install Accessory Drive

If an accessory drive plate is used, refer to Figs. 3 and 4 and proceed as follows:

1. Align the bolt holes in the accessory drive plate with the tapped holes in the camshaft gear. Then secure the drive plate with the four special shoulder bolts. Tighten the bolts to 45–50 lb–ft (61–68 Nm) torque.
2. If a gear–driven accessory is used, install the drive coupling (Fig. 3) and proceed as follows:
   a. Affix a new gasket to the mounting flange on the accessory.
   b. Place the accessory in position against the flywheel housing and rotate it, if necessary, to align the teeth of the drive hub with those in the drive coupling. Then secure the accessory to the flywheel housing with bolts and lock washers.
3. If a belt–driven accessory is used, refer to Fig. 4 and proceed as follows:
   a. Place the accessory drive retainer on a bench, with the mounting flange side up. Lubricate the outside diameter of the bearing with oil. Press or tap it (with the protruding face of the inner race facing toward the retainer) straight in until it contacts the shoulder in the retainer. Then install the lock ring.
   b. Turn the retainer over and coat the bore with sealant. Then press a new oil seal into the bore of the retainer with the lip of the seal facing the bearing. Wipe any excess sealant from the retainer.
   c. Turn the retainer over again, bearing side up, lubricate the drive shaft and press it in the bearing until the shoulder on the shaft contacts the bearing.
   d. Affix a new gasket to the mounting flange on the retainer. Then position the retainer and shaft assembly against the flywheel housing. Rotate the shaft slightly, if necessary, to permit the teeth of the shaft to mesh with the teeth in the accessory drive plate. Secure the retainer to the flywheel housing with five bolts and lock washers. Tighten the bolts to 30–35 lb–ft (41–47 Nm) torque.
   e. Install the key in the shaft. Then start the pulley on the shaft and tap it into place. Install the 3/4"–16 retaining nut. Tighten the nut to 120–140 lb–ft (163–190 Nm) torque.
   f. Slip the drive belts over the pulleys. Then position the accessory to provide the proper tension on the belts and secure it in place.

NOTICE: When installing or adjusting accessory drive belts, be sure the bolt at the accessory adjusting pivot point is properly tightened, as well as the bolt in the adjusting slot (refer to Section 15.1).

4. If an accessory drive hub is used, refer to Fig. 5 and proceed as follows:
   a. Align the bolt holes in the drive hub with the tapped holes in the camshaft gear. Then secure the drive hub to the gear with four shoulder bolts. Tighten the bolts to 45–50 lb–ft (61–68 Nm) torque.
   b Use a dial indicator to check the runout of the drive hub shaft. The runout must be within .010" total indicator reading.

c. Coat the retainer bore with sealant and press a new oil seal in place. The lip of the seal must face the engine when the retainer is installed.

d. Affix a new gasket to the mounting flange of the retainer. Then place the retainer against the flywheel housing and install the five attaching bolts and lock washers. Before tightening the bolts, insert tool J 21166 over the shaft and into the retainer bore to align the oil seal with the shaft. Tighten the retainer bolts to 30–35 lb–ft (41–47 Nm) torque and remove the oil seal aligning tool.

e. Install the key in the drive hub. Then start the pulley on the drive hub and tap it into place. Install the plain washer, lock washer and bolt. Tighten the bolt to 35 lb–ft (47 Nm) torque.

f. Slip the drive belt over the pulleys. Then position the accessory to provide the proper tension on the belt and secure it in place.

NOTICE: When installing or adjusting accessory drive belts, be sure the bolt at the accessory adjusting pivot point is properly tightened, as well as the bolt in the adjusting slot (refer to Section 15.1).

5. If a step–up gear is used, refer to Fig. 6 and proceed as follows:

a. Affix a new gasket to the figure "8" adaptor, them position the adaptor on the flywheel housing using a feeler gage or other means of centering on the camshaft gear.

b. Install and tighten the four upper adaptor bolts. Adjust the two set screws until they are snug against the flywheel housing.

c. Place alignment gage J 29893 in the step–up gear and secure it with the gage read point at the 8 o'clock set screw position.

d. Set the dial indicator on "0".

e. Bar the engine over. The gage must travel clockwise until the read point is at the 2 o'clock position set screw (180°).

NOTICE: The barring operation should always be performed in a clockwise direction. It is very important to make certain that the crankshaft end bolt has not been loosened during the barring operation. Serious engine damage may result if the vibration damper or pulley is not securely fastened to the crankshaft.

f. If the dial indicator reads between the initial "0" setting and ±.002", go to step j.

g. If the dial indicator reads more than ± .002" from the initial setting of "0", loosen the four upper adaptor bolts. Then back off the set screws on the adaptor, and readjust them until the dial indicator reading is one–half of the total variance.

h. Repeat steps c, d, e, f and g until the proper readings are obtained or a maximum of three attempts.

i. If the proper alignment readings cannot be obtained after three attempts, change the adaptor and repeat steps a through h.

j. Remove the alignment gage.

Make sure the alternator is properly fitted to the adaptor before it is bolted in place. Improper installation of the alternator can disturb adaptor alignment and cause gear train damage.

6. If the flywheel housing small hole covers were removed, install them as outlined in Section 1.5.

REAR ACCESSORY DRIVE (Blower Drive)

Whenever an accessory is to be driven by the blower drive gear, a hub with two lugs replaces the standard hub in the blower drive assembly (Fig. 7). An accessory drive assembly consisting of a pulley, shaft double–row bearing, oil seal and oil seal spacer and a driven hub and a housing is bolted to the flywheel housing.

A slotted coupling, which engages the lugs on the two hubs, provides the connection between the accessory drive and the blower drive gear.

Remove Accessory Drive

1. Loosen the alternator adjusting strap and alternator mounting bolts. Remove the drive belts.

2. Remove the bolts and lock washers and carefully withdraw the accessory drive assembly and the drive coupling.

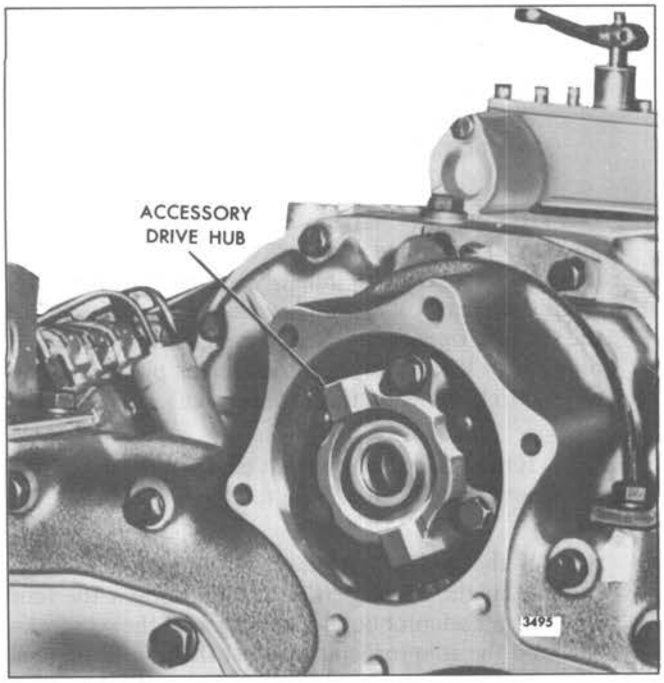


Fig. 7 – Accessory Drive Attached to Blower Drive Gear

3. Remove the blower drive shaft retaining ring. Then thread a No. 10–32 screw in the tapped hole and withdraw the blower drive shaft. Remove the screw used to withdraw the shaft.

4. Remove the three bolts and lock washers and withdraw the drive hub and two drive plates.

5. Disassemble the accessory drive as follows:

   a. Remove the pulley retaining nut. Then remove the pulley and the retaining key. Remove the oil seal spacer.

   b. Press the shaft and hub from the bearing.

   c. Press the shaft from the hub and remove the key from the shaft.

   d. Remove the lock ring and bearing from the housing.

   e. Press the oil seal from the housing with a suitable tool.

Inspection

Wash all of the parts, except the bearing, with fuel oil and dry them with compressed air.

CAUTION:To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.

A shielded type bearing should not be washed because of the difficulty in draining out all of the solvent.

Inspect the bearing for rough spots by holding the inner race and revolving the outer race slowly by hand. Any indication of rough spots is sufficient cause for rejection of a bearing.

Replace excessively worn or damaged parts.

Assemble Accessory Drive

1. Install a key in the hub end of the shaft. Lubricate the shaft and press the hub tight against the shoulder on the shaft.

2. Install a new oil seal in the housing.

3. Install the bearing in the housing. Install the lock ring.

4. Use a sleeve to support the inner race of the bearing, lubricate the shaft and press the hub and shaft assembly in the bearing until the shoulder on the shaft contacts the inner race of the bearing.

5. Install a key in the pulley end of the shaft. Lubricate the shaft and press the pulley on the shaft until it contacts the inner race of the oil seal spacer.

6. Install the 3/4"–16 pulley retaining nut and tighten it to 120–140 lb–ft (163–190 Nm) torque.

Install Accessory Drive

1. Install the drive hub and the two drive plates on the blower drive gear.

2. Install the blower drive shaft and secure it in place with the snap ring.

3. Place a new gasket on the mounting flange of the accessory drive housing.

4. Place the slotted drive coupling on the hub of the accessory drive assembly. Then align the slots in the coupling with the lugs on the drive hub which is attached to the blower drive gear and carefully position the accessory drive against the flywheel housing. Secure the accessory drive assembly to the flywheel housing with bolts and lock washers.

5. Place the drive belts over the pulleys and adjust the tension on the belts. Then tighten the accessory mounting bolts.

6. If the flywheel housing small hole covers were removed, install them as outlined in Section 1.5.

REAR LEFT BANK ACCESSORY DRIVE

When required, an accessory drive gear is provided in the left–bank accessory pad in the flywheel housing as shown in Fig. 8. The accessory drive assembly is similar to the blower drive gear and support assembly. The accessory drive gear, mounted on a support which is attached to the cylinder block rear end plate, is driven by the left–bank camshaft gear. The bushing–type bearings in the gear are pressure lubricated through an external oil line.

Remove Accessory Drive

1. Remove the bolts and lock washers securing the hydraulic pump to the flywheel housing. Then withdraw the pump and gasket.
2. Remove the pump drive coupling.
3. Remove the three bolts and lock washers securing the accessory drive hub to the accessory drive gear. Then withdraw the drive hub.

Disassemble Accessory Drive

If further disassembly is required, the flywheel housing, gear train, accessory drive lubrication tube and cylinder block rear end plate must first be removed. Then proceed as follows:

1. Remove the two bolts and copper washers securing the accessory drive support assembly to the rear end plate. Then withdraw the support assembly and remove the gasket.
2. Clamp the support assembly in a vise equipped with soft jaws.
3. Straighten the lugs on the lock washer and remove the gear retaining nut. Withdraw the lock washer, thrust washer, thrust bearings and accessory drive gear from the support.

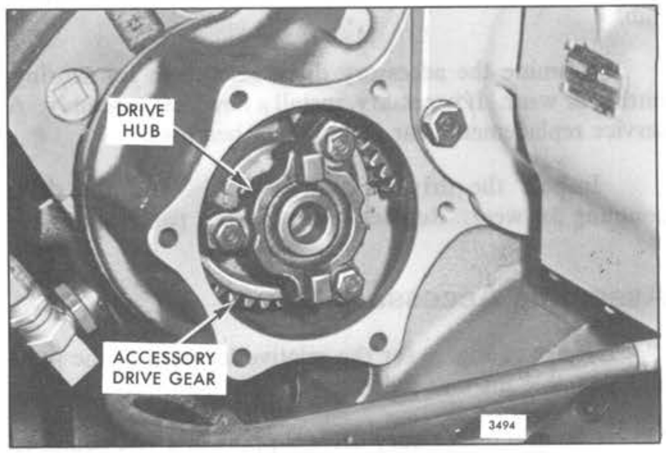


Fig. 8 – Rear Left Bank Accessory Drive Mounting

Inspection

Clean the parts with fuel oil and dry them with compressed air. Make sure the oil passage in the gear support is clean.

Replace the thrust bearings and thrust washer if they are worn excessively or scored.

Check the inside diameter of the accessory drive gear bearings (bushing type) and the outside diameter of the hub on the gear support. The clearance between the bearings and the support hub is .001" to .0025" with new parts. Replace the parts when the clearance exceeds .005" on used parts.

If new bearings are installed, the outer end of each bearing must be pressed in flush to .010" below the face of the gear. The bearings must be reamed to size (1.6260" to 1.6265" inside diameter) and to a finish of 20 microinches after installation. The bearing bores must also be square with the machined faces of the bolt bosses on the gear within .003" total indicator reading and concentric with the outside diameter of the gear.

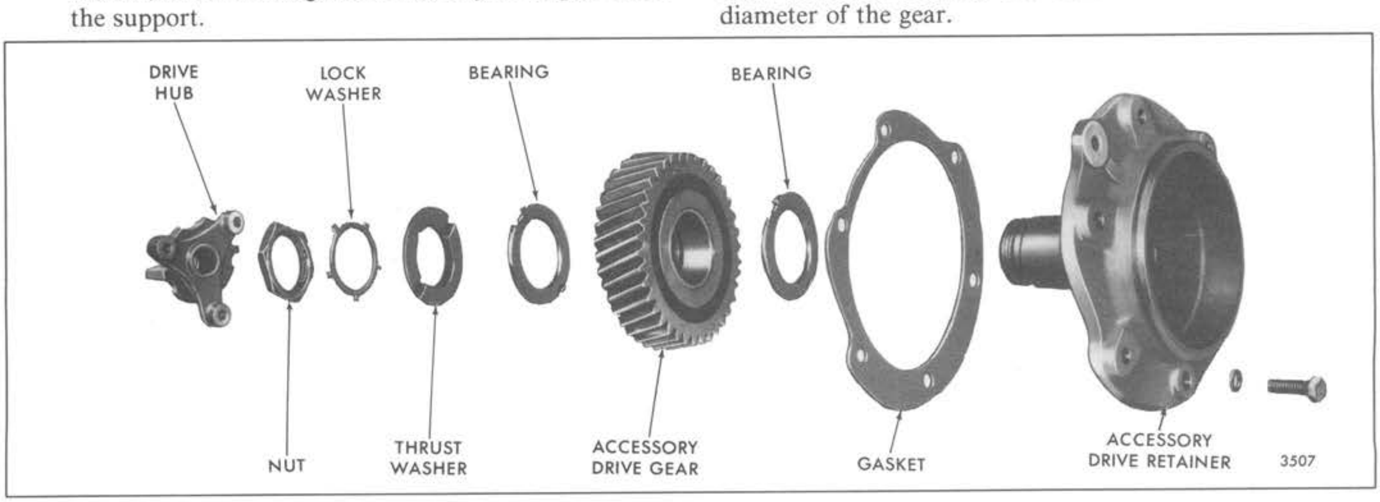


Fig. 9 – Accessory Drive Details and Relative Location of Parts

The thrust washer retaining pin must extend approximately .080" above the threaded end of the support hub.

Examine the accessory drive gear teeth for scoring, pitting or wear. If necessary, install a new gear assembly. A service replacement gear includes the bearings.

Inspect the drive and driven hubs and the drive coupling for wear. Replace severely worn parts.

Assemble Accessory Drive

Refer to Fig. 9 for the relative location of the parts and assemble them as follows:

1. Clamp the accessory drive support in a vise equipped with soft jaws. Then install one of the thrust bearings so the tangs on the bearing register with the holes in the support.

2. Lubricate the hub of the support, the bearings in the gear, both thrust bearings and the thrust washer with clean engine oil.

3. Slide the gear on the hub, with the flat side of the gear toward the support.

4. Install the second thrust bearing on the support, with the tangs on the bearing facing away from the gear.

5. Install the thrust washer so the slots in the washer register with the tangs on the thrust bearing and the pin in the support hub registers with the slot in the bore of the washer.

   NOTICE: The new thrust washer with two I.D. keyways and the new locking washer with a longer tang must be used together for optimum nut locking performance.

6. Secure the gear, thrust bearings and thrust washer with a lock washer and nut. Tighten the nut to 50–60 lb–ft (68–81 Nm) torque and bend the lugs on the lock washer against the flats on the nut.

7. Check the clearance between the thrust washer and the thrust bearing with a feeler gage. This clearance must not exceed .012" with used parts. With new parts, the specified clearance is .005" to .010".

8. Affix a new gasket to the accessory drive support. Then attach the accessory drive gear and support assembly to the cylinder block rear end plate with two bolts and copper washers. Tighten the bolts to 25–30 lb–ft (34–41 Nm) torque.

9. Install the rear end plate and gear train.

10. Check the backlash between the accessory drive gear and the camshaft gear. The backlash must be between .002" and .008" with new gears and must not exceed .010" with worn gears.

11. Install the flywheel housing.

12. Install the accessory drive lubrication tube.

Install Accessory Drive

1. Position the drive hub on the accessory drive gear and secure it with three bolts and lock washers.

2. Affix a new gasket to the mounting flange on the hydraulic pump.

3. Place the slotted drive coupling on the pump driven hub. Align the slots in the coupling with the lugs on the drive hub and carefully position the pump against the flywheel housing. Secure the pump to the flywheel housing with bolts and lock washers.

4. If the flywheel housing small hole covers were removed, install them as outlined in Section 1.5.

BALANCE WEIGHT COVER

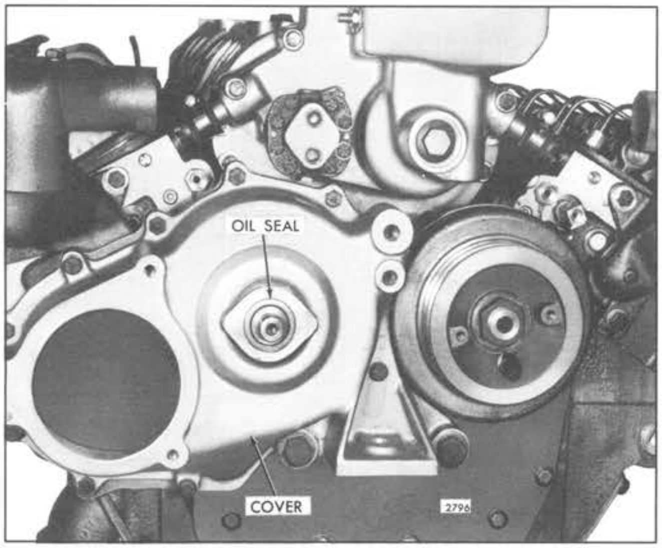


Fig. 1 – Balance Weight Cover Mounting

The balance weight cover (Fig. 1) encloses the combination balance weight and water pump drive gear on the front end of the right cylinder bank camshaft. This cover also serves as a support for the water pump.

The balance weight cover requires no servicing. However, when an engine is being completely reconditioned, or the right bank camshaft, camshaft bearings or water pump drive gear need replacing, the balance weight cover must be removed.

Remove Cover

1. Drain the cooling system.
2. Remove the water pump and any other parts required to permit removal of the balance weight cover.
3. Remove the bolts, washers and lock washers which secure the balance weight cover to the front end plate and the cylinder block.
4. Since the cover is doweled to the end plate, it will be necessary to tap the ends of the cover with a soft hammer to loosen it.
5. Remove all traces of the old gasket material from the cover and the end plate.

Install Cover

1. Affix a new gasket to the balance weight cover.
2. An accessory drive shaft oil seal is pressed into the balance weight cover on some engines (Fig. 1). If necessary, replace the oil seal as follows:
   a. Drive the old oil seal out of the cover.
   b. The new oil seal is plastic coated on the outside diameter for sealing purposes. Do not remove this coating. Position the seal with the sealing lip pointing toward the inner side of the cover.
   c. Drive the seal in with installer J 9791 until it is flush with the outer surface of the cover.
   d. Coat the lip of the seal with grease.
3. Install the balance weight cover on the engine and secure it with bolts, nuts, lock washers and plain washers. Tighten the 3/8"–16 bolts to 30–35 lb-ft (41–47N•m) torque, 3/8"–24 bolts and nuts to 35–39 lb-ft (47–53 N•m) torque, 1/2"–13 bolts to 71–75 lb-ft (96–102 N•m) torque and the 5/8"–11 bolts to 137–147 lb-ft (186–200 N•m) torque.
4. Install the water pump and any other parts that were removed.
5. Fill the cooling system.

SHOP NOTES - TROUBLESHOOTING SPECIFICATIONS - SERVICE TOOLS

SHOP NOTES

CYLINDER BLOCK LINE BORING

To repair the main bearing saddles in a cylinder block which has been damaged by spun main bearings, it is necessary to machine the damaged saddle to accept an insert. The insert and a new unfinished main bearing service cap are then line bored to the proper diminsions to accept standard main bearing shells.

The line bore operation is an acceptable warranty procedure.

Instructions for using the cylinder block line boring tool J 29005 are listed below:

> The use of this tool is dependent upon the existence of two or more undamaged main bearing saddles, one of which *must* be the rear main saddle. The cylinder block assembly of 12 and 16 cylinder engines must be separated and each "half-block" line bored separately. If line boring is to be accomplished in a suitably equipped machine shop, refer to the information in *Dimensions for Machine Shop Line Boring Cylinder Block*.

1. Remove all the plugs and main bearing caps and clean the useable cylinder block.
2. Determine which two undamaged main bearing saddles are to be used as alignment locations. Since the rear main bearing saddle cannot be repaired with this tool set, it *must* be one of the undamaged saddles. These saddles should be as far apart as possible.

In a block where the front and rear main bearing cap and saddle are serviceable, the journals in between can be repaired successively without removal of the centering rings from the front and rear positions. In the case where the only good main bearing bores are next to each other, the centering rings will have to be mounted there and marked for indexing. The closest bore will then be repaired first. The rear centering ring will remain in position and the other centering ring will be moved into the just repaired saddle so that the next damaged saddle can be repaired. The centering ring being moved should be indexed the same when moved from saddle to saddle.

3. Set the centering rings (4.8125") into the alignment saddles and install the main bearing caps. Do not tighten the bolts.
4. Slide the boring bar through the centering rings. Lubricate the ring hole with clean engine oil during installation. The bar should rotate freely (Fig. 1). Tighten the mmain bearing cap bolts on the caps holding the centering rings to the torque specified, 230–240 lb-ft (312–325 N•m). If the centering rings are loose in the saddle after tightening the bolts, use .001" paper shims, as necessary, between the ring and the main bearing cap and between the ring and the block.

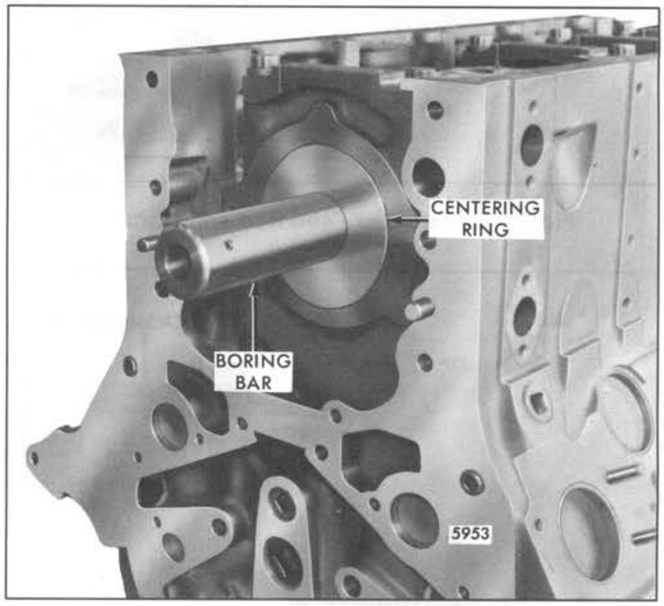


Fig. 1 – Location of Boring Bar

5. Install the caps on all the remaining saddles, except the saddle to be machined, and tighten the bolts hand tight. Install the insert hold-down bolts into the bolt holes of the saddle to be machined. Do not tighten the bolts. This is only to keep chips out of the bolt holes.
6. Fasten the torsion bar and the hydraulic feed unit on either end of the cylinder block. Index the flat on the feed rod into the boring bar. Snug the set screw (Fig. 2).
7. Zero the micrometer with the test block supplied (Fig. 3). The micrometer is .050" per revolution, not .025" as normally seen on micrometers.
8. Install the cutting tool holder on the micrometer test fixture. Use only the straight Allen wrench supplied in the kit. Set the cutting tool for the first cut of .040" (Fig. 4). The point of the cutting tool should be in the center of the micrometer barrel.
9. Install the cutting tool on the boring bar. Excessive tightening of the Allen head screws is not required.

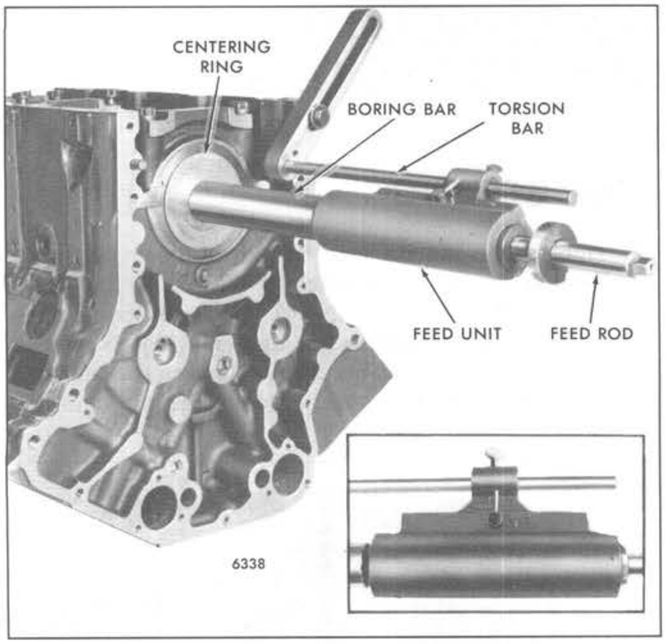


Fig. 2 – Location of Feed Rod and Unite

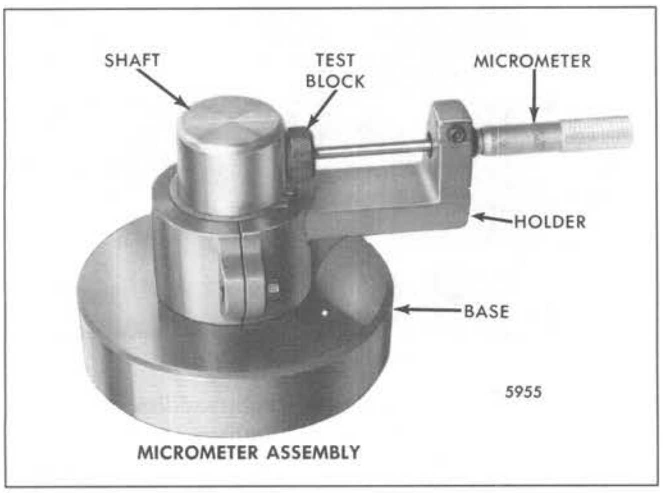


Fig. 3 – Test Fixture and Micrometer

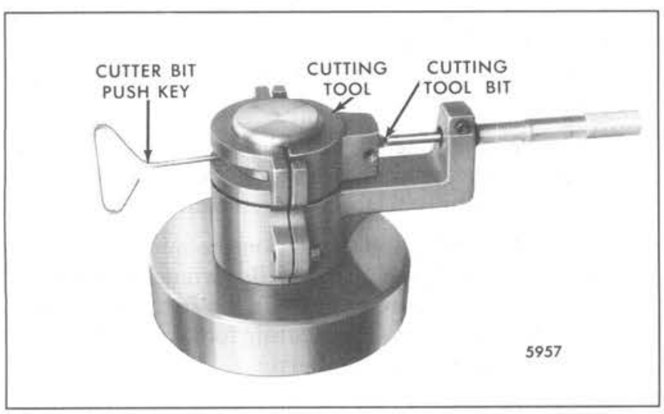


Fig. 4 – Installing Cutting Tool Holder

EXAMPLE:

	Block	Insert/cap
Bore diameter	4.812″	4.712″
First cut	+.040″	+.040″
Set tool	4.852″	4.752″
Second cut	+.040″	+.040″
Set tool	4.892″	4.792″
Final cut	+.020″	+.020″
Final dimension	4.912″/4.913″	4.812″/4.813″

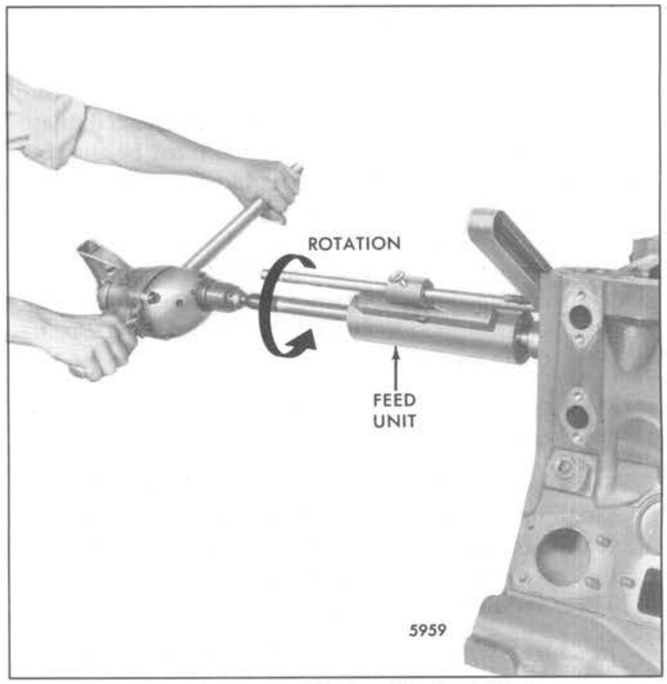


Fig. 5 – Use of Hydraulic Feed Unit

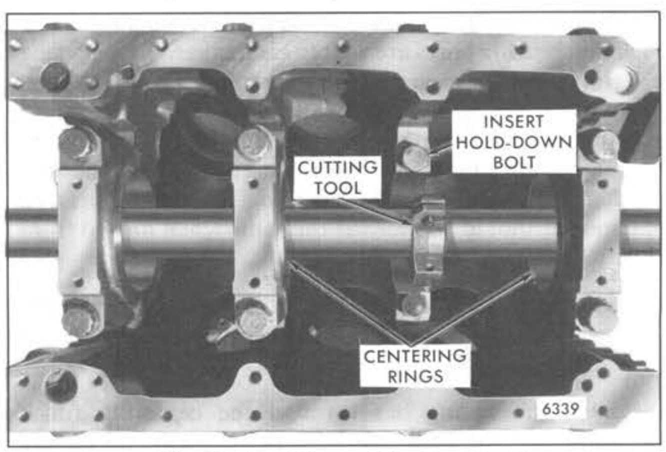


Fig. 6 – Position of Cutting Tool

The tool feeds away from the operator and rotates clockwise as viewed by the operator (Fig. 5). When installing the cutter, be sure the sharp portion of the bit is in the cutting position (Fig. 6).

10. Lubricate the boring bar at the centering rings with clean engine oil before each cut.

11. Use a 1/2" drill motor of 300–400 rpm. Lubricate and install the universal drive in the drill chuck. Move the hydraulic feed unit lever to the "closed" position.

12. Line bore the distressed saddle using the three cuts and the dimensions given in Step 8.

13. If other bores are to be machined, remove the insert hold–down bolts and cover the machined saddle with a new unfinished service line bore cap, tightening the bolts hand tight. Proceed to the next saddle to be machined and repeat the steps beginning with Step 5.

14. Remove the boring bar and clean the reworked saddles.

15. After the saddles have been reworked, inserts must be installed. Install and align the insert with the hold–down bolts and plates provided. Use the plate with a "step" on the side of the insert opposite the tang. The hold–down plates will retain the insert in position. Tighten the hold–down bolts to 20 lb–ft (27 N•m) torque (Fig. 7).

16. Check the insert for alignment and fit.

17. Using a 1/8" drill bit, drill four holes in the saddle 1/4" deep through the four predrilled holes in the insert (Fig. 8).

18. Clean the drilled holes with compressed air and install the rivets.

19. Secure the rivets with a hammer and punch. Be careful not to strike the insert directly, as the insert will distort. Two or three blows on the punch are usually sufficient to secure the rivet (Fig. 9). Rivets are intended for locating more than retention. The bearing and cap provide retention of the insert.

20. File off the excess rivet material (Fig. 10).

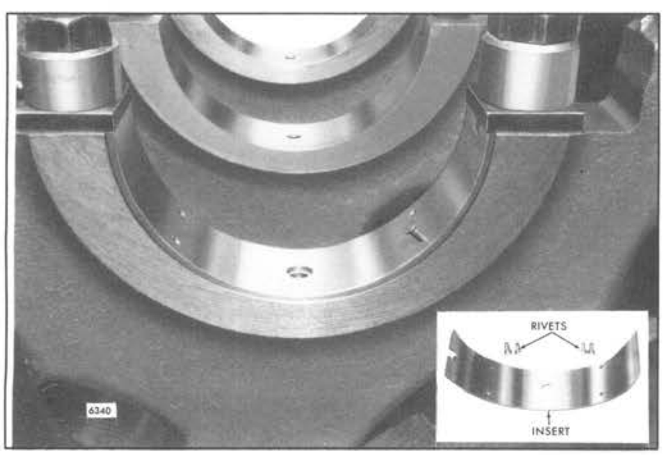


Fig. 7 – Position of Bushing and Hold Down Plate

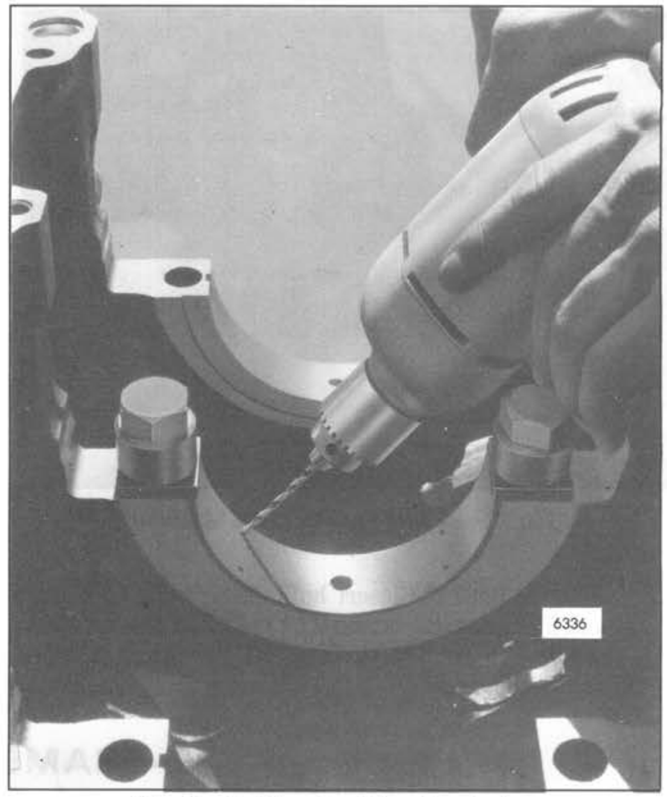


Fig. 8 – Drilling for Rivet Instllation

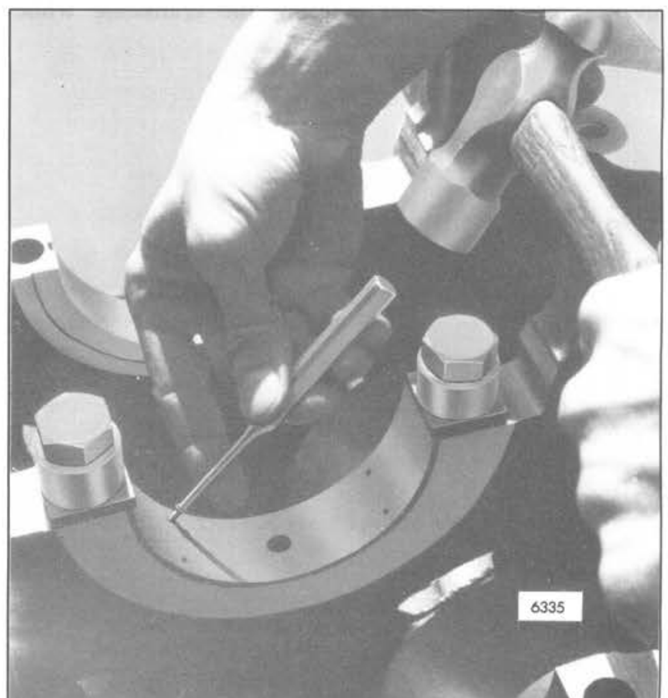


Fig. 9 – Securing the Rivets

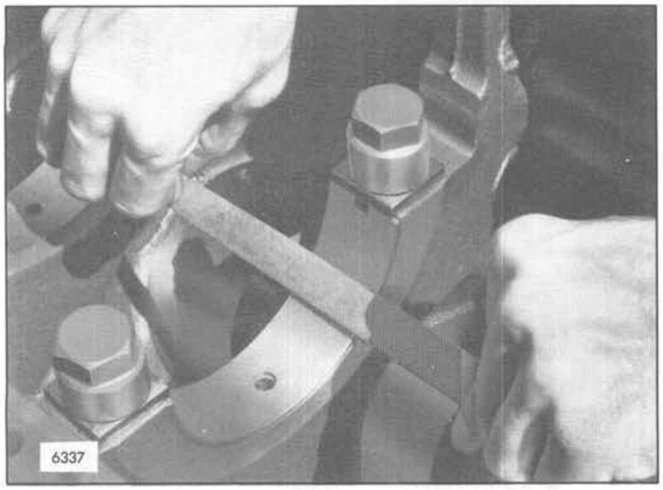


Fig. 10 – Filing Excess Rivet Material

21. Remove both the insert hold–down bolts and plates and file the excess material on the insert flush with the saddle–cap parting surface. If the insert is loose, secure the rivets.

22. Install unfinished service bore caps on all repaired main bearing saddles and tighten the bolts to the specified torque 230–240 lb–ft (312–325 N•m).

23. Line bore the unfinished cap and insert to the standard bore dimension using the previous procedure and dimensions in Step 8.

24. Remove burrs and debris and clean with a spray lubricant.

25. Check the finished bore with the "Go – No–Go" test rings mounted on the boring bar. The "Go" ring should pass through the reworked saddle and cap bore with a slight drag. If centering rings are removed during the line boring operation, mark the ring and saddle to insure proper installation alignment.

If the cylinder block is line bored properly, there will be no more than .001" overall misalignment from one end of the block to the other or no more than .0005" between adjacent bores.

26. Clean the cylinder block, reinstall the plugs and proceed with the rebuild.

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.

DIMENSIONS FOR MACHINE SHOP LINE BORING CYLINDER BLOCK

If the criteria for the use of Tool J 29005 (two undamaged main bearing saddles, one of which must be the rear main saddle) cannot be met, or if it is desired to salvage the cylinder block by line boring in a suitably equipped machine shop. There are critical dimensions which must be maintained.

1. The cylinder block assembly of 12 and 16 cylinder engines must be separated and each "half-block" line bored separately.
2. Remove all plugs and main bearing caps and clean the cylinder block.
3. The surface from which all critical dimensions are measured for line boring are the reamed locating holes (.937"–.938" in Dia.) at each end of the left bank pan rail looking from the gear train end of the cylinder block (Fig. 11). The center line of the crankshaft is 4.999"–5.001" in from the center line of the reamed locating holes and 4.748"–4.752" up from the pan rail surface.
4. Machine the main bearing saddle bore(s) to the dimension shown in Table 1 (4.912"–4.913").
5. Install insert(s) in the machined bearing saddles using the procedure outlined for Tool J 29005 beginning with Step 15.
6. Install new unfinished service line bore caps on the machined main bearing saddles and tighten the bolts to the specified torque 230–140 lb-ft (312–325 N•m). Main bearing cap bolts are specially designed and must not be replaced by ordinary bolts.
7. Line bore the installed inserts and unfinished service caps to the standard bore dimensions (Table 1).

Main bearing bore for installation of inserts
4.912 - 4.913
Finished main bearing bore with inserts installed
4.812 - 4.813

TABLE 1

8. The straightness of the finished bore must not vary more than .001" from end to end in the cylinder block or more than .0005" between adjacent bores.
9. Clean the cylinder block and reinstall the plugs.
10. Check and assemble the line bored block(s) and proceed with the rebuild.

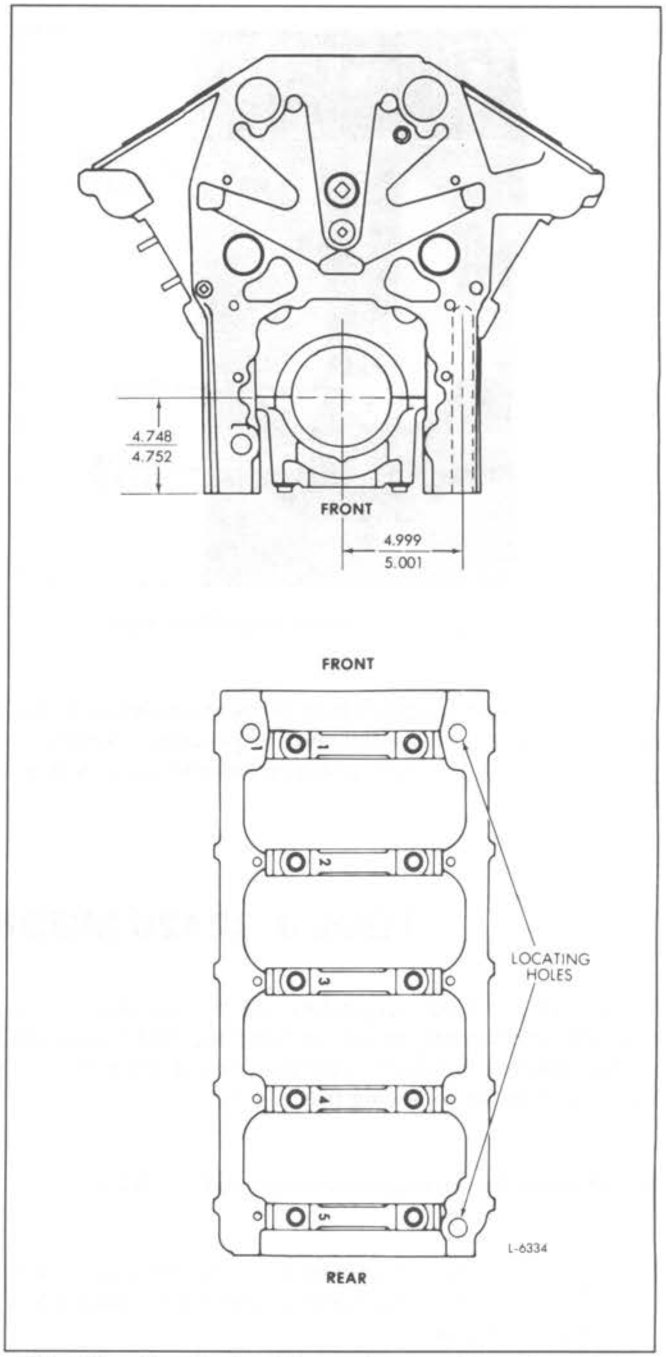


Fig. 11 – Line Boring Dimensions and Locating Holes

REPLACING CYLINDER HEAD BOLT HOLE PLUG

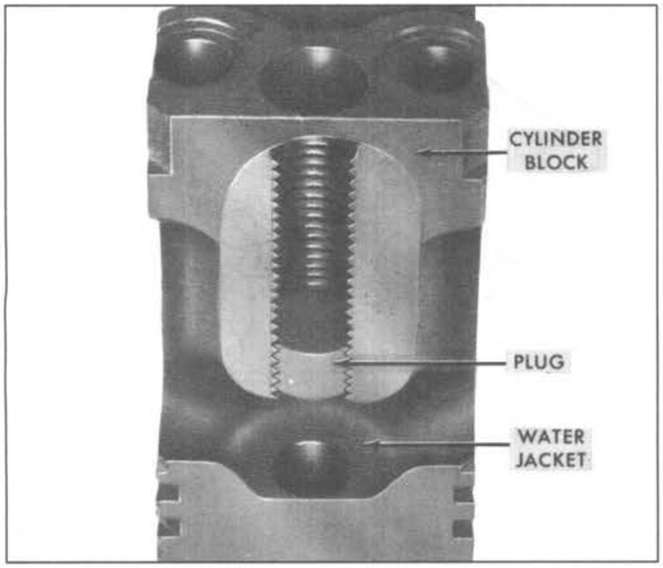


Fig. 12 – Location of Cylinder Head Bolt Hole Plug

The cylinder head bolt hole plugs are designed to seal the head bolt holes from the coolant passages. Replace a cylinder head bolt hole plug in the cylinder block, as follows (Fig. 12):

1. Remove the old plug and clean the threads of all old sealant by running bottom tap J 25384 down the hole. The threads must be clean and dry before applying sealant.

2. Apply a sufficient quantity of Loctite 290 Sealant, or equivalent, to the threads in the block at the minimum depth of the stud plug (1.980"), as well as to the plug itself. *Some commonly used pipe sealants have been found to be ineffective for this application.* Screw the plug in until the top of the plug is 1.980" minimum to 2.070" maximum below the block surface for bolt clearance. Do not apply any sealant to the top of the plug after installation. Allow the sealant to set for twelve (12) hours and pressure check for five (5) minutes at 40 psi (276 kPa).

3. Remove excess Loctite from the bolt hole threads by running an 11/16" bottom tap until it bottoms on the plug. Run the tap in by hand. *Power equipment (impact gun, etc.) should not be used as they may cause the tap to disturb the Loctite seal.*

Inspect the bolt hole for debris before and after these operations.

TOOL J 22425 MODIFICATION PROCEDURE

Existing J 22425 expanders can be reworked to the revised expander configuration by removing the O–rings and carefully drilling the guide stud holes to a depth of 1–3/4" (Fig. 13). Use the following procedure:

1. Remove the O–rings from expander J 22425.

2. Loosely clamp the expander on the table of a drill press. Make sure that the expander is not clamped in a crooked fashion.

   NOTICE: Expander J 22425 is made of hard plastic. To avoid damage, do not exert too much pressure on it during the clamping operation.

3. Install a 19/32" drill bit into the chuck of the drill press. Be sure that the cutting edges of the drill bit are free from burrs. Set the required depth on the depth gage of the drill press.

4. Insert the drill bit into one of the expander guide stud holes and operate the drill press at a very slow speed (75–100 rpm) to center the drill in the existing 19/32" hole. Tighten the clamp.

5. Slowly deepen the guide stud hole from 3/4" to 1–3/4". Drill at 75–100 rpm to keep from drilling too deep.

6. Repeat Steps 4 and 5 for the other guide stud hole.

7. Remove the expander from the drill press and completely wash all cuttings from it with clean mineral spirits. Dry with compressed air.

   CAUTION: Do not exceed 20 psi (138 kPa) air pressure. Wear adequate eye protection to avoid personal injury.

8. With an electric engraving pencil, reidentify the reworked expander to read "J 22425–A Modified". Cross out the former tool number "J 22425".

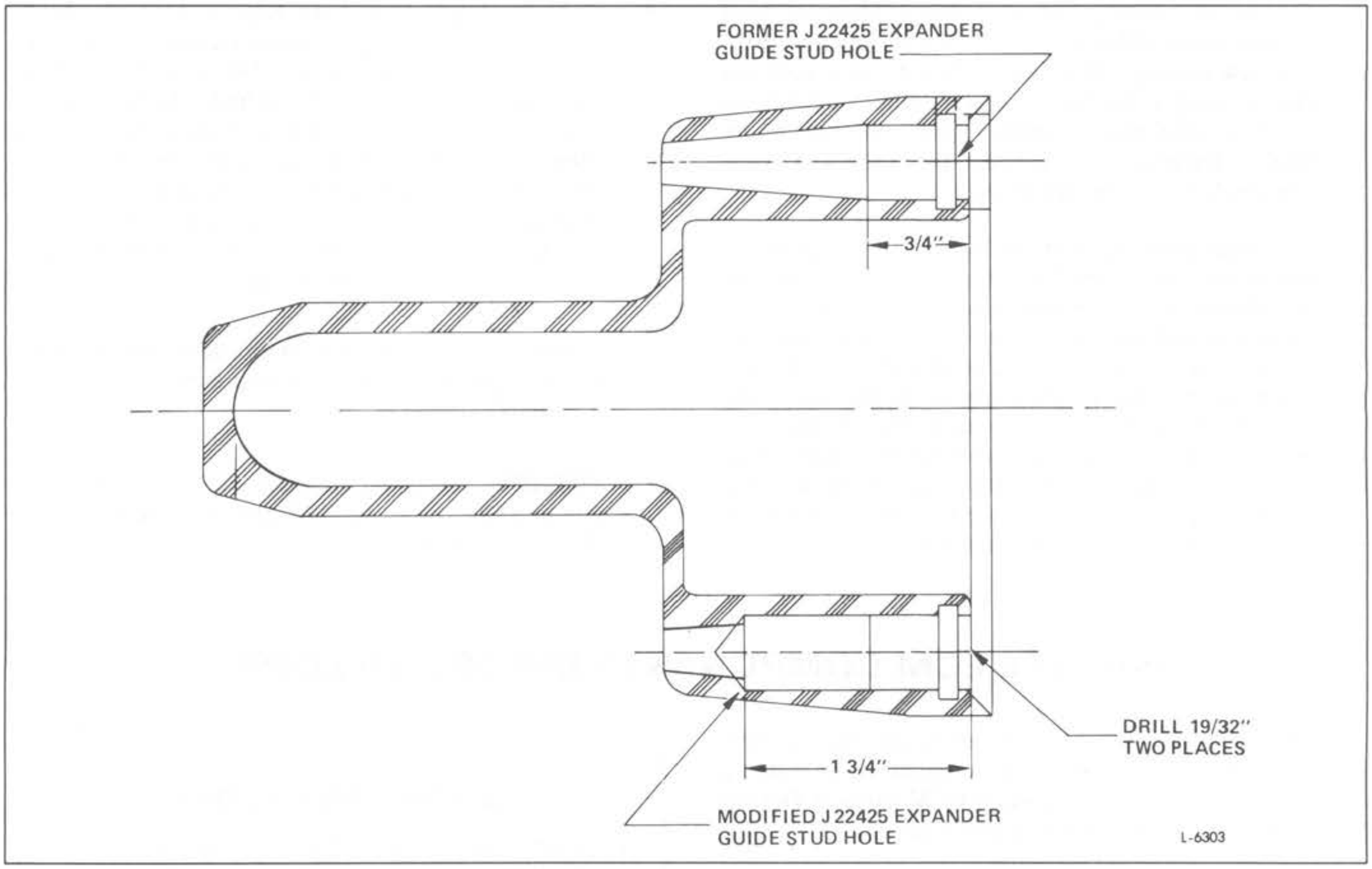


Fig. 13 – Comparison of Original and Reworked Expander J 22425

WELDING ENGINE CYLINDER HEADS

The welding of cylinder heads has been used as a salvage procedure for several years. As a salvage procedure, the resultant product has not been considered as good as a new casting. The use of this procedure has cause some concern because of the differences in what has been called a welded cylinder head.

Detroit Diesel Corporation's position of the use of welded cylinder heads has been requested from several areas in the past. It is important to note that no data of statistical significance has been made available by welders or end users. Based on the inquiries received and the amount of cylinder heads being welded in the field, Detroit Diesel Corporation has investigated the methods of the welding and resultant integrity of welded heads as compared to new cylinder heads used on Detroit Diesel engines. Since the procedure used when welding, subsequent machining and the rebuild methods of the cylinder head may result in unacceptable service life, there should be no implied approval of any welding source or welded components.

The following is Detroit Diesel Corporation's position on various aspects related to welded cylinder heads.

1. Welding is considered the process of elevating the original cylinder head casting to approximately 1100°F or 593°C (a temperature that is at least equivalent to stress relieving) and the addition of alloyed cast iron welding rod to the crack area while in the molten state. Low temperature, low voltage welding is considered a cosmetic salvage and should never be accepted as a structural repair.

2. Mechanical plugging is a salvage procedure that usually results in excessive installation stresses at the repaired area and should never be confused with or accepted as equivalent to welding. This procedure should not be used on cylinder heads.

3. If properly performed, welding of a cylinder head may be a salvage procedure *if the welding is done outside of the fire circle*. Service life of a welded cylinder head, however, will not be equivalent to a new casting even if the fire circle area of the original casting has not been welded. A cracked casting is usually the result of an overheat and the casting may be damaged in areas other than the visible crack.

4. Comparative testing indicated that welding inside of the fire circle will result in a service life less than 50% of a new casting. This has resulted in the conclusion that welding in the fire circle should not be done. In order to eliminate potential future malfunctions on Detroit Diesel engines, cylinder heads cracked in the fire–circle should be destroyed.

5. Updating Series 92 cylinder heads of the large water nozzle style to the small water nozzle style is desirable if a plug of the same material is used and the cylinder head, plug and welding rod are heated to a molten state to insure adequate fusion and complete penetration of the weld through the thickness of the fire deck. The plug should not be inserted with a press fit since this would cause stresses that could cause the cylinder head to crack later. Use care to insure that the small water nozzle hole has been drilled on the same centerline as the previous large water nozzle hole.

6. Cylinder heads that have been welded should be checked for acceptability using Sections 1.2 through 1.2.2 of the Service Manual. This includes checking for cracks, thickness of the cylinder head, warpage, camshaft follower clearance and the press fit of all other components. Various conditions have been found with welded cylinder heads that could cause malfunctions of secondary components if these are not checked. If any discrepancy can not be repaired, such as cylinder head thickness, the part should not be used.

7. Components that are used with these cylinder heads should also be checked. Components that are not acceptable should not be used.

NOTICE: Secondary damage to other engine components could result from not checking these components.

ISOLATE ECM COMPONENTS BEFORE WELDING

Damage may occur to ECM (electronic control module) components if they are not isolated before welding is performed on the vehicle. To avoid ECM damage, Detroit Diesel recommends the following precautions:

1. Before welding, completely isolate the DDEC system from the vehicle by disconnecting the power and ground *leads at the battery*. Disconnecting the leads at the battery ensures that the DDEC system will remain isolated, along with any other component susceptible to damage by welding.

2. Instruct personnel involved in vehicle welding that the battery leads *must* be removed before they weld on any vehicle.

3. Apply precautionary labels in highly visible areas such as the battery box cover, dashboard, sun visor, etc. Labels should read:

WELDING PRECAUTION

DISCONNECT BATTERY POWER AND GROUND LEADS BEFORE WELDING. OTHERWISE, DAMAGE TO ELECTRONIC COMPONENTS MAY OCCUR.

NOTICE: Use of this precaution assumes an electronic component ground directly to the battery, as recommended by Detroit Diesel. If grounded otherwise, disconnecting the battery leads will not isolate the ECM system from the chassis ground. In this event, the system may be damaged during the welding procedure.

REUSING CROSSHEAD PISTON ASSEMBLY COMPONENTS

Components of the piston assemblies can, in certain instances, be reused. Undamaged piston pins, crowns and bushings that meet dimensional limits for used parts can be reused if installed within the same piston assembly from which they were removed.

The crown, pin and bushing of a crosshead piston assembly should be considered as matched. If a crown is replaced, the piston pin and bushing must also be replaced. The reason for this is that the bushing takes the shape of the saddle area of the piston dome during engine operation. Installing a used bushing in a new crown can result in uneven piston pin loading and possible piston pin damage. If a bushing needs replacement a new pin must also be used. Conversely, if a new pin is required, the bushing must also be replaced. Before reusing any crosshead piston assembly components, see wear limits in this Section.

CHECKING BEARING CLEARANCES

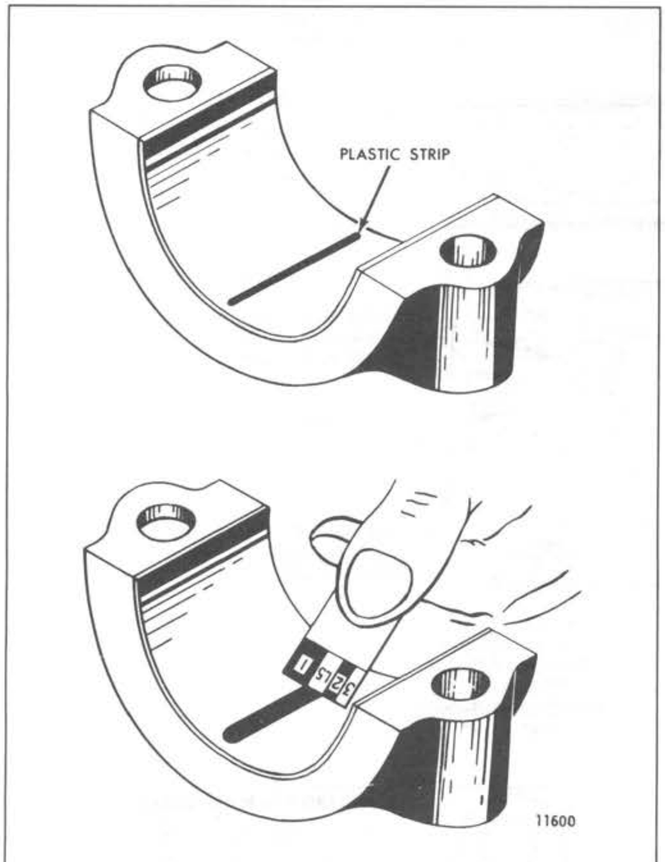


Fig. 14 – Using Plastic Strip to Measure Bearing-to-Crankshaft Clearance

A strip of soft plastic squeezed between the crankshaft journal and the connecting rod bearing or main bearing may be used to measure the bearing clearances.

The strip is a specially molded plastic "wire" manufactured commercially and is available in three sizes and colors. Type PG–1 (green) has a clearance range of .001" to .003", type PR–1 (red) has a range of .002" to .006" and type PB–1 (blue) has a range of .004" to .009".

The plastic strip may be used for checking the bearing clearances as follows:

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

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

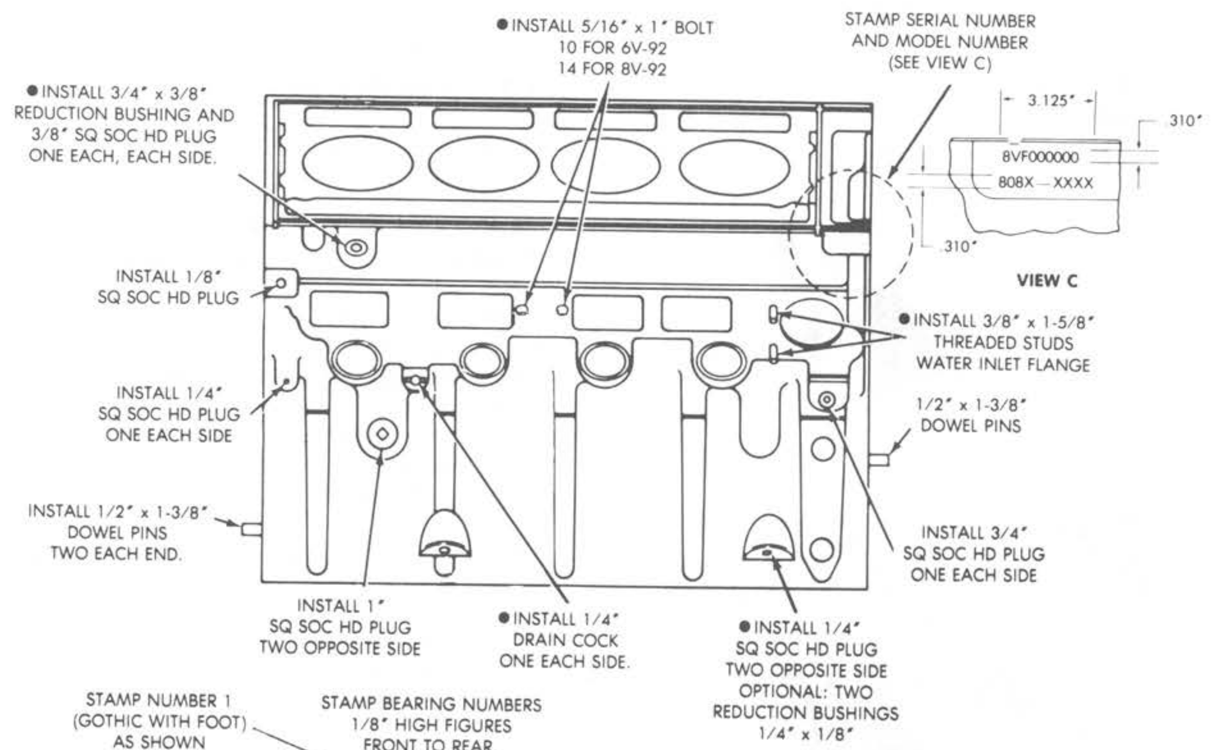
2. Place a piece of the plastic strip the full width of the bearing shell, about 1/4" off center (Fig. 14).

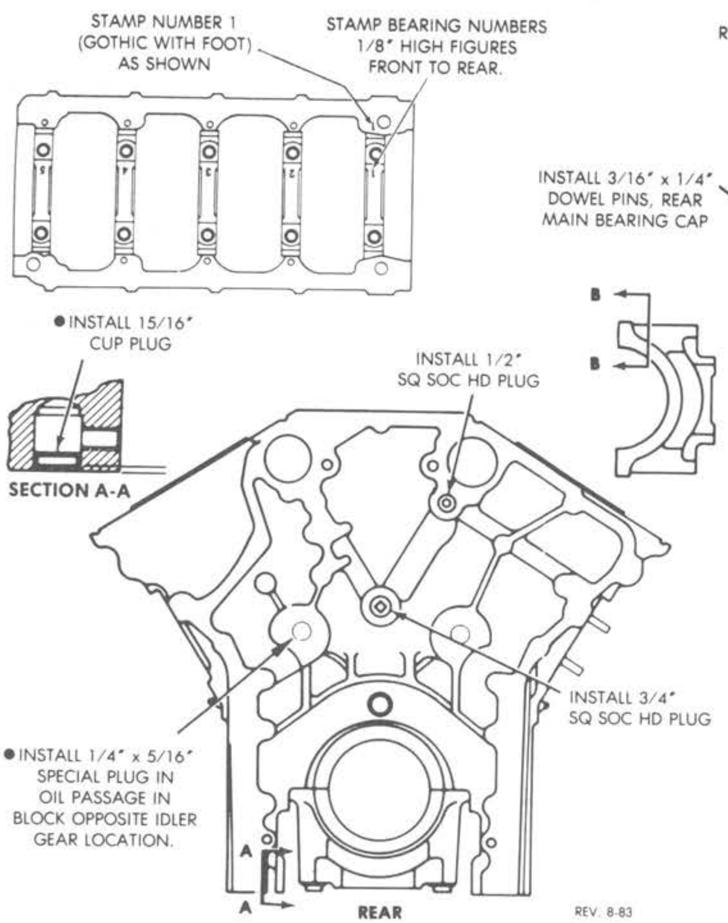
3. Rotate the crankshaft about 30° from bottom dead center and reinstall the bearing cap. Tighten the bolts to the specified torque.

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. 14). 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.

CYLINDER BLOCK PLUGGING INSTRUCTIONS (6V AND 8V ENGINES)





SECTION B-B

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
1	78-85	106-115

● APPLY LOCTITE J 26558-92 PIPE SEALER OR EQUIVALENT PRIOR TO INSTALLATION.

IDENTIFICATION CHART

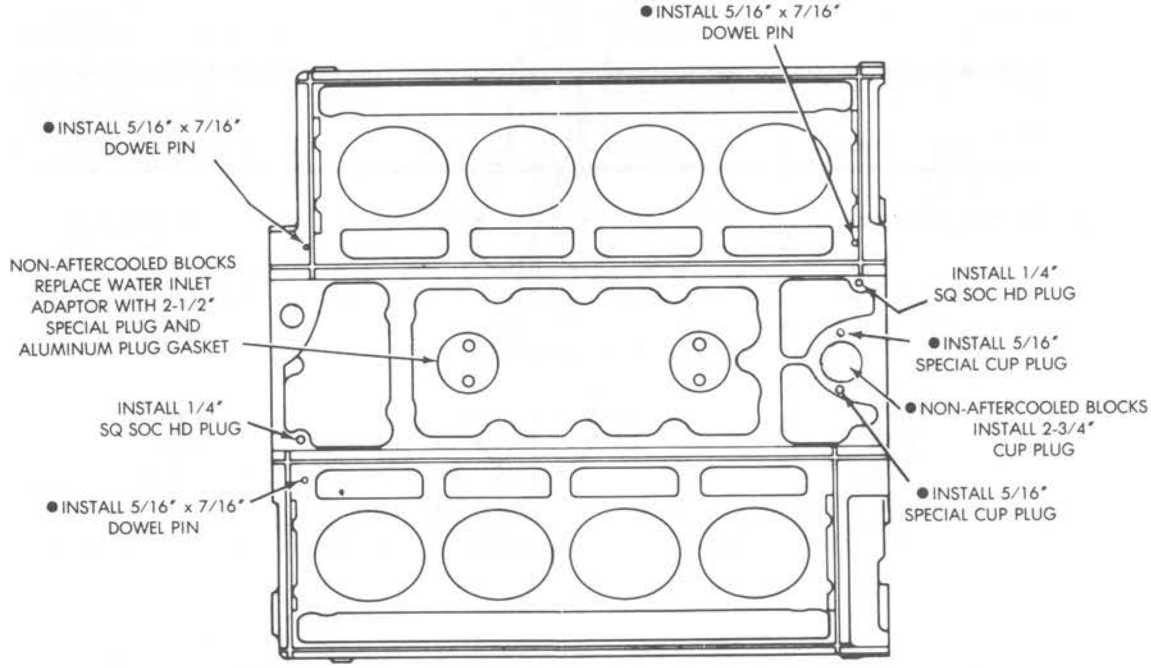
Description	Part No.	Installation**
PIPE PLUGS*		
1/8" Sq Soc Hd Pipe	8924380	
1/4" Sq Soc Hd Pipe	8923847	
3/8" Sq Soc Hd Pipe	8924517	
1/2" Sq Soc Hd Pipe	8923916	
3/4" Sq Soc Hd (Short) Pipe	8923313	Below Surface
1" Sq Soc Hd Pipe	8924750	
OTHER PLUGS		
5/16" Spl Cup	5123862	
15/16" Cup	9428477	To .12" below surface
1" Stnls Steel Cup	5139988	
2 1/2" Spl	5138646	
2 3/4" Spl Cup	5144559	
1/4" x 5/16" Spl	5154319	

*Preapplied sealant

**Install plugs flush to below top of finished surfaces of block except where specific instructions are given.

Description	Part No.	Installation**
OTHER ITEMS		
5/16" x 7/16" Dwl Pin	5103045	Flush with surface
1/2" x 1-3/8" Dwl Pin	5151576	To .630" ± .030 projection
3/16" x 1/4" Dwl Pin	141346	To .115" ± .005 projection
3/8" x 1-5/8" Stud	5150362	To 1.00" ± .030 projection
5/16" x 1" Bolt	8920631	To 1.00" ± .030 projection
1/4" Drain Cock	8924140	
3/8" Drain Cock	118536	
3/4" x 3/8" Red Bush	5146913	
1/4" x 1/8" Red Bush	8924142	
Aluminum Plug Gasket	5138659	

CYLINDER BLOCK PLUGGING INSTRUCTIONS (6V AND 8V 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
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3/4	33-37	45-50
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1" Sq Soc Hd Pipe	8924750	
OTHER PLUGS		
5/16" Spl Cup	5123862	
15/16" Cup	9428477	To .12" below surface
1" Stnls Steel Cup	5139988	
2-1/2" Spl	5138646	
2-3/4" Spl Cup	5144559	
1/4" x 5/16" Spl	5154319	

*Preapplied sealant

**Install plugs flush to below top of finished surfaces of block except where specific instructions are given

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1/4" Drain Cock	8924140	
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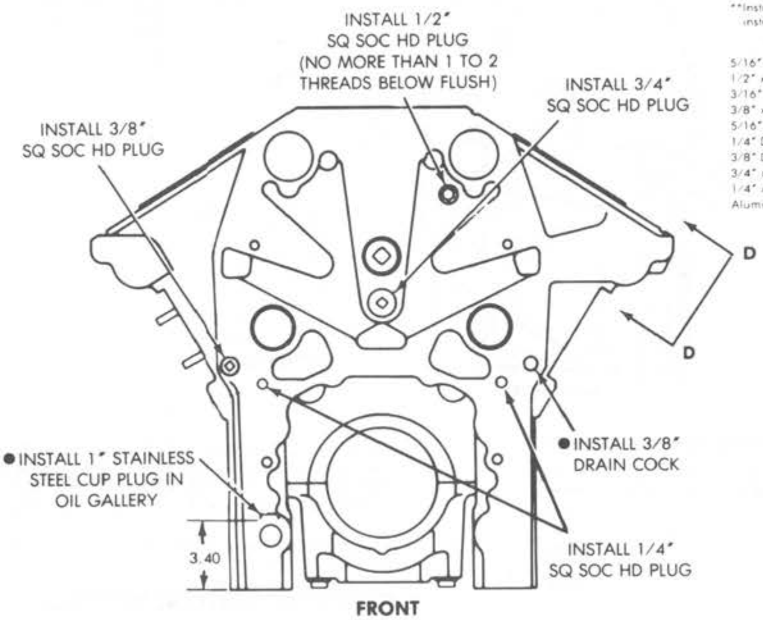
1/4" x 1/8" Red Bush	8924142	
Aluminum Plug Gasket	5138659	

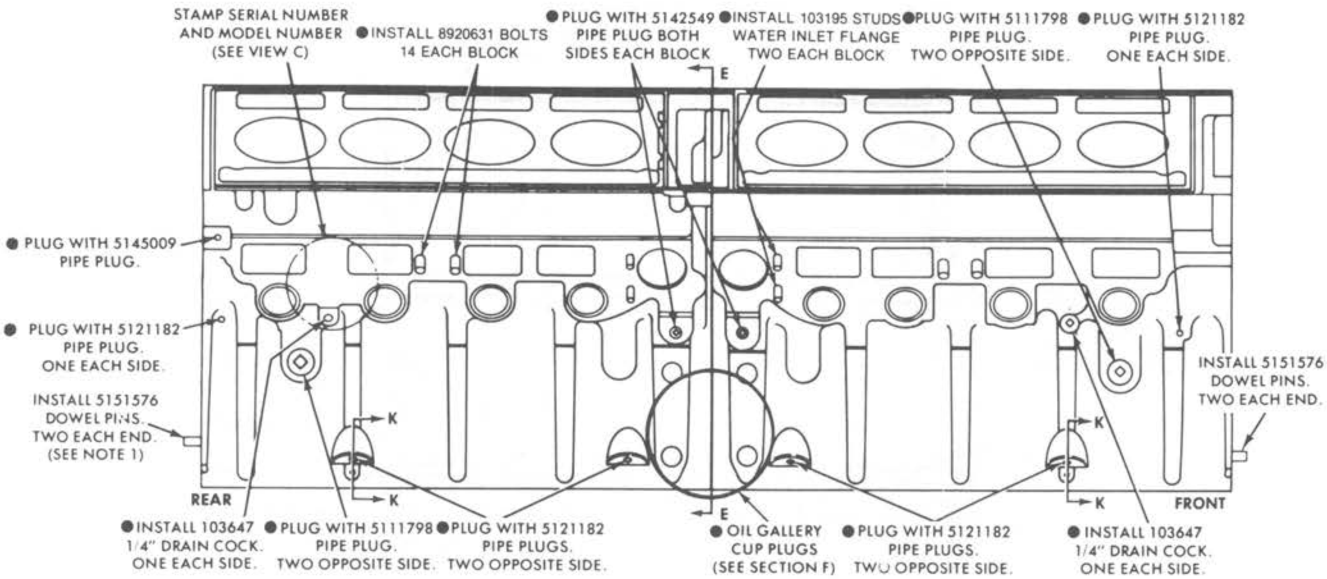


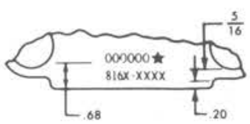
FRONT

SECTION D-D

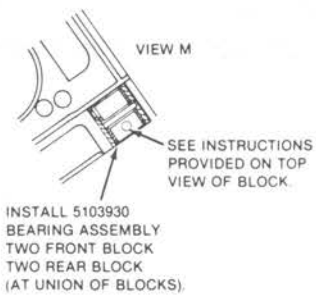
REV. 8-83

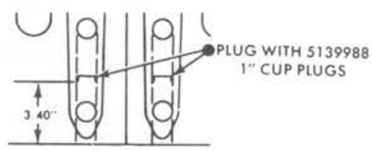
CYLINDER BLOCK PLUGGING INSTRUCTIONS (12V AND 16V ENGINES)



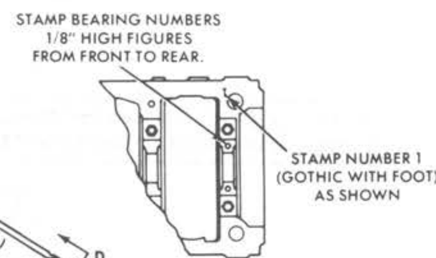


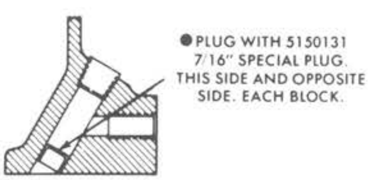
VIEW C



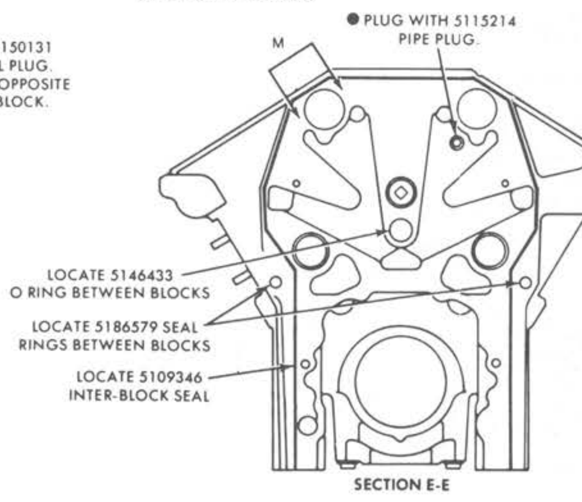


SECTION F

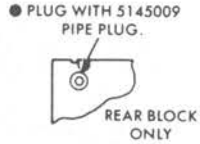




SECTION K-K



SECTION E-E



SECTION D-D

PIPE PLUG IDENTIFICATION CHART

5145009 — 1/8" HEX SOC. HD.
5121182 — 1/4" HEX SOC. HD.
5145014 — 3/8" HEX SOC. HD.
5115214 — 1/2" HEX SOC. HD.
5142549 — 3/4" SHORT SQ. SOC. HD.
5111798 — 1" SQ. SOC. HD.

REV. 1-80

STANARD 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
1	72-85	106-115

CAUTION — Do Not Over Torque Teflon Wrapped Pipe Plugs.

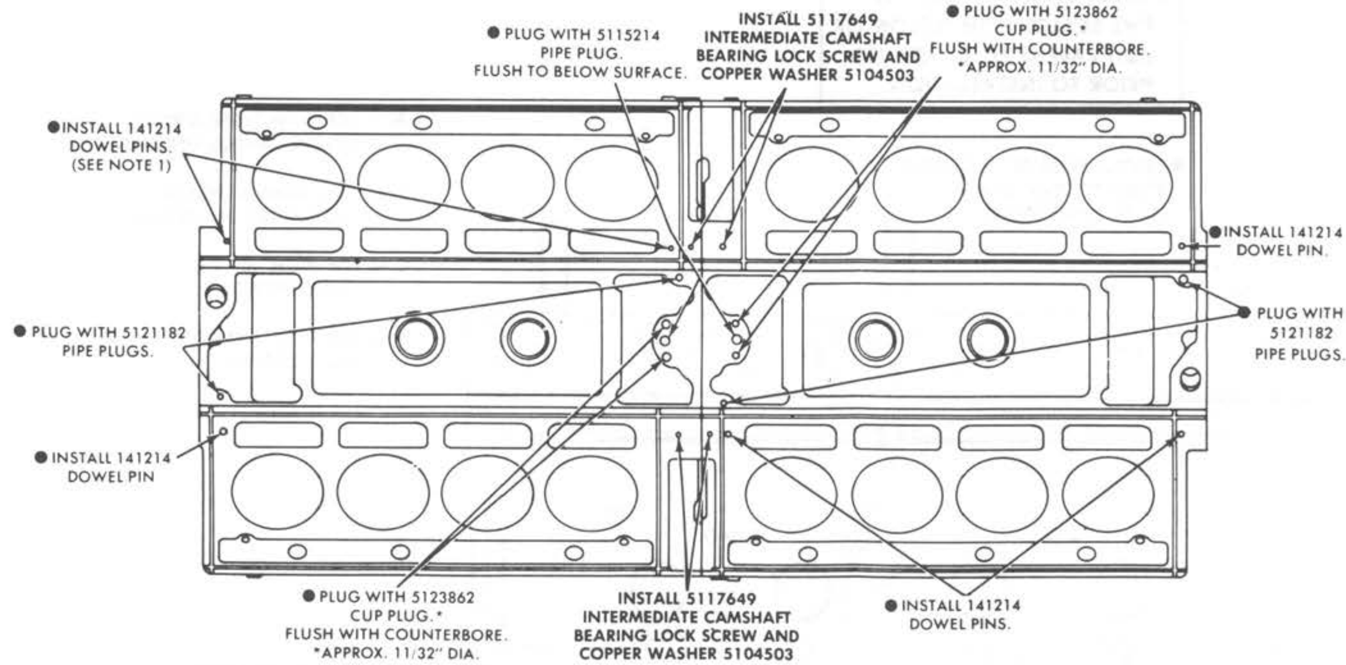
NOTES

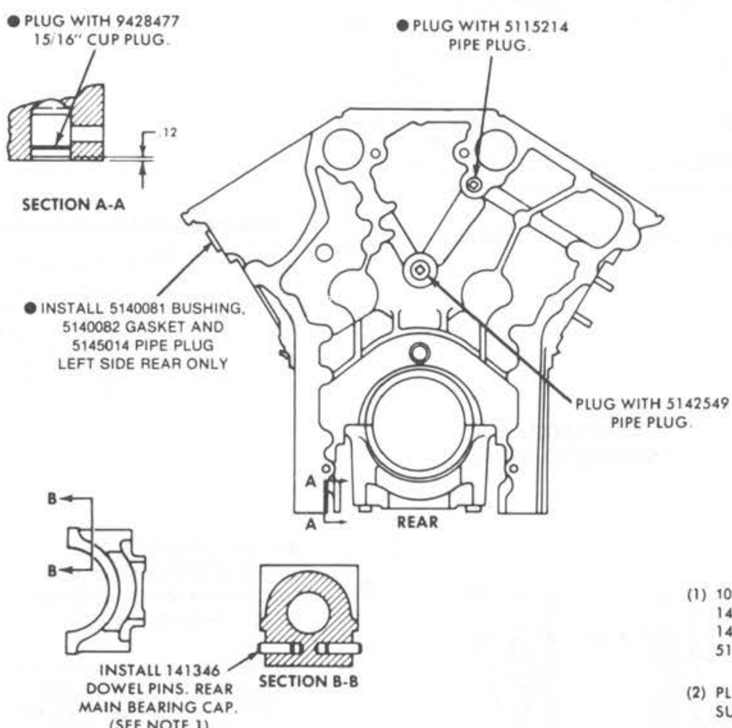
(1) 103195 STUDS — INSTALL TO 1.00 ± .030 PROJECTION.
141214 DOWEL PINS — INSTALL FLUSH WITH SURFACE.
141346 DOWEL PINS — DRIVE TO .115 ± .005 PROJECTION.
5151576 DOWEL PINS — DRIVE TO .880 ± .010 PROJECTION.

(2) PLUGS INSTALL 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.**

CYLINDER BLOCK PLUGGING INSTRUCTIONS (12V AND 16V ENGINES)





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STANARD 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
1	72-85	106-115

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APPLY LOCTITE J-26558-92 PIPE SEALER WITH TEFLON OR EQUIVALENT TO BE APPLIED PRIOR TO INSTALLATION.

REV. 1-80

CYLINDER HEAD PLUGGING INSTRUCTIONS (FOUR VALVE)

● APPLY LOCTITE J 26558-92 PIPE SEALER WITH TEFLON OR EQUIVALENT TO BE APPLIED PRIOR TO INSTALLATION.

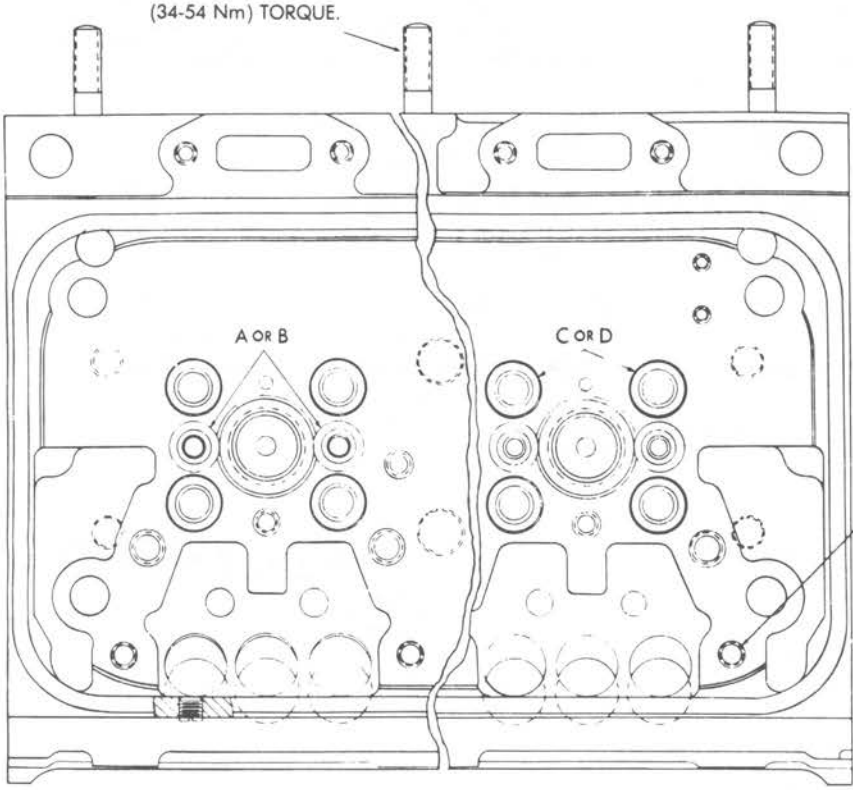
● INSTALL EXHAUST MANIFOLD STUDS TO 25-40 lb-ft (34-54 Nm) TORQUE.

A — USE WITH THREE SPRING DESIGN (SPRING UNDER BRIDGE).

B — TWO SPRING DESIGN (NO SPRING UNDER BRIDGE).

C — USE WITH .581 I.D. VALVE SPRING.

D — USE WITH .645 I.D. VALVE SPRING.

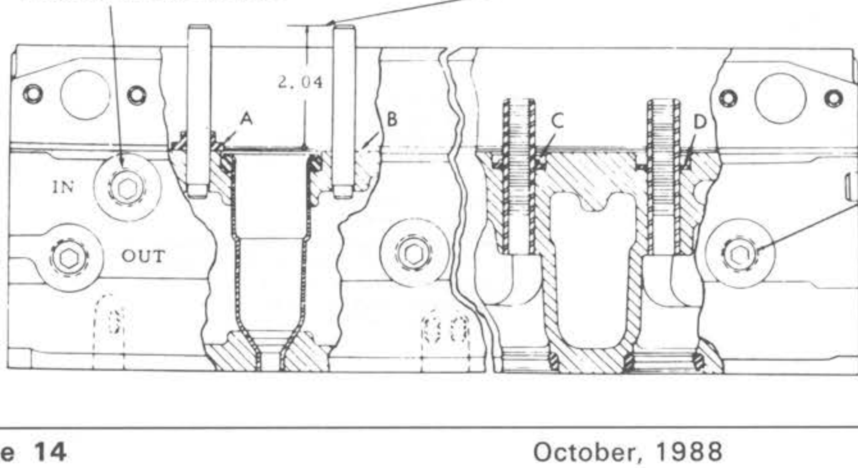


INSTALL FUEL MANIFOLD CONNECTORS AND WASHERS.

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

● INSTALL SPECIAL 1/4 PIPE PLUGS IN ALL MANIFOLD END AND SIDE POSITIONS EXCEPT FUEL INLET AND OUTLET POSITIONS CONVENIENT FOR ASSEMBLY OF FLEXIBLE HOSE ON IN-LINE ENGINES.

BRIDGE GUIDES TO BE INSTALLED AS SHOWN.

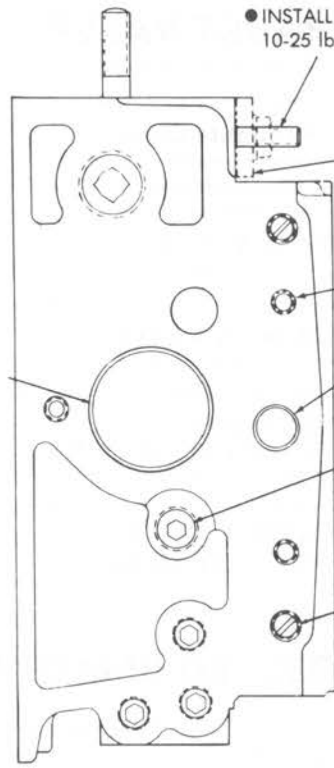


● INSTALL RESTRICTED (R) ORIFICE CONNECTOR IN CONVENIENT LOCATION IN FUEL MANIFOLD OUTLET.

NOTE: USE .1065" CONNECTOR (MARKED R10) WITH 90CMM INJECTORS. USE .080" CONNECTOR (MARKED R80, R08 OR R8) WITH ALL OTHER INJECTORS.

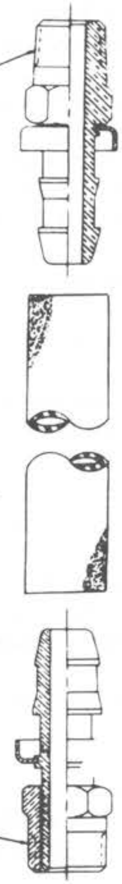
REV. 1-81

CYLINDER HEAD PLUGGING INSTRUCTIONS (FOUR VALVE)



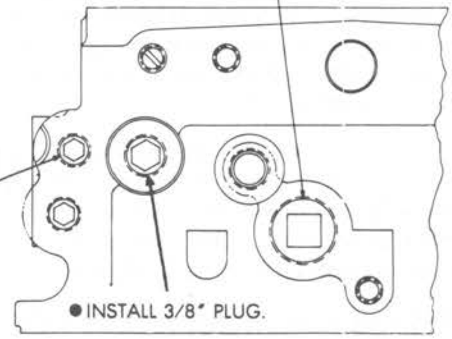
STANDARD PIPE PLUG TORQUE		
PIPE PLUG SIZE	lb-ft	Nm
1/8	10-12	14-16
1/4	14-16	19-22
3/8	18-22	24-30
1/2	23-27	31-37
3/4	33-37	45-50

● APPLY LOCTITE J 26558-92 PIPE SEALER WITH TEFLON OR EQUIVALENT TO BE APPLIED PRIOR TO INSTALLATION.



TO ASSEMBLE HOSE & FITTINGS

1. CUT HOSE TO REQUIRED LENGTH. OIL INSIDE OF HOSE AND OUTSIDE OF NIPPLES.
2. PUSH HOSE ON FITTING UNDERNEATH PROTECTIVE CAP.



REV. 1-81

TROUBLESHOOTING

EXHAUST VALVE

Probable Causes

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

SUGGESTED REMEDY

1. Check for carbon deposits, a bent valve guide, defective spring or antifreeze (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 the 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, a 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 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 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 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	LIMITS
CYLINDER BLOCK			
Block bore:			
Diameter (upper pilot)–(A)	5.3595"	5.3620"	5.3635"
Diameter (lower two seal ring lands)–(B)	5.3365"	5.3385"	5.3395"
Diameter (water jacket)–(C)	5.2160"	5.2175"	5.2185"
Diameter (water jacket)–(D)	5.2160"	5.2180"	5.2185"
Out–of–round		.0010"	
Taper (Lower bore)		.0010"	
Cylinder liner counterbore:			
Diameter	5.5550"	5.5600"	
Depth (standard)	.4755"	.4770"	
Depth (.015" deeper)	.4905"	.4920"	
Main bearing bore:			
Inside diameter (vertical axis)	4.8120"	4.8130"	
Main bearing saddle to main bearing cap			.0020"
Top surface of block:			
Centerline of main bearing bore to top of block	16.1840"	16.1890"	
Flatness—transverse (all)			.0030"
Flatness—longitudinal (6V and 12V)			.0060"
Flatness—longitudinal (8V and 16V)			.0070"
Depth of counterbores (top surface):			
Cylinder head seal strip groove	.0970"	.1070"	
Combination water and oil holes	.0840"	.0890"	
CYLINDER HEAD			
Flatness—transverse			.0040"
Flatness—longitudinal (6V and 12V engine)			.0055"
Flatness—longitudinal (8V and 16V engine)			.0080"
Surface Finish (with 1mm Dia. Stylus)		90AA	
Distance between top deck and fire deck	3.5560"	3.5680"	3.5360"
Water nozzles (former)	.0040" rec	Flush	
Water nozzles (current)	.0150" rec	Flush	
Cam follower bores	1.0620"	1.0630"	1.0650"
Exhaust valve insert counterbore:			
Diameter	1.4400"	1.4410"	
Depth	.3395"	.3505"	

ENGINE PARTS (Standard Size, New)	MINIMUM	MAXIMUM	LIMITS
ROCKER ARMS AND SHAFTS			
Diameter—rocker shaft	.8735"	.8740"	
Diameter—inside (rocker arm bushing)	.8750"	.8760"	
Clearance—shaft-to-bushing	.0010"	.0025"	.0040"
CAM FOLLOWERS			
Diameter	1.0600"	1.0610"	
Clearance—follower-to-head	.0010"	.0030"	.0060"
Rollers and pins:			
Clearance—pin-to-bushing	.0013"	.0021"	.010"Horiz.
Side clearance—roller to follower	.0110"	.0230"	.0230"
EXHAUST VALVE SEAT INSERTS			
Outside diameter	1.4415"	1.4425"	
Seat width	.0470"	.0770"	
Valve seat runout		.0020"	.0020"
EXHAUST VALVES			
Stem diameter	.3100"	.3108"	.3090"
Valve head-to-cylinder head 30°	.023" recess	.006" protr	.038"
VALVE GUIDES			
Height above cylinder head	.6700"	.7100"	
Diameter—inside	.3125"	.3135"	.3140"
Clearance—valve-to-guide	.0017"	.0035"	.0050"
VALVE BRIDGE GUIDES			
Height above cylinder head	2.0400"	2.0400"	
CRANKSHAFT			
Journal diameter—main bearing	4.4985"	4.5002"	
Journal diameter—conn. rod bearing	2.9985"	3.0002"	
Journal out-of-round		.0005"	.0005"
Journal taper			
Main Bearing		.0004"	.0004"
Connecting rod (full length)		.0008"	
Connecting rod (half length)		.0004"	
+ Runout on journals—total indicator reading:			
6V (mounted on No. 1 and 4 journals):			
At No. 2 and No. 3 journals		.0020"	
8V (mounted on No. 1 and 5 journals):			
At No. 2 and No. 4 journals		.0020"	
At No. 3 journal		.0040"	

+ Runout tolerance given for guidance when regrinding crankshaft. When the runout on adjacent journals is in the opposite direction, the sum must not exceed .003" total indicator reading. When the runout on adjacent journals is in the same direction, the difference must not exceed .003" total indicator reading. When high spots of the 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	LIMITS
12V (mounted or No. 1 and 8 journals):			
At No. 2 and No. 7 journals		.0020"	
At No. 3 and No. 6 journals		.0040"	
At No. 4 and No. 5 journals		.0060"	
16V (mounted on No. 1 and 10 journals):			
At No. 2 and No. 9 journals		.0020"	
At No. 3 and No. 8 journals		.0040"	
At No. 4 and No. 7 journals		.0060"	
At No. 5 and No. 6 journals		.0080"	
Thrust washer thickness	.1190"	.1220"	
End play (end thrust clearance)	.0040"	.0110"	.0180"
MAIN BEARING			
Inside diameter (vertical axis)	4.5016"	4.5040"	
Bearing–to–journal clearance	.0014"	.0055"	.0055"
Bearing thickness 90° from parting line	.1545"	.1552"	
CROSS–HEAD PISTONS AND RINGS			
Piston crown:			
Saddle–to–crown distance:			
N.A. piston (19:1 compr. ratio)	2.7025"	2.7095"	
T piston (17:1 compr. ratio)	2.7025"	2.7095"	
Diameter:			
At top	4.8104"	4.8134"	
Below both compression rings	4.8273"	4.8303"	
Above and below seal ring groove	4.4650"	4.4750"	
Above and below bearing saddle	3.2360"	3.2370"	
Compression rings:			
Gap (top–fire ring)	.0250"	.0450"	.0600"
Gap (No. 2 and 3)	.0250"	.0450"	.0600"
Clearance—ring–to–groove:			
*Top (Keystone fire ring)	.0010"	.0050"	.0070"
No. 2 (rectangular section)	.0100"	.0130"	.0220"
No. 3 (rectangular section)	.0040"	.0070"	.0130"
Seal ring:			
Gap (in skirt counterbore)	.0020"	.0170"	
Clearance	.0005"	.0030"	.0040"
Piston skirt:			
#Diameter (includes tin)	4.8318"	4.8340"	
Clearance—skirt–to–liner	.0051"	.0097"	.0120"
Seal ring bore	4.5000"	4.5030"	
Piston pin bore	1.5025"	1.5035"	1.5040"
Oil control rings:			
Gap (two rings in lower groove)	.0100"	.0250"	.0430"
Gap (two rings in upper groove—turbo)	.0070"	.0170"	.0350"
Gap (two rings in upper groove—non–turbo)	.0100"	.0250"	.0430"
Clearance	.0015"	.0055"	.0080"

*Measured with Keystone fire ring flush with outside diameter of piston crown.
#Diameter above and below the piston pin may be 4.8280".

ENGINE PARTS (Standard Size, New)	MINIMUM	MAXIMUM	LIMITS
PISTON PINS (CROSS–HEAD PISTON)			
Diameter	1.4996"	1.5000"	1.4980"
Slipper bearing (bushing):			
Thickness at center	.0870"	.0880"	.0860"
Clearance (edge of bushing to groove in piston)	.0005"	.0105"	.0120"
CONNECTING ROD BEARING			
Inside diameter (vertical axis)	3.0005"	3.0035"	
Bearing–to–journal clearance	.0008"	.0045"	.0045"
Bearing thickness 90° from parting line	.1240"	.1245"	
CYLINDER LINER			
Outside diameter (upper surface)	5.3577"	5.3595"	
Outside diameter (seal ring surface)	5.3347"	5.3365"	
Outside diameter (lower surface)	5.2142"	5.2160"	
Inside diameter	4.8390"	4.8415"	
Out–of–round—inside diameter		.0020"	.0025"
Taper—inside diameter		.0015"	.0025"
Depth of flange BELOW block	.0418"	.0482"	
Variation in depth between adjacent liners		.0015"	
CAMSHAFT			
Diameter (at bearing journals):			
Front and rear (6V and 12V engines)	1.4970"	1.4975"	
Front and rear (8V and 16V engines)	1.4960"	1.4965"	
Center and intermediate	1.4980"	1.4985"	
Runout at center bearing (when mounted on end bearings)		.0020"	
End thrust	.0030"	.0150"	.0180"
Thrust washer thickness	.1190"	.1220"	
CAMSHAFT BEARINGS			
Inside diameter:			
Front and rear	1.5000"	1.5010"	
Center and intermediate	1.5010"	1.5030"	
Clearance—bearing–to–shaft:			
Front and rear (6V, 12V and 16V engines)	.0025"	.0040"	.0060"
Front and rear (8V engines)	.0035"	.0050"	.0060"
Center and intermediate	.0025"	.0050"	.0090"
Outside diameter:			
Front and rear	2.1875"	2.1880"	
Center and intermediate	2.1840"	2.1860"	
Diameter of cylinder block bore	2.1875"	2.1889"	
Clearance—bearings–to–block:			
Front and rear	.0005" press	.0014" loose	
Intermediate	.0015"	.0045"	
CAMSHAFT GEARS			
Inside diameter	1.1865"	1.1875"	
Clearance—gear–to–shaft	.0015" press	.0000"	
Backlash	.0020"	.0080"	.0100"

ENGINE PARTS (Standard Size, New)	MINIMUM	MAXIMUM	LIMITS
IDLER GEAR			
Backlash	.0020"	.0080"	.0100"
Pre-load—Variation on pull 2 lbs. 11 oz.	1/2 lb.	4 lb.	
CRANKSHAFT TIMING GEAR			
Inside diameter	5.2490"	5.2510"	
Clearance—gear-to-shaft	.001" press	.001" loose	
Backlash	.0020"	.0080"	.0100"
BLOWER DRIVE GEAR (STEP-UP GEAR) NON-TURBO - 2.6:1 RATIO			
Inside diameter (support bushing)	1.8770"	1.8780"	
Hub diameter (at bearing)	1.8745"	1.8755"	
Hub-to-support bushing clearance	.0015"	.0035"	
Thrust washer thickness	.1190"	.1210"	
End thrust	.0030"	.0170"	.0190"
BLOWER DRIVE GEAR TURBO - 2.1:1 RATIO			
Backlash	.0020"	.0080"	.0100"
Inside diameter (support bushing)	1.6260"	1.6265"	
Hub diameter (at bearing)	1.6240"	1.6250"	
Hub-to-support bushing clearance	.0010"	.0025"	.0050"
Thrust washer thickness	.2350"	.2450"	
Thrust bearing thickness	.0590"	.0610"	
End thrust	.0050"	.0100"	.0120"
BLOWER DRIVE STEP-UP GEAR			
Backlash	.0020"	.0080"	.0100"
LEFT BANK ACCESSORY DRIVE GEAR 2.1:1 RATIO			
Backlash	.0020"	.0080"	.0100"
Inside diameter (support bushing)	1.6260"	1.6265"	
Hub diameter (at bearing)	1.6240"	1.6250"	
Hub-to-support bushing clearance	.0010"	.0025"	.0050"
Thrust washer thickness	.2350"	.2450"	
Thrust bearing thickness	.0590"	.0610"	
End thrust	.0050"	.0100"	.0120"

STANDARD BOLT AND NUT TORQUE SPECIFICATIONS

THREAD SIZE	260M BOLTS TORQUE (lb–ft)	N•m	THREAD SIZE	280M OR BETTER TORQUE (lb–ft)	N•m
1/4–20	5–7	7–9	1/4–20	7–9	10–12
1/4–28	6–8	8–11	1/4–28	8–10	11–14
5/16–18	10–13	14–18	5/16–18	13–17	18–23
5/16–24	11–14	15–19	5/16–24	15–19	20–26
3/8–16	23–26	31–35	3/8–16	30–35	41–47
3/8–24	26–29	35–40	3/8–24	35–39	47–53
7/16–14	35–38	47–51	7/16–14	46–50	62–68
7/16–20	43–46	58–62	7/16–20	57–61	77–83
1/2–13	53–56	72–76	1/2–13	71–75	96–102
1/2–20	62–70	84–95	1/2–20	83–93	113–126
9/16–12	68–75	92–102	9/16–12	90–100	122–136
9/16–18	80–88	109–119	9/16–18	107–117	146–159
5/8–11	103–110	140–149	5/8–11	137–147	186–200
5/8–18	126–134	171–181	5/8–18	168–178	228–242
3/4–10	180–188	244–254	3/4–10	240–250	325–339
3/4–16	218–225	295–305	3/4–16	290–300	393–407
7/8–9	308–315	417–427	7/8–9	410–420	556–569
7/8–14	356–364	483–494	7/8–14	475–485	644–657
1–8	435–443	590–600	1–8	580–590	786–800
1–14	514–521	697–705	1–14	685–695	928–942

Grade identification markings are normally stamped on the heads of the bolts. To aid identification of the various bolts used in Detroit Diesel engines, refer to the following chart.

Grade Identification Marking on Bolt Head	GM Number	SAE Grade Designation	Nominal Size Diameter (inch)	Tensile Strength Min. (psi)
None	GM 255-M	1	No. 6 thru 1 1/2	60,000
None	GM 260-M	2	No. 6 thru 3/4 over 3/4 to 1 1/2	74,000 60,000
Bolts and Screws	GM 280-M	5	No. 6 thru 1 over 1 to 1 1/2	120,000 105,000
Hex Head Sems Only	GM 275-M	5.1	No. 6 thru 3/8	120,000
Bolts and Screws	GM 290-M	7	1/4 thru 1 1/2	133,000
Bolts and Screws	GM 300-M	8	1/4 thru 1 1/2	150,000
Bolts and Screws	GM 455-M	None	No. 6 thru 1 1/2	55,000

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BOLT IDENTIFICATION CHART

EXCEPTIONS TO STANDARD BOLT AND NUT TORQUE SPECIFICATIONS

APPLICATION	THREAD	(lb–ft)	(lb–in)	(N•m)
Cam follower guide bolt	1/4–20	12–15		16–20
Injector control shaft bracket bolt	1/4–20	10–12		14–16
Air box cover bolt	5/16–18	8–12		11–16
Blower drive gear support to thrust collar bolt	5/16–18	16–21		22–28
Oil pan bolts (lower pan)	5/16–18	10–12		14–16
Exhaust valve bridge adjusting screw locknut	5/16–24	20–25		27–34
Idler gear bearing retainer bolts	5/16–24	24–29		33–39
Camshaft end bearing bolts	3/8–16	35–40		47–54
Engine front cover bolts	3/8–16	25–30		31–41
Engine front cover bolts (16V)	3/8–16	40–45		54–64
Flywheel housing bolts	3/8–16	25–30		34–41
Front accessory drive pulley bolt	3/8–16	25		34
Front end plate bolt (into water jacket plug)	3/8–16	20–25		27–34
Idler gear hub and spacer bolts (hex head)	3/8–16	40–45		54–61
Idler gear hub and spacer bolts (flange hex head)	3/8–16	30–35		41–47
Injector clamp bolts	3/8–16	20–25		27–34
Oil pan bolts (upper)	3/8–16	15–20		20–27
Water manifold cover bolt	3/8–16	20–25		27–34
Accessory drive disc to camshaft gear bolt	3/8–24	45–50		61–68
Accessory drive hub to camshaft gear bolt	3/8–24	45–50		61–68
Balance weight–to–camshaft gear bolt	3/8–24	15–18		20–24
Blower drive gear hub to spring plate bolt	3/8–24	40–45		54–61
Blower drive step–up gear bolt	3/8–24	50–60		68–81
Blower drive support bolts and nuts (T engines)	3/8–24	25–30		34–41
Camshaft intermediate bearing lock screw	3/8–24	15–20		20–27
Engine front cover bolts (16V—threaded into plug nuts)	3/8–24	25–30		34–41
Exhaust manifold outlet flange nuts (brass)	3/8–24	20–25		27–34
Flywheel housing bolts (threaded into plug nuts)	3/8–24	25–30		34–41
Flywheel housing cover (small cover) stud nut	3/8–24	20–25		27–34
Flywheel housing cover (small hole) bolt	3/8–24	30–35		41–47
Fuel pipe nuts (uncoated)	3/8–24	—	160	18.3
Fuel pipe nuts (Endurion®)	3/8–24	—	130	14.69
Fuel pipe nuts (Jacobs brake)	3/8–24	—	120	13.6
Fuel pipe nuts (Load limiting device)	3/8–24	—	160	18.3
Fuel pipe nuts (DDEC engines)	3/8–24	—	145	15.6
Injector clamp nut	3/8–24	20–25		27–34
Left bank accessory drive support bolts and nuts	3/8–24	25–30		34–41
Water manifold cover nuts	3/8–24	20–25		27–34

EXCEPTIONS TO STANDARD BOLT AND NUT TORQUE SPECIFICATIONS (CONT'D)

APPLICATION	THREAD	(lb–ft)	(lb–in)	(N•m)
Flywheel housing cover (large hole)	7/16–14	30–35		41–47
Generator drive bearing retaining bolt	7/16–14	30–35		41–47
Generator drive oil seal retaining bolt	7/16–14	30–35		41–47
Rear accessory drive pulley bolt	7/16–14	35		47
Connecting rod nut (Lubrite)	7/16–20	60–70		81–95
Cross–head piston pin to conn. rod bolt	7/16–20	55–60		75–81
Exhaust manifold nuts	7/16–20	30–35		41–47
Fuel manifold connector nuts	7/16–20	30–35		41–47
Vibration damper hub bolt (8V engine)	7/16–20	75–85		102–115
Alternator drive bearing retaining bolt	1/2–13	30–35		41–47
Alternator drive oil seal retaining bolt	1/2–13	30–35		41–47
Crankshaft front cover and trunnion bolts (16V)	1/2–13	90–100		122–136
Crankshaft front cover bolts	1/2–13	80–90		108–122
Flywheel housing bolts	1/2–13	90–100		122–136
Flywheel housing cover (large hole) bolt	1/2–13	30–35		41–47
Idler gear hub and dummy hub bolt	1/2–13	80–90		108–122
+Rocker shaft bolts	1/2–13	90–100		122–136
Engine drive shaft flexible coupling bolt	1/2–20	96–115		130–156
**Camshaft gear bolt (right–bank–300M)	9/16–18	180–190		244–258
**Flywheel bolts (see Sect. 1.4)	9/16–18			
**Vibration damper bolt	9/16–18	155–165		211–224
**Cylinder head bolts	11/16–11	230–240		312–325
**Main bearing bolts (assembly) (captured washer)	11/16–11	230–240		312–325
**Main bearing bolts (former)	11/16–11	250–260		339–352
**Main bearing bolts (bolting) (captured washer)	11/16–11	230–240		312–325
**Main bearing bolts (bolting) (former)	11/16–11	250–260		339–352
Accessory drive pulley nut	3/4–16	120–140		163–190
Crankshaft end bolt	1–14	290–310		393–421
Camshaft nut	1 1/8–18	300–325		407–441
Blower drive gear hub nut (T engines)	1 7/16–16	50–60		68–81
Left bank accessory drive gear nut	1 7/16–16	50–60		68–81

+75–85 lb–ft (102–115 N•m) torque on the two bolts attaching load limit or power control screw bracket (if used) to the rocker arm shaft bracket.

**Lubricate at assembly with International Compound No. 2, or equivalent (refer to Parts Catalog or Microfiche, Section 12.8000A).

STANDARD PIPE PLUG TORQUE SPECIFICATIONS

Use sealing compound on plugs without gaskets or teflon.

NPTF SIZE THREAD	TORQUE (lb–ft)	TORQUE N•m	NPTF SIZE THREAD	TORQUE (lb–ft)	TORQUE N•m
1/8	10–12	14–16	3/4	33–37	45–50
1/4	14–16	19–22	1	75–85	102–115
3/8	18–22	24–30	1-1/4	95–105	129–143
1/2	23–27	31–37	1-1/2	110–130	150–177

SPECIAL PLUG TORQUE SPECIFICATIONS

APPLICATION	*PLUG	ASSEMBLY
Oil gallery plug	3/8" Dryseal PTF thread	#Assemble with max. 0.0625" protrusion from surface
Cylinder head (side)	3/8–16"	Assemble flush to 0.0625" protrusion from surface
Cylinder head (end)	3/4" Dryseal PTF–SAE short	Flush to 0.1250" recessed
Core hole plug (air box floor)	2 1/2"–16	230–270 lb–ft (312–366 Nm) torque
Oil drain plug (Nylon washer)	18mm	25–35 lb–ft (34–47 Nm) torque

*Apply sealing compound to plugs used without gaskets or teflon.
#After installation, a 1.2187" diameter rod inserted in oil line must pass inner face of plug.

STUD TORQUE SPECIFICATIONS

APPLICATION	(lb–in)	(N•m)
Exhaust manifold stud	25–40	34–54
Water manifold cover stud	10–25	14–34

SERVICE TOOLS

TOOL NAME	TOOL NO.
CYLINDER BLOCK	
Adapter (1 5/8" diameter plugs)	J 21850
Aftercooler Adaptor Cup Plug Installer	J 28711
Aftercooler Adaptor Plug Remover and Installer	J 25275
Aftercooler Cup Plug Installer (2 1/2" diameter)	J 24597
Alignment Tool	J 21799
Block Assembly Wrench Set	J 25451–B
Block Thread Repair Kit	J 29513
Cup Plug Installer (1" diameter)	J 33420
Cylinder Block Air Box Plugging Tool	J 29571
Cylinder Block Line Boring Tool	J 29005
Cylinder Block Tap	J 25384
Cylinder Diameter Checking Gage	J 5347–B
Cylinder Hone Set (2 1/2" to 5 3/4")	J 5902–01
Dial Bore Gage Master Setting Fixture	J 23059–01
Dial Indicator Set	J 22273–01
Diesel Engine Parts Dolly	J 6387
Handle	J 7079–2
Loctite "Chisel" Gasket Remover	PT 7275
Master Ring Gage for Block Bore	J 24564
Overhaul Stand (6V and 8V Engines)	J 29109
Overhaul Stand (12V and 16V Engines)	J 9384–04
Overhaul Stand Adaptor (6V and 8V Engines)	J 33850
Overhaul Stand Adaptor (12V and 16V Engines)	J 8650
Pipe Plug Remover/Installer (1/8" Dia.)	J 34650
Special Plug Remover (dry cylinder block)	J 21996–01
Special Plug Remover	J 23019
CYLINDER HEAD	
• Load Cell kit, Cam Follower Roller Fixture	J 33421–25
• Cam Follower Service Fixture	J 33421–A
Cylinder Head Bolt Hole Cleanout Tap	J 25384
Cylinder Head Guide Studs (Set of 2)	J 24748
Cylinder Head Holding Plate Set	J 3087–01
Cylinder Head Lifting Fixture	J 22062–01
Engine Barring Tool	J 22582
Feeler Gage Set (.0015" to .015")	J 3172
Feeler Stock (.0015")	J 23185
Fuel Line Nut Wrench	J 8932B
Injector Fuel Hole Brush	J 8152
Pressure Checking Tool	J 28454
Push Rod Remover (Set of 3)	J 3092–01
Slide Hammer	J 2619–01
Spring Tester	J 22738–02
Valve Bridge Holding Fixture	J 21772
Valve Bridge Guide Remover (Broken)	J 7453
Valve Bridge Guide Remover Set	J 7091–01

TOOL NAME	TOOL NO.
Valve Bridge Guide Installer	J 7482
Valve Guide Cleaner	J 5437
Valve Guide Installer (Machined)	J 21520
Valve Guide Remover	J 6569–A
Valve Seat Dial Gage	J 8165–2
Valve Guide Oil Seal Installer	J 35373
Valve Seat Grinder (Model V.I.P.)*	J 7040A
–Valve Seat Dial Gage	J 8165–2
–Valve Seat Grinder	J 8165–1A
Valve Seat Grinder Adaptor Set	J 24566
Valve Seat Insert Installer	J 24357
Valve Seat Insert Remover Assembly	J 23479–492
Valve Seat Insert Remover Collet (Part of 23479–492)	J 23479–33
Valve Spring Checking Gage	J 25076–B
Valve Spring Compressor	J 7455–A
Water Nozzle Installer (Intermediate)	J 24857–A
CRANKSHAFT	
6V and 8V – Front Oil Seal Installer (No Handle)	J 9783
Rear Oil Seal Installer (Std. and O.S. Seals)	J 21112–B
Handle	J 3154–A
Guide Studs (C/S with Dowels)	J 9727–2
Guide Studs (C/S with no Dowels)	J 9727–5
Expander (Std. Seal)	J 4239
Handle	J 8092
Guide Studs	J 25002
Expander (O.S. Seal) (No Handle or Guide Studs)	J 8682
Sleeve Installer (O.S. Seal)	J 21983
Handle	J 8092
Guide Studs	J 25002
12V and 16V – Front Oil Seal Installer (No Handle)	
Installer (Std. and O.S. Seals)	J 9727–A
Handle	J 3154–1A
Guide Studs	J 9727–5
Expander (Std. Seal) (No Handle)	J 22425–A
Guide Studs	J 25002
Expander (O.S. Seal) (No Handle or Guide Studs)	J 4195–01
Installer (O.S. Seal)	J 4194–01
Handle	J 8092
Guide Studs	J 9727–5
Dial Indicator Set	J 5959–01
Engine Barring Tool	J 22582
Flywheel Housing Alignment Studs	J 1927–01
Micrometer Ball Attachment	J 4757
Torque Wrench Adaptor (Two piece crankshaft)	
12V and 16V engines	J 22898–A
Universal Bar Type Puller	J 24420–B

*Consists Of Single Dash (–) Items Below.

TOOL NAME	TOOL NO.
FLYWHEEL	
Flywheel Lifting Fixture	J 25026
Flywheel Lifting Tool	J 6361–01
Oil Seal Removing and Replacing Tool Set	J 3154–04
Slide Hammer Set	J 5901–01
FLYWHEEL HOUSING	
Flywheel Housing Aligning Studs (Set of 4)	J 1927–01
Flywheel Housing Concentricity Gage Set	J 9737–C
PISTON, CONNECTING ROD AND CYLINDER LINER	
Connecting Rod Holding Fixture	J 7632
Cylinder Liner Master Ring Gage	J 24564
Cylinder Hone Set (2 1/2" to 5 3/4" range)	J 5902–01
Cylinder Liner Hold–Down Tool	J 24565–02
Cylinder Liner Remover Set	J 24563–A
Dial Bore Gage Setting Fixture	J 23059–01
Dial Indicator Set	J 24898
Feeler Gage Set	J 3172
Micrometer Ball Attachment	J 4757
Piston Crown Identification Gage	J 25397–A
Piston Pin Alignment Tool	J 24285
Piston Pin Retainer Installer	J 23762–A
Piston Pin Retainer Leak Detector (Plastic)	J 23987–B
Piston Pin Retainer Leak Detector (All Metal)	J 35134
Piston Ring Compressor	J 24227
Piston Ring Remover and Installer	J 8128
Piston to Liner Feeler Gage Set	J 5438–01
Seal Ring Compressor	J 24226
CAMSHAFT	
Accessory Drive Hub Oil Seal Aligning Tool	J 21166
Alternator Drive Step–Up Gear Alignment Gage	J 29893
Balance Weight Cover Oil Seal Installer	J 9791
Camshaft Gear Puller	J 1902–B
Camshaft Gear Puller Adaptor Plate Set	J 6202–01
Camshaft and Oil Pump Gear Installer	J 1903
Dial Indicator and Attachment Set	J 5959–01
Puller Adaptor	J 7932
Slide Hammer Set	J 6471–02
Spring Scale	J 8129
Universal Bar Type Puller	J 24420–B

SECTION 2

FUEL SYSTEM AND GOVERNORS

CONTENTS

FUEL SYSTEM

The fuel system (Fig. 1) 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 fuel injector.

The fuel manifolds are identified by the words "IN" (top passage) and "OUT" (bottom passage) which are cast or stamped 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 in one of the cylinder heads on 6 and 8V engines (two of the cylinder heads on 12 and 16V engines) to maintain the fuel system pressure. Refer to Section 13.2 for the size fitting required.

A check valve may be installed in the supply line between the fuel tank and the fuel strainer to prevent fuel from draining back when the engine is shut down.

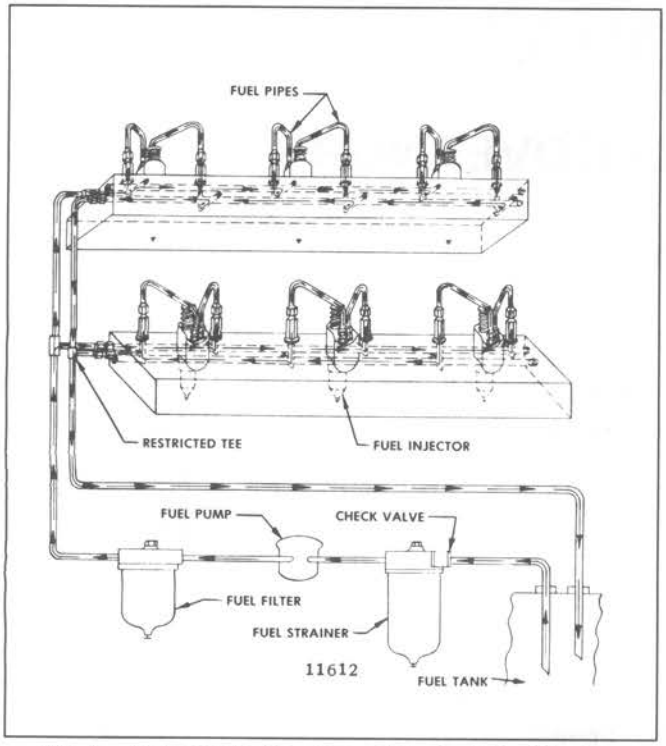


Fig. 1 – Schematic Diagram of Typical Fuel System

FUEL INJECTOR

MECHANICAL UNIT INJECTOR (MUI)

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 (Times – Atomizes – Meters – Pressurizes):

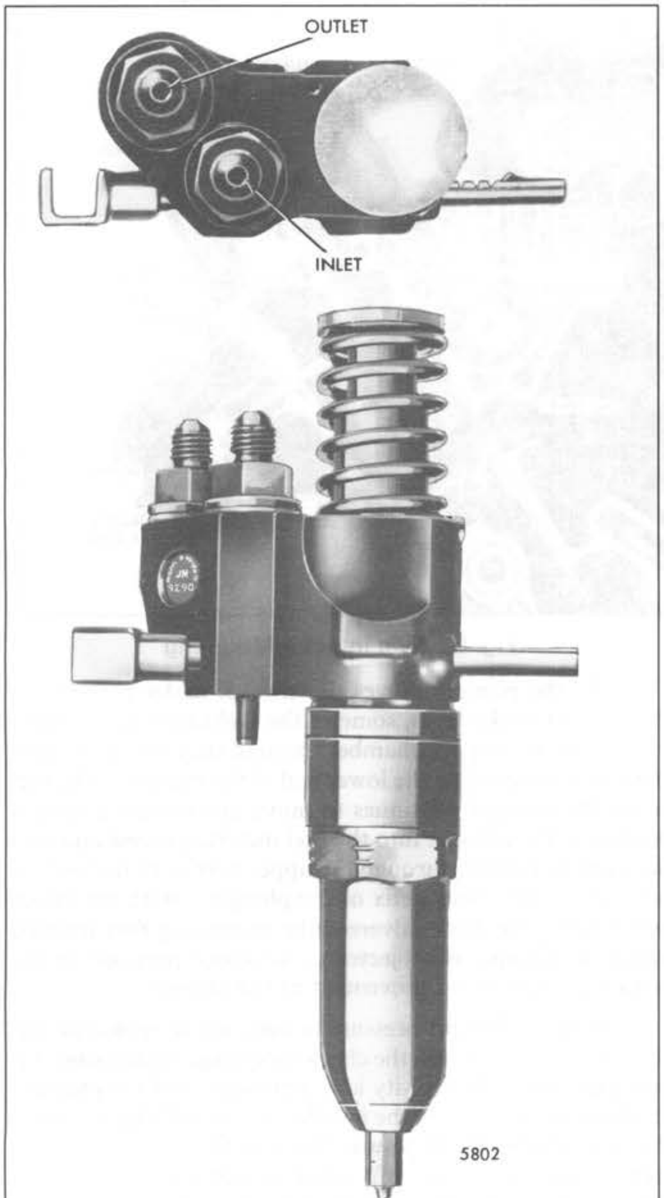


Fig. 1 – Fuel Injector Assembly

1. Accurately times the moment of fuel injection.
2. Atomizes the fuel for vaporization and mixing with the air in the combustion chamber.
3. Meters and injects the correct amount of fuel required to maintain engine speed and to handle the load.
4. Creates the high pressure required for proper fuel injection.

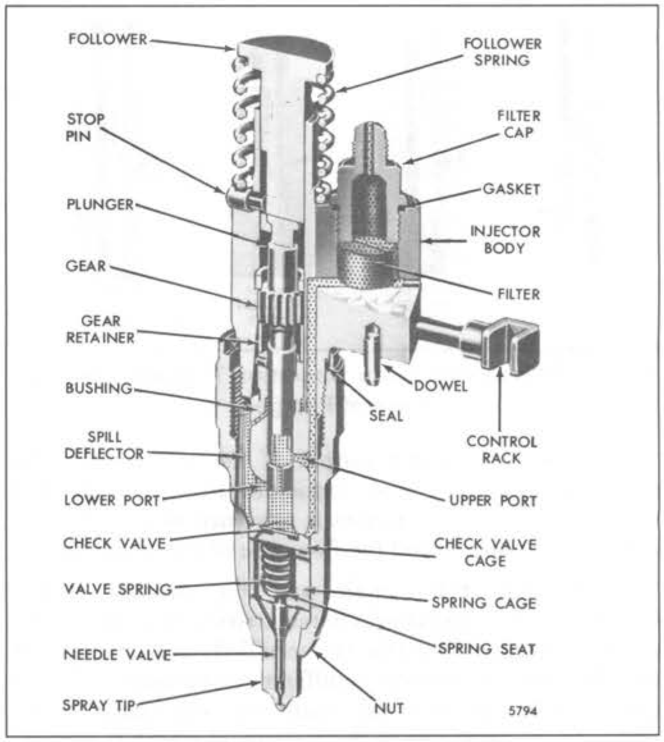


Fig. 2 – Cutaway View of Fuel Injector

Combustion required for satisfactory engine operation is obtained by injecting, under pressure, a small quantity of accurately timed, metered and finely atomized fuel oil into the combustion chamber.

Metering and timing during fuel injection is accomplished by an upper and lower helix machined in the lower end of the injector plunger. Fig. 3 illustrates the fuel metering from no load to full load by rotation of the plunger in the bushing.

Fig. 4 illustrates the phases of injector operation by the vertical travel of the injector plunger.

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.

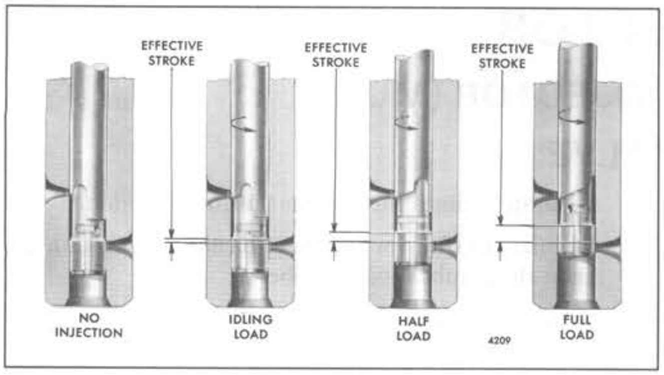


Fig. 3 – Fuel Metering from No Load to Full Load

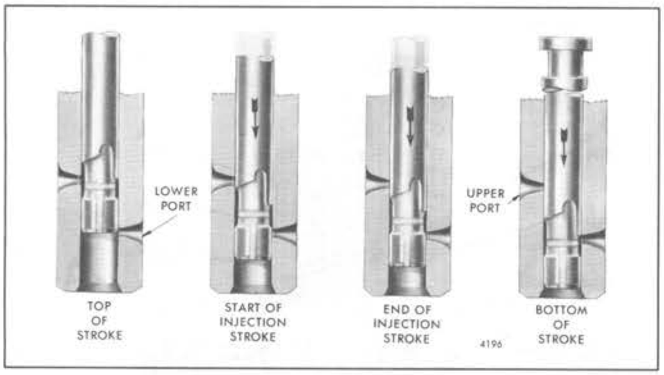


Fig. 4 – Phases of Injector Operation Through Vertical Travel of Plunger

To vary the power output of the engine, injectors having different fuel output capacities are used. The fuel output of the various injectors is governed by the effective stroke of the plunger and the flow rate of the spray tip.

Since the helix angle and the plunger design determines the operating characteristics of a particular injector, it is imperative that the specified injectors are used for each engine. If injectors of different types are mixed in an engine, erratic operation will result and may cause serious damage to the engine or to the equipment which it powers.

Each fuel injector has a circular disc pressed into a recess at the front side of the injector body for identification purposes (Fig. 1).

Each injector control rack (Fig. 2) is actuated by a lever on the injector control tube which, in turn, is connected to the governor by means of a fuel rod. These levers can be adjusted independently on the control tube, thus permitting a uniform setting or fine tuning of all injector racks.

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

Operation

Fuel, under low pressure, enters the injector at the inlet side through a filter cap and filter positioned over the racks (Fig. 2). From the filter, the fuel passes through a drilled passage into the supply chamber, that area between the plunger bushing and the spill deflector, in addition to that area under the injector plunger within the bushing. The plunger operates up and down in the bushing, and is supplied fuel through the two funnel–shaped ports in the bushing wall.

The motion of the injector rocker arm is transmitted to the plunger by the follower which bears against the follower spring (Fig. 5). In addition to the reciprocating motion, the plunger can be rotated around its axis by the gear which meshes with the control rack. To accomplish fuel metering, an upper helix and a lower helix are machined in the lower part of the plunger. The helix relationship to the ports changes with the rotation of the plunger.

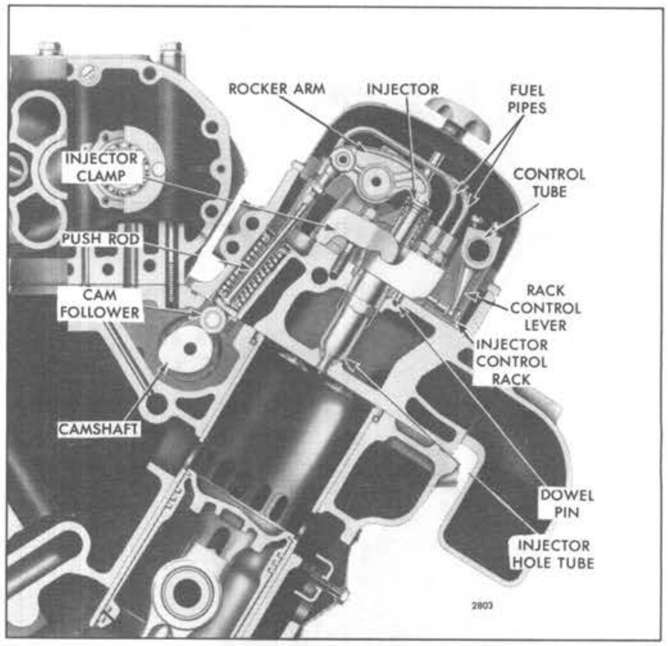


Fig. 5 – Fuel Injector Mounting

As the plunger moves downward, under pressure of the injector rocker arm, some of the fuel under the plunger moves into the supply chamber through the lower port until the port is covered by the lower end of the plunger. The fuel below the plunger continues to move up through a central passage in the plunger into the fuel metering recess and into the supply chamber through the upper port until that port is covered by the upper helix of the plunger. With the upper and lower ports both covered, the remaining fuel trapped under the plunger is subjected to increased pressure by the continued downward movement of the plunger.

When sufficient pressure is built up, it opens the flat check valve. The fuel in the check valve cage, spring cage, tip passages and tip fuel cavity is compressed until the pressure force acting upward on the needle valve is sufficient to open the valve against the downward force of the valve spring. As soon as the needle valve lifts off of its seat, the fuel is forced through the small orifices in the spray tip and atomized into the combustion chamber.

When the lower land of the plunger uncovers the lower port in the bushing, the fuel pressure below the plunger is relieved and the valve spring closes the needle valve, ending injection.

A pressure relief passage has been provided in the spring cage to permit bleed–off of fuel leaking past the needle pilot in the tip assembly.

A check valve, directly below the bushing, prevents leakage from the combustion chamber into the fuel injector in case the valve is accidentally held open by a small particle of dirt. The injector plunger is then returned to its *original* position by the injector follower spring. Fig. 4 shows the various phases of injector operation by the vertical travel of the injector plunger.

On the return upward movement of the plunger, the high pressure cylinder within the bushing is again filled with fuel oil through the ports. The constant circulation of fresh cool fuel through the injector renews the fuel supply in the chamber, helps cool the injector and also effectively removes all traces of air which might otherwise accumulate in the system and interfere with accurate metering of the fuel.

The fuel injector outlet opening, through which the excess fuel oil returns to the fuel return manifold and then back to the fuel tank, is directly adjacent to the inlet opening.

Changing the position of the helices, by rotating the plunger, retards or advances the closing of the ports and the beginning and ending of the injection period. At the same time, it increases or decreases the amount of fuel injected into the cylinder. Fig. 3 shows the various plunger positions from no load to full load. With the control rack pulled out all the way (no injection), the upper port is not closed by the helix until after the lower port is uncovered. Consequently, with the rack in this position, all of the fuel is forced back into the supply chamber and no injection of fuel takes place. With the control rack pushed all the way in (full injection), the upper port is closed shortly after the lower port has been covered, thus producing a maximum effective stroke and maximum injection. From this *no injection* position to *full injection* position (full rack movement), the contour of the upper helix advances the closing of the ports and the beginning of injection.

General Instructions For Injector Care And Overhaul

The fuel injector is one of the most important and precisely built parts of the engine. The injection of the correct amount of fuel into the combustion chamber at exactly the right time depends upon this unit. Because the injector operates against high compression pressure in the combustion chamber, efficient operation demands that the injector assembly is maintained in first–class condition at all times. Proper maintenance of the fuel system and the use of the recommended type fuel filters and clean water–free fuel are the keys to trouble–free operation of the injectors.

Due to the close tolerances of various injector parts, extreme cleanliness and strict adherence to service instructions is required.

Perform all injector repairs in a clean, well lighted room with a dust free atmosphere. An ideal injector room is slightly pressurized by means of an electric fan which draws air into the room through a filter. This pressure prevents particles of dirt and dust from entering the room through the doors and windows. A suitable air outlet will remove solvent fumes along with the outgoing air.

Provide the injector repair room with a supply of filtered, moisture–proof compressed air for drying the injector parts after they have been cleaned. Use wash pans of rust–proof material and deep enough to permit all of the injector parts to be completely covered by the cleaning solvent, when submerged in wire baskets of 16 mesh wire screen. Use baskets which will support the parts so as to avoid contact with the dirt which settles at the bottom of the pans.

Rags should never be used for cleaning injector parts since lint or other particles will clog parts of the injector when it is assembled. A lint–free paper tissue is a suitable material for wiping injector parts.

When servicing an injector, follow the general instructions outlined below:

1. Whenever the fuel pipes are removed from an injector, cover the filter caps with shipping caps to keep dirt out of the injectors and prevent damage. Also, protect the fuel pipes and fuel connectors from damage and the entry of dirt or other foreign material.
2. After an injector has been operated in an engine, do not remove the filter caps or filters while the injector is in the engine. Replace the filters only at the time of complete disassembly and overhaul of an injector.
3. Whenever an injector has been removed and reinstalled or replaced in an engine, make the following adjustments as outlined in Section 14:
   a. Time the injector.
   b. Position the injector control rack.
4. Whenever an engine is to be out of service for an extended period, purge the fuel system, then fill it with a good grade of rust preventive (refer to Section 15.3).
5. When a reconditioned injector is to be placed in stock, fill it with injector test oil J 26400. *Do not use fuel oil.* Install shipping caps on both filter caps immediately after filling. Store the injector in an *upright* position to prevent test oil leakage.

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

Remove Injector

1. Clean and remove the valve rocker cover. Discard the gasket.
2. Remove the fuel pipes from both the injector and the fuel connectors (Fig. 5).

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

3. Crank the engine to bring the upper ends of the push rods of the injector and valve rocker arms in line horizontally. If a wrench is used on the crankshaft bolt at the front of the engine, do not turn the crankshaft in a left–hand direction of rotation because the bolt could be loosened.

   CAUTION: To reduce the risk of personal injury when barring over or "bumping" the starter, personnel should keep their hands and clothing away from the moving parts of the engine as there is a remote possibility the engine could start.

4. Remove the two rocker shaft bracket bolts and swing the rocker arms away from the injector and valves (Fig. 6).
5. Remove the injector clamp bolt, special washer and clamp.
6. Loosen the inner and outer adjusting screws or adjusting screw and locknut on the injector rack control lever and slide the lever away from the injector.

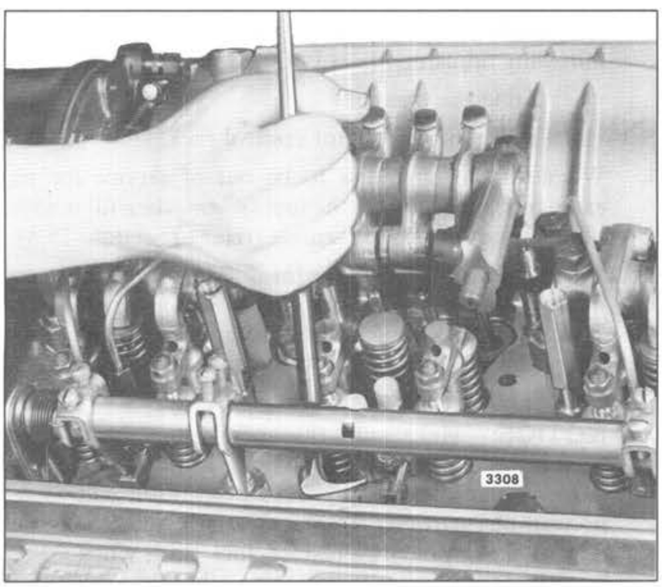


Fig. 6 – Removing Injector from Cylinder Head

7. Lift the injector from its seat in the cylinder head (Fig. 6).
8. Cover the injector hole in the cylinder head to keep foreign material out.
9. Clean the exterior of the injector with clean solvent and dry it with compressed air.

Inspect And Test Prior To Reuse

This inspection and test process is necessary if the injector is being considered for reuse rather than complete overhaul. Submerge the injector in clean solvent to wash it. Blow dry with compressed air.

CAUTION:To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.

1. Inspect the following injector parts for external wear, rust and corrosion.

   Follower spring

   Injector body

   Body nut

   Spray tip

   Injector rack

   Filter caps

2. Inspect the following parts for wear or abrasion deterioration.

   Top of the follower

   Follower spring

   Injector body

   Spray tip orifices

3. Check the rack for freeness and the plunger movement in Tester J 29584.

   With the injector control rack held in the *no–fuel* position, operate the handle to depress the follower to the bottom of its stroke. Then, very slowly release the pressure on the handle while moving the control rack up and down until the follower reaches the top of its travel (Fig. 7). If the rack falls freely, the injector passes the test. If the injector fails the rack freeness test, either the plunger is scored or there is a misalignment of the body, bushing or nut due to irregular or dirty parts.

4. Check the injector for leaks using Tester J 23010–A as outlined in Section 2.0 – Shop Notes.
5. Check the spray pattern, atomization and valve opening pressure using Tester J 23010–A as outlined in Section 2.0 – Shop Notes.
6. Perform injector fuel output test using Calibrator J 22410–A as outlined in Section 2.0 – Shop Notes.

   If the injector passes the above tests, it can be reused.

Fig. 7 – Checking Rack for Freeness in Tester J 29584

If the results of the above tests reveal marginal performance, removal of the plunger may assist with further diagnosis of internal injector problems. Plungers that reveal scratches, score marks, abnormal wear, helix chipping or other obvious damage would indicate that the injector should not be reused.

Disassemble Injector

1. Support the injector upright in injector holding fixture J 22396 (Fig. 8) and remove the filter caps, gaskets and filters.

   Whenever a fuel injector is disassembled, discard the filters and gaskets and replace with new filters and gaskets. In the offset injector, a filter is used in the inlet side only. No filter is required in the outlet side (Fig. 9).

2. Compress the follower spring (Fig. 10). Then, raise the spring above the stop pin with a screwdriver and withdraw the pin. Allow the spring to rise gradually.
3. Refer to Fig. 11 and remove the plunger follower, plunger and spring as an assembly.
4. Using socket J 4983-01, loosen the nut on the injector body (Fig. 12).

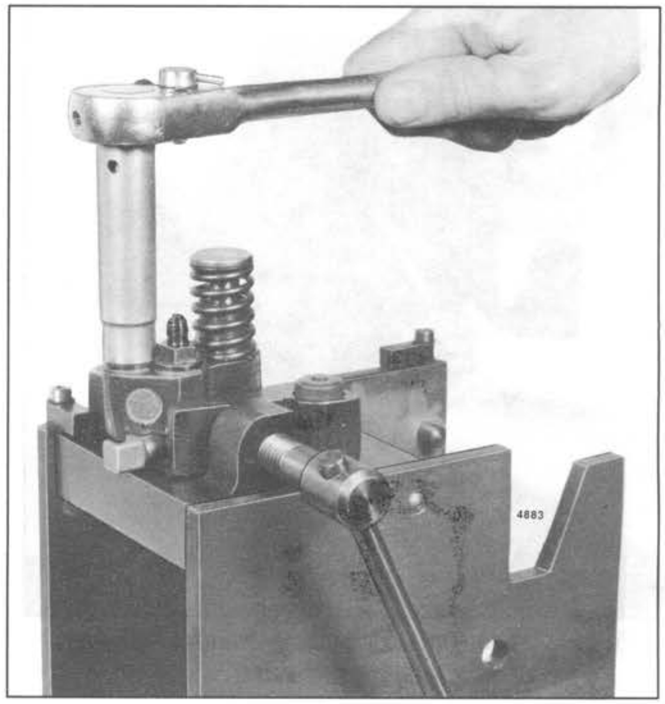


Fig. 8 – Removing Filter Cap

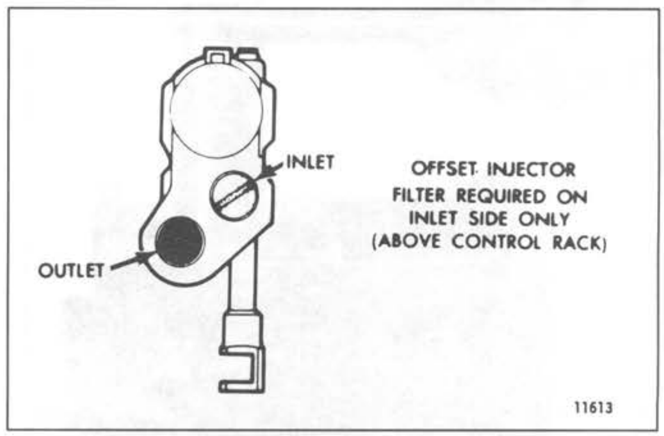


Fig. 9 – Location of Filter in Injector Body

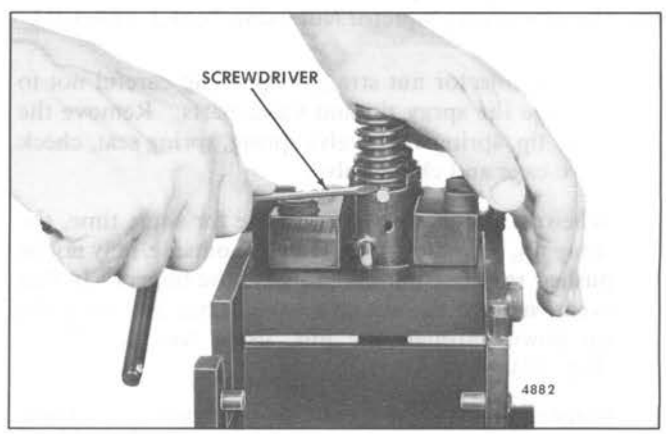


Fig. 10 – Removing Injector Follower Stop Pin

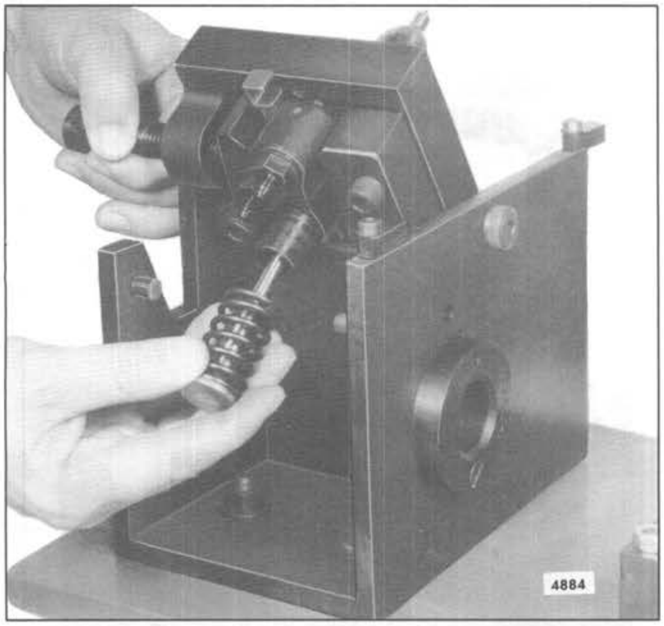


Fig. 11 – Removing or Installing Plunger Follower, Plunger and Spring

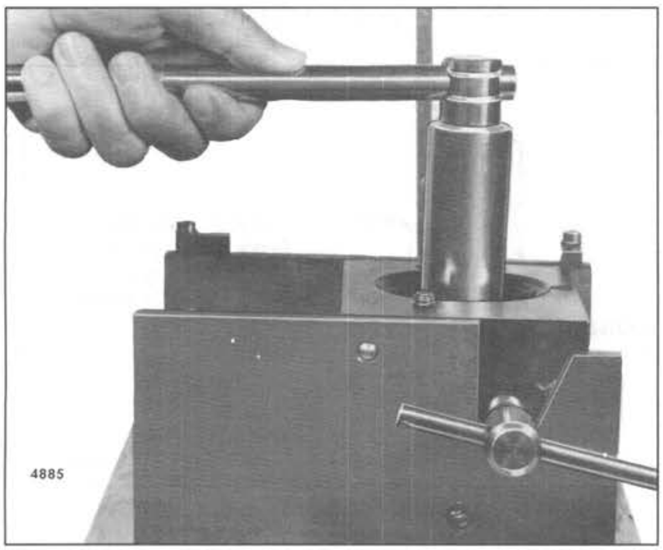


Fig. 12 – Removing Injector Nut using Tool J 4983–01

5. Lift the injector nut straight up, being careful not to dislodge the spray tip and valve parts. Remove the spray tip, spring cage, valve spring, spring seat, check valve cage and check valve.

   When an injector has been in use for some time, the spray tip, even though clean on the outside, may not be pushed readily from the nut with the fingers. In this event, support the nut on a wood block and drive the tip down through the nut, using tool J 1291–02 (Fig. 13).

6. Refer to Fig. 14 and remove the spill deflector. Then, lift the bushing straight out of the injector body.

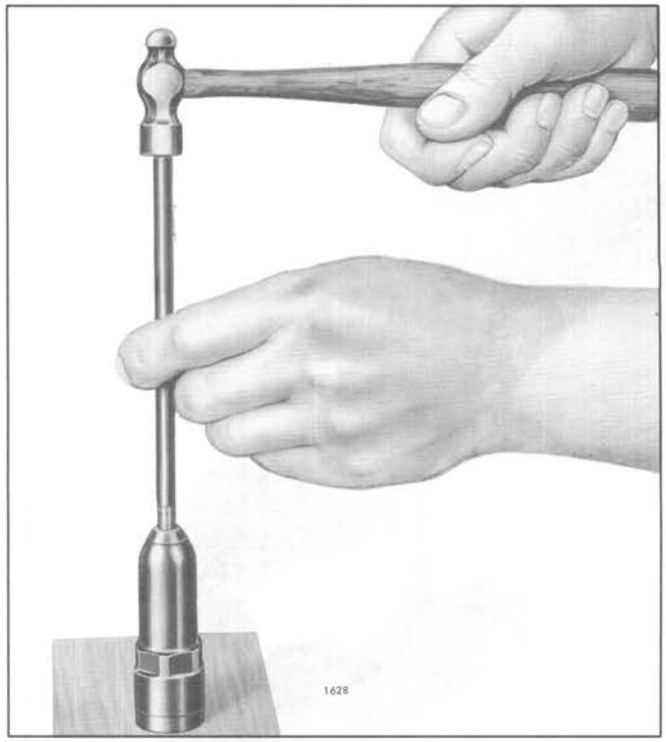


Fig. 13 – Removing Spray Tip from Injector Nut using Tool J 1291–02

7. Remove the injector body from the holding fixture. Turn the body upside down and catch the gear retainer and gear in your hand as they fall out of the body.

8. Withdraw the injector control rack from the injector body. Also, remove the seal ring from the body.

Clean Injector Parts

Since most injector problems are the result of dirt particles, it is essential that a clean area be provided on which to place the injector parts after cleaning and inspection.

Wash all of the parts with a suitable cleaning solvent and dry them with clean, filtered compressed air.

CAUTION:To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.

Use lint free towels to wipe off the parts. Clean out the passages, drilled holes and slots in all of the injector parts.

Carbon on the inside of the spray tip may be loosened for easy removal by soaking for approximately fifteen (15) minutes in a suitable solution prior to the external cleaning and buffing operation.

Clean the spray tip with tool J 24838 (Fig. 15).

NOTICE: Care must be exercised when inserting the carbon remover J 24838 in the spray tip to avoid contacting the needle valve seat in the tip.

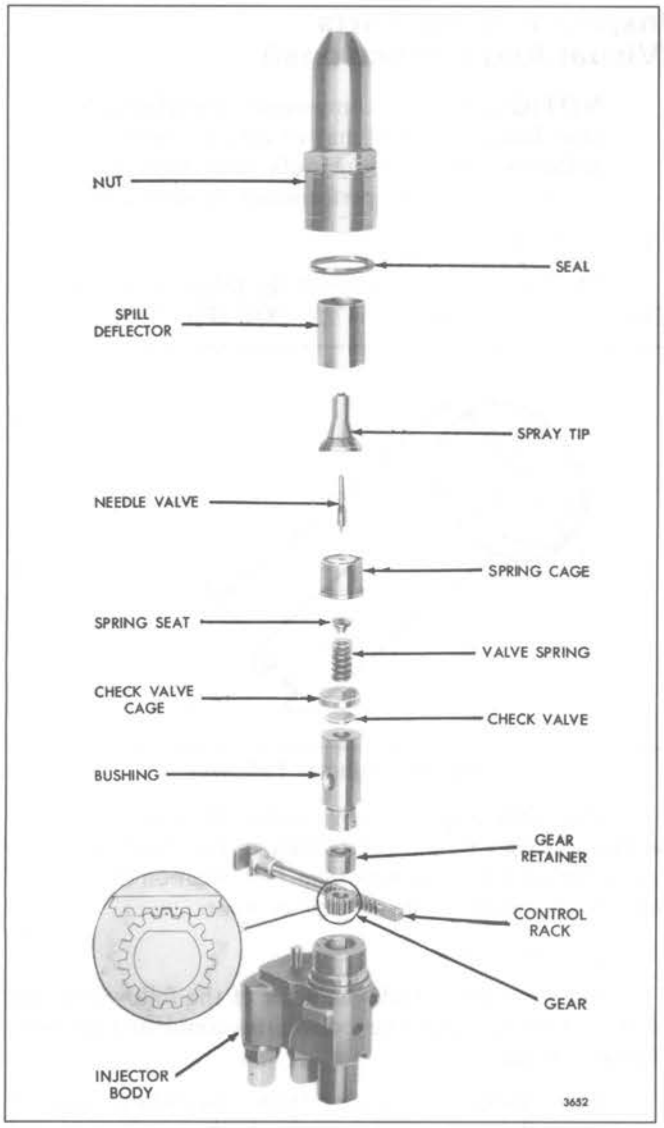


Fig. 14 – Injector Rack, Gear, Spray Tip and Valve Assembly Details and Relative Location of Parts

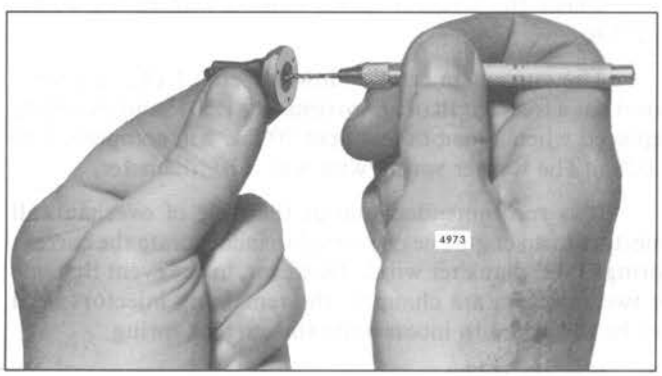


Fig. 15 – Cleaning Injector Spray Tip with Tool J 24838

Wash the tip in solvent and dry it with compressed air. Clean the spray tip orifices with pin vise J 4298–1 and the proper size spray tip cleaning wire. Use wire J 21460–01 to clean .0055" diameter holes and wire J 21461–01 to clean .006" diameter holes (Fig. 16).

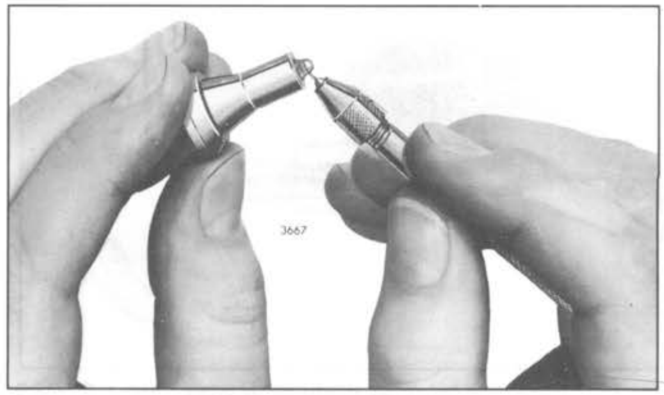


Fig. 16 – Cleaning Spray Tip Orifices with Tool J 4298–1

Before using the wire, hone the end until it is smooth and free of burrs and taper the end a distance of 1/16" with stone J 8170. Allow the wire to extend 1/8" from tool J 4298–1. Ultra sonic cleaning is also an acceptable method.

The exterior surface of an injector spray tip may be cleaned by using a brass wire buffing wheel, tool J 7944. To obtain a good polishing effect and longer brush life, the buffing wheel should be installed on a motor that turns the wheel at approximately 3000 rpm. A convenient method of holding the spray tip while cleaning and polishing is to place the tip over the drill end of the spray tip cleaner tool J 24838 and hold the body of the tip against the buffing wheel. In this way, the spray tip is rotated while being buffed.

NOTICE: Do not buff the spray tip area excessively. *Do not use a steel wire buffing wheel or the spray tip holes may be distorted.*

When the body of the spray tip is clean, lightly buff the tip end in the same manner to clean the spray tip orifice area.

Wash the spray tip in clean solvent and dry it with compressed air.

Clean and brush all of the passages in the injector body, using fuel hole cleaning brush J 8152 and rack hole cleaning brush J 8150. Blow out the passages and dry them with compressed air.

Carefully, insert reamer J 21089 in the injector body (Fig. 17). Turn it in a clockwise direction a few turns, then remove the reamer and check the face of the ring for reamer contact over the entire face of the ring. If necessary, repeat the reaming procedure until the reamer does make contact with the entire face of the ring. Clean up the opposite side of the ring in the same manner.

NOTICE: Do not damage the injector body ring during this operation. This spiral ring forms part of the injector body and is not serviced. If the ring is damaged, the injector body must be replaced.

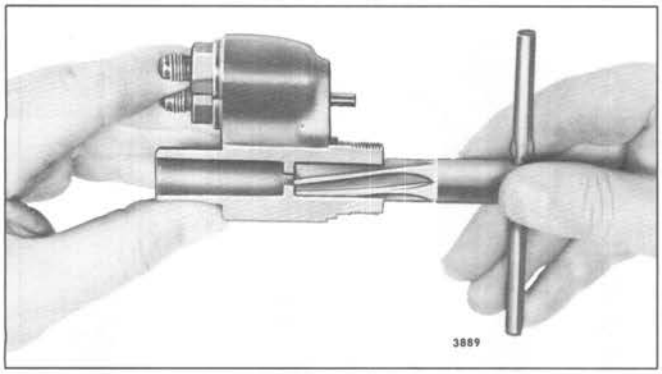


Fig. 17 – Cleaning Injector Body Ring with Tool J 21089

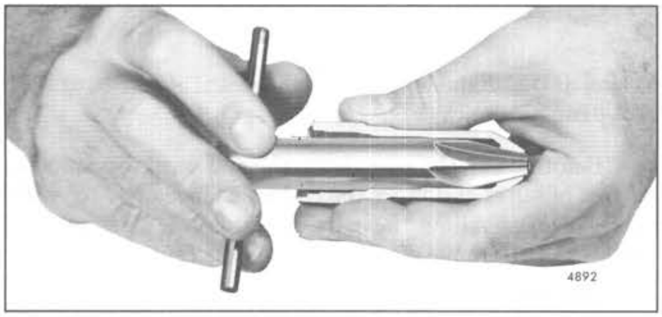


Fig. 18 – Cleaning Injector Nut Lower End with Tool J 9418–5

Carefully, insert reamer (J 21089) into the ring bore of the injector body. Turn the reamer in a clockwise direction and remove any burrs inside the ring bore. Do not dislodge the ring. Then, wash the injector body in clean solvent and dry it with compressed air.

Remove the carbon deposits from the lower end of the injector nut with reamer J 9418–5 (Fig. 18). Clean the tip seat with reamer J 9418–1. Use care to minimize removing metal or setting up burrs on the spray tip seat. Remove only enough metal to produce a clean uniform seat to prevent leakage between the tip and the nut.

Wash the injector nut in clean solvent and dry it with compressed air. Carbon deposits on the spray tip seating surfaces of the injector nut will result in poor sealing and consequent fuel leakage around the spray tip.

When handling the injector plunger, do not touch the finished plunger surfaces with your fingers. Wash the plunger and bushing with clean solvent and dry them with compressed air. Be sure the high pressure bleed hole in the side of the bushing is not plugged. If this hole is plugged, fuel leakage will occur at the upper end of the bushing where it will drain out of the injector body vent and rack holes, during engine operation, causing a serious oil dilution problem. *Keep the plunger/bushing together as they are matched parts.*

After washing, submerge the parts in a clean receptable containing clean test oil. *Keep the parts of each injector assembly together.*

Inspect Injector Parts (Visual And Dimensional)

NOTICE: Injector components manufactured after January 1, 1988 may or may not be blued, at the discretion of the manufacturer. Bluing has no effect on a part's performance or service life.

1. Follower:

Measure between the top of the follower and the slot. This dimension must be 1.647 ± .002" (Fig. 19).

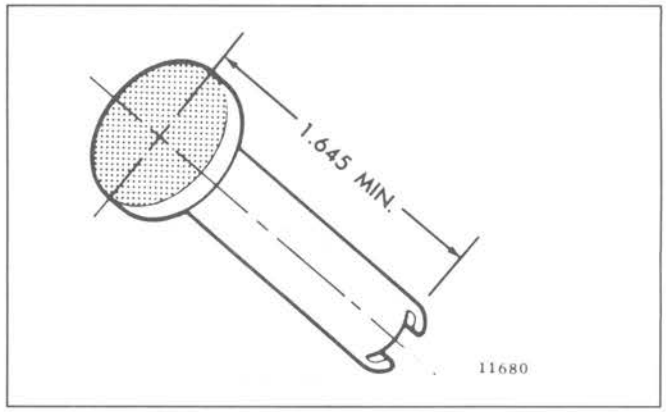


Fig. 19 – Injector Follower

Check the stop pin groove in the side of the follower to be sure it is smooth and not damaged. The follower should not be reused if there is more than .002" wear on the top or if there is any other visible damage or wear.

2. Follower Spring:

Examine the outside diameter of the follower spring coils for wear caused by the rocker arms contacting the coils. If worn, do not reuse.

Also, inspect for damage from rust pitting, nicks or notches in the coils, broken coils, broken coil ends and notches under the coil ends. If damaged, do not reuse.

Check the follower spring tension with spring Tester J 29196.

The current injector follower spring (.142" diameter wire) has a free length of approximately 1.504" and should be replaced when a load of less than 70 lbs. will compress it to 1.028". The former spring wire was .120" diameter.

It is recommended that at the time of overhaul, all injectors in an engine be converted to incorporate the current spring (1.42" diameter wire). However, in the event that one or two injectors are changed, the remaining injectors need not be reworked to incorporate the current spring.

3. Injector Body:

Inspect the injector body threads, the bushing seating surface and the filter cap gasket sealing surfaces for damage. Then, inspect the rack hole, body seal ring sealing surface, clamp radius and dowel pin.

4. Filter Cap:

Check the condition of the jumper line sealing surfaces on the filter caps, the copper gasket sealing surfaces, the threads and the fuel passage.

5. Control Rack:

Check the injector control rack for straightness, the teeth for wear and the width of the notch in the clevis. Also, check the rack for nicks, burrs, rust and hardness.

The notch in the clevis should be .3125" to .3145". A .250" inside diameter bushing may be used to check the rack for straightness. A slightly bent rack will not pass freely back and forth through the bore of the bushing.

6. Gear and Gear Retainer:

Inspect the gear and the gear retainer for nicks, burrs or rust and the gear teeth for wear.

• 7. & 8. Plunger and Bushing Assembly.

• Effective with injectors manufactured in October of 1985, P&B (plunger and bushing) assemblies have a revised finish on the inside diameter of the bushing that provides greater resistance to scoring during injector operation. Revised P&B assemblies are identified with a black locating pin at the top of the bushing. New injector assemblies containing revised P&B's are date stamped on the body with a "10–85" (for October, 1985) or later build date.

• Revised P&B assemblies are physically interchangeable with early P&B assemblies. However, because of the increased resistance to scoring provided by the revised assemblies, DDC recommends using the revised assemblies when rebuilding fuel injectors.

•NOTICE: Do not attempt to install the plunger of one P&B into the bushing of another P&B, and vise versa. Since components of P&B assemblies are supplied as matched sets, any attempt to mix them can result in P&B seizure and serious injector damage.

7. Bushing:

Check the bushing lapped sealing surface for scratches, the bushing internal diameter for scoring, the condition of the dowell pin and check for corrosion or varnish (Fig. 20).

8. Plunger:

Check the plunger for corrosion or varnish, scoring, scratching or wear and chips along the edge of the helix (Fig. 21).

9. Check Valve:

Inspect the check valve for cracks and scratches on the lapped surfaces or for corrosion and varnish.

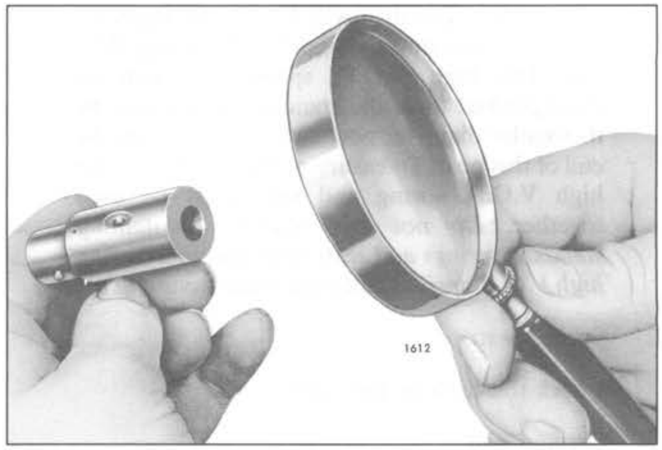
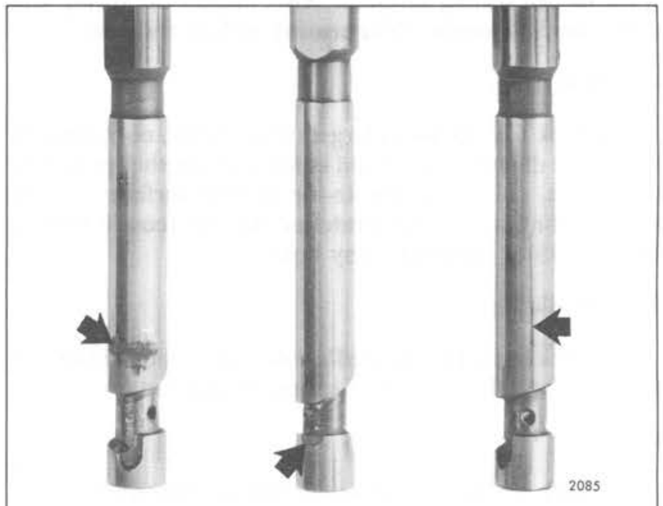


Fig. 20 – Examining Sealing Surface with a Magnifying Glass



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. 21 – Unusable Injector Plungers

10. Check Valve Cage:

Inspect the check valve cage for cracks and scratches on the lapped surfaces or for corrosion, varnish and wear.

11. Valve Spring:

Check the injector valve spring for wear on the coil ends, broken coil ends and notches under the coil ends. Then, check for corrosion, nicks and cavitation erosion on the inside at approximately 1–1/2 coils from the end.

•NOTICE: A high V.O.P. (valve opening pressure) valve spring and seat are being used in certain high output engine injectors. The high V.O.P. spring is made of a thicker diameter wire than the standard valve spring and has a smaller inside diameter (.174" I.D. vs 184" I.D.). A no. 15 (.180") drill may be used to distinguish the two springs. The drill will fit into the standard spring, but not into the high V.O.P. spring (Fig. 31). The high V.O.P. spring seat can be distinguished form the standard spring seat by its smaller diameter post and the groove on the end of this post. To ensure proper operation, the high V.O.P. spring and seat must be used together. *Do not mix injectors containing standard springs and seats with injectors having high V.O.P. springs and seats in the same engine.*

12. Spring Seat:

Check the surfaces for wear.

13. Spring Cage:

Inspect for cracks, corrosion or varnish and scratches on the lapped sealing surfaces. Also, inspect the spring seat surface and the needle valve seating surface for wear.

14. Spray Tip:

Check for cracks, enlarged spray holes, corrosion on the outside diameter taper and oxide scale on the spray hole end. Then, check the nut–to–tip sealing surface and the lapped sealing surface for scratches. Do not reuse if there is scale, cracks or enlarged spray holes.

15. Needle Valve:

Check the spray tip needle valve for erosion at the seat shoulder, scratches and overheating (discolored).

16. Nut:

Check the nut for damaged threads, the condition of the seal ring seating area, the condition of spray tip seating area and the spray tip hole for being corroded irregularly.

17. Spill Deflector:

Inspect both ends of the spill deflector for sharp edges or burrs.

18. Part Thickness:

Check the minimum thickness of the parts (see Table 1).

19. Needle Valve Lift:

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)

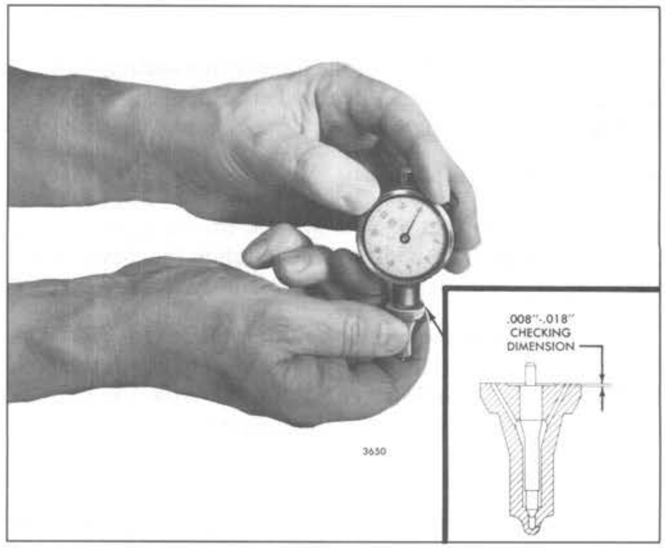


Fig. 22 – Checking Needle Valve Lift with Tool J 9462–02

Measure the needle valve lift, using tool J 9462–02 (Fig. 22) as follows:

a. Zero the indicator by placing the bottom surface of the plunger assembly on a flat surface and zero the indicator dial.

b. Place the spray tip and needle valve assembly tight against the bottom of the gage with the quill of the needle valve in the hole in the plunger.

c. While holding the spray tip and needle valve assembly tight against the gage, read the needle valve lift on the indicator. The lift should be .008" to .018". If it exceeds .018", the tip assembly must be replaced. If it is less than .008", inspect for foreign material between the needle valve and the tip seat.

d. If the needle valve lift is within limits, install a new needle valve spring and recheck the valve opening pressure and valve action. Low valve opening pressure or poor atomization with a new spring and seat indicates the spray tip and needle valve assembly should be replaced.

20. Classify Spray Tip:

Match the plunger/bushing assembly with the proper tip using Flow Gage J 25600–A (see Section 2.0).

Recondition Injector

If any of the injector parts listed below cannot be reconditioned satisfactorily, use new parts. All parts must be cleaned to be free of rust, varnish and carbon before reuse.

1. Follower:

■ Resurface or replace if worn beyond dimensional limits.

2. Follower Spring:

■Reuse unless damaged, worn or won't meet test specifications.

3. Body:

■Lap bushing seat.

■Reblue (*optional*).

■Repair damaged threads.

■Replace body if the clamp radius is badly worn or if the threads are less than 90% good.

4. Filter Caps:

■Recondition tapered seat.

■Clean and deburr hole.

■Reblue (*optional*).

■Replace if the threads or sealing surfaces are damaged.

5. Control Rack:

■Deburr teeth – check for straightness.

■Replace if the teeth show significant wear.

6. Gear and Gear Retainer:

■Deburr.

■Replace if cracked or significantly worn.

7. Bushing:

■If scored, cracked or if residue cannot be removed, replace plunger and bushing assembly.

■Lap the check valve seat (sealing) surface.

8. Plunger:

■Clean – remove varnish.

■If scored, chipped or scratched, replace plunger and bushing assembly.

9. Check Valve:

■Lap both flat (sealing) surfaces.

■Replace if scratched, cracked or badly worn.

10. Check Valve Cage:

■Lap both flat sealing surfaces.

■Replace if cracked or too thin (see Table 1).

11. Valve Spring:

■Replace. Do not reuse unless there is absolutely no wear or damage.

12. Spring Seat:

■Replace if there is a hole worn in the rounded end where the needle quill touches.

13. Spring Cage:

■Lap both flat (sealing) surfaces.

■Replace if cracked or too thin (see Table 1) or if the needle has worn a pocket around the small hole.

14. Spray Tip:

■Regrind seat.

■Lap flat sealing surface.

■Regrind the needle conicol seat.

■Replace if beyond flow limits i.e., erroded spray holes.

15. Nut:

■Remove carbon from the seat and tapered I.D.

■Reblue (*optional*).

■Replace if the threads are damaged more than 10% or if the small I.D. is badly erroded.

16. Spill Deflector:

■Remove burrs.

■Reuse if the ends are smooth and even and the deflector is not cracked.

Normally, new parts do not require lapping prior to use. Wash the service parts in clean solvent to remove the solitified preservative. However, if new parts become nicked or burred during handling, then lapping will be necessary to provide adequate sealing between the flat parts.

The sealing surface of current spray tips is precision lapped by a new process which leaves the surface with a dull satin–like finish; the lapped surface on former spray tips was bright and shiny (Fig. 23). It is not recommended to lap the surface of a *new* current spray tip.

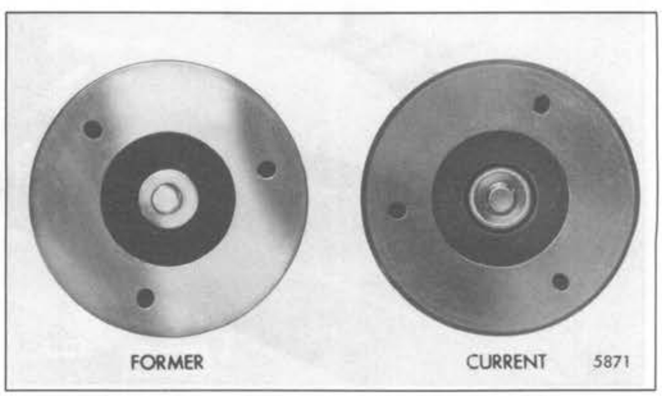


Fig. 23 – Spray Tip Sealing Surface Identification

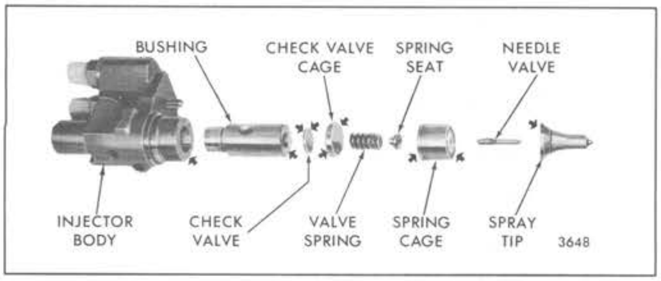


Fig. 24 - Sealing Surfaces which may Require Lapping

Lapping Injector Parts

If necessary, lap the sealing surfaces indicated in Fig. 24 as follows:

1. Clean the lapping blocks (J 22090) with compressed air. Do not use a cloth or any other material for this purpose.
2. Spread a good quality 600 grit dry lapping powder on one of the lapping blocks.
3. Place the part to be lapped flat on the block (Fig. 25) and, using a figure eight motion, move it back and forth across the block. Do not press on the part, but use just enough pressure to keep the part flat on the block. It is important that the part be kept flat on the block at all times.
4. After each four or five passes, clean the lapping powder from the part by drawing it across a clean piece of tissue placed on a flat surface and inspect the part. *Do not lap excessively.*
5. When the part is flat, wash it in cleaning solvent and dry it with compressed air.

CAUTION:To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.

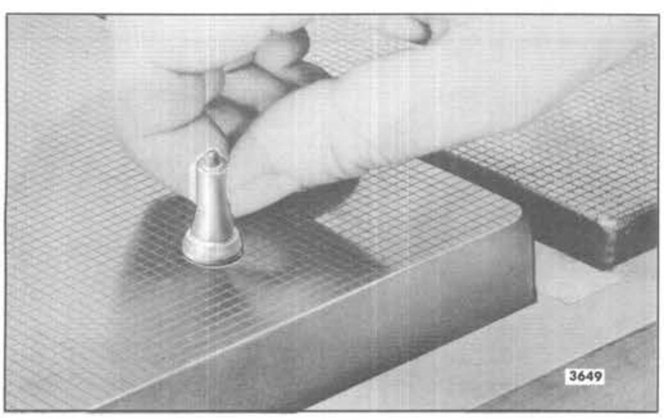


Fig. 25 - Lapping Spray Tip on Lapping Blocks J 22090

6. Place the dry part on the second block. After applying lapping powder, move the part lightly across the block in a figure eight motion several times to give it a smooth finish. *Do not lap excessively.* Again wash the part in cleaning solvent and dry it with compressed air.
7. Place the dry part on the third block. Do not use lapping powder on this block. Keep the part flat and move it across the block several times, using the figure eight motion. Lapping the dry part in this manner gives it the "mirror" finish required for perfect sealing.
8. Wash all of the lapped parts in clean solvent and dry them with compressed air.

Assemble Injector

1. Secure the body in vise J 22396–1.
2. Insert new filter(s) in the top of the body (Fig. 26). The current production filter (stainless steel wire mesh pellet) is installed dimple end down, slotted end up. The current service filter (fiberglass–filled nylon cone) must be installed with the pointed (cone) end up.

   Insert a new filter in the inlet side (located over the injector rack) in an offset injector. No filter is required at the outlet side (Fig. 27).
3. Place a new gasket on each filter cap. Lubricate the threads and install the filter caps. Tighten the filter caps to 65–75 lb–ft (88–102 N•m) torque with a 9/16" deep socket (Fig. 28).

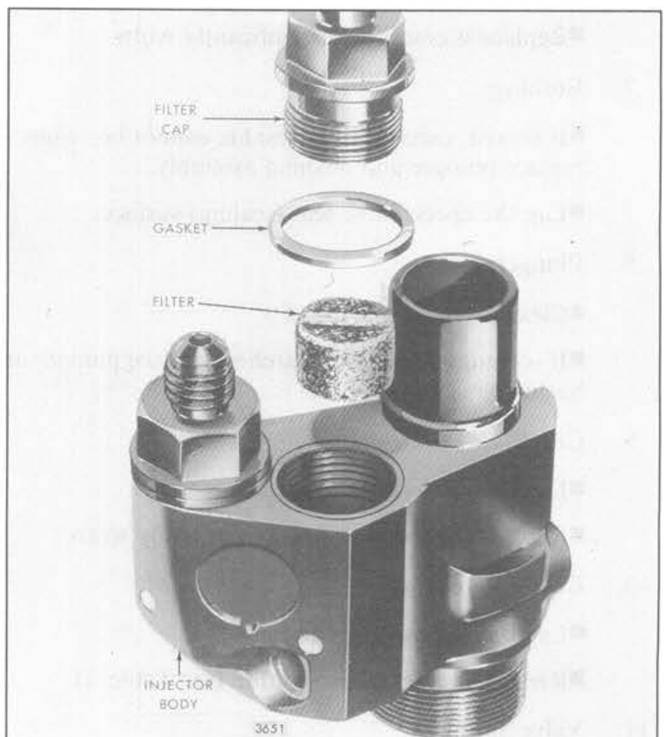


Fig. 26 - Details of Injector Filters and Caps and Their Relative Location

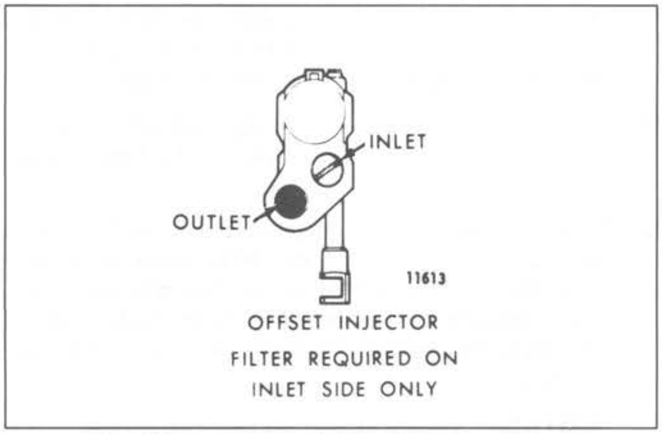


Fig. 27 – Location of Filter in Injector Body

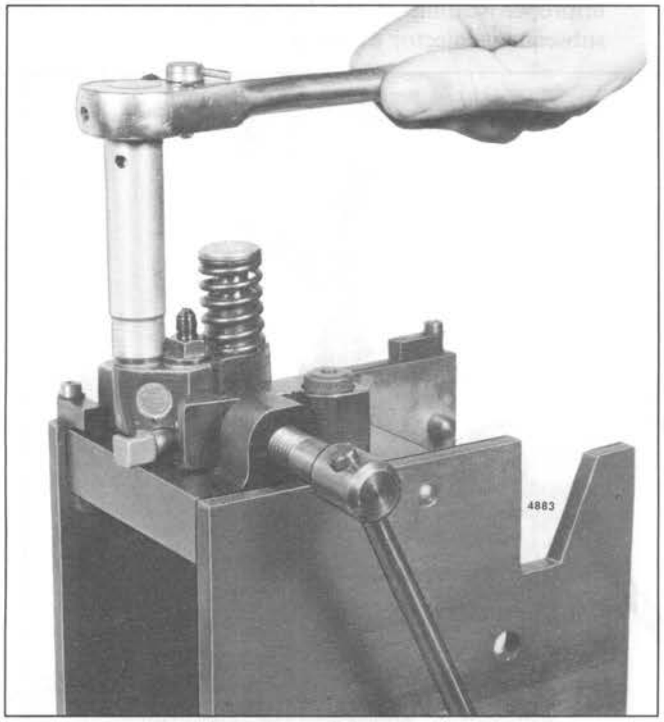


Fig. 28 – Installing Filter Cap

4. Install clean shipping caps to protect the sealing surfaces and to prevent dirt from entering the injector.

5. Lubricate the injector nut seal ring installer J 29197 with injector test oil. Remove the injector from the vise and hold the injector body, bottom end up. Place the installer over the threads of the injector body.

•6. Lubricate the new seal ring and place the new seal over the nose of the protector and down onto the shoulder of the injector body. Do not allow the seal to roll or twist.

A new round (in cross–section) injector nut seal ring replaced the former diamond–shaped ring, effective with injectors manufactured approximately November 1, 1987. Only the round seal is serviced.

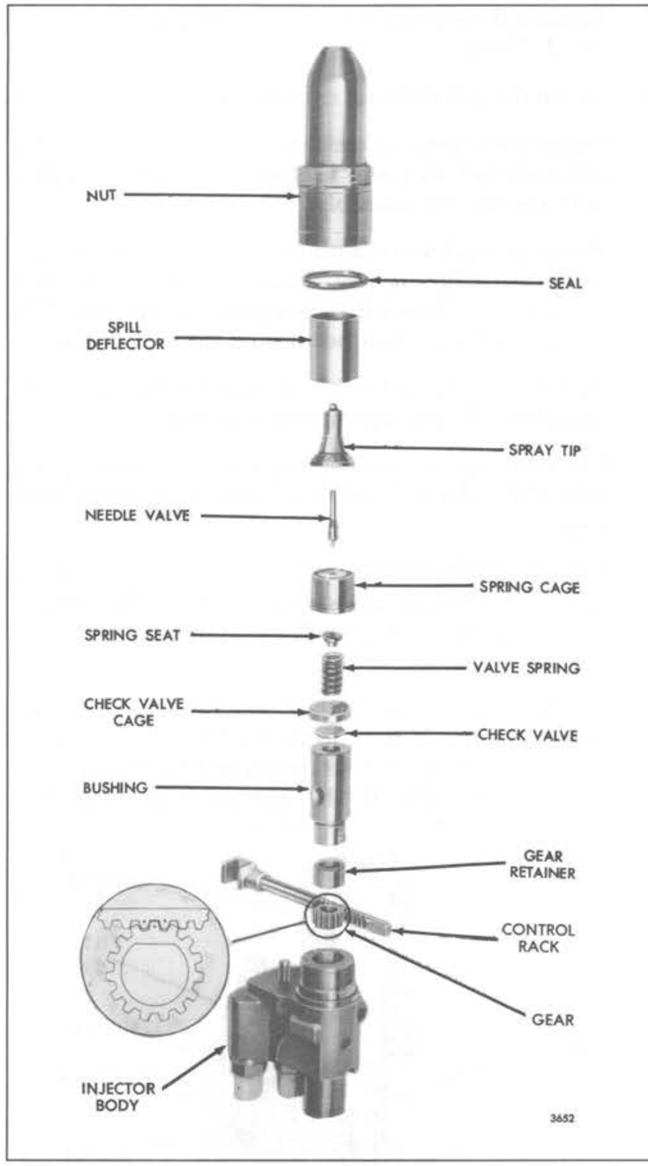


Fig. 29 – Injector Rack, Gear, Spray Tip and Valve Assembly Details and Relative Location of Parts

7. Remove the protector (J 29197).

8. Slide the control rack into the injector body.

9. Refer to Fig. 29 and note the marked teeth on the control rack and gear. Then, look into the body bore and move the rack until you can see the drill marks. Hold the rack in this position.

10. Place the gear in the injector body so that the marked tooth is engaged between the two marked teeth on the rack (Fig. 29).

11. Place the gear retainer on top of the gear.

12. Align the locating pin in the bushing with the slot in the injector body, then slide the end of the bushing into place.

13. Support the injector body, bottom end up, in injector vise J 22396–1.
14. Install the spill deflector over the barrel of the bushing.
15. Perform the spray tip test, as outlined in Section 2.0 using injector tip Tester J 22640–A before proceeding with the injector assembly.
16. Place the check valve (without the .010" hole) centrally on the top of the bushing. Then, place the check valve cage over the check valve and against the bushing. The check valve cage must not rest on the check valve.
17. Insert the spring seat in the valve spring, then insert the assembly into the cage, spring seat first.
18. Place the spring cage, spring seat and valve spring assembly (valve spring down) on top of the check valve cage.
19. Put the needle, tapered end down, into the spray tip (Fig. 30). Then, place the spray tip assembly on top of the spring cage with the quill end of the needle valve in the hole in the spring cage.
20. Lubricate the threads in the injector nut and carefully thread the nut on the injector body by hand. Rotate the spray tip between your thumb and first finger while threading the nut on the injector body (Fig. 31).

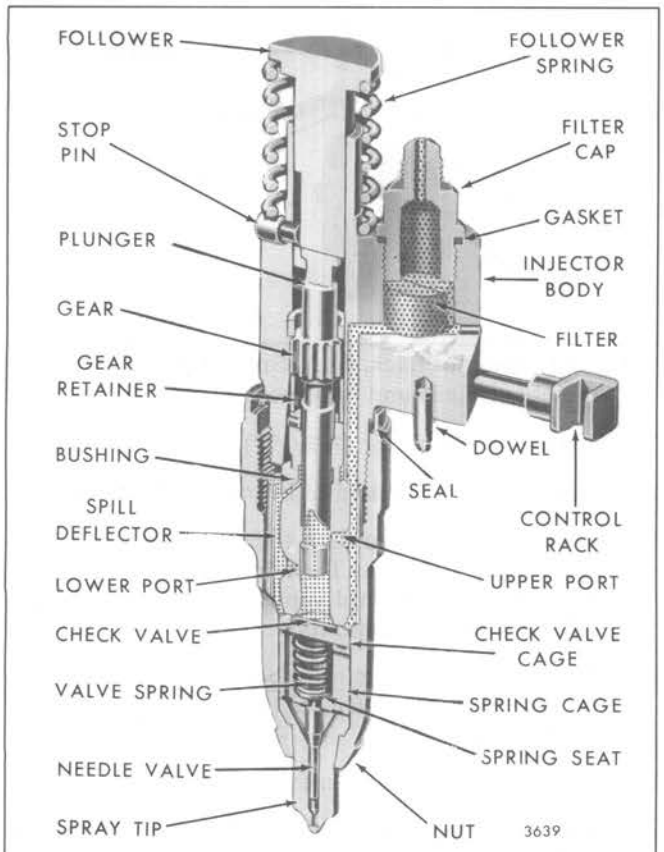


Fig. 30 – Cutaway View of Fuel Injector

Tighten the nut as tight as possible by hand. At this point there should be sufficient force on the spray tip to make it impossible to turn with your fingers.

21. Use socket J 4983–01 and a torque wrench to tighten the injector nut to 75–85 lb–ft (102–115 N•m) torque (Fig. 32).
22. After assembling a fuel injector, always check the area between the nut and the body. If the seal is still visible after the nut is assembled, try another nut and a new seal which may allow assembly on the body without extruding the seal and forcing it out of the body–nut crevice.

NOTICE: Do not exceed the specified torque. Otherwise, the nut may be stretched and result in improper sealing of the lapped surfaces in a subsequent injector overhaul.

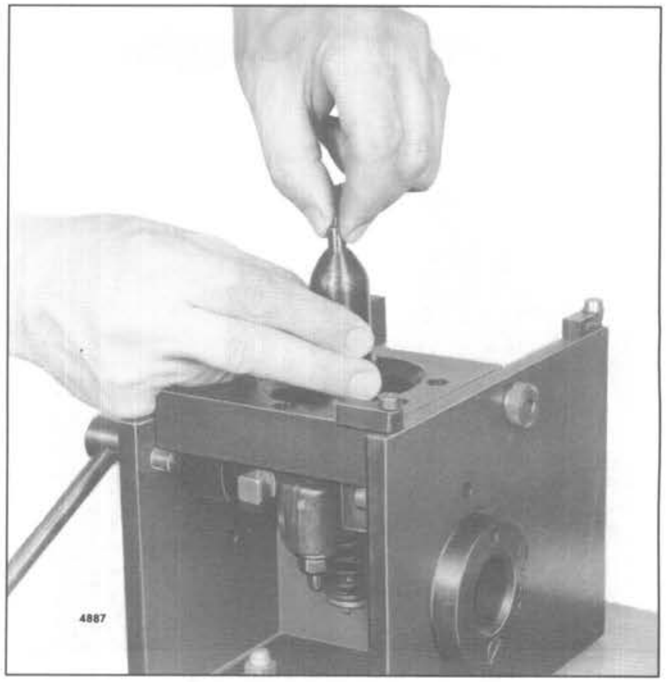


Fig. 31 – Tightening Injector Nut by Hand

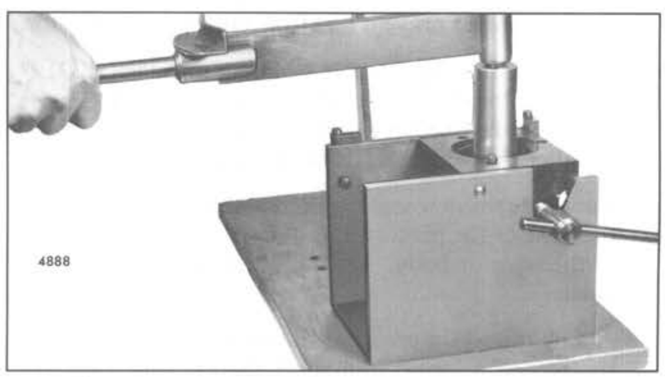


Fig. 32 – Tightening Injector Nut with Torque Wrench using Tool J 4983–01

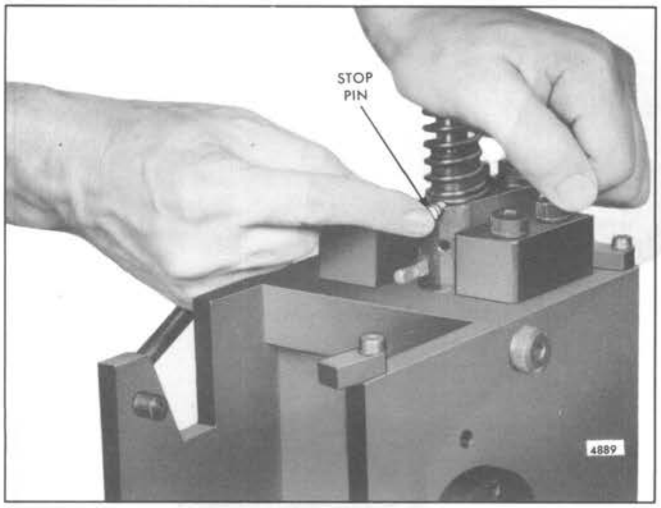


Fig. 33 – Installing Injector Follower Stop Pin

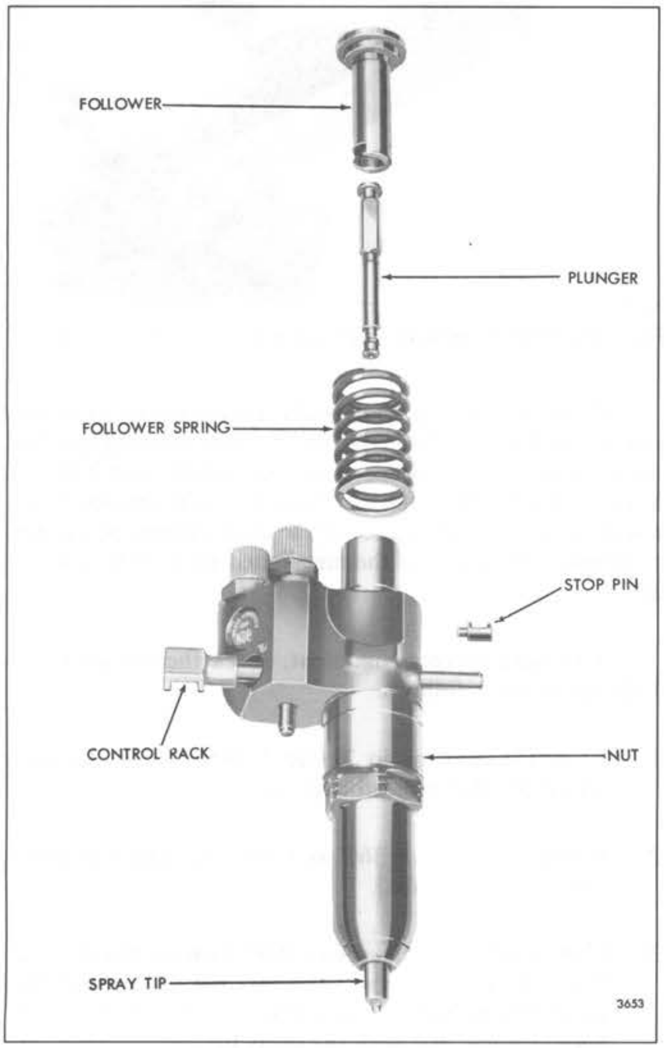


Fig. 34 – Injector Plunger, Follower and Relative Location of Parts

23. Turn the injector over and push the rack all the way in.
24. Place the follower spring on the injector body.
25. Refer to Fig. 33 and place the stop pin on the injector body so that the follower spring rests on the narrow flange of the stop pin.
26. Refer to Fig. 34 and slide the head of the plunger into the follower.
27. Align the slot in the follower with the stop pin hole in the injector body.
28. Align the flat side of the plunger with the flat in the gear.
29. Insert the free end of the plunger in the injector body. Press down on the follower and at the same time press the stop pin into position. When in place, the spring will hold the stop pin in position.

Check Injector Output

Perform the injector fuel output test using Calibrator J 22410–A as outlined in Section 2.0 – Shop Notes.

Check Atomization And Spray Pattern

This test determines spray pattern uniformity and atomization.

1. Clamp the injector properly and purge the air from the system (Fig. 35).
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.

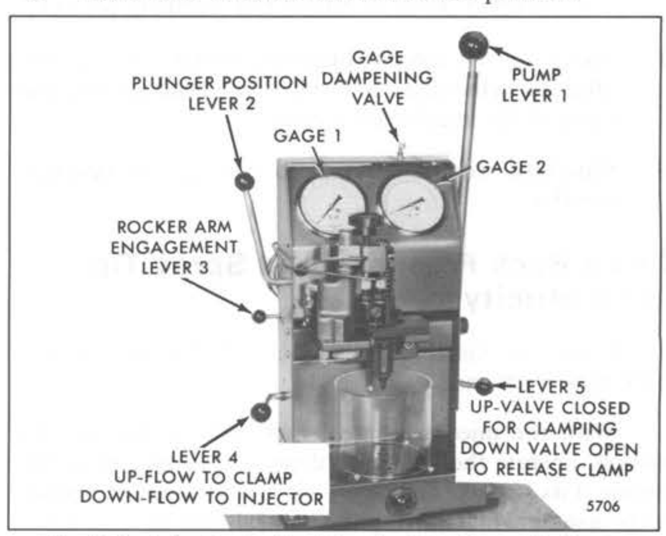


Fig. 35 – Injector in Position for Testing with Tester J 23010–A

6. The injector follower should be depressed rapidly using pump lever 1 (at 40 to 80 strokes per minute) to simulate operation in the engine. Observe the spray pattern to see that all spray orifices are open and dispersing the test oil evenly. The beginning and ending of injection should be sharp and the test oil should be finely atomized with no drops of test oil forming on the end of the tip.

Check Pressure Holding And Test For Leaks

This test determines if the body–to–bushing mating surfaces in the injector are sealing properly and indicates proper plunger–to–bushing fit.

1. Clamp the injector properly in Tester J 23010–A and purge the air from the system (Fig. 35).
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 slowly reaches 100–200 psi (689–1378 kPa), check for injector nut seal ring leaks. Then, increase the gage reading to 1500–2000 psi (10 335–13 780 kPa). Check for leaks at the filter cap gaskets and the body plugs. Note the time for the pressure to drop from 1500 psi to 1000 psi (10 335 kPa to 6890 kPa). This should not occur in less than 7 seconds. This test determines if the body–to–bushing mating surfaces in the injector are sealing properly.
5. Unclamp the injector.
6. Open the Thru–Flow valve to release pressure in the system.
7. Move lever 5 *down* to release the clamping pressure.
8. Swing out the adaptor plate and remove the injector after the nylon seals in the clamping head are free and clean of the injector filter caps.
9. Carefully, return lever 5 to the *up (horizontal)* position.

Check Rack Freeness And Spray Tip Concentricity

Place the injector in Tester J 29584 (Fig. 36) and check rack freeness.

With the injector control rack held in the *no–fuel* position, operate the handle to depress the follower to the bottom of its stroke. Then, very slowly release the pressure on the handle while moving the control rack up and down until the follower reaches the top of its travel. If the rack falls freely the injector passes the test.

Fig. 36 – Checking Rack for Freeness in Tester J 29584

If the rack does not fall freely, loosen the injector nut, turn the tip, then retighten the nut. Loosen and retighten the nut a couple of times, if necessary. Generally, this will free the rack. Then, if the rack isn't free, change the injector nut. In some cases it may be necessary to disassemble the injector to eliminate the cause of the misaligned parts or to remove dirt.

To assure correct alignment, check the concentricity of the spray tip as follows:

1. Place the injector in Tester J 29584 (Fig. 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. Loosen the injector nut, center the spray tip and tighten the nut to 75–85 lb–ft (102–115 N•m) torque. Recheck the spray tip concentricity. If, after several attempts, the spray tip cannot be positioned satisfactorily, replace the injector nut.

Box And Store Injector

If the reconditioned injector is to be placed in stock, fill it with injector test oil J 26400. *Do not use fuel oil.* Install shipping caps on both filter caps immediately after filling. Store the injector in an *upright* position to prevent test oil leakage.

Install Injector

Before installing an injector in an engine, remove the carbon deposits from the beveled seat of the injector tube in the cylinder head. This will assure correct alignment of the injector and prevent any undue stresses from being exerted against the spray tip.

Use injector tube bevel reamer J 5286–9 or a cylindrical wire brush, Section 2.1.4, to clean the carbon from the injector tube. Exercise care to remove ONLY the carbon so that the proper tip protrusion is maintained. Pack the flutes of the reamer with grease to retain the carbon removed from the tube.

Be sure the fuel injector is filled with fuel oil. If necessary, add clean fuel oil at the inlet filter cap until it runs out of the outlet filter cap.

Install the injector in the engine as follows:

1. Refer to Fig. 5 and insert the injector into the injector tube with the dowel pin in the injector body registering with the locating hole in the cylinder head.
2. Slide the injector rack control lever over so that it registers with the injector rack.
3. Install the injector clamp, special washer (with curved side toward injector clamp) and bolt. Tighten the bolt to 20–25 lb–ft (27–34 N•m) torque. Make sure that the clamp does not interfere with the injector follower spring or the exhaust valve springs.

   NOTICE: Check the injector control rack for free movement. Excess torque can cause the control rack to stick or bind.

4. Move the rocker arm assembly into position and secure the rocker arm brackets to the cylinder head by tightening the bolts to the torque specified in Section 2.0 – Specifications.

   NOTICE: On four valve cylinder heads, there is a possibility of damaging the exhaust valves if the exhaust valve bridge is not resting on the ends of the exhaust valves when tightening the rocker shaft bracket bolts. Refer to *Install Rocker Arm and Shaft* in Section 1.2.1 and note the position of the exhaust valve bridge before, during and after tightening the rocker shaft bolts.

•5. Remove the shipping caps. Align the fuel pipes and connect them to the injectors and the fuel connectors.

•NOTICE: DDC recommends that the original fuel pipes not be reused. New flared end fuel pipes should be installed. When installing flared end fuel pipes, use fuel pipe nut wrench J 8932–01 and "clicker" type torque wrench J 24405 (calibrated in inch– pounds) to apply proper torque and avoid damaging the fuel pipes. Refer to the chart for torque specifications. Fuel leakage from damaged or improperly installed fuel pipes can cause lube oil dilution, which may result in serious engine damage.

To help insure more consistent fastening, tighten fuel pipe nuts on jumper lines to the single values shown below. Use fuel line nut wrench J 8932–01 and "clicker" type torque wrench J 24405 (calibrated in inch–pounds).

Jumper Line Usage	Torque
Endurion®-coated	130 lb-in. (14.69 N·m)
Uncoated	160 lb-in. (18.3 N·m)
Jacobs Brakes*	120 lb-in. (13.6 N·m)
Load limiting devices	160 lb-in. (18.3 N·m)
DDEC Engines	145 lb-in. (15.6 N·m)

**Not serviced. Available from Jacobs Manufacturing Company.*

•

•NOTICE: Because of their low friction surface, Endurion® –coated nuts on fuel jumper lines must be tightened to 130 lb–in (14.69 N•m) torque, instead of the 160 lb–in (18.3 N•m) required with uncoated nuts. To avoid possible confusion when tightening jumper line nuts, do not mix lines with uncoated and Endurion® –coated nuts on the same cylinder head.

• Jacobs brake jumper lines and jumper lines used with load–limiting devices do not have coated nuts. Tighten these to the values shown on the Chart.

NOTICE: Do not bend the fuel pipes and do not exceed the specified torque. Excessive tightening will twist or fracture the flared end of the fuel line and result in leaks. Lubricating oil diluted by fuel oil can cause serious damage to the engine bearings (refer to *Fuel Jumper Line Maintenance and Reuse & Pressurize Fuel System – Check for Leaks* in Section 2.0 – Shop Notes).

An indication of fuel leakage at the fittings of the fuel injector supply lines and connector nut seals could be either low lubricating oil pressure (dilution) or fuel odor coming from the crankcase breathers or an open oil filler cap. When any of the above are detected, remove the valve rocker cover. A close inspection of the rocker cover, cylinder head, fuel lines and connectors will usually show if there is a fuel leakage problem. Under normal conditions, there should be a coating of lubricating oil throughout the cylinder head area and puddles of oil where the fuel pipes contact the connectors and where the fuel connectors contact the cylinder head. If these areas do not have the normal coating of lubricating oil, it is likely that fuel oil is leaking and washing off the lubricating oil. Remove and replace the leaking fuel pipes and/or connectors. Use a new gasket and reinstall the rocker cover. Then, drain the lubricating oil and change the oil filter elements. Refer to Section 13.3 (Lubrication Specifications) and refill the crankcase to the proper level with the recommended grade of oil.

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 (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 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.

The new service–only injector hole tube can be distinguished from the former by the size of the large I.D. (1.198"–1.201" vs. 1.180"–1.183") and by the Detroit Diesel logo plus the number "606" stamped on the top flange. The former tube was marked with either "GM" or the Detroit Diesel logo on the top flange.

The new tube takes less time to install than the former tube because the large I.D. (inside diameter) of the new tube does not require reaming. Reaming is only necessary at the small I.D. and the injector nut seat. Reaming must be done carefully and without undue force or speed so as to avoid cutting through the thin wall of the injector tube.

NOTICE: 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.

Repair Leaking Injector Tube

To enable the repair of a leaking fuel injector hole tube at the seal ring, without removing the cylinder head from the cylinder block, a new injector hole tube swaging tool J 28611–A is now available.

Before removing the fuel injector, pressurize the cooling system at the radiator to verify the injector tube seal ring leak. Then, with the fuel injector removed, insert the swaging tool into the fuel injector hole tube. The tool is tapered and flanged to prevent damage to the cylinder head or injector tube. Hit the top of the tool moderately with a one pound hammer two or three blows seating the tool. This will cause the top edge of the injector hole tube to expand, thus increasing the crush on the injector tube seal ring and seal the leak. Install the fuel injector and again pressurize the cooling system to verify the leak has been stopped.

This tool was designed mainly for use on engines built between July, 1973 and August, 1977 with fuel injector hole tube seal rings that may be pressure senstive and, if so, could take a heat set. The result being a coolant leak at the seal ring.

The use of the swaging tool, as stated above, will restore tension to the seal ring.

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 5286–4C in the injector tube. This tool or installer J 5486–20 may be used with semi–finished, service–only injector hole tubes (identified by the number "606" stamped on the top flange). 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).

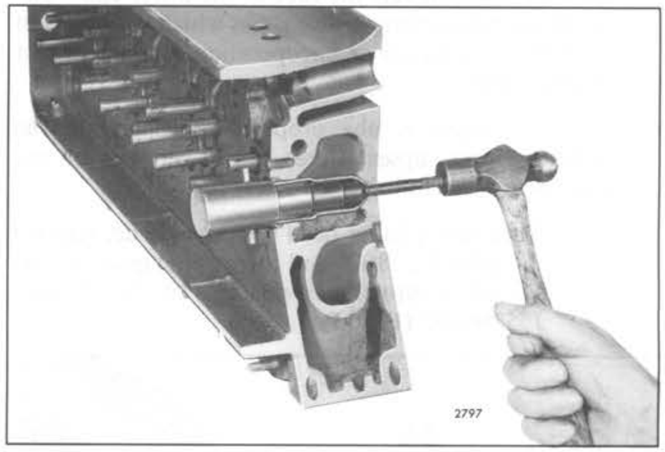


Fig. 1 – Removing Injector Tube with Tools J 5286–4C and J 5286–5

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.

NOTICE: 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 5286–4C in the injector tube. Then, insert the pilot J 5286–5 through the small opening of the injector tube and thread it into the tapped end of the installer (Fig.–2). For proper installation of any injector hole tube, the tool must contact the tube at the bottom before it touches the flange at the top. The clearance at the top, between the flange and the tool, should be .001" to .010".

3. Slip the injector tube into the injector bore and drive it in place (Fig. 2). Sealing is accomplished between the head counterbore (inside diameter) and outside diameter of the injector tube. The tube flange is merely used to retain the seal ring.

   During installation the tube will stretch slightly before the tool contacts the flange, thus allowing the tool to properlyinstall the tube. If there is no clearance at the flange, the tube will buckle slightly during installation until the toolcontacts the tube at the lower end. The buckling causes compressive stress which will result in tube cracking during engineoperation and subsequent engine damage.

4. With the injector tube properly positioned in the cylinder head, upset (flare) the lower end of the injector tube as follows:

   a. Turn the cylinder head bottom side up, remove the pilot J 5286–5 and thread the upsetting die J 5286–6 into the tapped end of the installer J 5286–4C (Fig. 3).

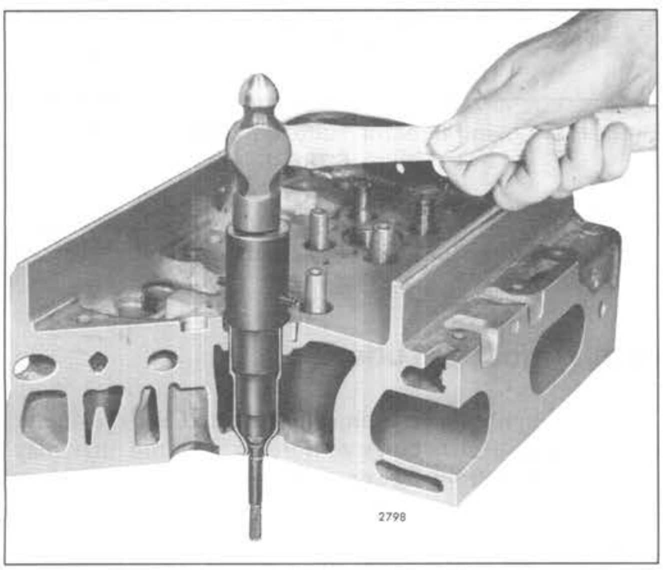


Fig. 2 – Installing Injector Tube with Tools J 5286–4C and J 5286–5

   b. Then, using a socket and torque wrench, apply approximately 30 lb–ft (41 N•m) torque on the upsetting die.

   c. Remove the installing tools and ream the injector tube as outlined below.

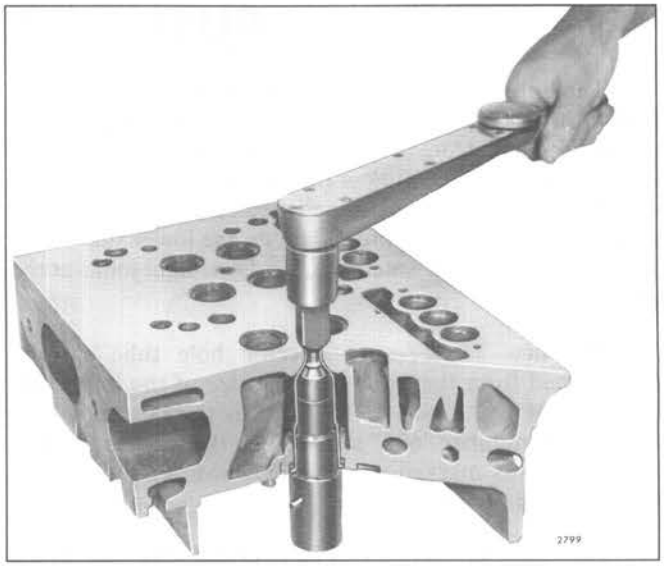


Fig. 3 – Upsetting Injector Tube with Tools J 5286–4C and J 5286–6

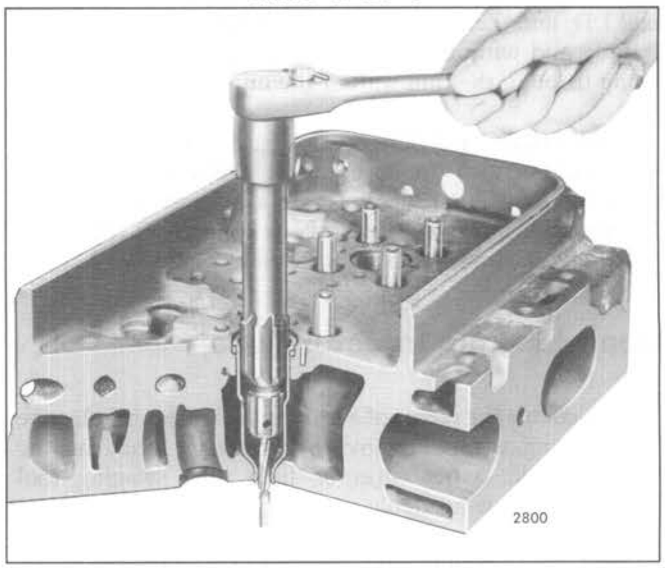


Fig. 4 – Reaming Injector Tube for Injector Body Nut and Spray Tip with Tool J 22525–1

Ream Injector Tube

After an injector tube has been installed in a cylinder head, it must be finished in three operations:

First, *hand reamed,* (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.

Third, *hand reamed,* (Fig. 5) to provide a good seating surface for the bevel or the lower end of the injector nut.

NOTICE: The reamer should be turned in a *clockwise direction* only, both when inserting and when withdrawing the reamer, because movement in the opposite direction will dull the cutting edges of the flutes.

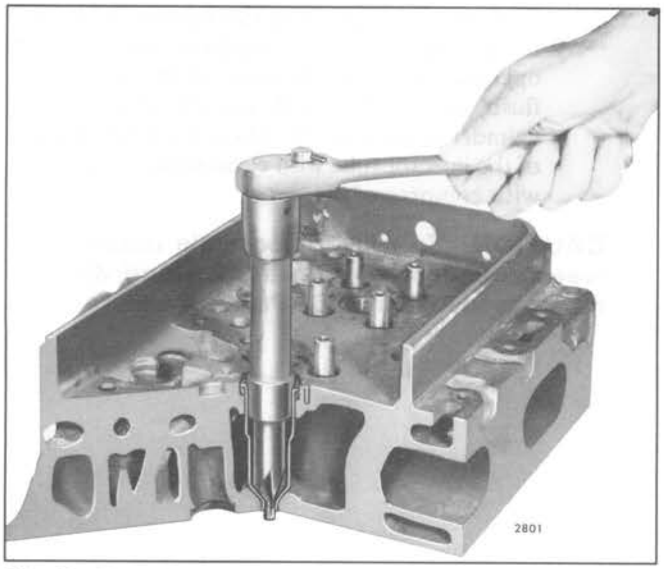


Fig. 5 – Reaming Injector Tube for Injector Nut with Tool J 5286–9

1. Ream the injector tube for the injector nut and spray tip. With the cylinder head right side up and the injector tube free from dirt, proceed with the first reaming operation as follows:

   a. Place a few drops of light cutting oil on the reamer flutes, then carefully position the reamer J 22525–1 in the injector tube.

   b. Turn the reamer in a clockwise direction (withdrawing the reamer frequently for removal of chips) until the lower shoulder of the reamer contacts the injector tube (Fig. 4). Clean out all of the chips.

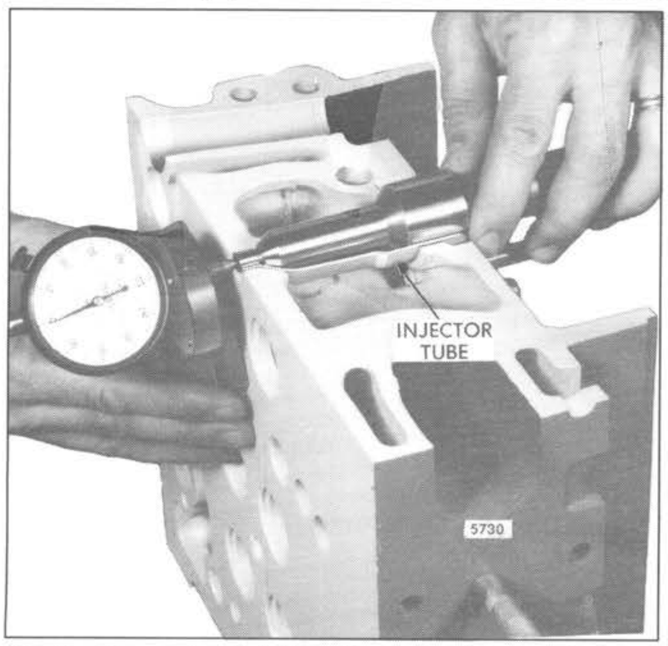


Fig. 6 – Measuring Relationship of Bevel Seat of Injector Tube to Fire Deck of Cylinder Head with Tool J 25521 and Gage J 22273

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 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 ± .014" with the fire deck of the cylinder head (Fig. 7).

NOTICE: 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.

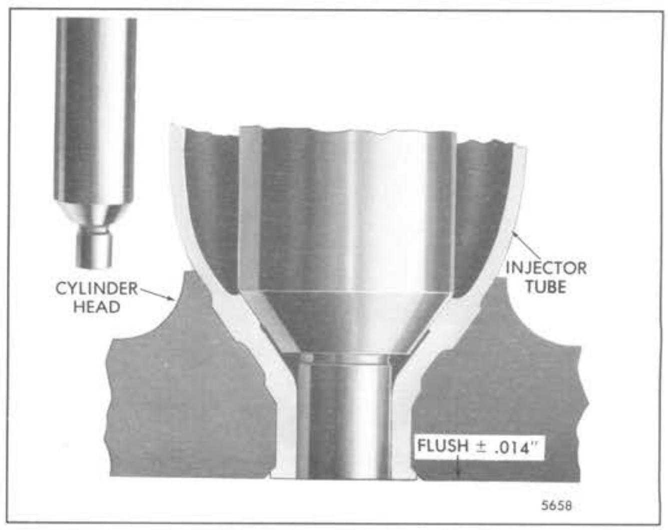


Fig. 7 – Measuring Relationship of Gage to Fire Deck of Cylinder Head with Tool J 25521

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.

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 (Fig. 7). Then, wash the interior of the injector tube with clean solvent and dry it with compressed air.

CAUTION: To prevent possible injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.

FUEL PUMP

The positive displacement gear–type fuel pump (Fig. 1) transfers fuel from the supply tank to the fuel injectors. 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.

The fuel pump is attached to the governor housing with three nylon patch bolts which prevents the oil in the governor housing from seeping out around the bolt threads. The pump is driven off the end of the right–hand helix blower rotor by means of a drive coupling fork attached to the end of the pump drive shaft and mating with a drive disc attached to the blower rotor (Fig. 2). The fuel pump is a left–hand rotating pump. Regardless of engine rotation, the pump will always rotate in a left–hand rotation.

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 means of two dowels. The dowels aid in maintaining gear shaft alignment. The mating surface 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.

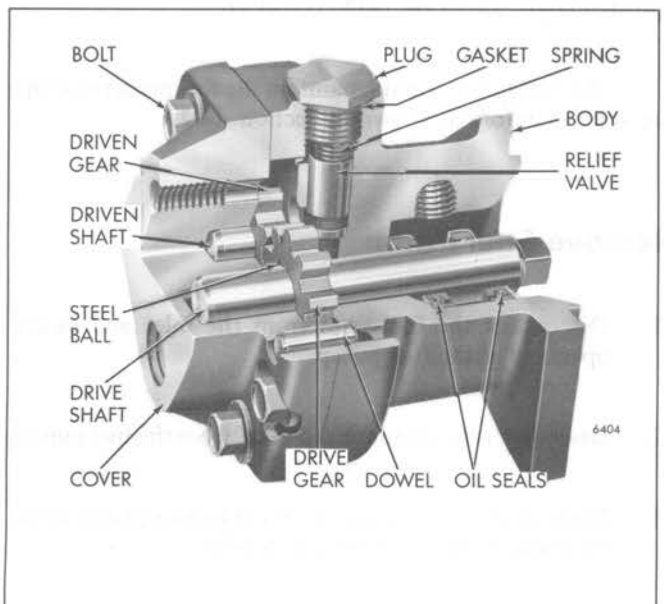


Fig. 1 – Typical Fuel Pump Assembly

The fuel pump body is recessed to provide running space for the pump gears (Fig. 3). 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 governor housing (Fig. 4). A small hole "E" (Fig. 3) 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 the same as the high lift fuel pumps, with the lips of the seals facing in the opposite direction of each other (Fig. 4). The former fuel pumps have the nitrile seals installed with both seal lips facing the mounting flange end of the pump. Both the polyacrylate and 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 retension between the seals could

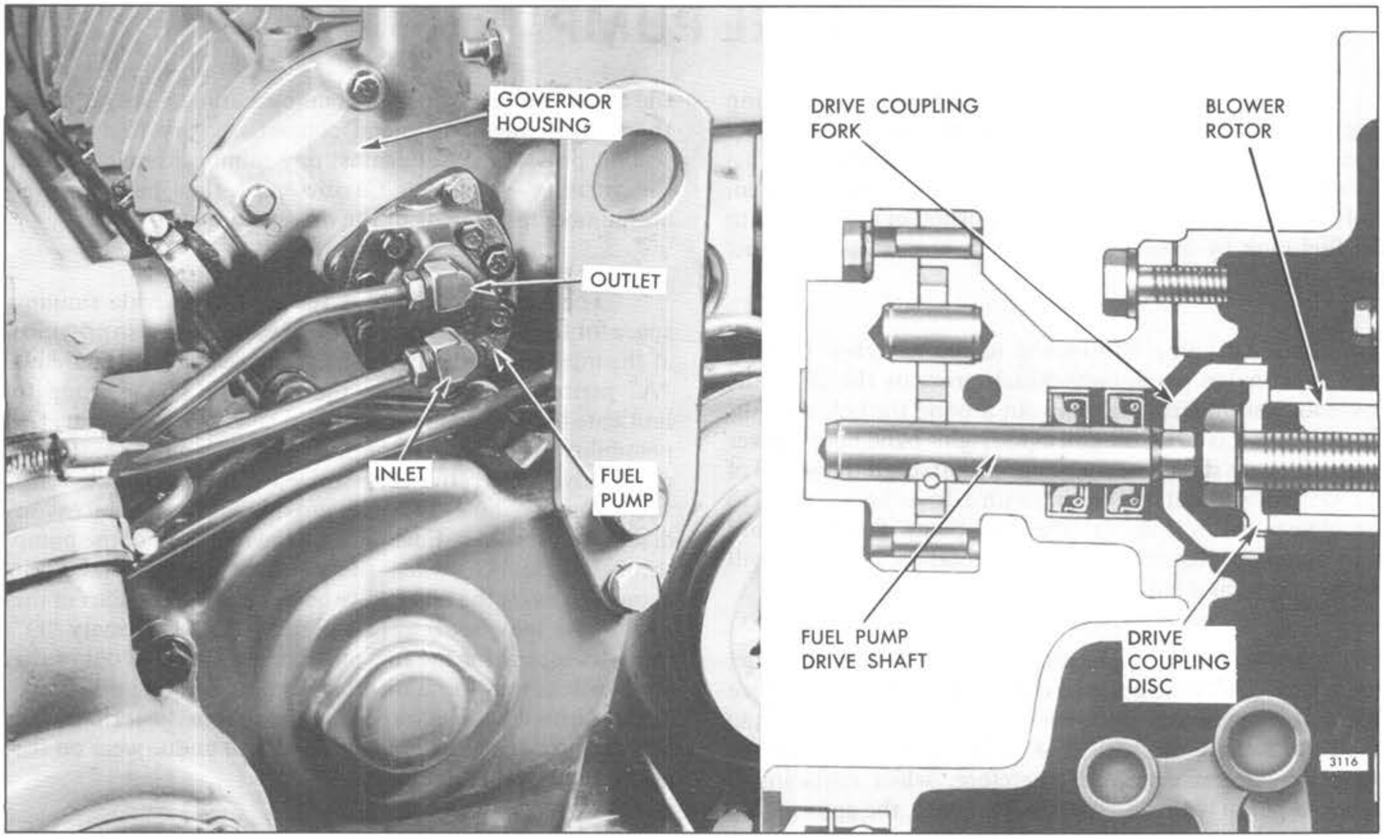


Fig. 2 – Typical Fuel Pump Mounting and Drive

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.

The drive and driven gears are a line–to–line to .001" press fit on their shafts. The drive gear is provided with a gear retaining ball to locate the gear on the shaft (Fig. 2).

A spring–loaded relief valve incorporated in the pump body normally remains in the closed position, operating only when pressure on the outlet side (to 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 oil is forced out into the outlet cavity. Since this is a continuous cycle and fuel is continually being forced into the outlet cavity, the fuel flows from the outlet cavity into the fuel lines and through the engine fuel system under pressure.

The pressure relief valve relieves the discharge pressure by bypassing the fuel from the outlet side of the pump to the inlet side when the discharge pressure reaches approximately 65–75 psi (448–517 kPa).

The fuel pump should maintain the fuel pressure at the fuel inlet manifold as shown in 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 from the governor housing.
4. Check the drive coupling fork and, if broken or worn, replace it with a new coupling.

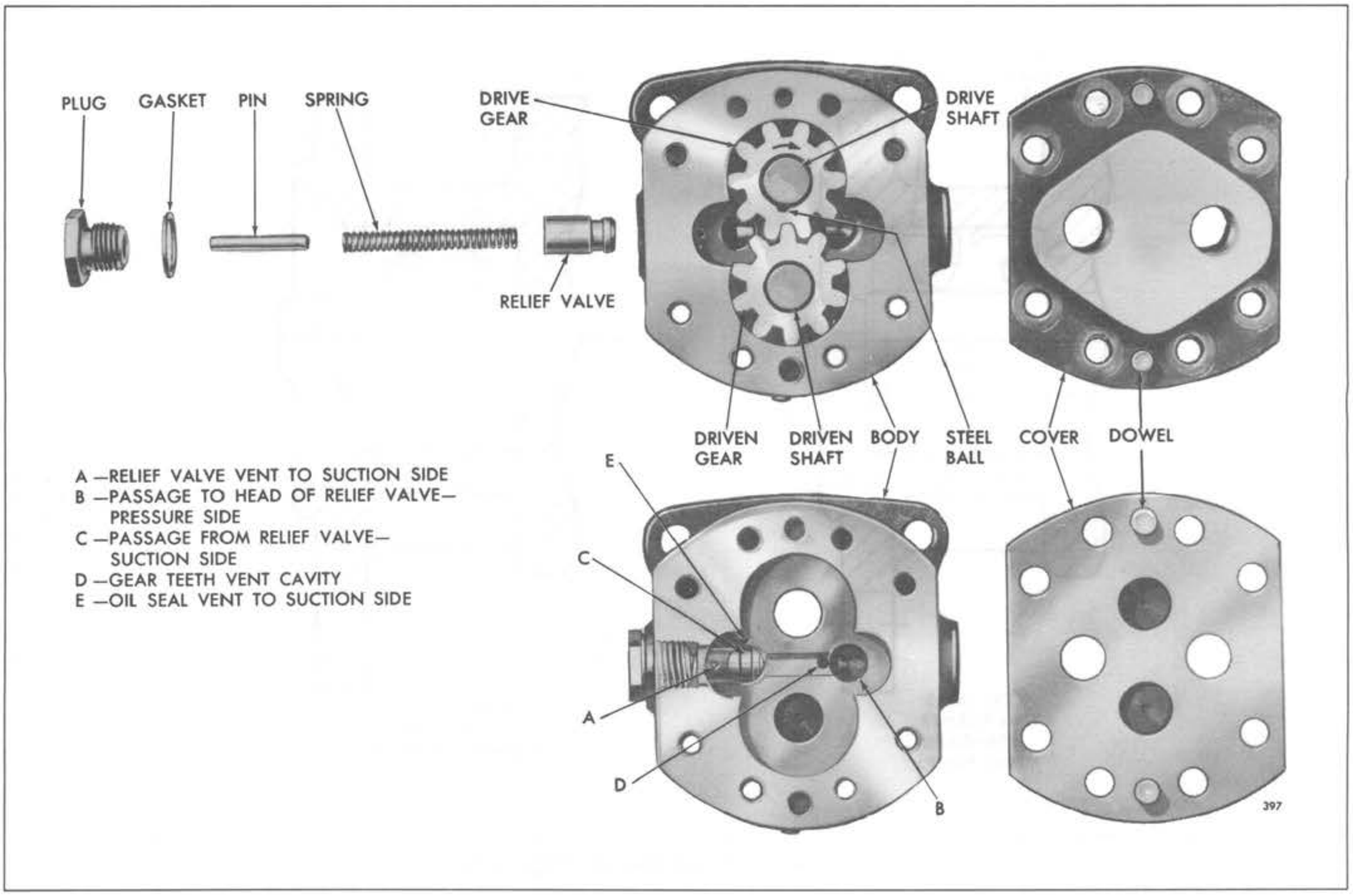


Fig. 3 – Fuel Pump Valving and Rotation

Disassemble Fuel Pump

With the fuel pump removed from the engine and mounted in holding fixture J 1508–10 as shown in Fig. 5, refer to Figs. 1 and 7 and disassemble the pump, as follows:

1. Remove 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. 6). Clamp the pump body in a bench vise and tap the end of the tool with a hammer to remove the outer and inner seals.

NOTICE: Observe the position of the oil seal lips before removing the old seals to permit installation of the new seals in the same position.

Inspection

Clean all of the parts in clean fuel oil and dry them with compressed air.

CAUTION:To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.

Oil seals, once removed from the pump body, must be discarded and replaced with new seals.

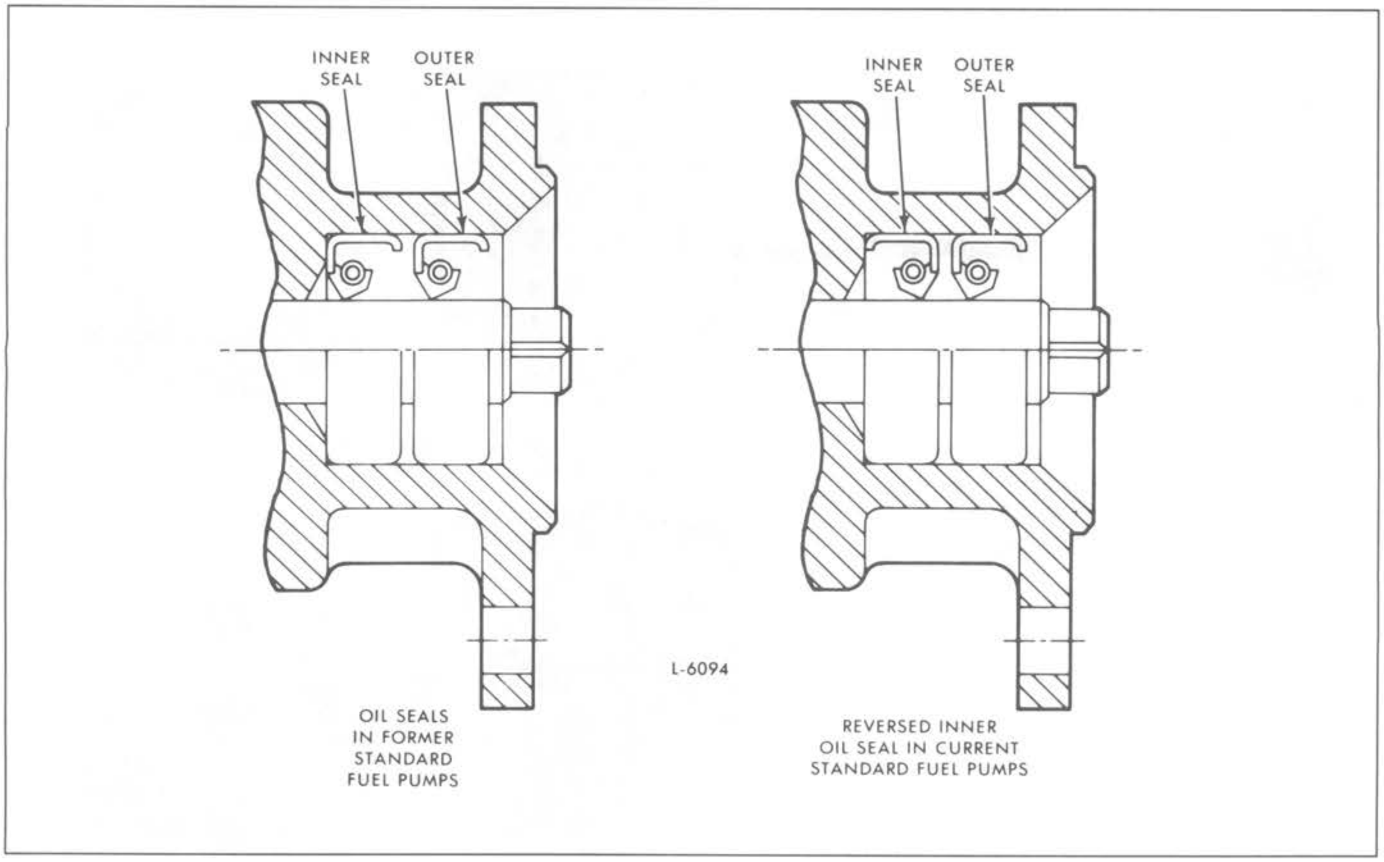


Fig. 4 – Fuel Pump Oil Seal Arrangements

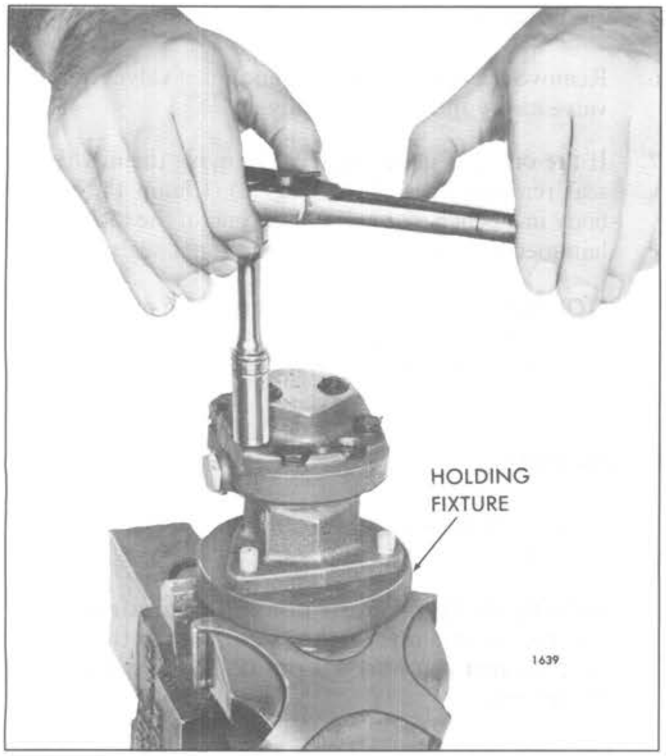


Fig. 5 – Removing Fuel Pump Cover

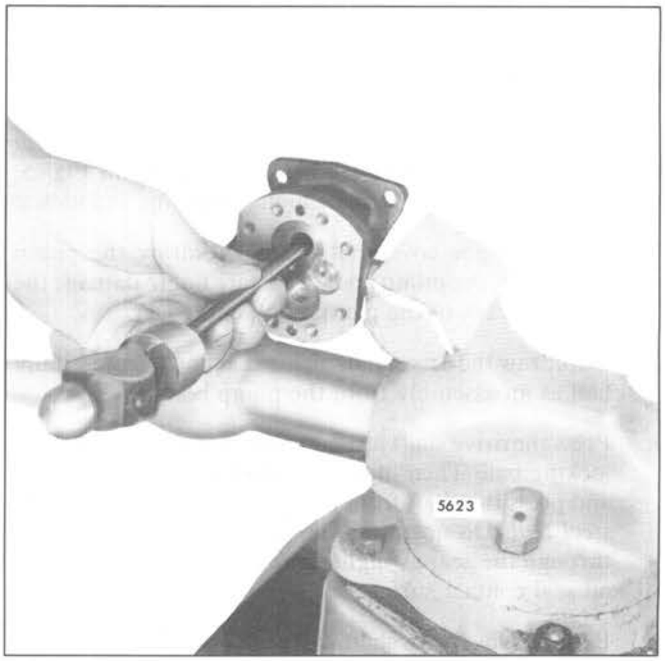


Fig. 6 – Removing Oil Seals using Tool J 1508-13

Check the pump gear teeth for scoring, chipping or wear. Check the ball slot in the drive gear for wear. If necessary, replace the gear.

Inspect the drive and driven shafts for scoring or wear. Replace the shafts if necessary. The driven shaft is serviced as a gear and shaft assembly only.

The mating faces of the pump body and cover must be flat and smooth and fit tightly together. Any scratches or slight damage may result in pressure leaks. Also check for wear at areas contacted by the gears and shafts. Replace the pump cover or body, if necessary.

The relief valve must be free from score marks and burrs and fit its seat in the pump body. If the valve is scored and cannot be cleaned up with fine emery cloth or crocus cloth, it must be replaced.

Current standard fuel pumps (with 1/4" wide gears) incorporate a 1/8" shorter pump body with three drain holes, a 1/8" shorter drive shaft and a cover with a 3/8" inlet opening. When replacing a former pump, a 3/8" x 1/4" reducing bushing is required for the inlet opening and the unused drain holes must be plugged.

Assemble Fuel Pump

Refer to Figs. 1, 3 and 7 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 in the same direction as the original seal which was removed.

NOTICE: 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. 8), 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

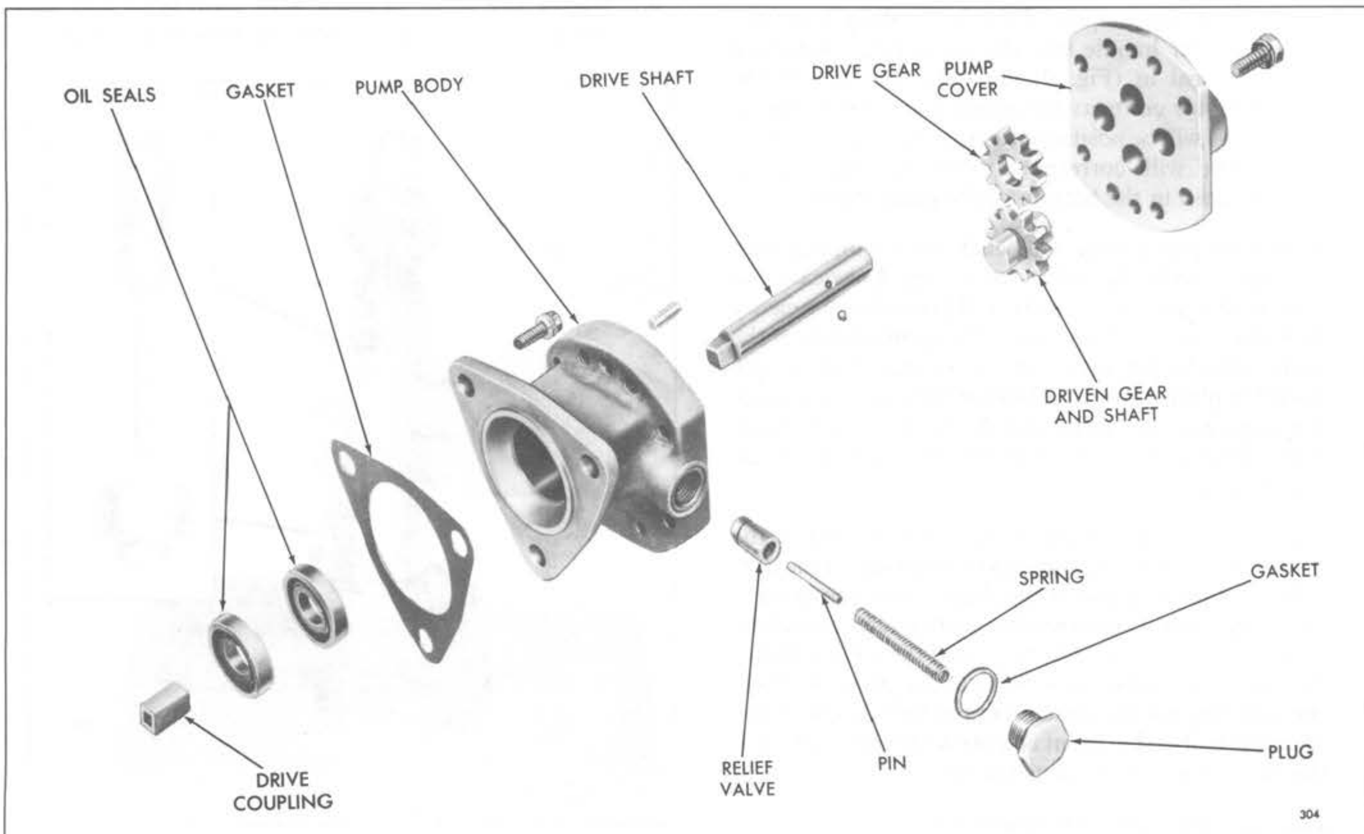


Fig. 7 – Fuel Pump Details and Relative Location of Parts

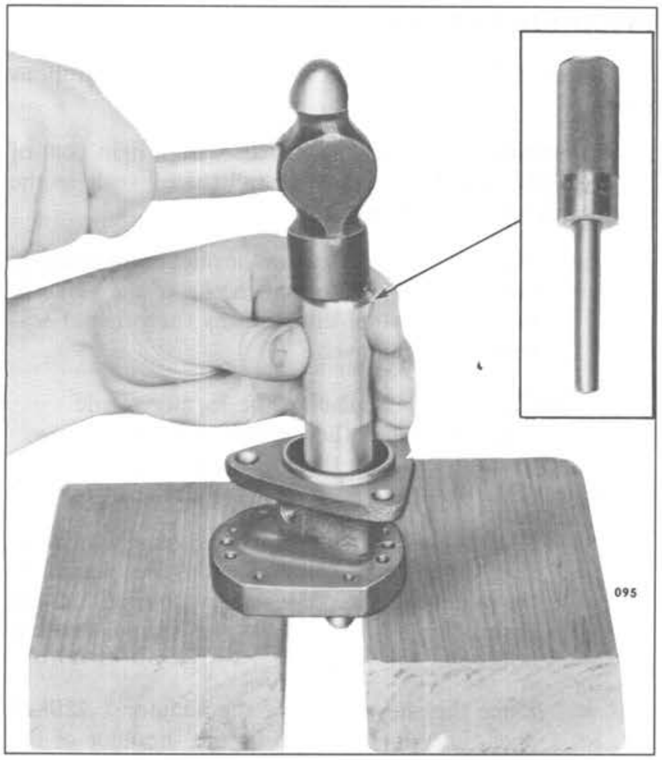


Fig. 8 – Installing Inner Oil Seal using Tool J 1508-8

facing the adaptor. Then insert the pilot of the installer handle into the pump body and drive the seal in (Fig. 9) until the shoulder of the adaptor contacts the pump body. Thus, the oil seals will be positioned so that the space between them will correspond with the drain holes located in the bottom of the pump body.

2. Clamp the pump body in a bench vise (equipped with soft jaws) with the valve cavity up. Lubricate the outside diameter of the valve and place it in the cavity with the hollow end up. Insert the spring inside of the valve and the pin inside of the spring. With a new gasket in place next to the head of the valve plug, place the plug over the spring and thread it into the pump body. Tighten the 1/2"-20 plug to 18–22 lb-ft (24–30 N•m) torque.

3. Install the fuel pump drive gear over the end of the drive shaft which is not squared (so the slot in the gear will face the plain end of the shaft). This operation is very important, otherwise fine score marks caused by pressing the gear into position from the square end of the shaft may cause rapid wear of the oil seals. Press the gear beyond the gear retaining ball detent. Then place the ball in the detent and press the gear back until the end of the slot contacts the ball.

4. Lubricate the pump shaft and insert the square end of the shaft into the opening at the gear side of the pump body and through the oil seals (Fig. 10).

5. Place the driven shaft and gear assembly in the pump body.

NOTICE: The driven gear must be centered on the shaft to give proper end clearance. Also, the chamfered end of the gear teeth of the production gear must face the pump body. If a service replacement gear with a slot is used, the slot must face toward the pump cover.

6. Lubricate the gears and shafts with clean engine oil.

7. Apply a thin coat of quality sealant on the face of the pump cover outside of the gear pocket area. Then place the cover against the pump body with the two dowel pins in the cover entering the holes in the pump body. The cover can be installed in only one position over the two shafts.

NOTICE: The coating of sealant must be extremely thin since the pump clearances have been set up on the basis of metal-to-metal contact. Too much sealant could increase the clearances and affect 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.

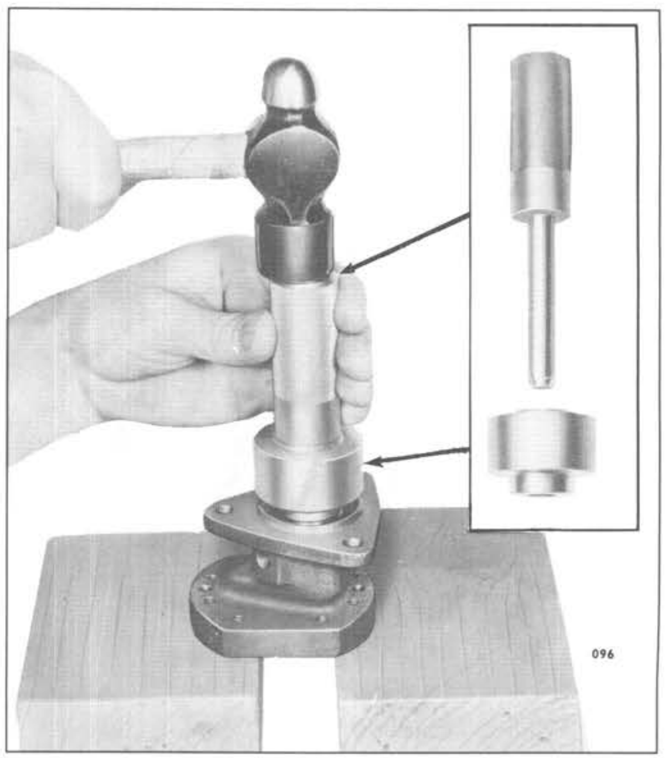


Fig. 9 – Installing Outer Oil Seal using Tools J 1508-8 and J 1508-9

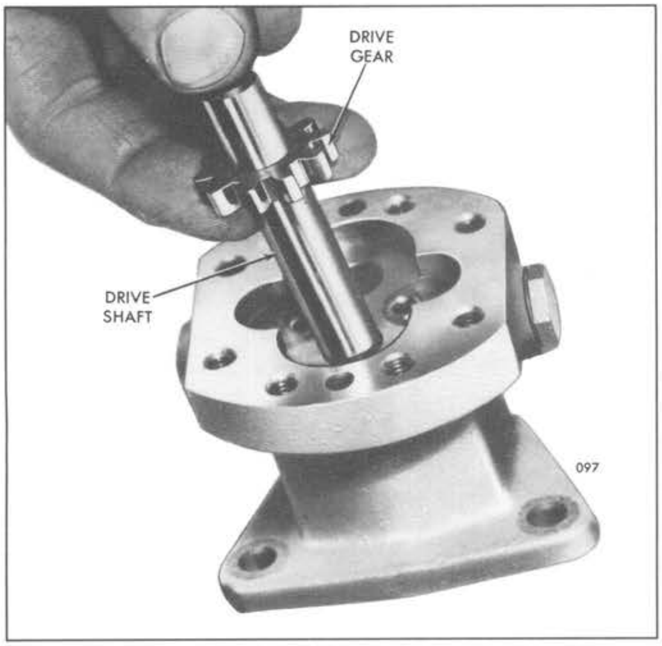


Fig. 10 – Installing Fuel Pump Drive Shaft and Gear Assembly

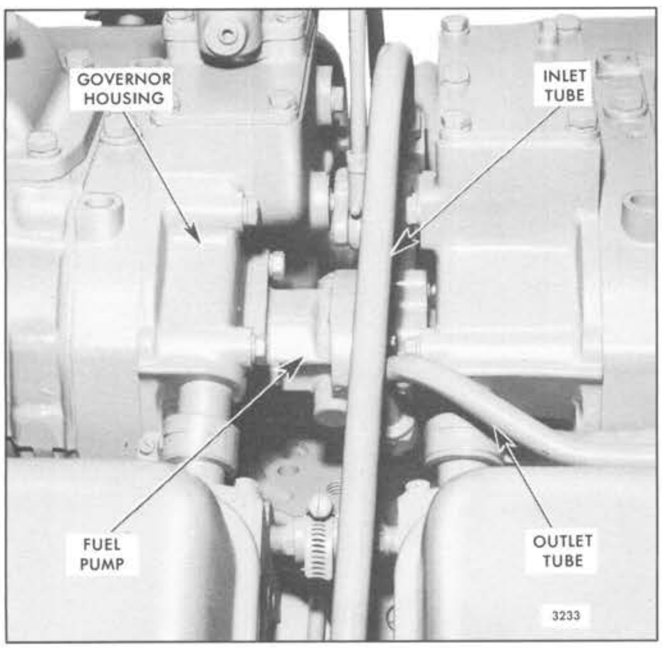


Fig. 11 – Typical Fuel Pump Mounting (16V Engine)

9. After assembly, rotate the pump shaft by hand to make certain that the parts rotate freely. If the shaft does not rotate freely, attempt to free it by tapping a corner of the pump.
10. Install 1/8" pipe plugs in the upper unused drain holes.
11. If the pump is not to be installed immediately, place plastic shipping plugs in the inlet and outlet openings to prevent dirt or other foreign material from entering the pump.

Install Fuel Pump

The pump must always be installed with the inlet opening in the pump cover (marked "L.H. IN") next to the balance weight cover on 6V and 8V engines. Refer to Fig. 2 and note that the fuel pump is bolted to the governor housing and is driven by the drive coupling fork and the drive disc which is attached to the blower rotor. Refer to Fig. 11 when installing the fuel pump on a 12V and 16V engine. Install the pump, as follows:

1. Affix a new gasket to the pump body mounting flange. Then place the drive coupling fork on the square end of the drive shaft.
2. Place the fuel pump against the governor housing, being certain that the drive coupling fork registers with the slots in the drive disc.
3. Secure the pump to the governor housing with three nylon patch bolts.

   NOTICE: To provide improved sealing against leakage, nylon patch bolts are used in place of the former bolt and seal assemblies.

4. If removed, install the inlet and outlet elbows in the pump cover. Before installing, coat the threads lightly with Gasoila, Permatex 2, or an equivalent non–hardening sealant.

   NOTICE: Do not use Teflon tape or paste on fittings, since this can result in fuel pump cover damage (cracking) before the required torque is reached.

To prevent sealant from entering the fuel system, do not apply it to the first two (2) threads of the fittings. Tighten fittings to the low end of the torque. If necessary, continue tightening until alignment is achieved, but do not exceed maximum torque. Tighten 1/4" fittings to 14 – 16 lb–ft (19 – 22 N•m), 3/8" fittings to 18 –22 lb–ft (24 – 30 N•m), and 1/2" fittings to 20 – 25 lb–ft (27 – 34 N•m) torque.

5. Connect the inlet and outlet fuel lines to the fuel pump elbows.
6. Connect the fuel pump drain tube, if used, to the pump body.
7. If the fuel pump is replaced or rebuilt, prime the fuel system before starting the engine using Tool J 5956. This will prevent the possibility of pump seizure upon initial starting.

FUEL STRAINER AND FUEL FILTER

(BOLT–ON TYPE)

A fuel strainer (primary) and fuel filter (secondary), Figs. 1 and 2, 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 moisture, sludge and other course debris. The fuel filter is installed between the fuel pump and the fuel inlet manifold. The replaceable paper–type (cellulose) element (Fig. 4) can remove particles as small as 10 microns. Fiberglass elements can remove particles as small as 5 microns.

NOTICE: A fuel tank of galvanized steel should never be used for fuel storage, as the fuel oil reacts chemically with the zinc coating to form powdery flakes which quickly clog the fuel filter and cause damage to the fuel pump and the fuel injectors.

The fuel strainer and fuel filter are essentially the same in construction and operation, and they will be treated as one in this section.

The filter and strainer, illustrated in Figs. 3 and 4, consist basically of a shell, a cover, and a replaceable filtering element. The assembly is made oil tight by a shell gasket, a cover nut or bolt, and a cover nut or bolt gasket.

The central stud is a permanent part of the shell and, when the unit is assembled, extends up through the cover where the nut or bolt holds the assembly together.

A filter element sets over the central stud inside the shell and is centered in the shell by the stud.

Operation

Since the fuel strainer is between the fuel supply tank and the fuel pump, it functions under suction. The fuel filter, placed between the fuel pump and the fuel inlet manifold in the cylinder head, operates under pressure. Fuel enters through the inlet passage in the cover and into the shell surrounding the filter element. Pressure or suction created by the pump causes the fuel to flow through the filter element where dirt particles are removed. Clean fuel flows to the interior of the filter element, up through the central passage in the cover and into the outlet passage, then to the fuel inlet manifold in the cylinder head.

If engine operation is erratic, indicating shortage of fuel or flow obstructions, refer to *Trouble Shooting* in Section 15.2 for corrective measures.

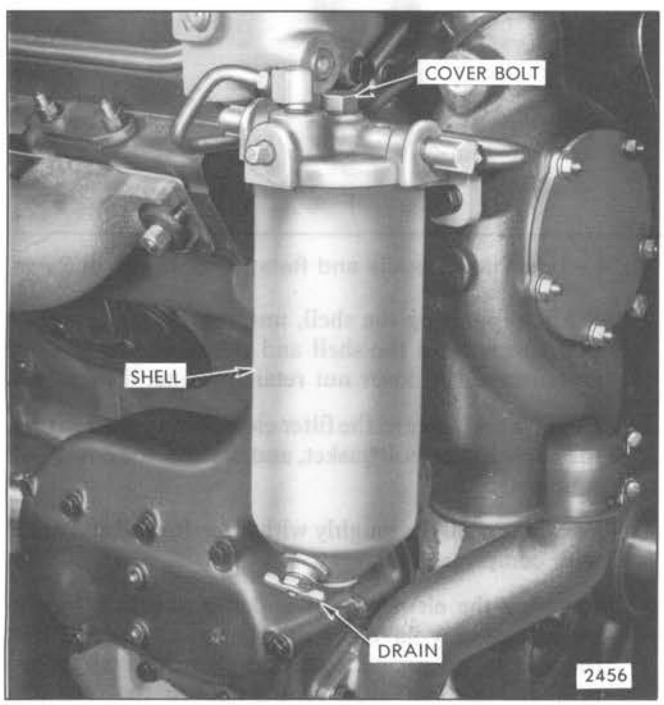


Fig. 1 – Typical Mounting of Fuel Filter

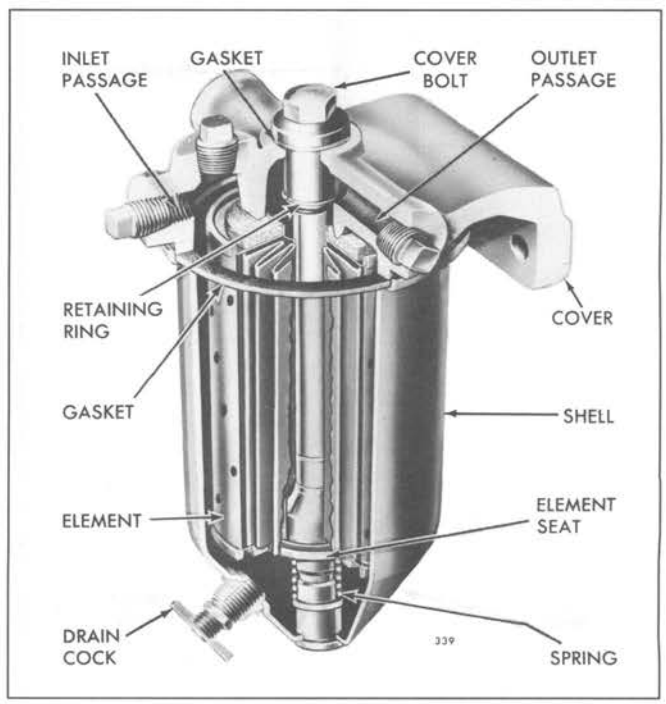


Fig. 2 – Fuel Filter Assembly

Replace Fuel Strainer Or Filter Element

The procedure for replacing an element is the same for the fuel strainer or fuel filter. Refer to Figs. 3 and 4 and replace the element as follows:

NOTICE: Only filter elements designed for fuel oil filtration should be used to filter the fuel.

1. With the engine stopped, place a container under the strainer or filter and open the drain cock. Loosen the cover nut or bolt just enough to allow the fuel oil to drain out freely. Then close the drain cock.

NOTICE: The wiring harness, starting motor or other electrical equipment must be shielded during the filter change, since fuel oil can permanently damage the electrical insulation.

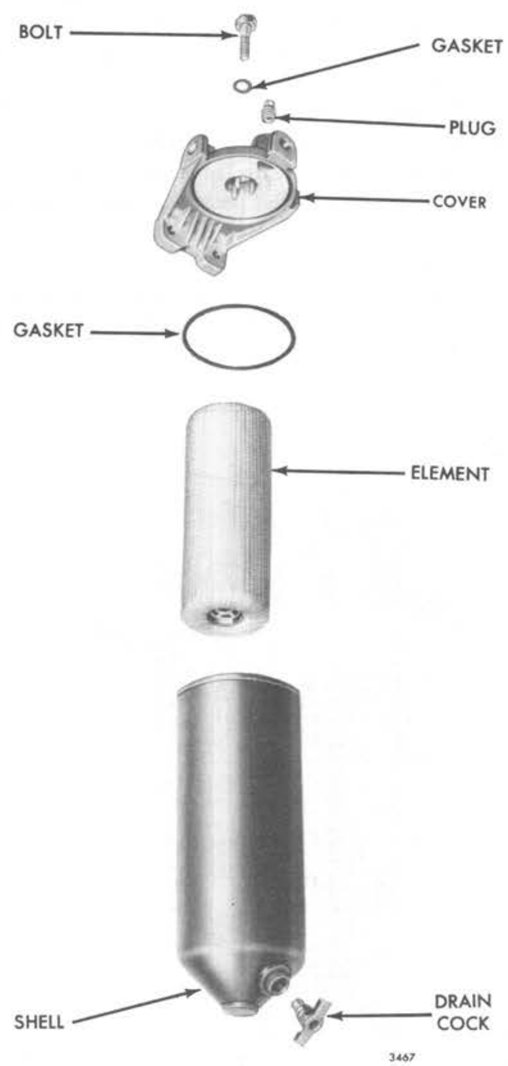


Fig. 3 – Typical Fuel Strainer Details

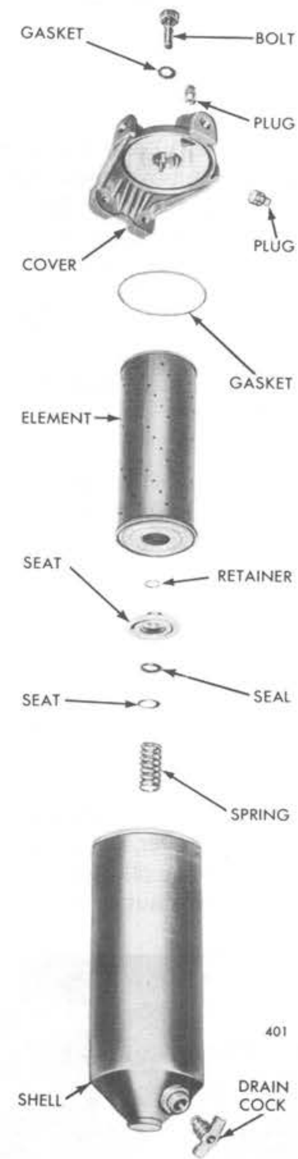


Fig. 4 – Fuel Filter Details and Relative Location of Parts

2. While supporting the shell, unscrew the cover nut or bolt and remove the shell and element. Also remove and discard the cover nut retaining ring, if used.
3. Remove and discard the filter element and shell gasket, the cover nut or bolt gasket, and, if used, the cover bolt snap ring.
4. Wash the shell thoroughly with clean fuel oil and dry it with compressed air.
5. Examine the element seat and the retaining ring to make sure they have not slipped out of place. Check the spring by pressing on the element seat. When released, the seat must return against the retaining ring.

NOTICE: The element seat, spring, washer and seal can not be removed from the strainer shell. If necessary, the shell assembly must be replaced. However, the components of the filter shell are serviced. Examine the filter retainer seal for cracks or hardening. If necessary, replace the seal.

6. Place a new element over the center stud and push it down against the element seat. Make sure the drain cock is closed, then fill the shell about two–thirds full with clean fuel oil.

NOTICE: Thoroughly soak the density–type *strainer* element in clean fuel oil before installing it. This will expel any air entrapped in the element and is conducive to a faster initial start.

7. Place a new shell gasket in the recess of the shell; also place a new gasket on the cover nut or bolt.

8. Place the shell and element in position under the cover. Then thread the cover bolt (or nut) in the center stud.

9. With the shell and the gasket properly positioned, tighten the cover bolt or nut just enough to prevent fuel leakage.

10. Remove the pipe plug at the top of the cover and complete filling of the shell with fuel. Fuel system primer J 5956 may be used to prime the entire fuel system.

11. Start the engine and check the fuel system for leaks.

FUEL STRAINER AND FUEL FILTER

(SPIN–ON TYPE)

A spin–on type fuel strainer and fuel filter is used on certain engines (Fig. 5). The spin–on filter cartridge consists of a shell, element and gasket combined into a unitized replacement assembly. No separate springs or seats are required to support the filters.

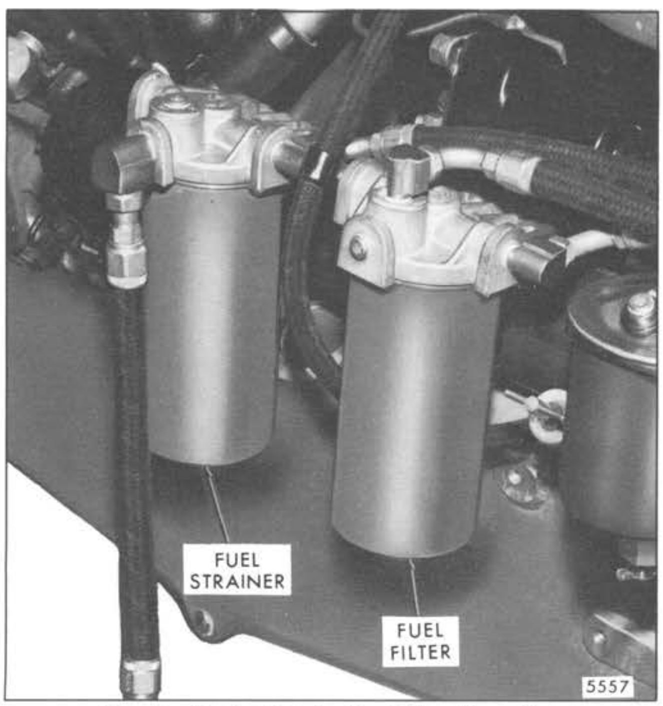


Fig. 5 – Typical Spin–On Filter Mounting

The filter covers incorporate a threaded sleeve to accept the spin–on filter cartridges. The word "Primary" is cast on the fuel strainer cover and the word "Secondary" is cast on the fuel filter cover for identification.

No drain cocks are provided on the spin–on filters. Where water is a problem, it is recommended that a water separator be installed. Otherwise, residue may be drained by removing and inverting the filter. Refill the filter with clean fuel oil before reinstalling it.

Filter Replacement

A 1" diameter twelve–point nut on the bottom of the filter is provided to facilitate removal and installation.

Replace the filter as follows:

1. Unscrew the filter (or strainer) and discard it.

2. Fill a new filter replacement cartridge about two–thirds full with clean fuel oil. Coat the seal gasket lightly with clean fuel oil.

3. Install the new filter assembly and tighten it to one–half of a turn beyond gasket contact.

4. Start the engine and check for leaks.

FUEL COOLER

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 (11°C) increment fuel temperature increase.

Remove Fuel Cooler

1. Disconnect the flexible hoses at the fuel cooler.
2. Loosen the hose clamps and slide the hoses back on the raw water pump tubes.

Clean Fuel Cooler

Clean the oil side of the cooler core first, then immerse it in the following solution: Add 1/2 pound (227 grams) 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

CAUTION: 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.

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.

Install Fuel Cooler

Reverse the procedure for removing the fuel cooler.

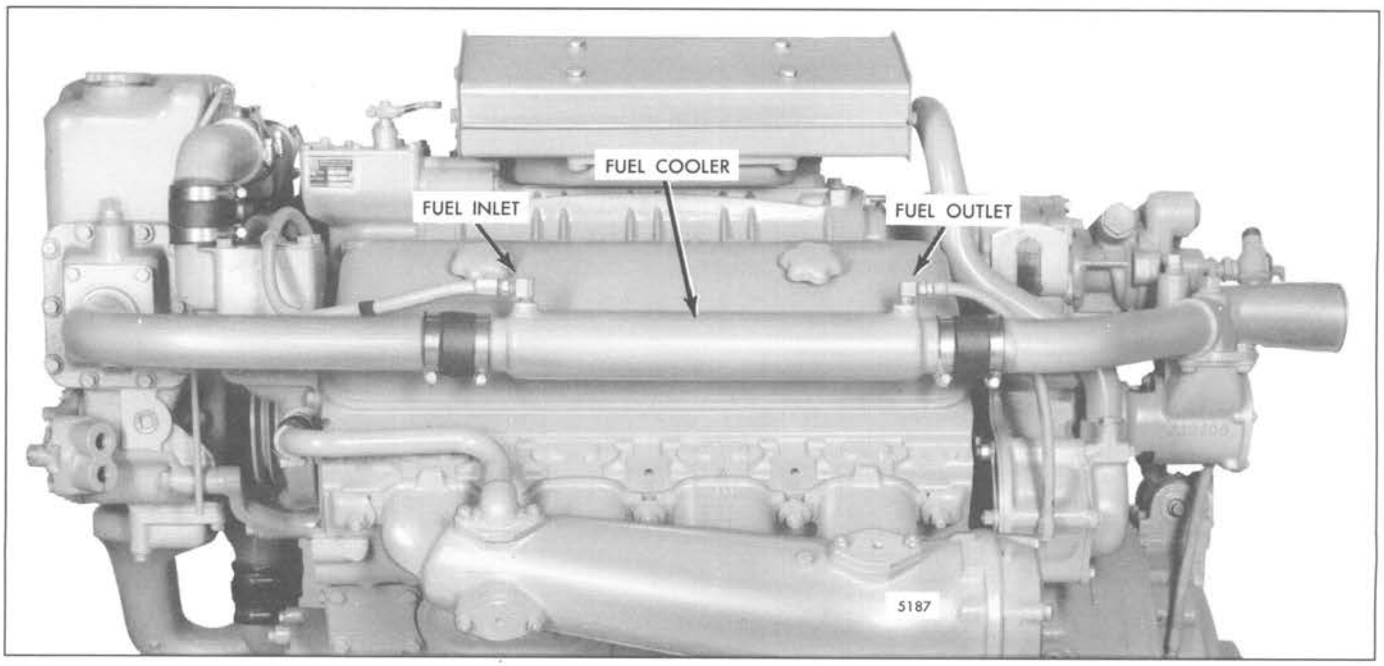


Fig. 1 – Fuel Cooler Mounting

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 governor is mounted on the front end of the blower and is driven by one of the blower rotors. 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.

Each type of governor has an identification plate located on the control housing, containing the governor assembly number, type, idle speed range and manufactured dated. 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 2.1.1.
3. Check for bind that may exist in the governor operating mechanism or in the linkage between the governor and the injector control tube.

With the fuel rod connected to the injector control tube lever, the mechanism should be free from bind throughout the entire travel of the injector racks. If friction exists in the mechanism, it may be located and corrected as follows:

1. If an injector rack sticks or moves too hard, it may be due to the injector hold–down clamp being too tight or improperly positioned. To correct this condition, loosen the injector clamp, reposition it and tighten the clamp bolt to 20–25 lb–ft (27–34 N•m) torque.
2. An injector which is not functioning properly may have a defective plunger and bushing or a bent injector rack. Recondition a faulty injector as outlined in Section 2.1.1.
3. An injector rack may bind as the result of an improperly positioned rack control lever. Loosen the rack control lever adjusting screws. If this relieves the bind, relocate the lever on the control tube and position the rack as outlined in Section 14.
4. The injector control tube may bind in its support brackets, thus preventing free movement of the injector racks to their *no–fuel* position due to tension of the return spring. This condition may be corrected by loosening and realigning the control tube supporting brackets. If the control tube support brackets were loosened, realigned and tightened, the injector racks must be repositioned as outlined in Section 14.
5. A bent injector control tube return spring may cause friction in the operation of the injector control tube. If the spring has been bent or otherwise distorted, install a new spring.
6. Check for bind at the pin which connects the fuel rod to the injector control tube lever; replace the pin, if necessary.

If, after making these checks, the governor fails to control the engine properly, remove and recondition the governor.

LIMITING SPEED MECHANICAL GOVERNOR

The limiting speed mechanical governors used on the V–92 engines performs the following two functions:

1. Controls the engine idling speed
2. Limits the maximum operating speed of the engine.

The limiting speed governors illustrated in Figs. 1 and 2 are double weight type.

A new double weight limiting speed governor is now being used to improve the performance of certain Series 92 engines. The new double weight limiting speed governor includes the lighter weight Fuel Squeezer engine weight system. These new double weight governors should replace the former single weight governors in cases where performance problems are being encountered.

A tamper–resistant double weight limiting speed governor is provided for highway vehicle engines (refer to Section 2.0).

The limiting speed governor illustrated in Fig. 3 is a single weight type and was utilized on 6V and 8V engine applications, except Fuel Squeezer and coach engines that require low idle speed control (below 500 rpm).

Each governor has an identification plate located on the governor housing, containing the governor assembly number, type and idle range speed.

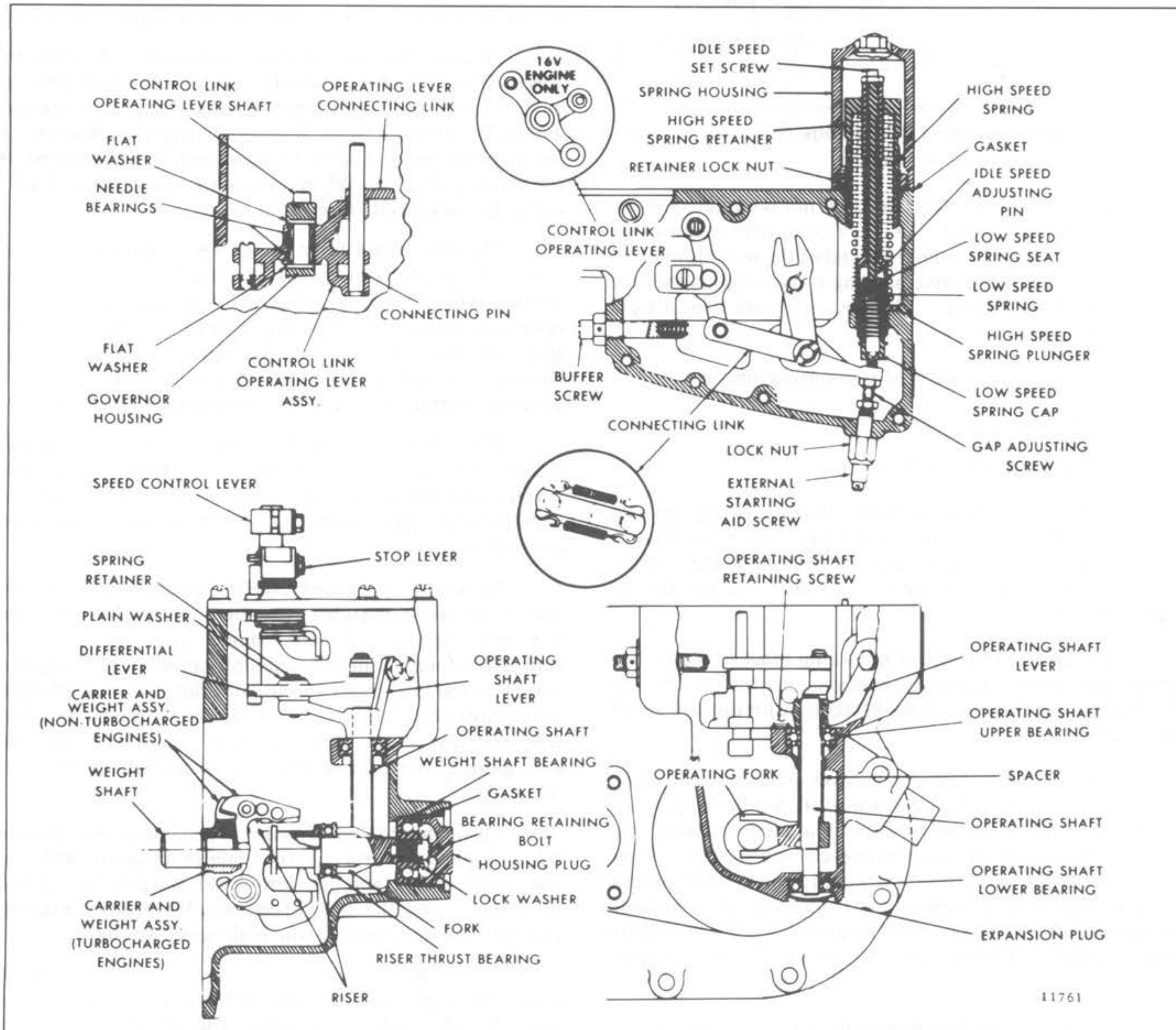


Fig. 1 – Cross Section of Double Weight Limiting Speed Mechanical Governor

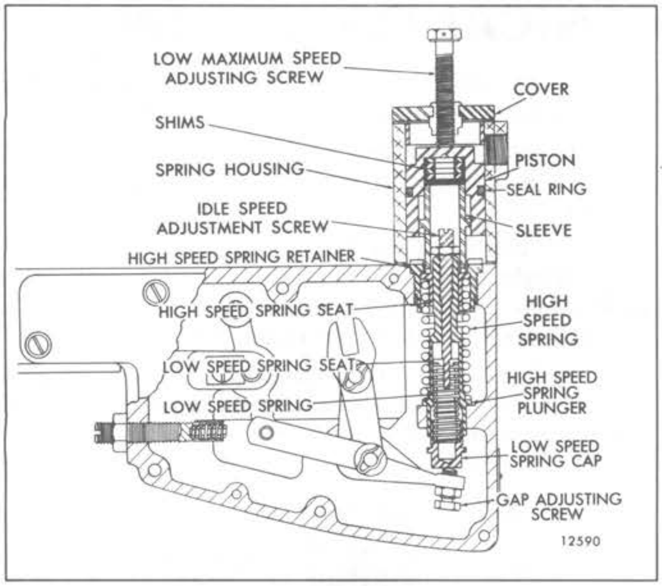


Fig. 2 – Cross Section of Dual Range Governor Spring Assembly

On 6V and 8V engines, the governor is mounted on the front end of the blower. On 12V and 16V engines, the governor is mounted on the front end of the rear blower and the governor auxiliary drive housing is mounted on the rear end of the front blower. The governors are driven by a blower rotor.

The governor consists of two subassemblies.

1. Control Housing Cover.
2. Control and Weight Housing.

To provide additional design features, a new die cast governor cover with serrated shafts and three bosses is now being used (Fig. 4). Two bosses are drilled for the limiting speed governors, one for the throttle shaft and one for the shutdown shaft.

If a customer furnished mounting bracket is attached to the new cover, it may be necessary to rework the old bracket to clear the unused cast bosses (one for limiting speed governors).

The new die cast governor cover assemblies include a 3/8" diameter serrated shutdown shaft for limiting speed governors. This assures positive clamping between the serrated levers and the shafts to prevent any slippage. Four serrations are eliminated on the shutdown shafts to permit certain customers to design a mating lever with missing serrations, which will provide a fixed position for particular requirements. Levers are not provided with missing serrations.

To reduce governor speed control lever shaft assembly stop pin wear and prolong bushing and "O" ring seal life, a yieldable speed control lever is available. This newly designed yieldable speed control lever cannot be used with the former stamped cover assemblies; however, a service yieldable speed control lever is available for use with the stamped cover.

The former and new cover and shaft assemblies are interchangeable on a governor. When only a former cover needs replacing, it will be necessary to replace the cover and shaft assembly. Only the new cover is serviced separately.

Operation (Standard Double–Weight Governor) – Fig. 1

The governor holds the injector racks in the *advanced fuel* position for starting when the speed control lever is in the *idle* position. Immediately after starting, the governor moves the injector racks to that position required for idling.

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. The starting aid screws are externally mounted in the front of the governor housing. It has a domed end and cannot be removed from the outside of the housing (Fig. 1). When the screw is not required, back it out as far as possible to make it ineffective.

The centrifugal force of the revolving governor low and high–speed weights (Fig. 1) is converted into linear motion which is transmitted through the riser and the 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 compress 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 .002" 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 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.

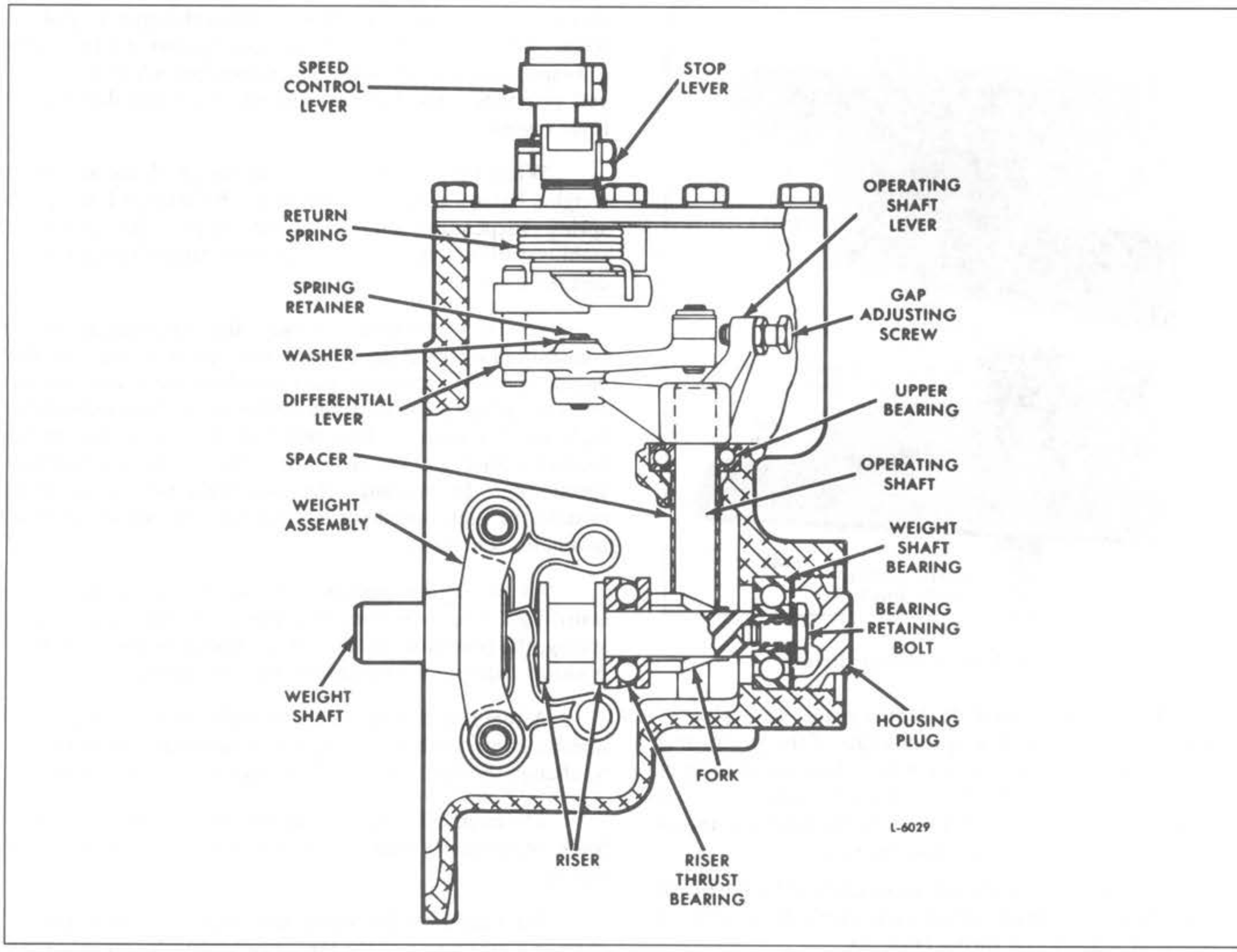


Fig. 3 – Cross-Section of Single Weight Limiting Speed Mechanical Governor

Fuel rods are connected to the differential lever and injector control tube levers through the control link operating lever and connecting link. 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 force exerted by the governor low-speed spring. When the governor speed control lever is placed in the *idle* position, the engine will operate at the speed where the force exerted by the governor low-speed weights will equal the force exerted by the governor low-speed spring.

Adjustment of the engine idle speed is accomplished by changing the force on the low-speed spring by means of the idle adjusting screw. Refer to Section 14.3 (6V and 8V engines) or 14.3.1 (12V and 16V engines) for the idle speed adjustment.

The engine maximum no-load speed is determined by the force exerted by the high-speed spring. When the governor speed 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 the high-speed spring retainer. Movement of the high-speed spring retainer will increase or decrease the tension on the high-speed spring. Refer to Section 14.3 (6V and 8V engines) or 14.3.1 (12V and 16V engines) for the maximum no-load speed adjustment.

Operation (Double Weight Dual High-Speed Range Governor) – Fig. 2

The mechanical double weight limiting speed dual range governor has been designed for use in applications that require a high maximum speed part of the time and a low maximum speed the remainder of the time.

This governor in vehicle application, due to its dual speed feature, permits a high engine speed in the lower gear ratios for maximum vehicle acceleration while providing a

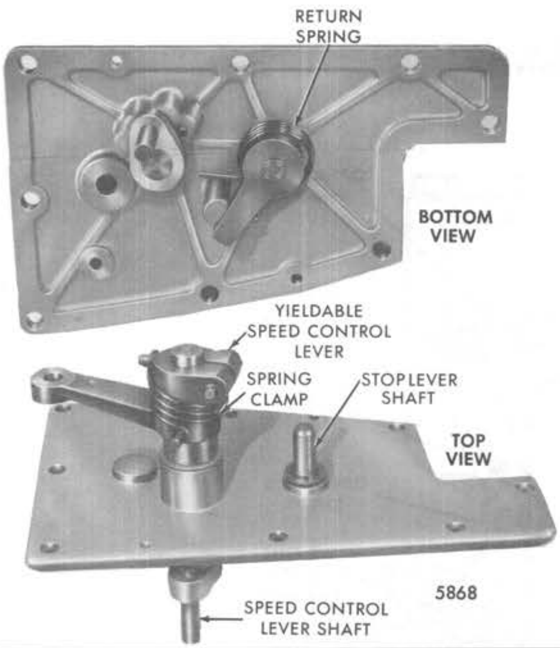


Fig. 4 – Die Cast Governor Covers

conservative vehicle speed in the higher gears. The valve for controlling the high and low–speed ranges of the governor is usually connected to the transmission. Thus, the shifting of the transmission from the lower gears to high gear will automatically shift the governor from its high maximum speed range to the low maximum speed range.

The two speed operation is accomplished by the use of air or oil pressure behind a piston to increase the tension on the governor high–speed spring (Fig. 2).

On current engines the spring assembly has been revised to include a shorter sleeve and a longer idle speed adjustment set screw. The new sleeve (1.64") and the new set screw (5/16"–24 x 2") must be used together in the spring assembly. Do not mix with the former sleeve (1.84") and set screw (5/16"–24 x 1 1/2").

The removal of air pressure from behind the piston permits the governor high–speed spring to force the piston against the low maximum speed adjusting screw that retains enough tension in the governor high–speed spring to operate the engine at the desired lower speed.

A seal ring is used to prevent leakage of air pressure past the piston assembly. The cylinder is lubricated at the time the piston assembly is installed by spreading an all purpose grease throughout the cylinder bore.

Operation (Single–Weight Governor) – Fig. 3

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 sha lever. One end of the 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 governor control lever.

In the low–speed range, the centrifugal force transmitted operates against the low–speed spring. As the engine speed is increased, the centrifugal force compresses the low–speed spring until the spring cap is tight against the high–speed plunger. This removes the low–speed spring from operation and the governor is then in the intermediate speed range. In this range, the centrifugal force is operating against the high–speed spring and thus the engine speed is manually controlled.

As the engine speed is increased to a point where the centrifugal force overcomes the pre–load of the high–speed spring, the governor will move the injector racks out to that position required for maximum no–load 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 control racks.

The engine idle speed is determined by the centrifugal force required to balance out tension on the low–speed spring.

Adjustment of the engine idle speed is accomplished by changing the tension of the low–speed spring by means of the idle adjusting screw. Refer to Section 14.3 for the idle speed adjustment.

The maximum no–load speed is determinded by the centrifugal force required to balance out the tension on the high–speed spring.

Adjustment of the maximum no–load speed is accomplished by the high–speed spring retainer. Movement of the high–speed spring retainer nut will increase or decrease the tension on the high–speed spring. Refer to Section 14.3 for the maximum no–load speed adjustment.

Lubrication

The governor is lubricated by a spray of lubricating oil from the blower end plate. The governor weights distribute this oil to all parts of the governor assembly requiring lubrication.

Oil returning from the governor is directed through passages in the blower end plate and cylinder block to the engine oil pan.

Remove Governor From Engine (6V And 8V Engines)

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.

1. Open the drain cocks and drain the engine cooling system.
2. Remove any accessories attached to the cylinder head, governor or front end of the engine that interfere with the removal of the governor assembly. On "TA" engines, see Section 3.4.1 and remove the blower.
3. Disconnect the control linkage from the speed control and stop levers (Fig. 5).
4. Remove the eight screws and lock washers securing the governor cover to the housing. Lift the cover and gasket from the housing.
5. Remove the fuel rods from the control link operating lever assembly (Fig. 1) and the injector control tube levers as follows:
   a. Remove the valve rocker covers from the cylinder heads. Discard the gaskets.
   b. Remove the right bank fuel rod by removing the screw type pin, in the control link operating lever, and the clevis pin in the control tube lever and withdraw the fuel rod from the governor.
   c. Remove the left bank fuel rod by removing the clevis pin in the control tube lever and lift the connecting pin up out of the control link operating lever approximately three–quarters of an inch. Then, withdraw the fuel rod from the governor.

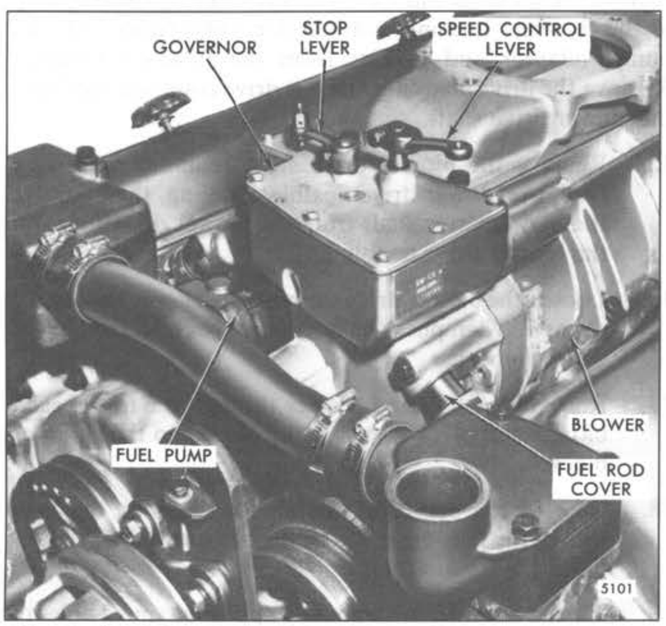


Fig. 5 – Limiting Speed Mechanical Governor Mounting (6V and 8V Engines)

6. Loosen the hose clamps at each end of the water bypass tube. Slide the hoses and clamps onto the bypass tube and remove the tube from the engine.
7. Disconnect and remove the fuel oil lines attached to the fuel pump and the crossover fuel oil line attached to each cylinder head.
8. Loosen the hose clamps on the fuel rod cover tube hoses next to each cylinder head and slide each hose and clamp up on the tube in the governor housing.
9. Note the location of the two copper, one plain and eight lock washers on the governor–to–blower bolts before removing them. Then, remove the ten bolts and washers (two inside and eight outside) securing the governor and fuel pump assembly to the blower.
10. Tap the sides of the governor housing lightly with a plastic hammer to loosen the governor from the blower. Then, pull the governor and fuel pump assembly straight out from the dowels in the blower end plate. Remove the governor–to–blower gasket.

The fuel pump drive coupling fork may stay on either the fuel pump or the blower rotor shaft. Remove the drive coupling fork.

11. Remove the three bolt and seal assemblies securing the fuel pump assembly to the governor housing. Remove the fuel pump and gasket from the governor housing.

Remove Governor From Engine (12V And 16V Engines)

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 assembly must be removed in order to remove the governor.

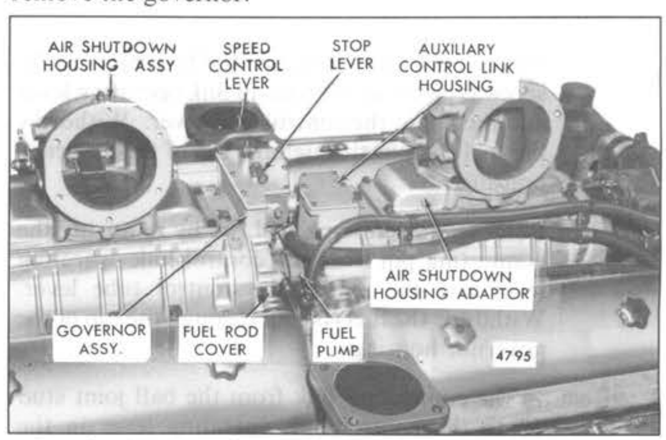


Fig. 6 – Limiting Speed Governor Mounting (12V and 16V Engines)

1. Disconnect the linkage attached to the governor speed control and stop levers (Fig. 6).

2. On a non–turbocharged engine, disconnect the air inlet tube attached to the air shutdown housing on each blower.

On a turbocharged engine, disconnect the tube from the turbocharger and the air shutdown housing on the rear blower.

On a marine engine, remove the air silencers from both air shutdown housings.

3. On a non–turbocharged engine, remove the air shutdown housings and the air shutdown adaptor from the rear blower.

On a marine engine, remove the air shutdown housings from the blowers.

Remove the two air shutdown housings, with attaching rod, as a unit.

On a turbocharged engine, disconnect the shutdown rod from the lever on the rear air shutdown housing. Then, remove the air shutdown housing and the air shutdown adaptor as an assembly from the blower.

4. Cover the top of the blower with masking tape to prevent the entry of foreign material.

5. Remove the rear cylinder head rocker covers. Discard the gaskets.

6. Remove the governor housing cover screws and lock washers, then remove the cover and gasket from the housing.

7. Remove the governor auxiliary control link housing cover screws and lock washers, then remove the cover and gasket from the housing.

8. Disconnect the fuel rods from the control link operating lever and the injector control tube levers as follows:

   a. Remove the right bank fuel rod by removing the screw type pin in the control link operating lever and the pin in the control tube lever. Withdraw the fuel rod out through the top of the governor housing.

   b. Remove the left bank fuel rod by removing the connecting pin from the control link operating lever and the pin in the control tube lever. Withdraw the fuel rod out through the top of the governor housing.

9. Remove the connecting link from the ball joint stud attached to the control link operating lever in the governor housing and the auxiliary control link housing by lifting or prying each end of the connecting link off of the ball joint studs. Then, remove the connecting link from the governor housing.

10. Loosen the fuel rod cover hose clamp at each side of the governor housing, then slide each hose against the governor housing. Tighten each clamp to retain it on the hose.

11. Loosen the hose clamp between the governor housing and the auxiliary control link housing, then slide the hose forward against the auxiliary control link housing. Tighten the clamp to retain it on the hose.

12. Disconnect the fuel pump inlet and outlet tubes or hoses from the fuel pump. Then, if necessary, remove the fuel pump from the governor housing.

13. Disconnect the blower drive support oil tube from the fitting in the blower drive support. Loosen the two bolts securing the oil tube seal ring retaining plate to the blower end plate, then push the oil tube into the end plate.

14. Remove the six bolts and lock washers securing the flywheel housing hole cover, at the blower drive support, then remove the cover and gasket.

On an engine equipped with a rear mounted battery–charging alternator, loosen and remove the alternator drive belt. Then, remove the alternator drive pulley nut and pulley from the alternator drive shaft. Remove the bolts and lock washers securing the alternator drive assembly to the flywheel housing, then remove the drive assembly, gasket and drive coupling from the flywheel housing.

On an engine equipped with a hydraulic oil pump, remove the six bolts and lock washers securing the oil pump to the flywheel housing and adaptor, then remove the oil pump, adaptor and gaskets from the flywheel housing. Remove the drive coupling and the drive coupling hub from the blower drive shaft.

15. Remove the blower drive shaft retaining snap ring from the blower drive flexible coupling, then remove the blower drive shaft from the blower drive hub and the blower drive coupling.

16. Loosen the blower drive support–to–blower hose (seal) clamps. Then push the hose (seal) back on the blower drive support.

17. Remove the bolt and washer through the top of each blower end plate, securing the blower to the cylinder block.

18. Remove the bolts and retaining washers on the each side of the blower, securing the blower to the cylinder block.

19. Thread eyebolts in diagonally opposite tapped holes in the top of the blower housing. Then, attach a rope sling and chain hoist to the eyebolts.

20. Lift the blower assembly slightly and move it forward to detach the blower from the hose (seal). Then, lift the blower away from the engine and place it on a bench. Remove the blower to cylinder block gasket.

21. With the blower and governor assembly removed from the engine, remove the ten bolts, lock washers, plain washer and copper washers securing the governor assembly to the blower end plate. Slide the governor assembly forward off of the dowel pins in the end plate, then remove the governor to blower end plate 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.

1. Disassemble the governor cover (Fig. 7 or 8) as follows:

All current Fuel Squeeezer engines have a governor cover with an extended hub and a longer speed control shaft (3.30" long). The cover also incorporates two hardened steel roll pins in the speed control shaft hub (Fig. 8).

a. Remove the lubrication fitting from the speed control shaft.

b. Loosen the speed control lever retaining bolt and lift the control lever from the speed control shaft.

c. Remove the spacer (if used), snap ring and two seal ring retaining washers, and seal ring from the speed control shaft. Withdraw the shaft from the cover.

d. Loosen the bolt securing the stop lever to the stop lever shaft and remove the stop lever.

e. Remove the snap ring, two seal ring retaining washers, and seal ring from the stop lever shaft. Withdraw the lever shaft and the lever shaft return spring from the cover.

f. Wash the cover assembly thoroughly in clean fuel oil and inspect the needle bearings and bushings for wear or damage. If the bearings and bushings are satisfactory for further use, removal is unnecessary.

g. If needle bearing removal is necessary, place the inner face of the cover over the opening on the bed of an arbor press. Place remover J 21967-01 on the top of the bearing and under the ram of the press, then press both bearings out of the cover (Fig. 9).

h. Remove the bushing or bearings from the stop lever shaft opening using remover J 8985 (Fig. 10).

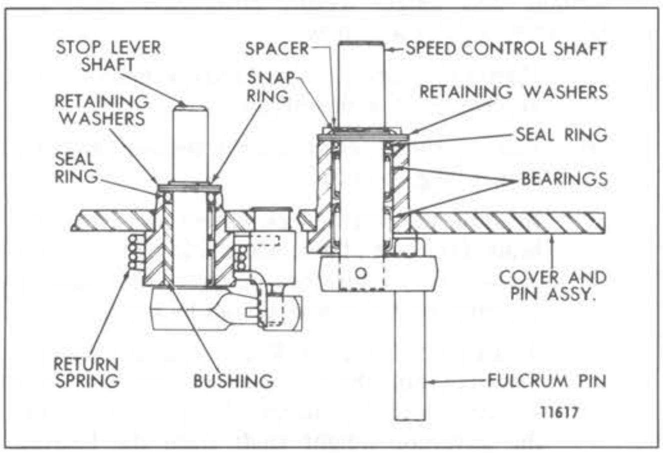


Fig. 7 – Cross Section of Former Governor Cover

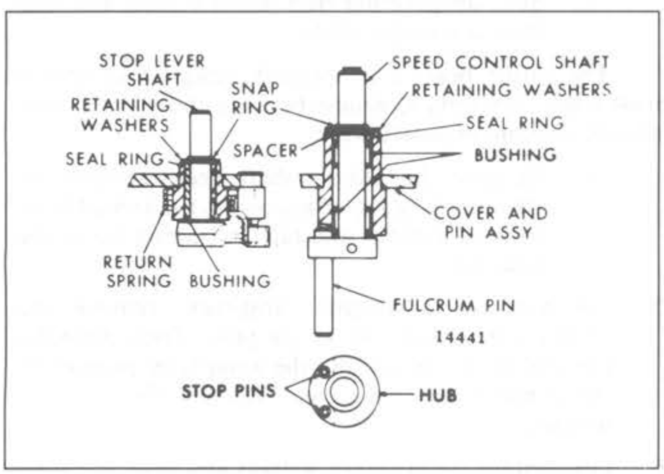


Fig. 8 – Cross-Section of Current Governor Cover

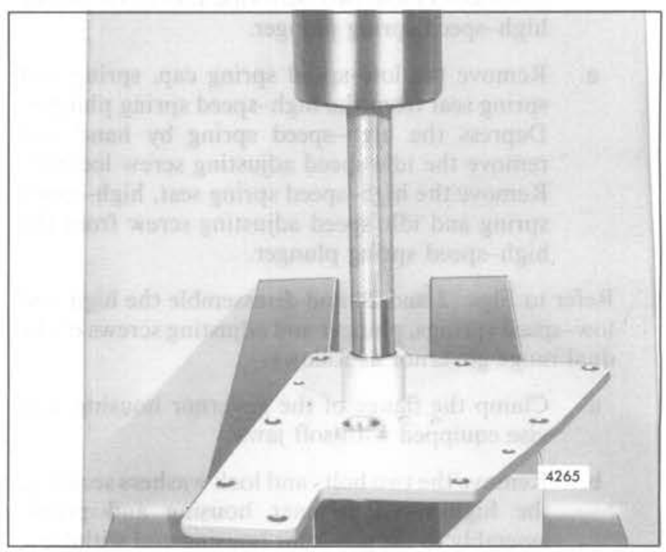


Fig. 9 – Removing Speed Control Shaft Bearing from Governor Cover using Tool J 21967-01

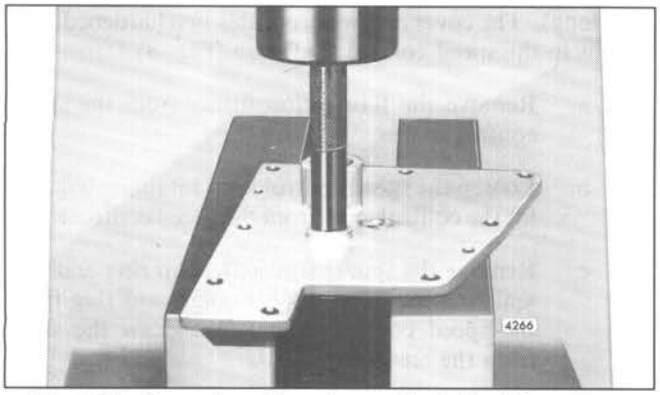


Fig. 10 – Removing Stop Lever Shaft Bushings from Governor Cover using Tool J 8985

2. Refer to Figs. 1 and 22 and disassemble the high and low–speed springs, plunger and adjusting screw (except dual–range governors):

   a. Clamp the flange of the governor housing in a vise equipped with soft jaws.

   b. Remove the two bolts and copper washers securing the high–speed spring retainer housing to the governor housing and withdraw the retainer housing and gasket.

   c. Loosen the high–speed spring retainer locknut (Fig. 1) with a spanner wrench (J 5345–5). Then, remove the high–speed spring retainer, idle speed adjusting screw, high–speed spring, spring plunger, low–speed spring, spring seat and spring cap as an assembly.

   d. For Fuel Squeezer engines refer to Fig. 22 and loosen the set screw in the Belleville spring retainer nut. Then, remove the retainer nut, two flat washers and two Belleville washers from the high–speed spring plunger.

   e. Remove the low–speed spring cap, spring and spring seat from the high–speed spring plunger. Depress the high–speed spring by hand and remove the idle speed adjusting screw locknut. Remove the high–speed spring seat, high–speed spring and idle speed adjusting screw from the high–speed spring plunger.

3. Refer to Figs. 2 and 24 and disassemble the high and low–speed springs, plunger and adjusting screws of the dual range governor as follows:

   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 high–speed retainer housing and piston assembly to the governor housing and withdraw the rtainer housing, piston, shims and sleeve as an assembly from the governor housing (Fig. 2).

   Current governors have a blocking ring in the spring housing to prevent removal of the seal from the rear end (cover end) of the spring housing, thus preventing seal ring damage.

   c. Remove the sleeve, shims, cover, cover gasket, piston and seal ring assembly from the high–speed spring retainer housing. Remove the retainer housing gasket.

   d. Remove the high–speed spring retainer with tool J 5345–5 and withdraw the retainer, idle speed adjusting screw, high–speed spring, spring plunger, low–speed spring, spring seat and spring cap as an assembly from the housing.

   e. Remove the low–speed spring cap, spring and spring seat from the high–speed spring plunger. Depress the high–speed spring by hand and remove the idle speed adjusting screw locknut. Remove the high–speed spring seat, high–speed spring and idle speed adjusting screw from the high–speed spring plunger.

4. Remove the governor weights and shaft assembly (double and single weight governors) 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 or 2).

   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. Thread a 5/16"–24 x 3" bolt into the bearing retaining bolt hole. Support the governor housing on the bed of an arbor press and press the governor weight shaft from the bearing (Fig. 11).

   e. Slide the governor riser thrust bearing and riser from the weight shaft.

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. On **non–turbocharged engines**, 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.

6. Disassemble the governor weights and shaft assembly on **turbocharged engines** as follows:

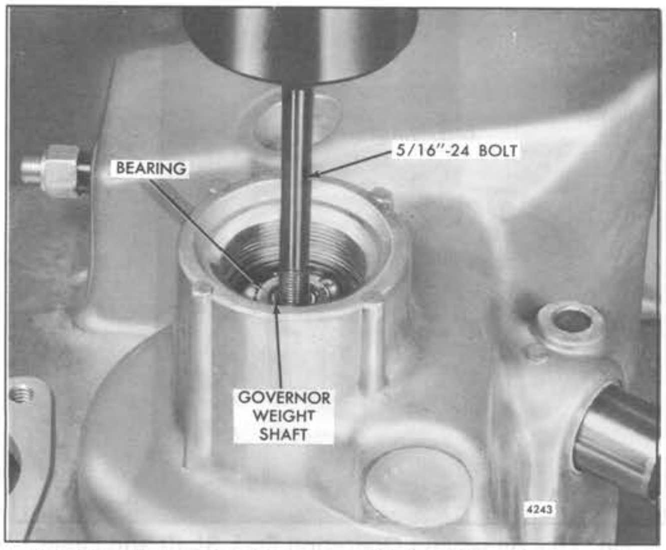


Fig. 11 – Removing Governor Weight Shaft Assembly from Governor Housing

a. If removal of the weights from the carrier is necessary, remove the retainers and press the weight pins from the low-speed weights (Fig. 12). The high-speed weights are not a press fit.

b. If removal of the weight carrier from the weight shaft is necessary, support the shaft, weight

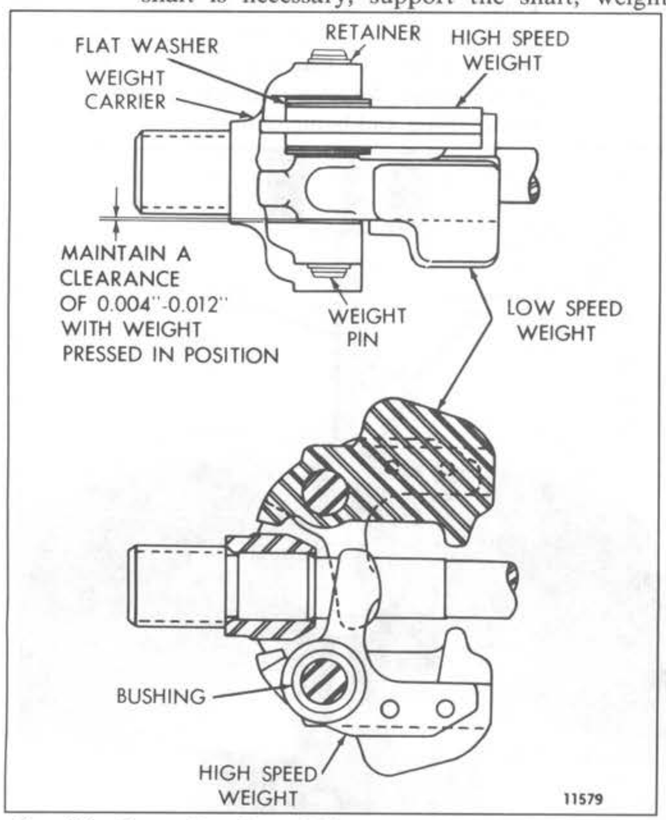


Fig. 12 – Cross Section of Governor Weight Assemblies (Turbocharged Engines)

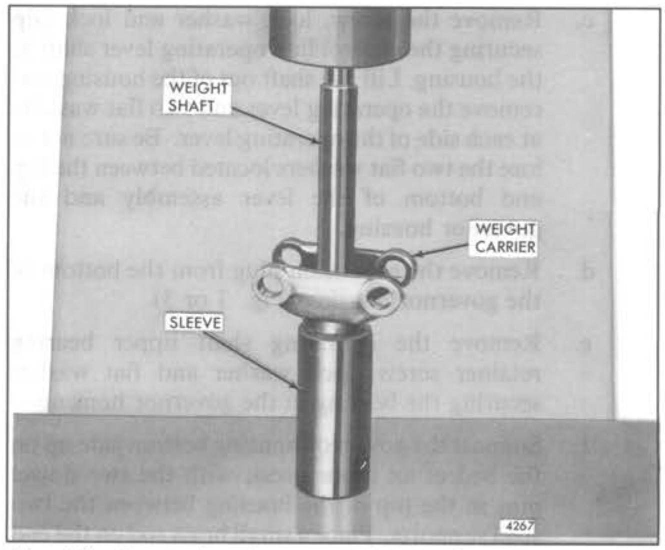


Fig. 13 – Removing Governor Weight Shaft from Weight Carrier

carrier and sleeve on the bed of an arbor press and press the shaft out of the weight carrier (Fig. 13).

c. Position the high-speed governor weight on a sleeve on the bed of an arbor press and press the bearing from the weight using replacer J 8985 (Fig. 14).

7. Remove the governor linkage and operating shaft from the governor housing as follows:

   a. Remove the spring retainer and plain washer securing the connecting link to the differential lever and remove the connecting link.

   b. Remove the spring retainer and plain washer securing the differential lever to the operating shaft lever and remove the differential lever. Remove the low-speed gap adjusting screw from the operating shaft lever, if necessary.

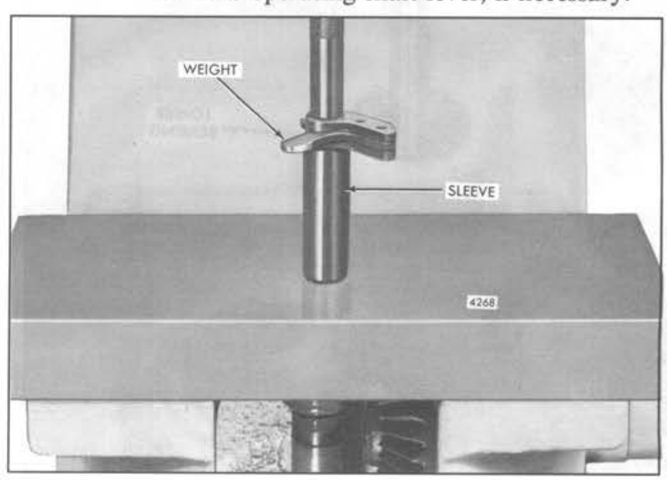


Fig. 14 – Removing Governor Weight Bearings using Tool J 8985

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. Be sure not to lose the two flat washers located between the top and bottom of the lever assembly and the governor housing.

d. Remove the expansion plug from the bottom of the governor housing (Fig. 1 or 3).

e. Remove the operating shaft upper bearing retainer screw, lock washer and flat washer securing the bearing in the governor housing.

f. Support the governor housing bottom side up on the bed of an arbor press, with the two dowel pins in the top of the housing between the two steel supports. Place a small brass rod on the end of the operating shaft and press the shaft out of the bearing (Fig. 15).

g. With the housing still supported on the bed of the press, place a 9/16" open end wrench under the operating fork (Fig. 16). Place a brass rod on the end of the shaft and press the fork off of the operating shaft. Remove the shaft, operating lever and bearing as an assembly from the housing.

h. Remove the operating shaft lower bearing from the bottom of the governor housing.

i. Slide the governor operating shaft spacer from the shaft.

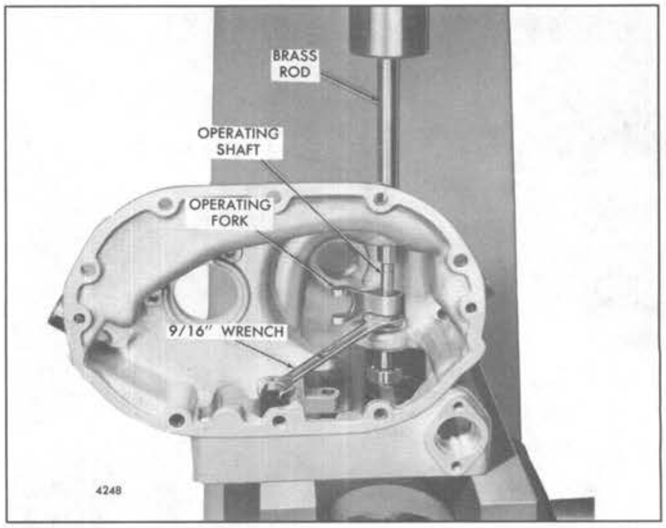


Fig. 16 – Removing Operating Fork Shaft and Lever Assembly from Governor Housing

j. Place a short 9/16" inside diameter sleeve over the end of the operating shaft and rest it against the inner race of the bearing on the operating shaft.

k. Support the operating shaft, lever, bearing and sleeve on a large washer or plate, with a 5/8" hole, on the bed of an arbor press (Fig. 17). Place a small brass rod on the end of the shaft and press the operating shaft out of the operating lever and bearing. Catch the shaft by hand when pressed from the lever and bearing to prevent it from falling and being damaged.

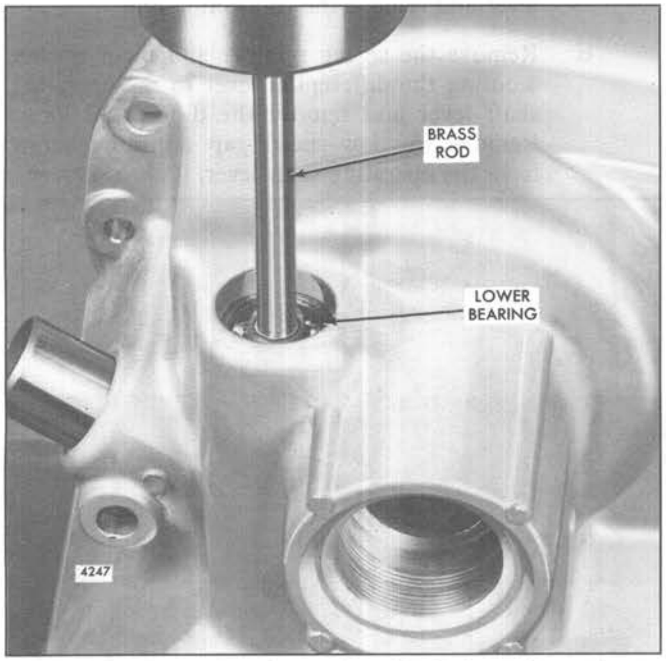


Fig. 15 – Removing Operating Shaft from Operating Shaft Lower Bearing

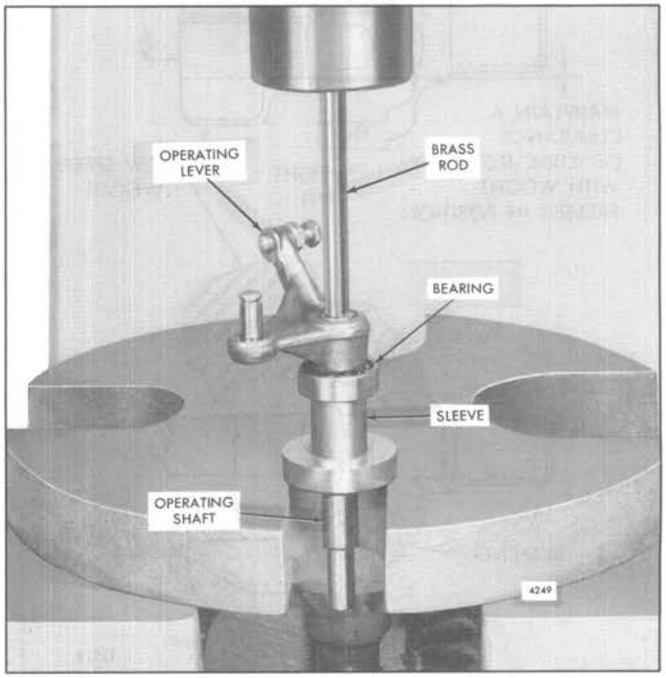


Fig. 17 – Removing Operating Lever and Upper Bearing From Operating Shaft

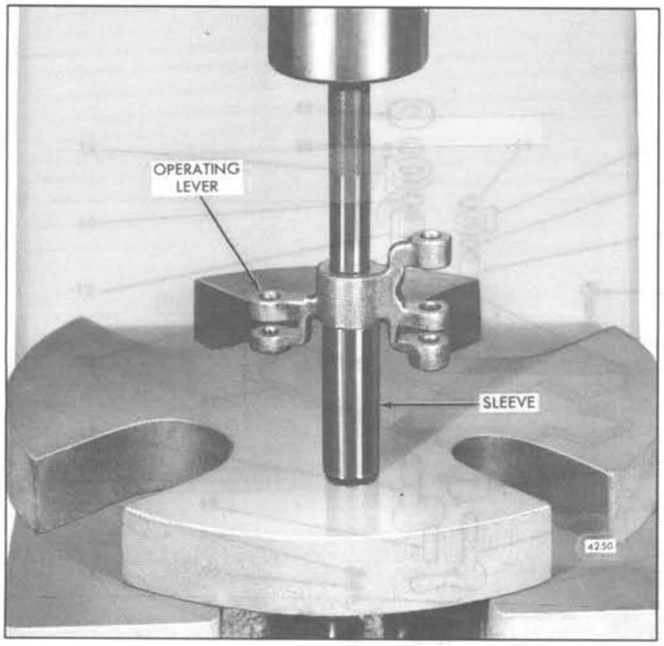


Fig. 18 – Removing Operating Lever Needle Bearings using Tool J 8985

NOTICE: Be sure that the bearing inner race is resting on the sleeve because the bearing could be damaged.

l. 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 bearings are satisfactory for further use, removal is unnecessary.

m. 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 press both bearings out of the lever (Fig. 18).

8. Remove the buffer screw from the governor housing.
9. Remove the external starting aid screw from the governor housing, if necessary.

Inspection

Wash all of the governor parts in clean fuel oil and dry them with compressed air.

CAUTION:To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.

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.

Examine the riser thrust bearing for excessive wear, flat spots or corrosion.

Examine the weight carrier pins and bushings in the weights for wear.

Examine the control link operating lever shaft and needle bearings for wear or damage.

If the speed control and stop lever shaft are worn excessively due to worn or damaged needle bearings and bushing, replace the shafts, needle bearings and bushing in the cover.

Inspect the spring seats, plunger, adjusting screws, lock nuts, pins, seal rings and any other parts in the governor housing for wear or defects that might affect governor operation.

When replacing a limiting speed governor housing (with or without a starting aid screw), only the current governor housing assembly with the external starting aid screw is serviced.

If the external starting aid screw is not required, back it out as far as possible to make it ineffective.

Replace all of the parts that are worn or damaged.

Assemble Governor

With all of the governor parts cleaned and inspected and the necessary new parts on hand, refer to Figs. 1 and 19 (double weight governors) or Fig. 3 (single weight governors) and assemble the governor as follows:

1. If removed, install the external starting aid screw in the governor housing.
2. Install the operating shaft and governor linkage in the governor housing as follows:
   a. Lubricate the inside diameter of the governor operating shaft upper bearing with engine oil. Start the bearing, numbered side up, straight on the large end of the operating shaft. Support the bearing and operating shaft on a 9/16" inside diameter sleeve on the bed of an arbor press, with the inner race of the bearing resting on the sleeve, then press the shaft into the bearing until 1/4" of the shaft protrudes through the bearing.

   Install the bearing, numbered side up, on the shaft and press it tight against the bearing washer.

   b. Lubricate the inside diameter of the governor operating shaft lever with engine oil. Start the lever, pivot pin in operating lever facing up, straight on the operating shaft with the flat on the shaft registering with the flat surface in the lever. Support the operating lever, bearing and shaft on the bed of an arbor press with a steel support directly under the center of the lever, then press the operating shaft through the bearing and lever until the end of the shaft contacts the steel support. The upper end of the shaft must be flush with the top surface of the lever.

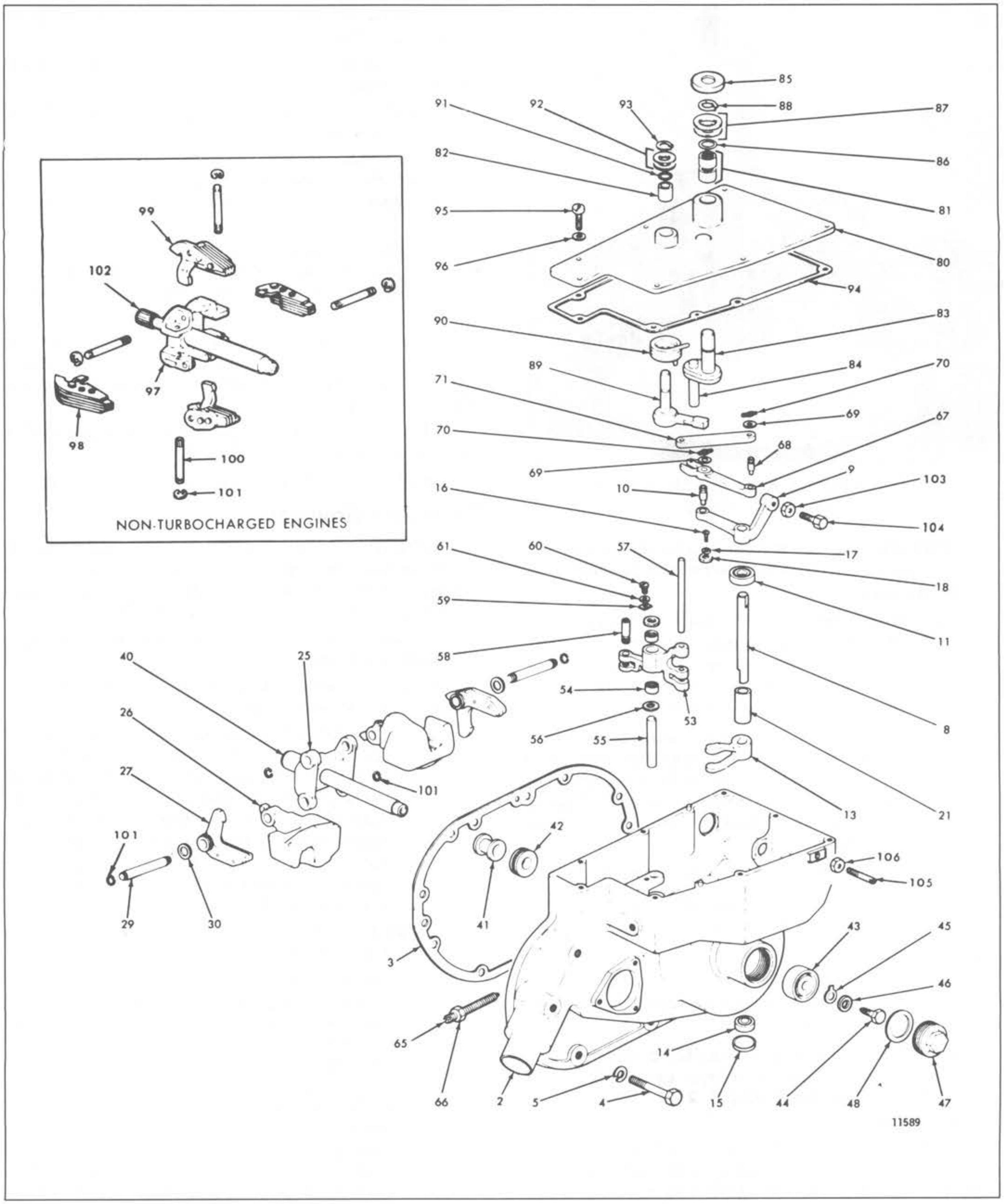


Fig. 19 – Limiting Speed Double Weight Governor Details and Relative Location of Parts

2. Housing--Governor
3. Gasket--Housing to Blower
4. Bolt--Housing to Blower
5. Lock Washer
8. Shaft--Governor Operating
9. Lever--Operating Shaft
10. Pin--Shaft Lever
11. Bearing--Operating Shaft (Upper)
13. Fork--Operating Shaft
14. Bearing--Operating Shaft (Lower)
15. Plug--Expansion
16. Screw--Bearing Retaining
17. Lock Washer
18. Flat Washer
19. Screw--Starting Aid Adjusting (Internal)
20. Screw--Gap Adjusting (Internal)
21. Spacer--Operating Shaft
25. Carrier--Governor Weight
26. Weight--Low Speed
27. Weight--High Speed
29. Pin--Weight
30. Flat Washer
31. Screw--Weight Pin Set
40. Shaft--Weight Carrier
41. Riser--Governor
42. Bearing--Riser Thrust
43. Bearing--Weight Carrier Shaft End
44. Bolt--Bearing Retainer
45. Lock Washer--Special
46. Flat Washer
47. Plug--Governor Housing
48. Gasket--Housing Plug
53. Lever--Control Link Operating
54. Bearing--Operating Lever
55. Shaft--Operating Lever
56. Washer--Operating Lever Shim
57. Pin--Fuel Rod Connecting (Long)
58. Pin--Fuel Rod Connecting (Short)
59. Clip--Operating Lever Shaft Lock
60. Screw--Lock Clip
61. Lock Washer
65. Screw--Buffer
66. Lock Nut--Buffer Screw
67. Lever--Governor Differential
68. Pin--Differential Lever
69. Washer--Differential Lever and Connecting Link Flat
70. Retainer--Spring
71. Link--Operating Lever Connecting
80. Cover--Governor Housing
81. Bearing--Speed Control Shaft
82. Bushing--Stop Lever Shaft
83. Shaft--Speed Control Lever
84. Pin--Fulcrum Lever
85. Spacer--Speed Control Shaft
86. Ring--Control Shaft Seal
87. Washer--Seal Ring Retainer
88. Snap Ring--Speed Control Shaft
89. Shaft--Stop Lever
90. Spring--Stop Lever Shaft Return
91. Ring--Stop Shaft Seal
92. Washer--Seal Ring Retainer
93. Snap Ring--Stop Shaft
94. Gasket--Governor Housing Cover
95. Screw--Housing Cover
96. Lock Washer
97. Carrier--Governor Weight
98. Weight--Low Speed
99. Weight--High Speed
100. Pin--Weight
101. Ring--Weight Pin Retainer
102. Shaft--Weight Carrier
103. Locknut
104. Screw, Gap Adjusting (External)
105. Screw, Starting Aid Adjusting (External)
106. Locknut

Fig. 19 – Limiting Speed Double Weight Governor Details and Relative Location of Parts

c. Place the operating shaft spacer over the lower end of the shaft and slide it against the upper bearing inner race.

d. Insert the end of the governor operating shaft, bearing, spacer and lever assembly through the upper bearing bore in the governor housing with the lever positioned (Figs. 1 or 3).

e. Lubricate the inside diameter of the governor operating shaft fork with engine oil, then place the operating fork over the lower end of the shaft with the finished cam surfaces on the fork fingers facing the rear of the governor housing and the flat on the shaft registering with the flat surface in the fork.

f. Support the governor housing and operating shaft assembly on the bed of an arbor press with the upper end of the operating shaft resting on a steel support (Fig. 20). Place a 7/16" inside diameter sleeve over the end of the shaft and against the fork, then press the fork tight against the shaft spacer on the shaft.

g. Lubricate the governor operating shaft lower bearing with engine oil. Start the bearing, numbered side up, straight in the governor housing and over the end of the operating shaft.

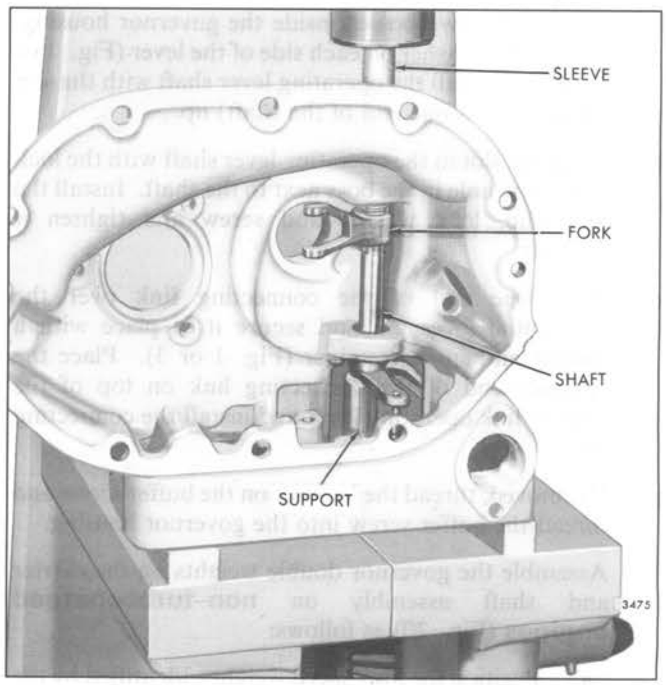


Fig. 20 – Installing Governor Operating Shaft Fork on Shaft

h. Support the governor housing and operating shaft assembly on the bed of an arbor press with the upper end of the operating shaft resting on a steel support

(Fig. 20). Place a 7/16" inside diameter sleeve on the inner race of the bearing and press the bearing on the shaft until it seats on the shoulder in the housing.

i. Install the governor operating shaft upper bearing retaining flat washer, lock washer and screw in the governor housing (Fig. 1 or 3).

j. Apply a thin coat of good quality sealant around the edge of a new expansion plug. Place the plug, concave side up, in the opening in the housing next to the lower operating shaft bearing. Tap the center of the plug with a hammer to secure the plug in the housing.

k. Place the differential lever over the pivot pin in the operating lever, pin in the lever up, and secure it in place with a plain washer and spring retainer.

l. If removed, place the control link operating lever on the bed of an arbor press with 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 8985 in the bearing and press the bearing into the lever until it is flush with the top surface of the lever. Reverse the lever on the press and install the second bearing in the same manner.

m. 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 or 3). Then, install the operating lever shaft with the slot (in the side at one end of the shaft) up.

n. 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.

o. Place one end of the connecting link over the differential lever pin and secure it in place with a washer and spring retainer (Fig. 1 or 3). Place the opposite end of the connecting link on top of the control link operating lever and install the connecting pin.

p. If removed, thread the locknut on the buffer screw and thread the buffer screw into the governor housing.

3. Assemble the governor double weights on the carrier and shaft assembly on **non-turbocharged engines** (Fig. 20) as follows:

   a. Position the low-speed weights, identified by the short cam arm, on opposite sides of the weight carrier.

   b. 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.

   c. Install the high-speed weights on the carrier in the same manner.

   d. Lubricate the weight shaft with clean engine oil.

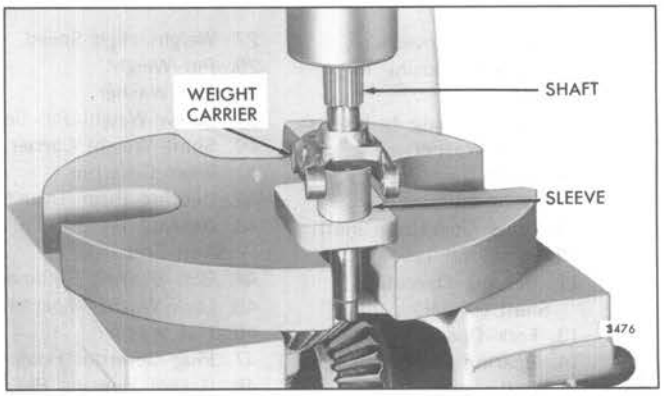


Fig. 21 – Installing Governor Weight Shaft in Weight Carrier

4. Assemble the governor double weight and shaft assembly on **turbocharged engines** (Fig. 20) as follows:

   If the governor weight carrier assembly was removed from the weight shaft, the low and high-speed 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 and a steel support (with 1" hole) over an opening in the bed of an arbor press (Fig. 21).

   b. Lubricate the weight shaft with engine oil. Then, insert the non-splined end of the shaft through the carrier, sleeve and hole in the steel support. Press the shaft straight into the carrier until the shoulder on the shaft is tight against the carrier.

   c. Refer to Fig. 12 and install a retainer on either end of the weight pin. Note the match marks placed on the weight carrier and weights at the time of disassembly. Then, slide the weight pin through the carrier, flat washer and the high-speed weight and its bushing.

   d. Place the low-speed weight in position. Then, press the weight pin through the low-speed weight and carrier until the retainer bottoms against the carrier. Maintain a clearance of .004"-.012" with the weight pressed in position. To maintain this clearance, insert a .004"-.012" shim between the low-speed weight and carrier while pressing the pin into position.

   e. Remove the shim and install the second weight pin retainer.

f. Install the second pair of weights (three pair of weights in the 12V and 16V turbocharged engine governor) in the carrier in the same manner as described above.

5. Assemble the governor–single weights as follows (Fig. 3):

a. Install the retainer in the groove of the weight pin. Place a flat washer over the pin and against the lock ring.

b. Start the pin through the opening in the weight carrier. Place a second washer over the pin and against the projecting arm of the weight carrier.

c. Position the governor weight between the projecting arms of the weight carrier. Push the pin through the governor weight.

d. Place the third flat washer over the pin and against the weight.

e. Then, push the pin completely through the weight carrier and place the fourth flat washer over the pin and against the projecting arm of the weight carrier. Install a second lock ring in the groove of the weight carrier pin.

f. Install the second governor weight in a similar manner.

6. Install the governor weight and shaft assembly in the governor housing as follows:

a. Slide the governor riser on the weight shaft and against the fingers of the high–speed weight.

b. Place the governor riser thrust bearing over the weight shaft with the bearing race having the smaller inside diameter against the riser. Incorrect installation of the bearing will result in erratic operation of the governor.

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. Place the weight shaft 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 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 (20–26 N•m) 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 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. Tighten the plug to 45 lb–ft (61 N•m) torque.

Rotate the governor weight assembly to see that there is no bind. If bind exists, remove the housing plug and check to see if the weight shaft bearing is fully seated in the governor housing.

7. Refer to Figs. 1 and 22 or 23 and assemble the high and low–speed spring, plunger and adjusting screw (except dual–range governors):

a. If removed, thread the retainer locknut on the high–speed spring retainer approximately 1–1/2". Place the high–speed spring on the high–speed spring plunger with the close wound coils inside the spring retainer and the spring against the shoulder of the plunger.

Current TA engines operating at 1750 rpm full load use a high–speed spring with one orange and one blue strip for identification. Engines operating at 1950–2100 rpm full load use a high–speed spring with two pink stripes for identification.

b. Insert the high–speed spring and plunger assembly in the high–speed spring retainer. Thread the idle speed adjusting screw into the threaded end of the plunger approximately 1/2". Then, thread the locknut on the idle speed adjusting screw.

c. Place the low–speed spring in the low–speed spring cap and the small end of the low–speed spring seat in the opposite end of the spring.

d. Insert the low–speed spring seat, spring and cap assembly into the high–speed spring plunger and over the idle speed adjusting pin.

e. For Fuel Squeezer engines, install the bushing in the end of the high–speed spring retainer (if removed) and align the two flat washers and two Belleville spring washers (Fig. 23). Then, install the set screw in the Belleville spring retainer nut and thread the retainer nut onto the high–speed plunger.

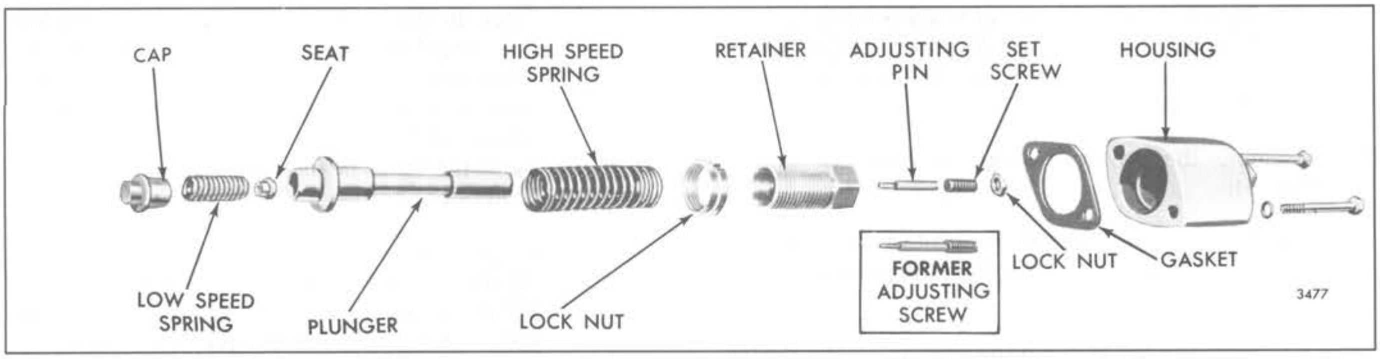


Fig. 22 – High and Low–Speed Springs and Plunger Details and Relative Location of Parts

f. Affix a new high–speed spring retainer housing gasket to the governor housing.

g. Insert the spring, plunger and retainer assembly into the opening in the governor housing and thread the retainer into the housing approximately one inch.

h. Install the high–speed spring retainer housing after the governor assembly has been installed on the engine and the governor adjustment procedures performed as outlined in Section 14.3 (6V and 8V engines), Section 14.3.5 (Fuel Squeezer Engines) or 14.3.1 (12V and 16V engines).

8. Refer to Figs. 2 and 24 and assemble the high and low–speed springs, plunger and adjusting screws (dual–range governor):

a. Thread the idle speed adjusting screw into the threaded end of the high–speed spring plunger approximately 1/2".

b. Place the high–speed spring guide in the end of the high–speed spring. Next, place the high–speed spring and guide over the end of the idle speed adjusting screw and plunger. Then, thread the locknut on the idle speed adjusting screw and against the spring guide.

c. Place the low–speed spring in the low–speed spring cap and the small end of the low–speed spring seat in the opposite end of the spring.

d. Insert the low–speed spring seat, spring and cap assembly into the high–speed spring plunger and over the idle speed adjusting screw.

e. Place the high–speed spring retainer over the high–speed spring guide. Then, insert the springs, plunger and retainer assembly into the opening in the governor housing and thread the retainer into the housing. Tighten the retainer in the housing with tool J 5345–5.

f. If removed, install the piston blocking ring in the outer end of the high–speed spring retainer housing with the ring gap straddling the threaded hole and flush with the outside face of the housing.

g. Place the piston seal ring in the groove in the speed adjusting piston.

h. Apply a thin coat of grease on the inside diameter of the retainer housing. Then, insert the solid end of the speed adjusting piston in the retainer housing.

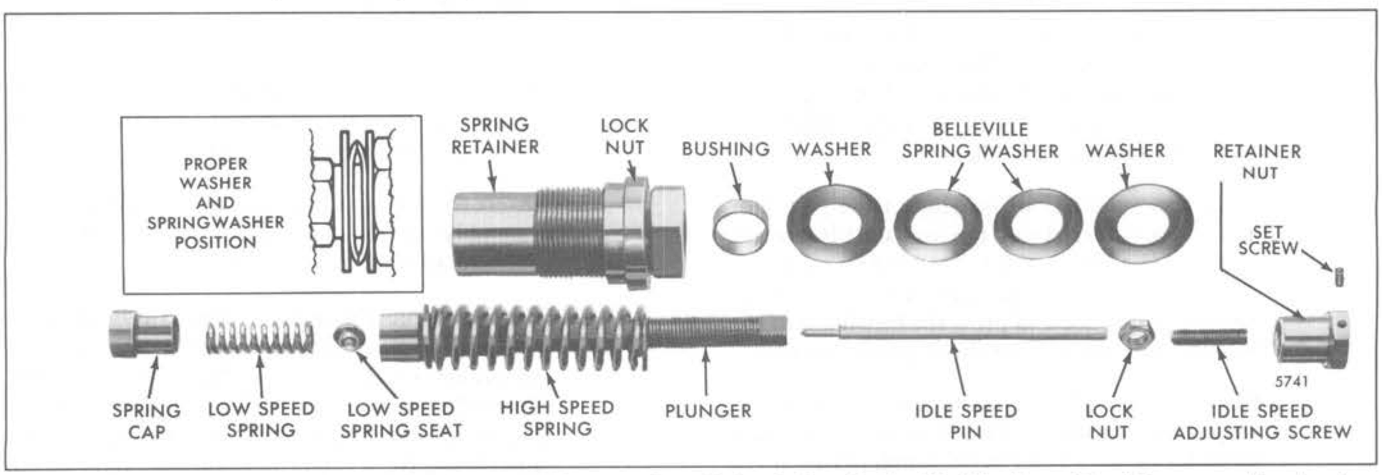


Fig. 23 – High and Low–Speed Springs and Plunger Details including Belleville Washers (Fuel Squeezer Engines)

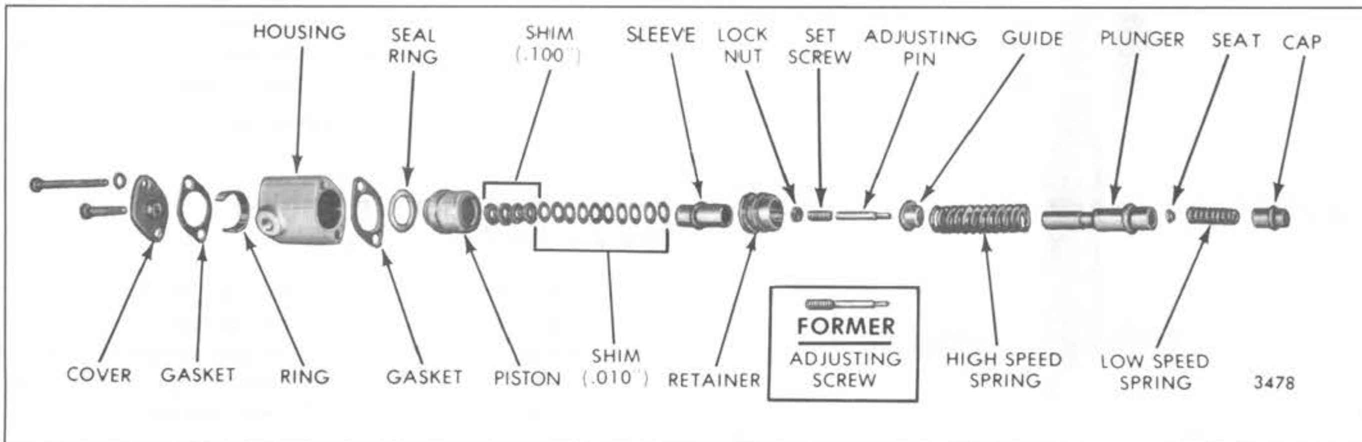


Fig. 24 – High and Low–Speed Springs, Plunger and Piston Details and Relative Location of Parts (Dual–Range)

i. Install the four thick and the ten thin high–speed spring shims down inside the speed adjusting piston. Then, insert the small end of the piston sleeve inside the piston and against the shims.

j. Affix a new high–speed spring retainer housing gasket to the governor housing.

k. If removed, thread the low maximum speed adjusting screw into the high–speed spring retainer housing cover approximately one inch. Then, affix a new gasket to the inside face of the cover.

l. Attach the high–speed spring retainer housing with piston, shims, sleeve and cover to the governor housing with two bolts and lock washers. Tighten the bolts to 13–17 lb–ft (18–23 Nm) torque.

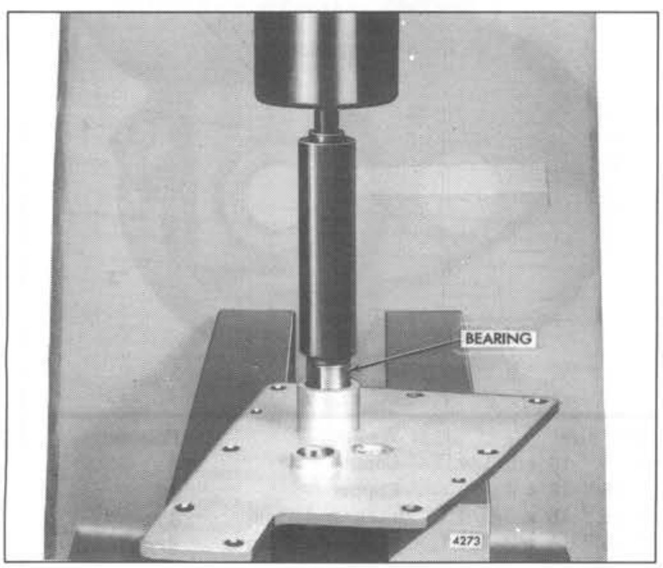


Fig. 25 – Installing Bearings in Governor Cover

9. Assemble the governor cover (Fig. 7 or Fuel Squeezer engine cover (Fig. 8) as follows:

a. If the speed control lever shaft needle bearing were removed from the cover, place the cover, inner face down, on two steel supports on the bed of an arbor press. Lubricate the outside diameter of a bearing with engine oil and start the bearing, numbered end up, straight in the bore in the cover boss.

b. Place the correct end of the bearing installer J 21068 in the bearing (Fig. 25). Installer J 21068 has a pilot on each end; one end is for the speed control shaft upper bearing and the other is for the stop shaft bushing or upper bearing. Then, press the bearing into the bore until the stop on the installer contacts the cover boss.

c. Reverse the governor cover, inner face up, on the bed of the arbor press. Lubricate the outside diameter of the lower 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. On a governor cover equipped with stop lever shaft needle bearing, install the needle bearings in the same manner as described in Steps a, b, c and d above. Use the small pilot end of installer J 21068 to install the bearings.

f. On a governor equipped with a stop lever shaft bushing, install the bushing in the cover (Fig. 26) in the same manner as described in Steps a and b above. Use the small pilot end of installer J 21068 to install the bushing.

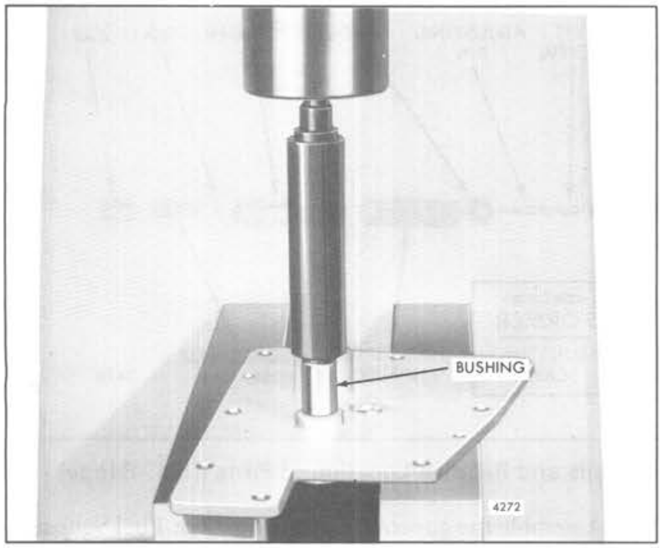


Fig. 26 – Installing Bushing in Governor Cover

g. Lubricate the stop lever shaft needle bearings or bushing with Shell Alvania No. 2 grease, or equivalent.

h. Place the stop lever shaft return spring over the boss on the inner face of the cover (Fig. 7 or 8). Insert the shaft part way through the bearings or bushing and hook the end of the return spring over the end of the lever, then push the shaft up in the cover. Position the end of the lever on the right side of the stop pin (Fig. 7 or 8).

New seal rings made of a Viton material are being used for the speed control lever shaft and for the stop lever shaft.

i. Place a new seal ring over the shaft and push it into the bearing bore and against the bearing or bushing. 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.

j. Install the stop lever on the shaft and secure it in place with the retaining bolt and lock washer.

k. Lubricate the speed control shaft needle bearings with Shell Alvania No. 2 grease, or equivalent. Then, insert the speed control shaft through the bearings.

l. 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.

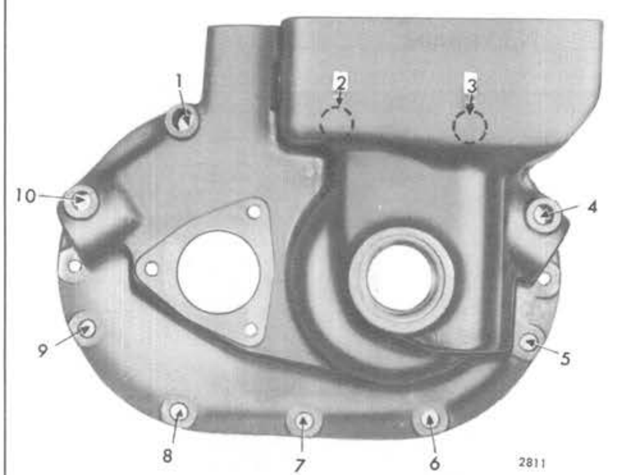
m. Install the spacer on the speed control shaft (slip fit) against the retaining washers and over the snap ring.

n. Install the speed control lever on the shaft and secure it in place with the retaining bolt and lock washer. Be sure the lever contacts the spacer.

o. Install the lubrication fitting in the speed control shaft.

Install Governor On Engine (6V And 8V Engines)

1. Affix a new gasket to the bolting flange of the fuel pump. Place the fuel pump against the governor housing in its *original* position and secure it in place with the three bolt and seal assemblies. Tighten the bolts to 13–17 lb–ft (18–23 N•m) torque.
2. If removed, place a fuel rod cover tube hose and clamp on each fuel rod cover tube at each side of the governor housing.
3. Affix a new gasket to the forward face of the blower end plate.
4. Place the fuel pump drive fork on the fuel pump shaft. Position the governor and fuel pump assembly in front of the blower. Rotate the fuel pump fork until the prongs of the fork align with the slots in the drive disc. Rotate the weight shaft and align the splines on the shaft with the splines in the blower rotor.
5. Push the governor straight in over the dowels in the blower end plate and against the gasket.
6. Refer to Fig. 27 for the locations, and install the bolts, lock washers, copper washers and plain washer securing the governor to the blower. Tighten the bolts to 13–17 lb–ft (18–23 N•m) torque.



Bolt Size:	Washer:	Position:
5/16″-18 x 5 1/4″	Copper	4
5/16″-18 x 4	Copper	10
5/16″-18 x 3 3/4″	Lock and Plain	1
5/16″-18 x 2 1/4″	Lock and Plain	2-3-5-6-7-8-9

Fig. 27 – Location and Size of Governor Retaining Bolts

7. Slide each fuel rod cover tube hose down on the cover tube attached to the cylinder heads and tighten the hose clamps.

8. Install and connect the crossover fuel oil line to each cylinder head and connect the fuel oil lines to the fuel pump.

9. Place the water bypass tube between the two thermostat housings and slide the hoses part way on the thermostat housings. Position the bypass tube so it clears the governor, fuel pump and fuel oil lines. Then, tighten the hose clamps.

10. Install the fuel rods between the cylinder heads and the governor as follows:

    a. Insert the lower end of the left–bank fuel rod down through the top of the governor housing and through the fuel rod cover tubes to the injector control tube lever.

    b. Raise the connecting pin up in the control link operating lever (Fig. 1). Insert the end of the fuel rod between the two bosses on the lever and insert the connecting pin through the fuel rod and into the lower boss.

    c. Connect the opposite end of the fuel rod to the injector control tube lever with a clevis pin and cotter pin.

    d. Insert the lower end of the right–bank fuel rod down through the top of the governor housing and through the fuel rod cover tubes to the injector control tube lever.

    e. Remove the short screw pin from the control link operating lever. Insert the end of the fuel rod between the two bosses on the lever and install the screw pin. Tighten the pin securely.

    f. Connect the opposite end of the fuel rod to the injector control tube lever with a clevis pin and cotter pin.

11. Affix a new gasket to the top of the governor housing. Place the governor cover assembly on the governor housing with the pin in the speed control shaft assembly in the slot of the differential lever and the dowel pins in the housing in the dowel pin holes in the cover.

12. Install the eight governor cover attaching screws and lock washers. The short cover attaching screw, with the drilled head, goes in the corner hole next to the high–speed spring retainer housing. Tighten the screws securely.

CAUTION: Before starting an engine after an engine speed control adjustment or after removal of the engine governor cover and lever assembly, the technician must determine that the injector racks move to the *no–fuel* position when the governor stop lever is placed in the *stop* position. Engine overspeed will result if the injector racks cannot be positioned at no fuel with the governor stop lever. An overspeeding engine can result in engine damage which could cause personal injury.

13. Using a new gasket reinstall the cylinder head rocker covers.

14. Install all of the accessories that were removed from the cylinder head, governor or the front end of the engine.

15. Connect the control linkage to the speed control and stop levers.

16. Close the drain cocks and fill the cooling system.

17. Perform the governor and injector rack control adjustment as outlined in Section 14.3.

Install Governor On Engine (12V And 16V Engines)

1. Affix a new governor housing gasket to the forward face of the blower end plate. Position the governor in front of the end plate. Align the splines of the weight shaft with the splines in the blower rotor, then push the weight shaft in the rotor and slide the governor housing over the dowel pins in the end plate and against the gasket.

2. Refer to Fig. 27 for the bolt location and install the bolts, lock washers, plain washer and copper washers which secure the governor to the blower. Tighten the bolts to 13–17 lb–ft (18–23 N•m) torque.

3. Affix a new blower housing gasket to the cylinder block with a good grade of gasket cement to prevent the gasket from shifting when the blower is lowered into position.

4. Thread eyebolts in diagonally opposite tapped holes in the top of the blower housing. Then, attach a rope sling and chain hoist to the eyebolts.

5. Lift the blower and governor assembly, at a slight angle, and position it on top of the cylinder block, with the flange of the rear end plate cover inside the blower drive shaft cover hose.

6. Thread a 7/16"–14 x 8–1/4" bolt and special washer finger tight in the center hole of each blower end plate. Then, install the 3/8"–16 x 5–1/2" bolts and retaining washers finger tight at each side of the blower housing. The lip at the beveled end of the bolt retaining washer goes in the small recess in the housing just above the bolt slot.

7. Tighten the bolts as follows:

   a. First, tighten the blower–to–block end plate bolts to 40–60 lb–ft (54–81 N•m) torque.

   b. Then, tighten the blower housing–to–block side angle bolts uniformly to 30–35 lb–ft (41–47 N•m) torque in 5 lb–ft (7 N•m) increments.

   c. Recheck the torque on the blower–to–block end plate bolts.

8. Slide the blower drive support–to–blower hose (seal) and clamps into position and tighten the clamps.

9. Insert the blower drive shaft through the blower drive flexible coupling and into the blower drive coupling and install the retaining snap ring in the groove in the coupling.

10. Affix a new gasket to the flywheel housing hole cover, then attach the cover to the flywheel housing with six bolts and lock washers.

    On an engine equipped with a rear mounted battery–charging alternator, affix a new gasket to the alternator drive assembly. Place the alternator drive coupling on the drive hub, then place the drive assembly into position and align the slots in the drive coupling with the drive hub on the blower drive gear. Place the drive assembly against the flywheel housing and install the bolts, lock washers and alternator adjusting strap. Install the alternator drive pulley and drive belt.

    On an engine equipped with a hydraulic oil pump, refer to *M. MH. Marine Service Manual* – Form 00SA1984.

11. Connect the blower drive support oil tube to the fitting in the blower drive support. Then, tighten the two seal ring retaining plate bolts to 13–17 lb–ft (18–23 N•m) torque.

12. Affix a new gasket to the fuel pump flange, then install the fuel pump drive fork and fuel pump on the governor housing. Connect the fuel pump inlet and outlet tubes or hoses to the fuel pump.

13. Slide the governor housing to auxiliary control link housing hose and clamp into position between the two housings and tighten the hose clamp.

14. Slide the fuel rod cover hose down on the cover tube attached to the cylinder head at each side of the governor housing and tighten the hose clamps.

15. Place the control link operating lever connecting link in position in the governor and auxiliary housings and connect it to the ball joint studs in the control link operating levers.

16. Install the fuel rods between the cylinder heads and the governor as follows:

    a. Insert the lower end of the left–bank fuel rod down through the top of the governor housing and through the fuel rod cover tubes to the injector control tube lever.

    b. Raise the connecting pin up in the control link operating lever (Fig. 1). Insert the end of the fuel rod between the two bosses on the lever and insert the connecting pin through the fuel rod and into the lower boss.

    c. Connect the opposite end of the fuel rod to the injector control tube lever with a clevis pin and cotter pin.

    d. Insert the lower end of the right–bank fuel rod down through the top of the governor housing and through the fuel rod cover tubes to the injector control tube lever.

    e. Remove the short screw pin from the control link operating lever. Insert the end of the fuel rod between the two bosses on the lever and install the screw pin. Tighten the pin securely.

    f. Connect the opposite end of the fuel rod to the injector control tube lever with a clevis pin and cotter pin.

17. Place a new auxiliary control link housing cover gasket on the housing, then install the cover and secure it in place with screws and lock washers.

18. Place a new governor housing cover gasket on the housing, then install the cover and secure it in place with screws and lock washers.

CAUTION: Before starting an engine after an engine speed control adjustment or after removal of the engine governor cover and lever assembly, the technician must determine that the injector racks move to the *no–fuel* position when the governor stop lever is placed in the *stop* position. Engine overspeed will result if the injector racks cannot be positioned at no fuel with the governor stop lever. An overspeeding engine can result in engine damage which could cause personal injury.

19. Using new gaskets reinstall the cylinder head rocker covers.

20. On a non–turbocharged engine, remove the cover from the top of the blower. Place the blower screen, wire side down, on top of the blower and install the air shutdown adaptor. Then, attach the air shutdown housings and gaskets to the adaptors.

    On a turbocharged engine, remove the cover from the top of the blower. Place the blower screen, wire side down, and install the air shutdown adaptor and air shutdown housing as an assembly on the blower. Then, attach the shutdown rod to the lever on the shutdown housing.

    On a marine engine, remove the cover from the top of the blowers. Place the blower screen, wire side down, on top of the blower and install the air shutdown housings.

21. On a non–turbocharged engine, connect the air inlet tubes to the air shutdown housings.

    On a turbocharged engine, attach the air inlet tube to the rear air shutdown housing and the turbocharger. On a marine engine, install the air silencers on the air shutdown housings.

22. Connect the linkage, that was removed, to the governor speed control and stop levers.

23. Perform an engine tune–up as outlined in Section 14.3.1.

LIMITING SPEED MECHANICAL GOVERNOR

(Variable Low-Speed)

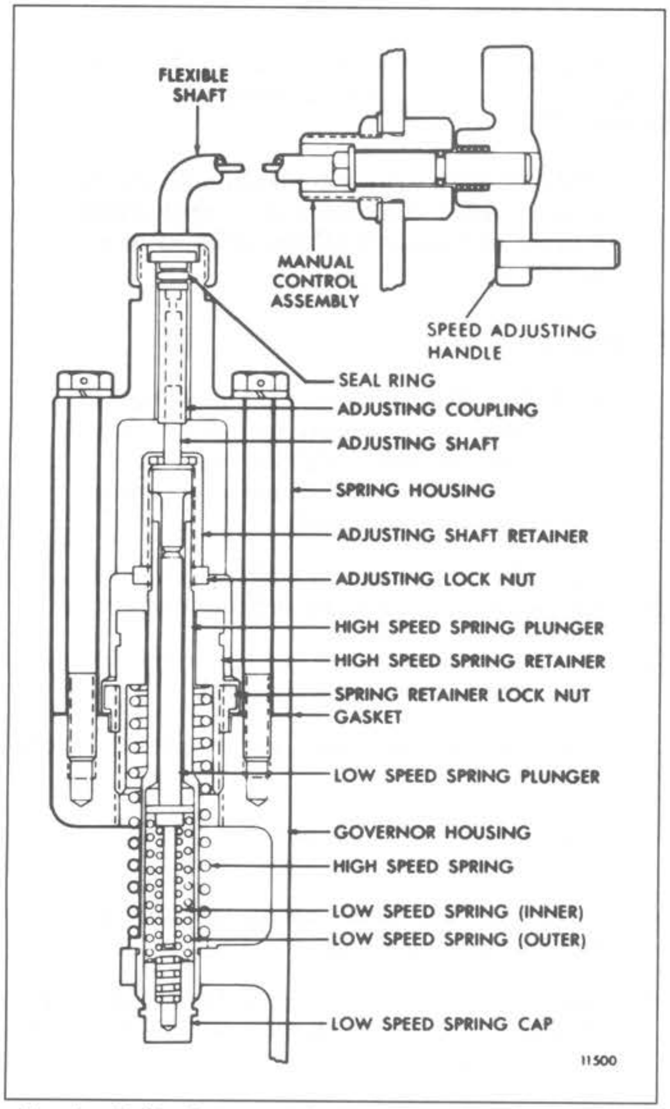


Fig. 1 – Cable Operated Governor Spring Housing and Components

The variable low-speed limiting speed mechanical governor is used on highway vehicle engines where the same engine powers both the vehicle and the auxiliary equipment for unloading bulk products (such as cement, grain and liquids) and a high idle speed range is desired during auxiliary operation.

The current governor is a single-weight type and provides an idle speed range of 500 to 1800 rpm. The governor is mounted on the front end of the blower and is driven by one of the blower rotors.

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 function 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).

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 GOVENOR

Remove Governor

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.

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, 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 copper 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 speed 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.

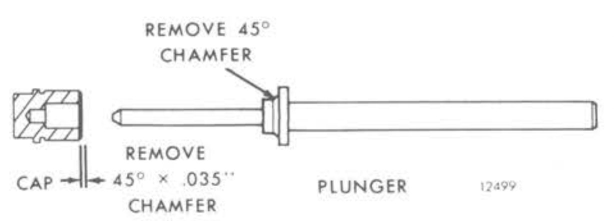


Fig. 2 – Rework Former Plunger and Cap

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.

CAUTION:To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.

Assemble Governor

NOTICE: 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, then assemble the spring housing and components (Fig. 1).

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.

   NOTICE: Place a new 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, 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.

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, 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 gaskets.

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. Discard the gasket.

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 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.

CAUTION:To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.

Assemble Governor

NOTICE: 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, then assemble the spring housing and components as follows (Fig. 3):

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.

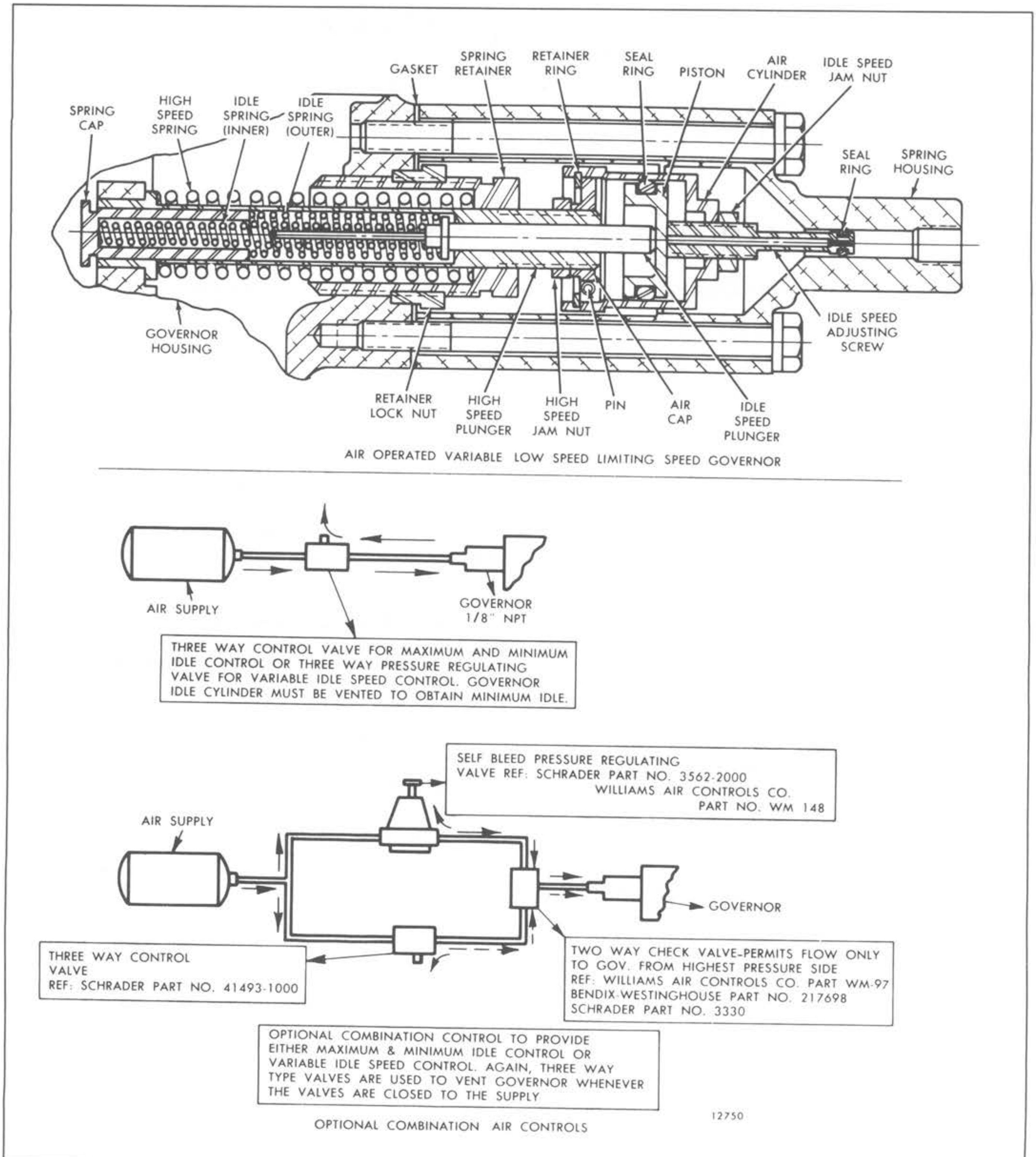


Fig. 3 – Air Operated Variable Low Speed Limiting Speed Governor and Air Controls

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.

   NOTICE: Place the new spring housing gasket in position before installing the assembly.

7. Thread the 1/2"–20 high–speed spring jam nut on the threaded end of the plunger approximately 1/2".

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 on the high–speed spring plunger and against the high–speed spring plunger and jam nut.

10. Place a new seal ring on the idle speed 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.

    NOTICE: Be sure and lubricate the bore of the spring housing with grease as stated in the above notice.

Intall Governor

Install the governor as outlined in Section 2.7.1, 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

(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.

NOTICE: 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 the bolts.

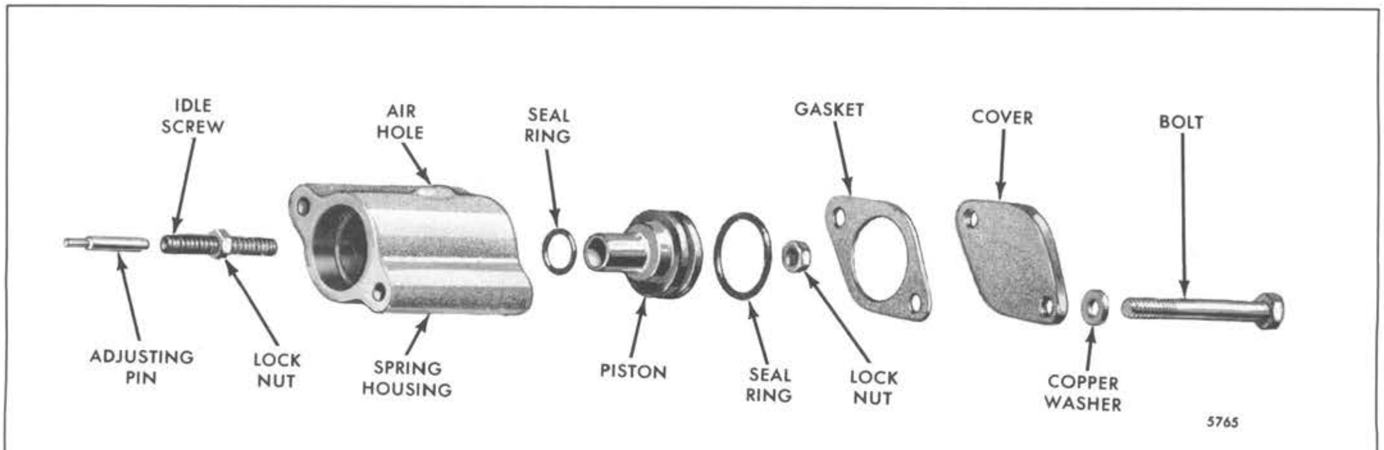


Fig. 1 – Air Operated Variable High Speed Limiting Speed Mechanical Governor Components

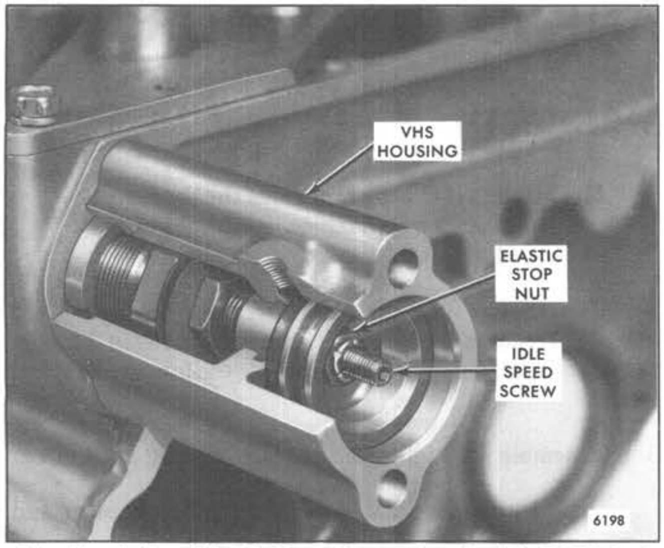


Fig. 2 – Adjust Elastic Stop Nut using Tool J 28598–A

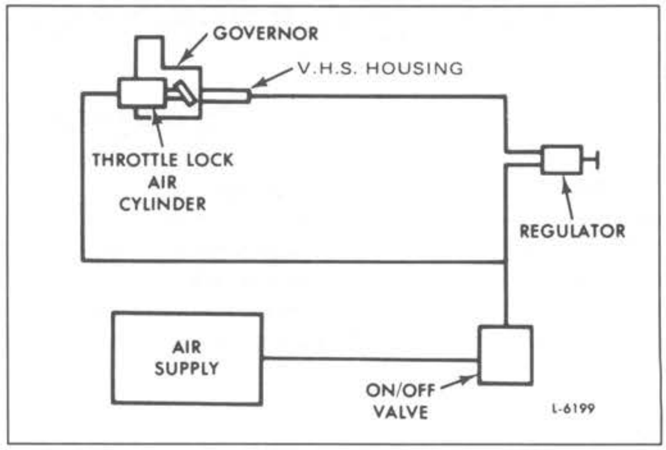


Fig. 3 – Schematic Drawing of Limiting Speed Mechanical Governor (Variable High Speed)

Install the air cylinder on the governor cover so that it does not interfere with the throttle linkage when no air pressure is 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.

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

The variable speed mechanical governor, illustrated in Fig. 1, performs the following 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 mechanical engine 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.

On 6V and 8V engines, the governor is mounted on the front end of the blower. On a 12V and 16V engines, the governor is mounted on the front end of the rear blower and the governor auxiliary drive housing is mounted on the rear

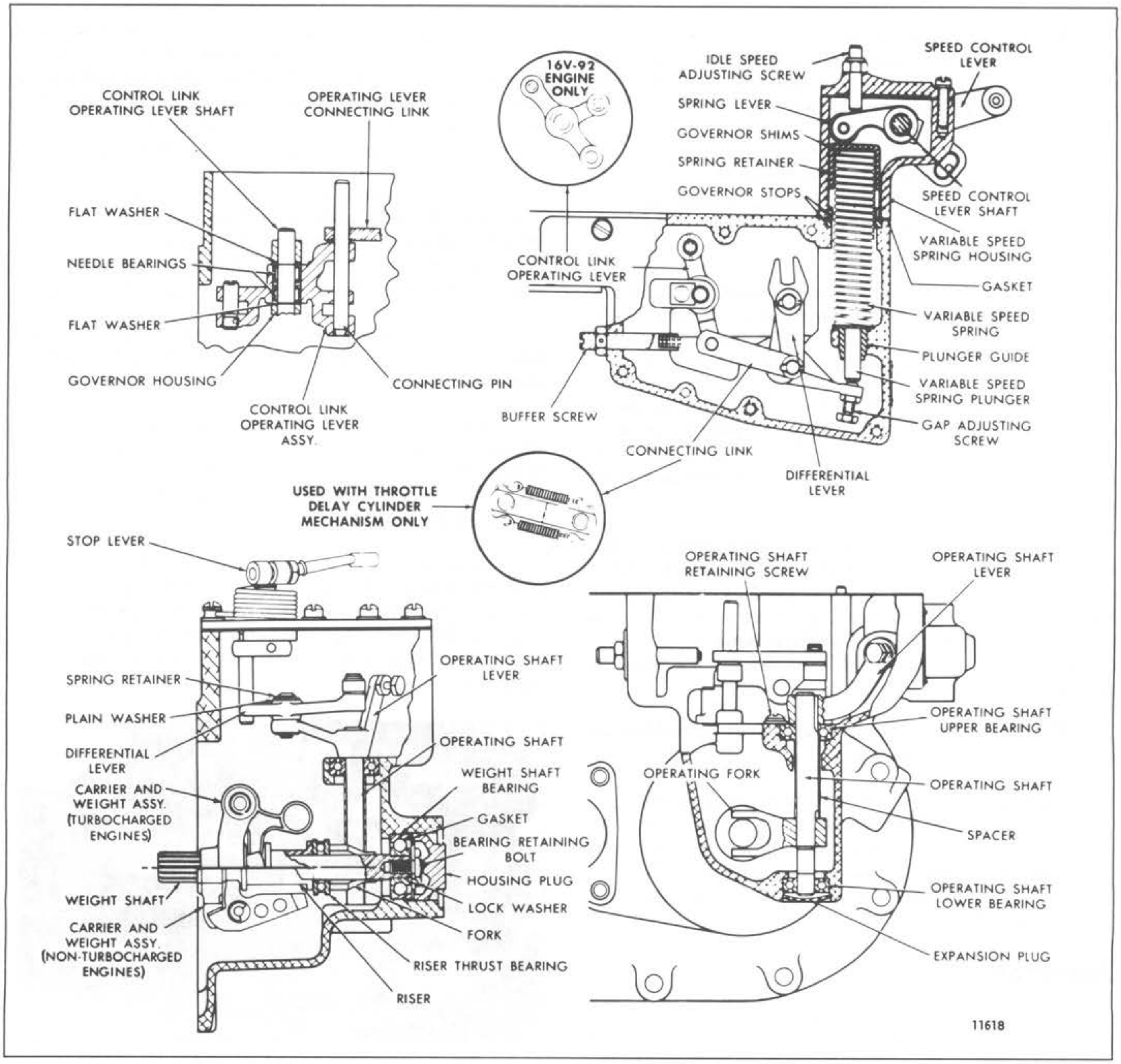


Fig. 1 – Cross Sections of Variable Speed Mechanical Governor

end of the front blower. The governors are driven by a blower rotor. The governor assembly consists of three subassemblies.

1. Control Housing Cover.
2. Variable Speed Spring Housing and Shaft.
3. Control and Weight Housing.

For 12V and 16V turbocharged engines, the governor has three weights and a heavier variable speed spring (Fig. 9).

To provide additional design features, a new die cast governor cover with serrated shafts and three bosses is now being used. One boss is drilled for the variable speed governor shutdown (run/stop) shaft.

NOTICE: If a customer furnished mounting bracket is attached to the new cover, it may be necessary to rework the old bracket to clear the unused cast bosses (two for variable speed governors).

The new die cast governor cover assemblies include a 1/2" diameter serrated shutdown shaft for variable speed governors. This assures positive clamping between the serrated levers and the shafts to prevent any slippage.

Four serrations are eliminated on the shutdown shafts to permit certain customers to design a mating lever with missing serrations, which will provide a fixed position for particular requirements. Levers are not provided with missing serrations.

To reduce governor speed control lever shaft assembly stop pin wear and prolong bushing and "0" ring seal life, a yieldable speed control lever is available. This newly designed yieldable speed control lever cannot be used with the former stamped cover assemblies; however, a service yieldable speed control lever is available for use with the stamped cover.

The former and new cover and shaft assemblies are interchangeable on a governor.

NOTICE: When only a former cover needs replacing, it will be necessary to replace the cover and shaft assembly. Only the new cover is serviced separately. The former control shafts and levers will continue to be serviced for the former governors.

Operation

Two manual controls are provided on the variable speed 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.

Adjustment of the engine idle speed is accomplished by changing the tension on the variable speed spring by means of the idle speed adjusting screw. Refer to Section 14.4 (6V and 8V engines) or 14.4.1 (12V and 16V engines) for the idle speed adjustment.

Adjustment of the maximum no–load speed is accomplished by varying the tension on the variable speed spring by the installation or removal of stops and shims (Fig. 1). Refer to Section 14.4 (6 and 8V engines) or 14.4.1 (12V and 16V engines) for the maximum no–load speed adjustment.

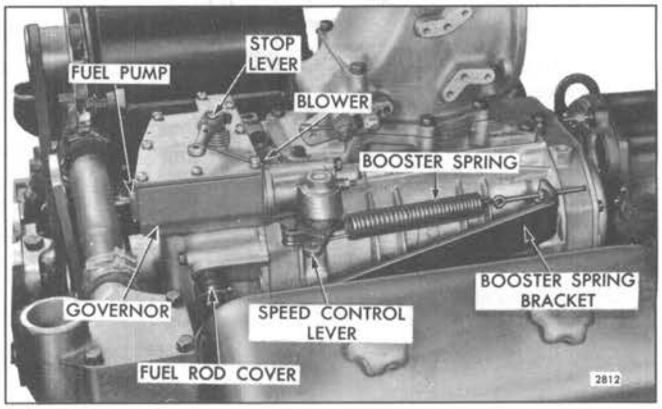


Fig. 2 – Variable Speed Governor Mounting (6V and 8V Engines)

Lubrication

The governor is lubricated by a spray of lubricating oil from the blower end plate. The governor weights distribute this oil to all parts of the governor assembly requiring lubrication.

Oil returning from the governor is directed through passages in the blower end plate and cylinder block to the engine oil pan.

Remove Governor From Engine (6V and 8V Engines)

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.

1. Open the drain cocks and drain the engine cooling system.
2. Remove any accessories attached to the cylinder head, governor or front end of the engine that interfere with the removal of the governor assembly.
3. Disconnect the control linkage from the speed control and stop levers (Fig. 2).
4. Remove the end of the stop lever return spring from behind the head of the special governor cover attaching screw. Then remove the eight screws and lock washers securing the governor cover to the housing. Lift the cover and gasket from the housing.
5. Remove the fuel rods from the control link operating lever assembly and the injector control tube levers as follows (Fig. 1):
   a. Remove the valve rocker covers from the cylinder heads.
   b. Remove the right bank fuel rod by removing the screw type pin, in the control link operating lever, and the clevis pin in the control tube lever and withdraw the fuel rod from the governor.
   c. Remove the left–bank fuel rod by removing the clevis pin in the control tube lever and lift the connecting pin up out of the control link operating lever approximately three–quarters of an inch. Then withdraw the fuel rod from the governor.
6. Loosen the hose clamps at each end of the water bypass tube. Slide the hoses and clamps onto the bypass tube and remove the tube from the engine.
7. Disconnect and remove the fuel oil lines attached to the fuel pump and the crossover fuel oil line attached to each cylinder head.
8. Loosen the outer booster spring adjusting nut and remove the booster spring from the speed control lever.
9. Loosen the hose clamps on the fuel rod cover tube hoses next to each cylinder head and slide each hose and clamp up on the tube in the governor housing.
10. Note the location of the two copper, one plain and eight lock washers on the governor to blower bolts before removing them. Then remove the ten bolts and washers (two inside and eight outside) securing the governor and fuel pump assembly to the blower.
11. Tap the sides of the governor housing slightly with a plastic hammer to loosen the governor from the blower. Then pull the governor and fuel pump assembly straight out from the dowels in the blower end plate. Remove the governor to blower gasket.

    NOTICE: The fuel pump drive coupling fork may stay on either the fuel pump or the blower rotor shaft. Remove the drive coupling fork.

12. Remove the three bolt and seal assemblies securing the fuel pump assembly to the governor housing. Remove the fuel pump and gasket from the governor housing.

Remove Governor From Engine (12V and 16V Engines)

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.

1. Disconnect the linkage attached to the governor speed control and stop levers.
2. On a non–turbocharged engine, disconnect the air inlet tube attached to the air shutdown housing on each blower.

   On a turbocharged engine, disconnect the tube from the turbocharger and the air shutdown housing on the rear blower.

   On a marine engine, remove the air silencers from both air shutdown housings.

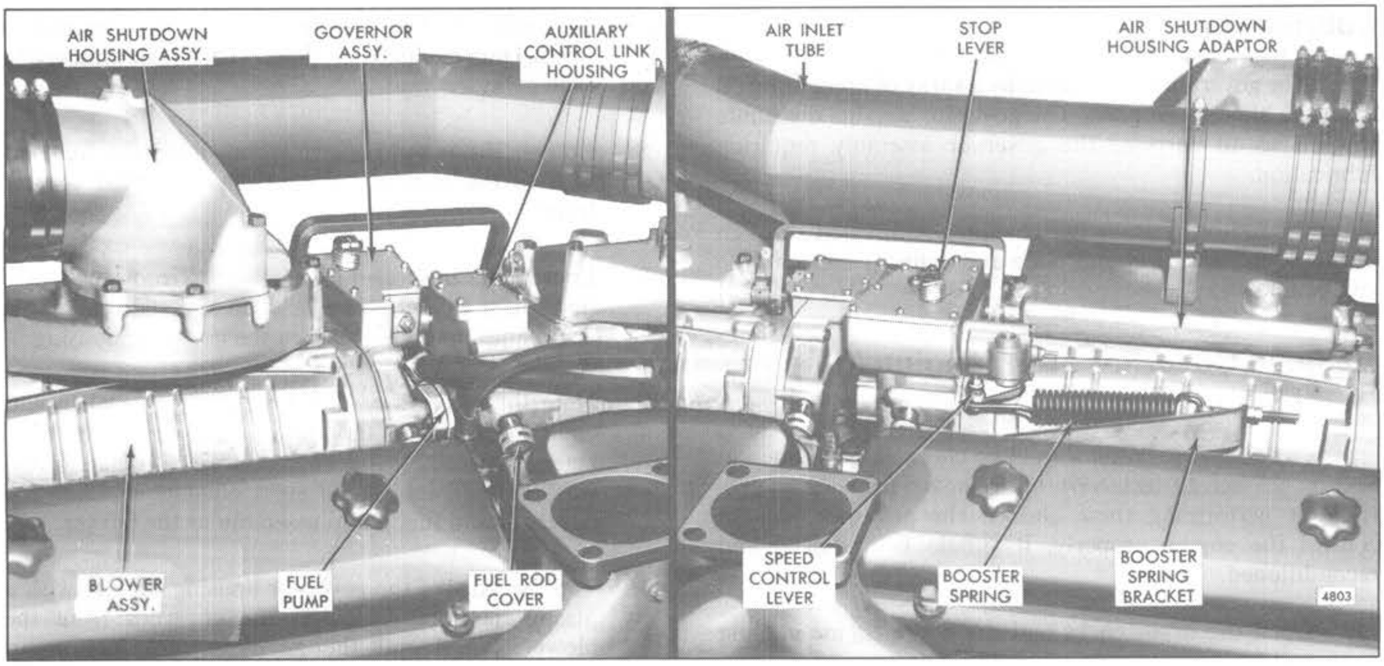


Fig. 3 – Variable Speed Governor Mounting (12V and 16V Engines)

3. On a non–turbocharged engine, remove the air shutdown housings and the air shutdown adaptor from the rear blower.

   NOTICE: Remove the two air shutdown housings, with attaching rod, as a unit from the adaptors or the blowers.

   On a turbocharged engine, disconnect the shutdown rod from the lever on the rear air shutdown housing. Then remove the air shutdown housing and the air shutdown adaptor as an assembly from the blower.

4. Cover the top of the blower with masking tape to prevent the entry of foreign material.

5. Remove the rear cylinder head rocker covers.

6. Remove the end of the stop lever return spring from behind the head of the special governor cover attaching screw. Then remove the eight screws and lock washers securing the governor cover to the housing. Lift the cover and gasket from the housing.

7. Remove the governor auxiliary control link housing cover screws and lock washers, then remove the cover and gasket from the housing.

8. Disconnect the fuel rods from the control link operating lever and the injector control tube levers as follows:

   a. Remove the right bank fuel rod by removing the screw type pin in the control link operating lever and the pin in the control tube lever. Withdraw the fuel rod out through the top of the governor housing.

   b. Remove the left bank fuel rod by removing the connecting pin from the control link operating lever and the pin in the control tube lever. Withdraw the fuel rod out through the top of the governor housing.

9. Remove the connecting link from the ball joint stud attached to the control link operating lever in the governor housing and the auxiliary control link housing by lifting, or prying each end of the connecting link off of the ball joint studs. Then remove the connecting link from the governor housing.

10. Loosen the fuel rod cover hose clamp at each side of the governor housing. Then slide each hose against the governor housing. Tighten each clamp to retain it on the hose.

11. Loosen the hose clamp between the governor housing and the auxiliary control link housing. Then slide the hose forward against the auxiliary control link housing. Tighten the clamp to retain it on the hose.

12. Disconnect the fuel pump inlet and outlet tubes or hoses from the fuel pump. Then remove the fuel pump from the governor housing.

13. Loosen the outer booster spring adjusting nut and remove the booster spring from the speed control lever. Then remove the booster spring bracket from the cylinder head.

14. Disconnect the blower drive support oil tube from the fitting in the blower drive support. Loosen the two bolts securing the oil tube seal ring retaining plate to the blower end plate, then push the oil tube into the end plate.

15. Remove the six bolts and lock washers securing the flywheel housing hole cover, at the blower drive support, then remove the cover and gasket.

On an engine equipped with a rear mounted battery–charging alternator, loosen and remove the alternator drive belt. Then remove the alternator drive pulley nut and pulley from the alternator drive shaft. Remove the bolts and lock washers securing the alternator drive assembly to the flywheel housing, then remove the drive assembly, gasket and drive coupling from the flywheel housing.

On an engine equipped with a hydraulic oil pump, remove the six bolts and lock washers securing the oil pump to the flywheel housing and adaptor, then remove the oil pump, adaptor and gaskets from the flywheel housing. Remove the drive coupling and the drive coupling hub from the blower drive shaft.

16. Remove the blower drive shaft retaining snap ring from the blower drive coupling, then remove the blower drive shaft from the blower drive hub and the blower drive support.

17. Loosen the blower drive support–to–blower hose (seal) clamps. Then push the hose (seal) back on the blower drive support.

18. Remove the bolt and washer through the top of each blower end plate securing the blower to the cylinder block.

19. Remove the bolts and retaining washers on each side of the blower securing the blower to the cylinder block.

20. Thread eyebolts in diagonally opposite tapped holes in the top of the blower housing. Then attach a rope sling and chain hoist to the eyebolts.

21. Lift the blower assembly slightly and move it forward to detach the blower from the hose (seal). Then lift the blower away from the engine and place it on a bench. Remove the blower to cylinder block gasket.

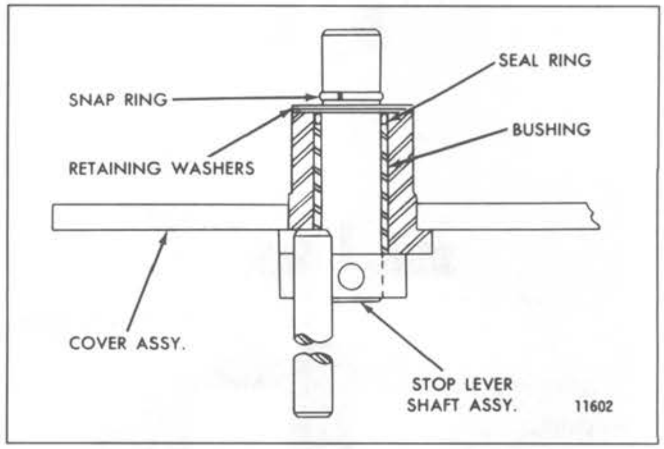


Fig. 4 – Cross Section of Governor Cover Assembly

22. With the blower and governor assembly removed from the engine, remove the ten bolts, lock washers, plain washer and copper washers securing the governor assembly to the blower end plate. Slide the governor assembly forward off of the dowel pins in the end plate, then remove the governor to blower end plate gasket.

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.

1. Disassemble the governor cover as follows (Fig. 4):

   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. Remove the return spring from the shaft.

   c. Remove the snap ring from the groove in the stop lever shaft and remove the two seal ring retaining washers.

   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 (containing the bushing) thoroughly in clean fuel oil and inspect the bushing for wear and damage. If the bushing is satisfactory for further use, removal is unnecessary.

   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. 5).

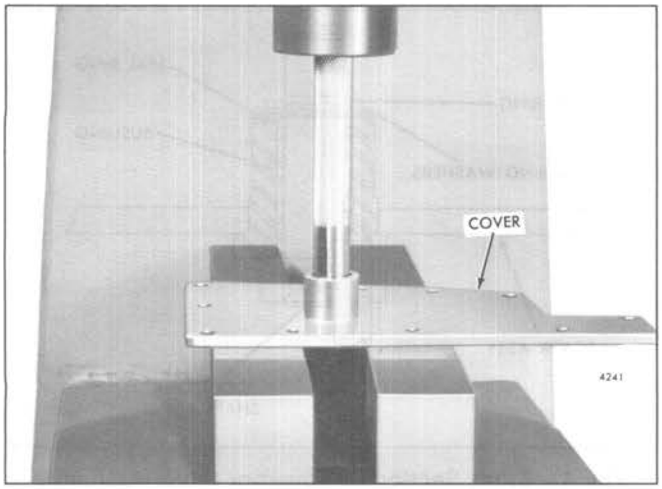


Fig. 5 – Removing Stop Lever Shaft Bushing from the Governor Cover using Tool J 21967-01

2. Remove the variable speed spring, spring plunger and spring housing 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 two bolts and lock washers securing the variable speed spring housing to the governor housing. Then withdraw the spring housing, spring retainer, shims, split stop and spring as an assembly from the governor housing. Remove the spring housing gasket.

   c. Remove the variable speed spring, split stop, shims and spring retainer from the spring housing. Then remove the spring plunger from the plunger guide.

   d. Remove the spring retainer solid stop from the governor housing.

   e. If necessary, remove the variable speed spring plunger guide from the governor housing with a small brass rod and hammer.

3. Disassemble the variable speed spring housing:

   a. Loosen the bolt securing the speed control lever to the speed control shaft and pull the lever from the shaft.

   b. Remove the Woodruff key and flat washer from the speed control shaft.

   c. Remove the pipe plug in the top of the variable speed spring housing. Then remove the variable speed spring lever set screw from the speed control shaft and spring lever (Fig. 6).

   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 (if used) in the side of the housing over the opening of the sleeve.

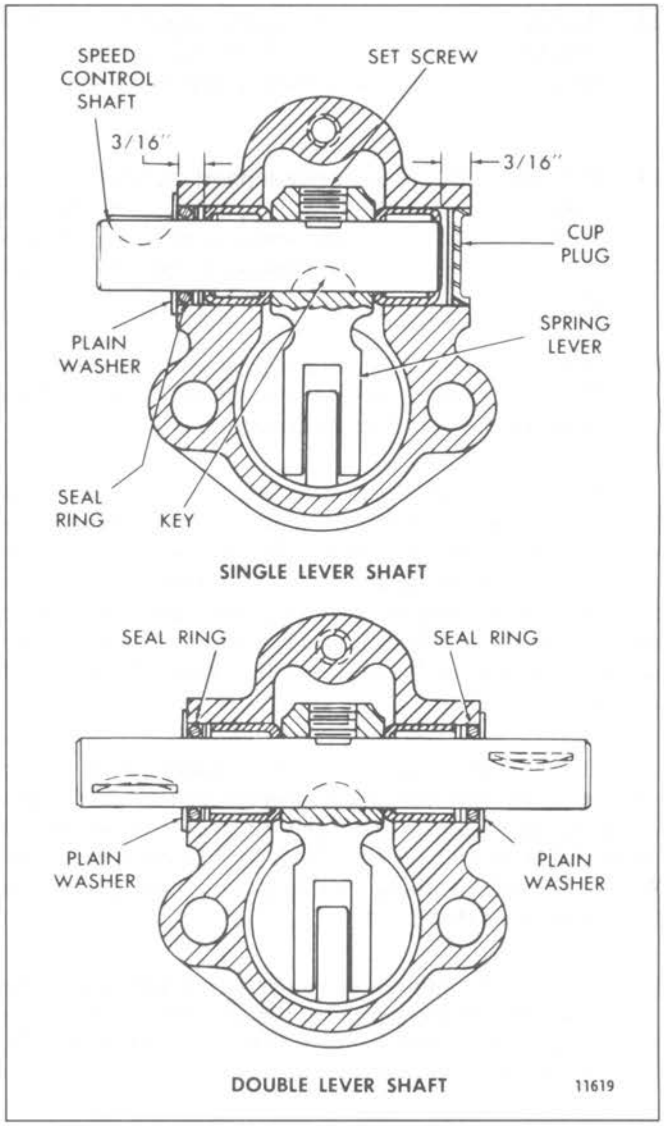


Fig. 6 – Cross Section of Governor Variable Speed Spring Housing

   e. Place a small brass rod on the end of the shaft, as shown in Fig. 7, and press the plug (if used) and bearing out of the spring housing.

   f. Remove the spring lever from the spring housing and the bearing from the speed control shaft. Discard the bearing. If necessary, remove the Woodruff key from the shaft.

NOTICE: 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 attempt to reuse the bearing.

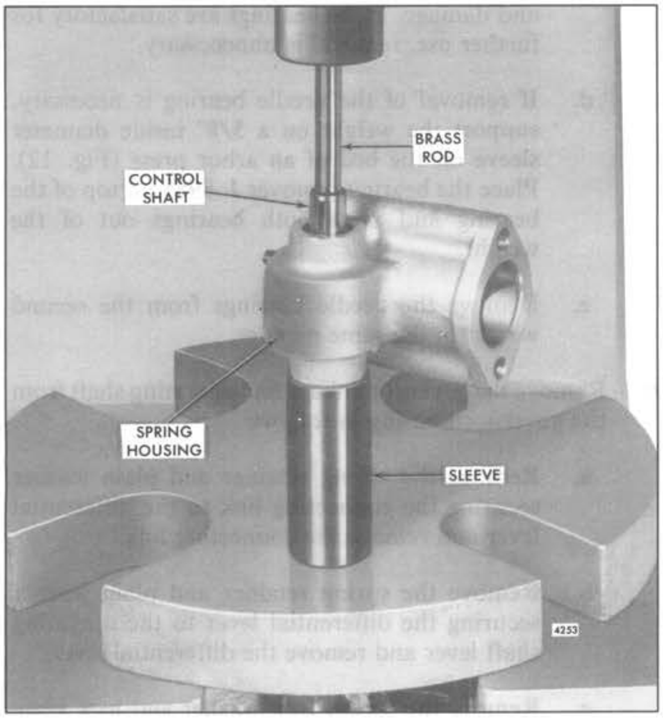


Fig. 7 – Removing Speed Control Shaft, Bearing and Cup Plug from Variable Speed Spring Housing

g. At this stage of disassembly, wash the spring housing (containing the remaining bearing) thoroughly in clean fuel oil and inspect the needle bearing for wear and damage. If the bearing is satisfactory for further use, removal is unnecessary.

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. Thread a 5/16"–24 x 3" bolt into the bearing retaining bolt hole. Support the governor housing on the bed of an arbor press and press the governor weight shaft from the bearing as shown in Fig. 8.

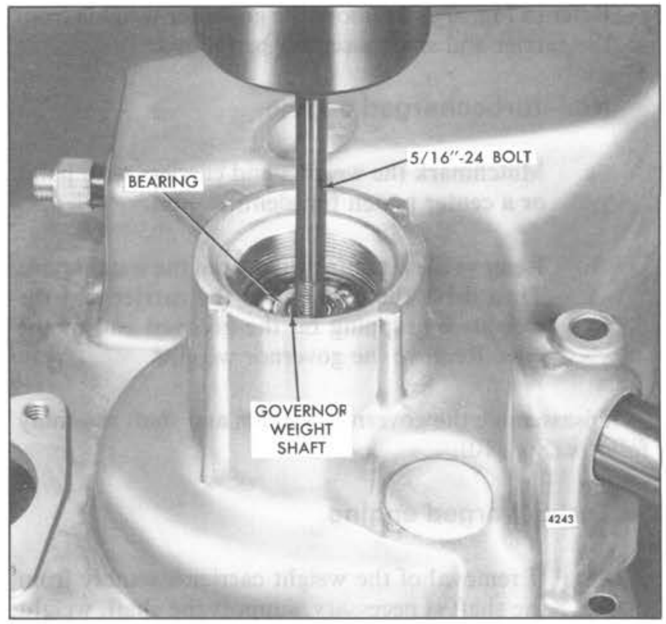


Fig. 8 – Removing Governor Weight Shaft Assembly from Governor Housing

e. Slide the governor riser thrust bearing and riser from the weight shaft.

NOTICE: 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.

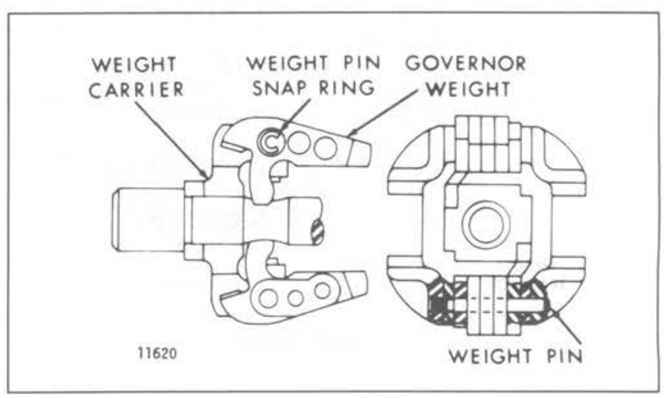


Fig. 9 – Cross Section of Governor Weight Assembly (Non–Turbocharged Engines)

5. Refer to Fig. 9 and remove the governor weights from the carrier and shaft assembly as follows:

Non–turbocharged engine

a. Matchmark the weights and carriers with paint or a center punch for identification.

b. 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.

Disassemble the governor weights and shaft assembly as follows (Fig. 10):

Turbocharged engine

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. 11, and press the shaft out of the weight carrier assembly.

b. Refer to Fig. 10 and remove the lock ring from the weight pin with a pair of snap ring pliers. Then remove the weight pin, flat washers and weight assembly from the weight carrier. Remove the second weight from the carrier in the same manner.

c. At this stage of disassembly, wash the weights (containing the needle bearing) thoroughly in clean fuel oil and inspect the bearings for wear and damage. If the bearings are satisfactory for further use, removal is unnecessary.

d. If removal of the needle bearing is necessary, support the weight on a 5/8" inside diameter sleeve on the bed of an arbor press (Fig. 12). Place the bearing remover J 8985 on top of the bearing and press both bearings out of the weight.

e. Remove the needle bearings from the second weight in the same manner.

6. Remove the governor linkage and operating shaft from the governor housing as follows:

a. Remove the spring retainer and plain washer securing the connecting link to the differential lever and remove the connecting link.

b. Remove the spring retainer and plain washer securing the differential lever to the operating shaft lever and remove the differential lever.

c. Remove the screw, lock washer and lock plate securing the control link operating lever shaft in the housing. Lift the shaft up out of the housing and remove the operating lever and two flat washers at each side of the operating lever.

NOTICE: Be sure not to lose the two flat washers located between the top and bottom of the lever assembly and the governor housing.

d. Remove the expansion plug from the bottom of the governor housing (Fig. 1).

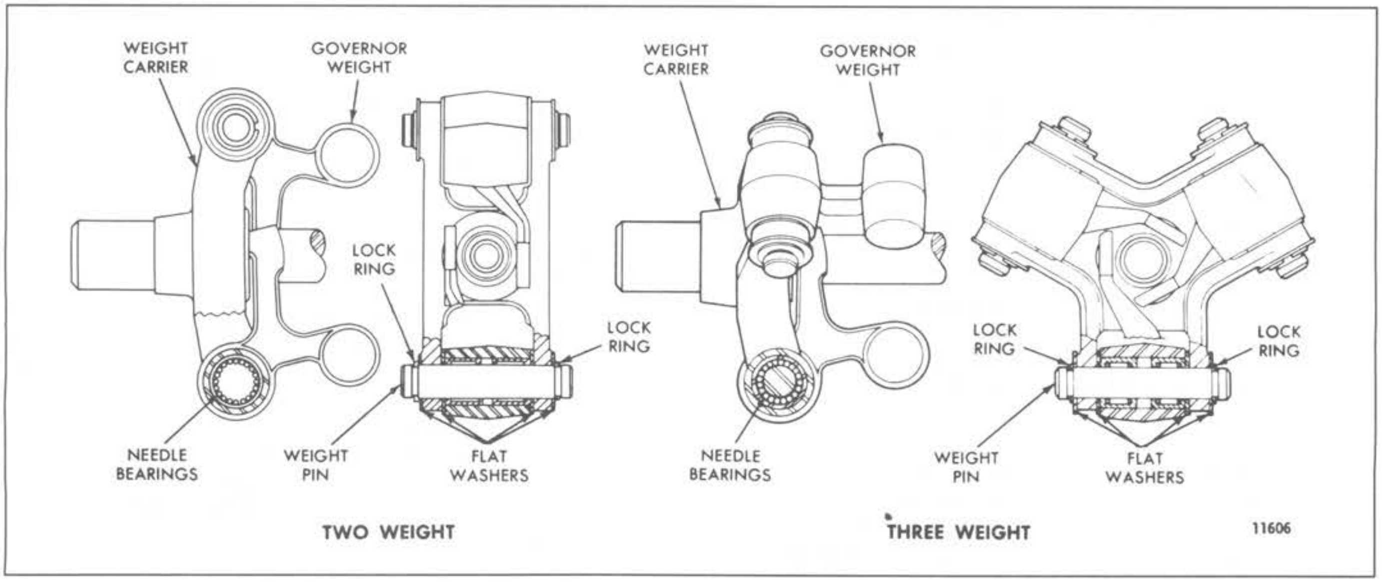


Fig. 10 – Cross Section of Governor Weight Assemblies (Turbocharged Engines)

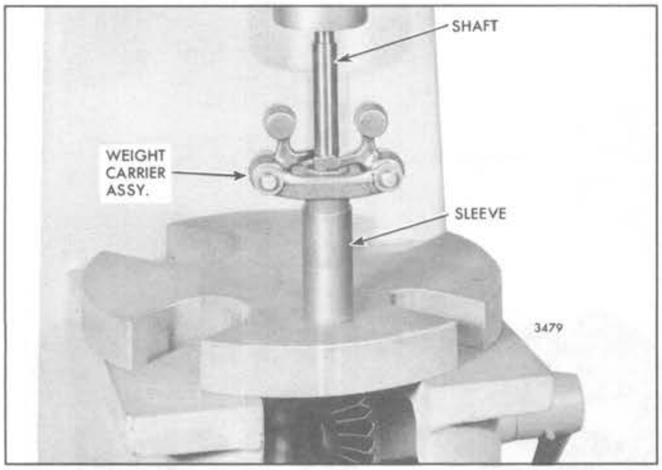


Fig. 11 – Removing Governor Weight Shaft from Weight Carrier Assembly

e. Remove the operating shaft upper bearing retaining screw, lock washer and flat washer securing the bearing in the governor housing.

f. Support the governor housing bottom side up on the bed of an arbor press, with the two dowel pins in the top of the housing between the two steel supports. Refer to Fig. 13 and place a small brass rod on the end of the operating shaft and press the shaft out of the bearing.

g. With the housing still supported on the bed of the press, place a 9/16" open end wrench under the operating fork as shown in Fig. 14. Place a brass rod on the end of the shaft and press the fork off of the operating shaft. Remove the shaft, operating lever and bearing as an assembly from the housing.

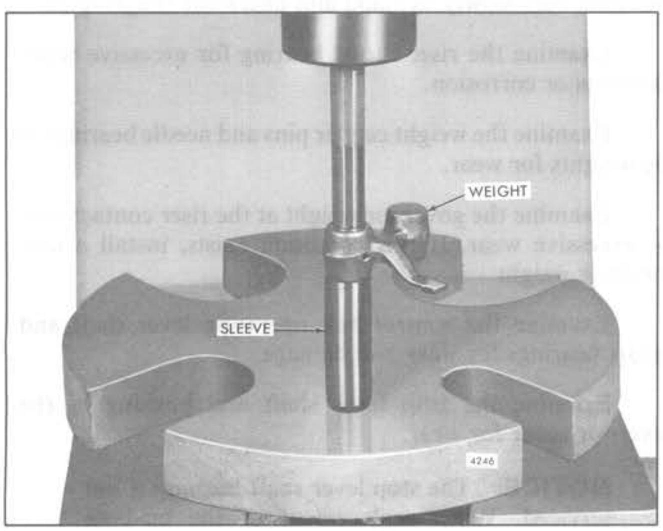


Fig. 12 – Removing Governor Weight Bearings using Tool J 8985

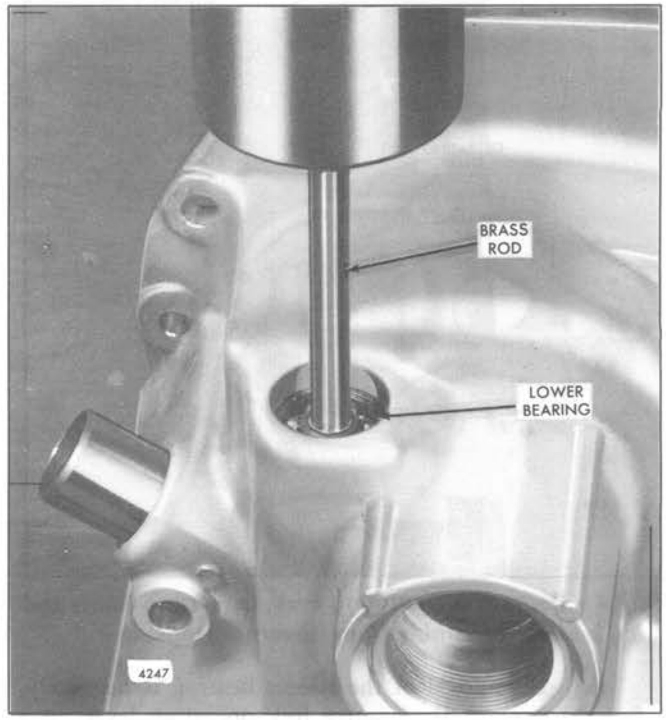


Fig. 13 – Removing Operating Shaft from Operating Shaft Lower Bearing

h. Remove the operating shaft lower bearing from the bottom of the governor housing.

i. Slide the governor operating shaft spacer from the shaft.

j. Place a short 9/16" inside diameter sleeve over the end of the operating shaft and rest it against the inner race of the bearing on the current operating shaft, or the flat washer under the bearing on the former operating shaft.

k. Support the operating shaft, lever, bearing and sleeve on a large washer or plate, with a 5/8" hole, on the bed of an arbor press as shown in Fig. 15. Place a small brass rod on the end of the shaft and press the operating shaft out of the operating lever and bearing. Catch the shaft by hand when pressed from the lever and bearing to prevent it from falling and being damaged.

NOTICE: Be sure that the bearing inner race is resting on the sleeve or the bearing may be damaged.

l. At this stage of disassembly, 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 bearings are satisfactory for further use, removal is unnecessary.

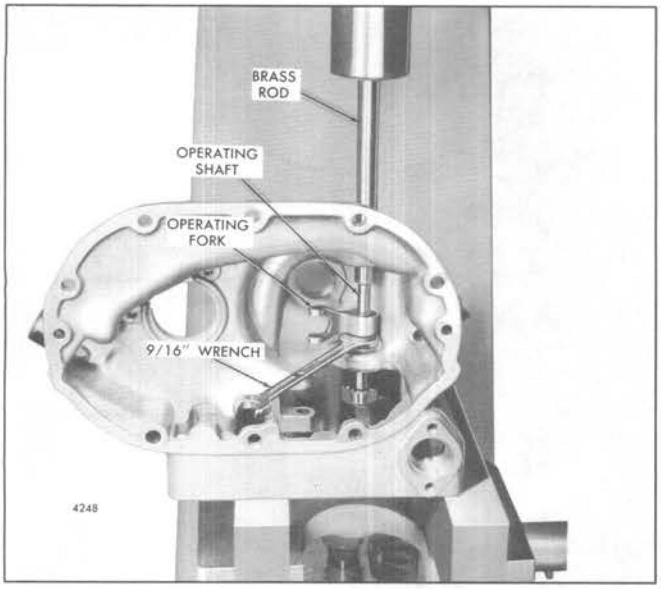


Fig. 14 – Removing Operating Fork, Operating Shaft and Lever Assembly from Governor Housing

m. 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 press both bearings out of the lever as shown in Fig. 16.

7. Remove the buffer screw from the governor housing.

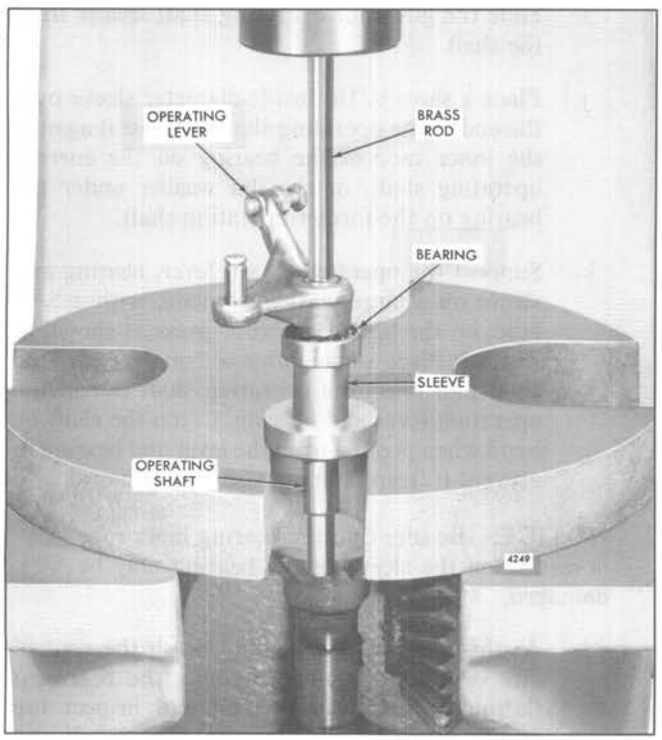


Fig. 15 – Removing Operating Lever and Upper Bearing from Operating Shaft

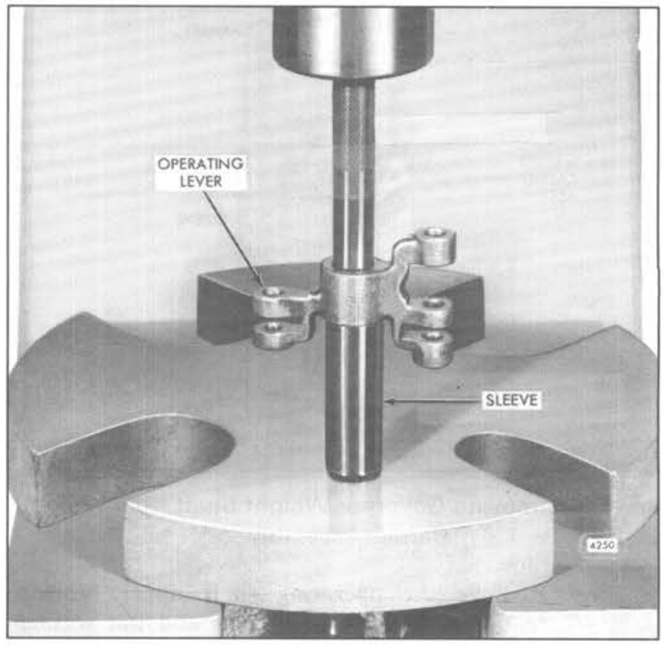


Fig. 16 – Removing Operating Lever Needle Bearings using Tool J 8985

Inspection

Wash all of the governor parts in clean fuel oil and dry them with compressed air.

CAUTION:To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.

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.

Examine the riser thrust bearing for excessive wear, flat spots or corrosion.

Examine the weight carrier pins and needle bearings in the weights for wear.

Examine the governor weight at the riser contact area for excessive wear. If this condition exists, install a new governor weight.

Examine the control link operating lever shaft and needle bearings for wear and damage.

Examine the stop lever shaft and bushing in the governor cover for wear.

NOTICE: 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 speed control lever shaft and needle bearings in the variable speed spring housing for wear.

Examine the variable speed spring lever roller and pin for excessive wear. The 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.

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 parts that are 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 and 17 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. Lubricate the inside diameter of the governor operating shaft upper bearing with engine oil. Start the bearing, numbered side up, straight on the large end of the operating shaft. Support the bearing and operating shaft on a 9/16" inside diameter sleeve on the bed of an arbor press, with the inner race of the bearing resting on the sleeve. Then press the shaft into the bearing until 1/4" of the shaft protrudes through the bearing.

   b. Lubricate the inside diameter of the governor operating shaft lever with engine oil. Start the lever, pivot pin in the operating lever facing up, straight on the operating shaft with the flat on the shaft registering with the flat surface in the lever. Support the operating lever, bearing and shaft on the bed of an arbor press with a steel support directly under the center of the lever, then press the operating shaft through the bearing and lever until the end of the shaft contacts the steel support.

   NOTICE: The upper end of the shaft must be flush with the top surface of the lever.

   c. Place the operating shaft spacer over the lower end of the shaft and slide it against the upper bearing inner race.

   d. Insert the end of the governor operating shaft, bearing, spacer and lever assembly through the upper bearing bore in the governor housing with the lever positioned as shown in Fig. 1.

   e. Lubricate the inside diameter of the governor operating shaft fork with engine oil. Then place the operating fork over the lower end of the shaft, with the finished cam surfaces on the fork fingers facing the rear of the governor housing and the flat on the shaft registering with the flat surface in the fork.

   f. Support the governor housing and operating shaft assembly on the bed of an arbor press with the upper end of the operating shaft resting on a steel support as shown in Fig. 18. Place a 7/16" inside diameter sleeve over the end of the shaft and against the fork. Then press the fork tight against the shaft spacer on the shaft.

   g. Lubricate the governor operating shaft lower bearing with engine oil. Start the bearing, numbered side up, straight in the governor housing and over the end of the operating shaft.

   h. Support the governor housing and operating shaft assembly on the bed of an arbor press with the upper end of the operating shaft resting on a steel support as shown in Fig. 18. Place a 7/16" inside diameter sleeve on the inner race of the bearing and press the bearing on the shaft until it seats on the shoulder in the housing.

   i. Install the governor operating shaft upper bearing retaining flat washer, lock washer and screw in the governor housing (Fig. 1).

   j. Apply a thin coat of good quality sealant around the edge of a new expansion plug.

Place the plug, concave side up, in the opening in the housing next to the lower operating shaft bearing. Tap the center of the plug with a hammer to secure the plug in the housing.

   k. Place the differential lever over the pivot pin in the operating lever, with the pin in the lever up, and secure it in place with with a plain washer and spring retainer.

   l. If previously removed, install the governor gap adjusting screw and lock nut in the tapped hole in the operating shaft lever.

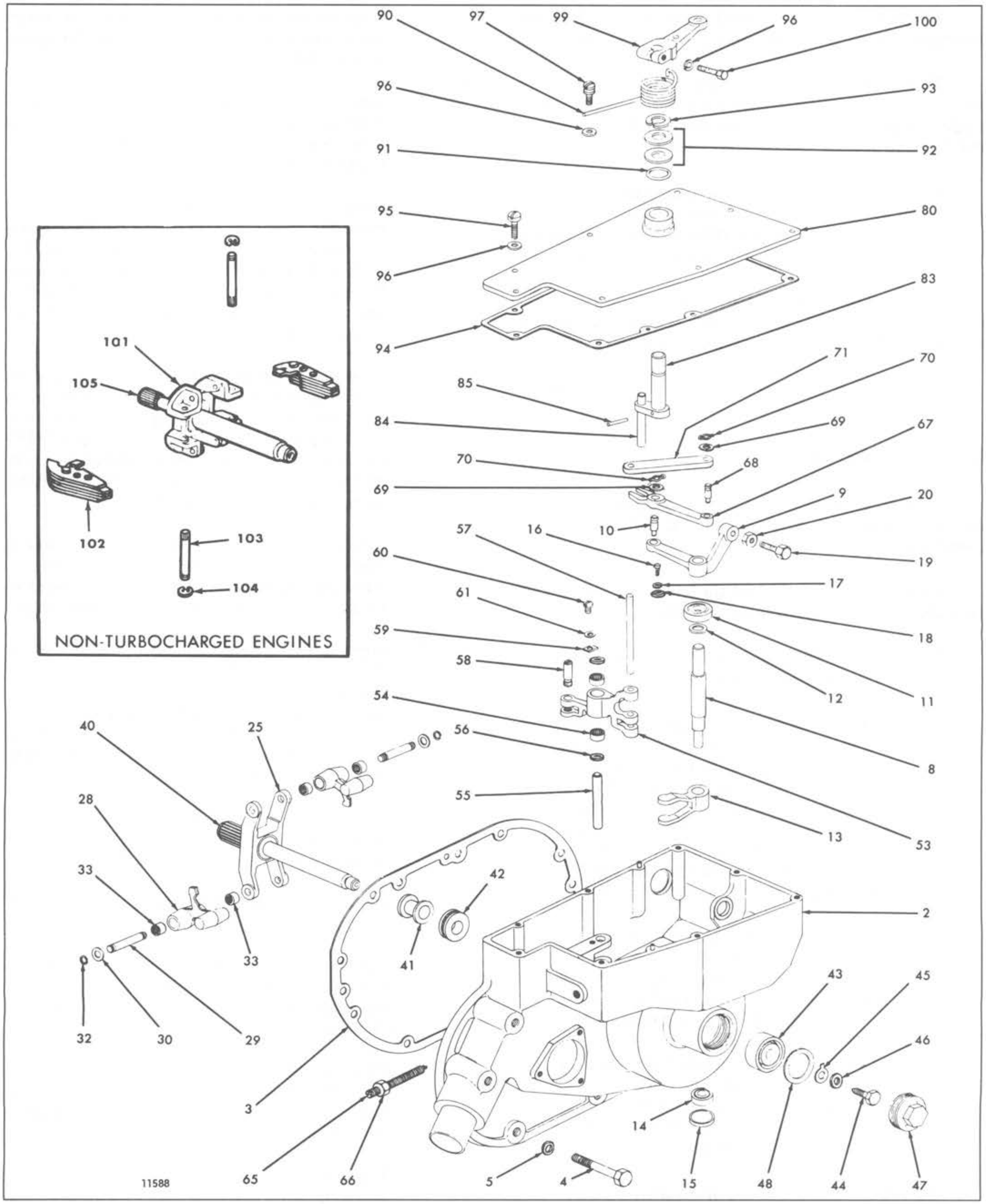


Fig. 17 – Variable Speed Governor Details and Relative Location of Parts

2. Housing—Governor
3. Gasket—Housing to Blower
4. Bolt—Housing to Blower
5. Lock Washer
8. Shaft—Governor Operating
9. Lever—Operating Shaft
10. Pin—Shaft Lever
11. Bearing—Operating Shaft (Upper)
13. Fork—Operating Shaft
14. Bearing—Operating Shaft (Lower)
15. Plug—Expansion
16. Screw—Bearing Retaining
17. Lock Washer
18. Flat Washer
19. Screw—Gap Adjusting
20. Lock Nut
21. Spacer—Operating Shaft
25. Carrier—Governor Weight
28. Weight—Governor
29. Pin—Weight
30. Flat Washer
32. Snap Ring—Weight Pin
33. Bearing—Weight
40. Shaft—Weight Carrier
41. Riser—Governor
42. Bearing—Riser Thrust
43. Bearing—Weight Carrier Shaft End
44. Bolt—Bearing Retainer
45. Lock Washer—Special
46. Flat Washer
47. Plug—Governor Housing
48. Gasket—Housing Plug
53. Lever—Control Link Operating
54. Bearing—Operating Lever
55. Shaft—Operating Lever
56. Washer—Operating Lever Shim
57. Pin—Fuel Rod Connecting (Short)
58. Pin—Fuel Rod Connecting (Long)
59. Clip—Operating Lever Shaft Lock
60. Screw—Lock Clip
61. Lock Washer
65. Screw—Buffer
66. Lock Nut—Buffer Screw
67. Lever—Governor Differential
68. Pin—Differential Lever
69. Washer—Differential Lever and Connecting Link Flat
70. Retainer—Spring
71. Link—Operating Lever Connecting
80. Cover—Governor Housing
83. Shaft—Stop Lever
84. Pin—Fulcrum Lever
85. Pin—Stop Lever Shaft
90. Spring—Stop Lever Shaft Return
91. Ring—Stop Shaft Seal
92. Washer—Seal Ring Retainer
93. Snap Ring—Stop Shaft
94. Gasket—Governor Housing Cover
95. Screw—Housing Cover
96. Lock Washer
97. Screw—Housing Cover Special
99. Lever—Governor Stop
100. Bolt—Stop Lever
101. Carrier—Governor Weight
102. Weight—Governor
103. Pin—Weight
104. Ring—Weight Pin Retainer
105. Shaft—Weight Carrier

Fig. 17 – Variable Speed Governor Details and Relative Location of Parts

m. 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 outer surface of 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 8985 in the bearing and press the bearing into the lever until it is flush with the top surface of the lever. Reverse the lever on the press and install the second bearing in the same manner.

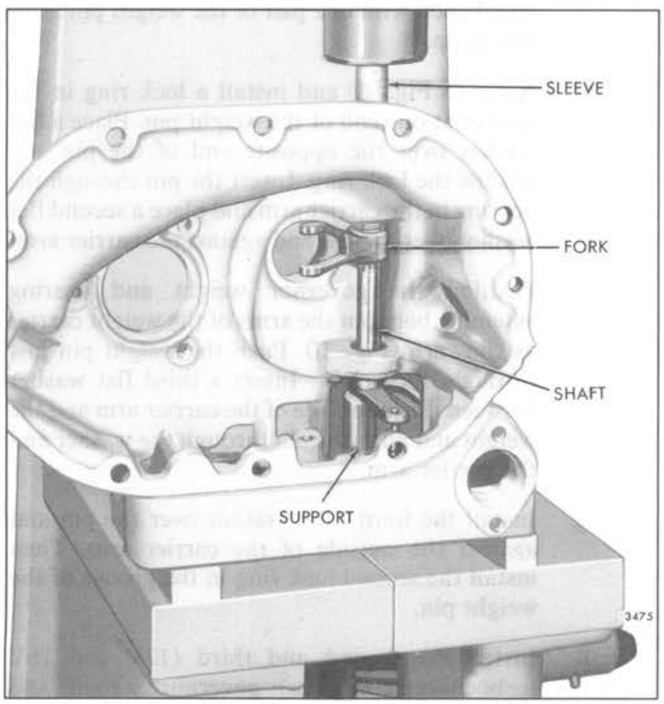


Fig. 18 – Installing Governor Operating Shaft Fork on Shaft

n. Lubricate the control link operating lever needle bearings with Shell Alvania No. 2 grease, or equivalent. Place the 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 control link operating lever shaft with the slot (in the side at one end of the shaft) up.

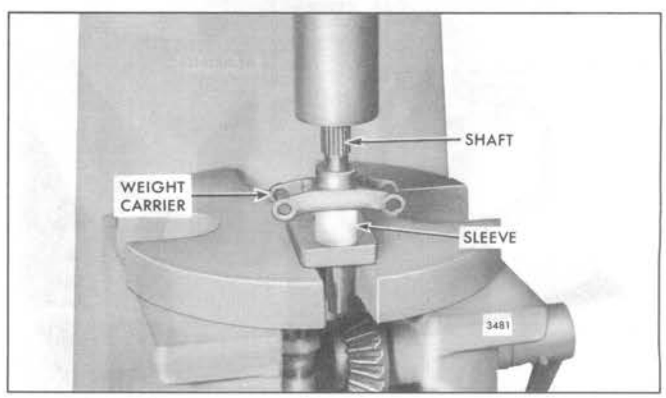


Fig. 19 – Installing Governor Weight Shaft in Weight Carrier

o. Align the slot in the control link 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 the screw securely.

p. 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.

q. If removed, thread the lock nut on the buffer screw and thread the buffer screw (Fig. 1) into the governor housing.

2. Assemble the governor weights and carrier and shaft assembly as follows:

Non–turbocharged engines

a. Refer to Fig. 9 and position the weights on opposite sides of the weight carrier. Note the matchmarks placed on the weight carrier and weights at the time of disassembly.

b. 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.

c. Lubricate the weight shaft with clean engine oil.

Assemble the governor weight and shaft assembly as follows:

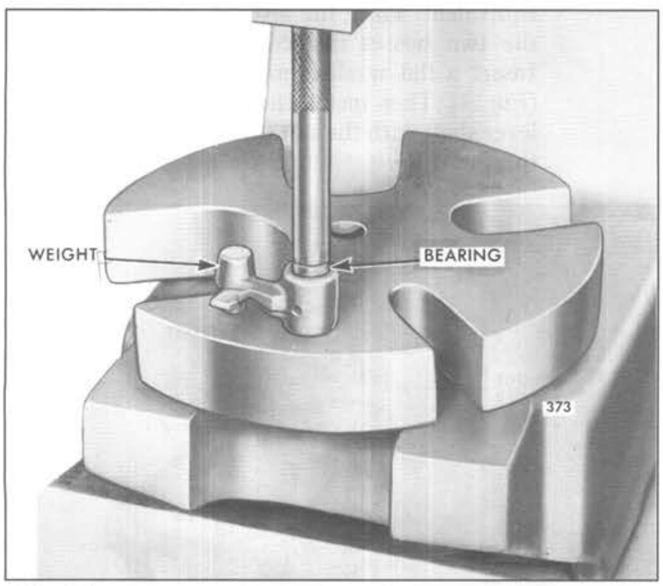


Fig. 20 – Installing Bearings in Governor Weight using Tool J 8985

Turbocharged engine

a. Support the weight carrier (rear face up) on a sleeve and a steel support (with a 1" hole) over an opening in the bed of an arbor press as shown in Fig. 19.

b. Lubricate the weight shaft with engine oil. Then insert the non–splined end of the shaft through the carrier, sleeve and hole in the steel support. Press the shaft straight into the carrier until the shoulder on the shaft is tight against the carrier.

c. If removed, place the governor weight, either end up, on the bed of an arbor press. Lubricate the outer surface of the bearing with engine oil and start the bearing, numbered end up, straight into the bore of the weight.

d. Insert the pilot end of installer J 8985 in the bearing and under the ram of the press as shown in Fig. 20. Then press the bearing straight in the weight until it is flush with the top of the weight. Reverse the weight on the press and install the second bearing in the same manner.

e. Install the bearings in the second weight in the same manner as described in Steps c and d above.

f. Lubricate the needle bearings with Shell Alvania No. 2 grease, or equivalent.

g. Position the weight carrier and shaft assembly on a bench with one pair of the weight pin arms facing up.

h. Refer to Fig. 10 and install a lock ring in the groove at one end of the weight pin. Place a flat washer over the opposite end of the pin and against the lock ring. Insert the pin through the bearing in the carrier arm and place a second flat washer over the pin and against the carrier arm.

i. Position the governor weight and bearing assembly between the arms of the weight carrier as shown in Fig. 10. Push the weight pin just through the weight. Insert a third flat washer between the inner face of the carrier arm and the weight and push the pin through the washer and the carrier arm.

j. Install the fourth flat washer over the pin and against the outside of the carrier arm. Then install the second lock ring in the groove of the weight pin.

k. Install the second and third (12V and 16V turbocharged engines) governor weight and bearing assemblies in the carrier in the same manner as described in Steps h, i and j above.

3. Install the governor weight and shaft assembly in the governor housing as follows:

   a. Slide the governor riser on the weight shaft and against the fingers of the high speed weight.

   b. Place the governor riser thrust bearing over the weight shaft with the bearing race having the smaller 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. Place the weight shaft 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 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 (20–26 N•m) torque. Bend the tang on the lock washer against the head of the bolt.

   g. Place a gasket in the housing and against the bearing. Apply a Loctite sealant grade HV, or equivalent, to the full 360° circumference of the plug and thread the plug into the tapped end of the governor weight housing. Tighten the plug to 45 lb–ft (61 N•m) torque.

NOTICE: Rotate the governor weight assembly. If 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. 6 and 21 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. 6.

   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.

   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. 22. Then press the bearing in the housing until the shoulder on the installer contacts the housing.

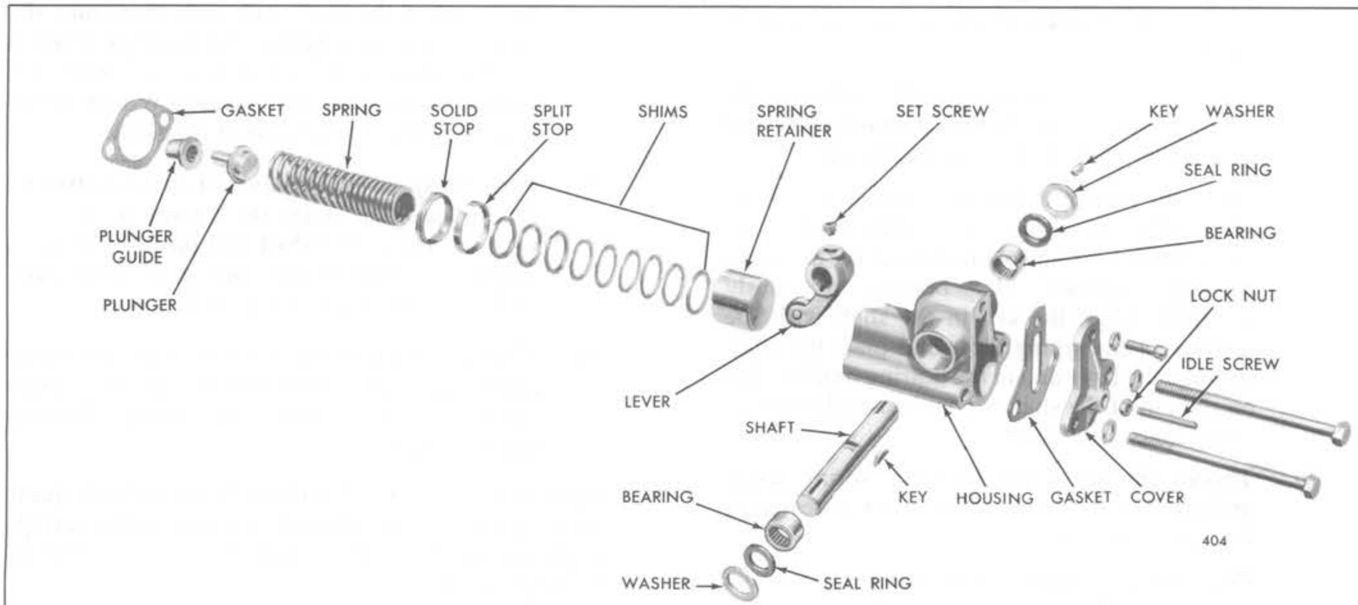


Fig. 21 – Variable Speed Spring Housing Details and Relative Location of Parts

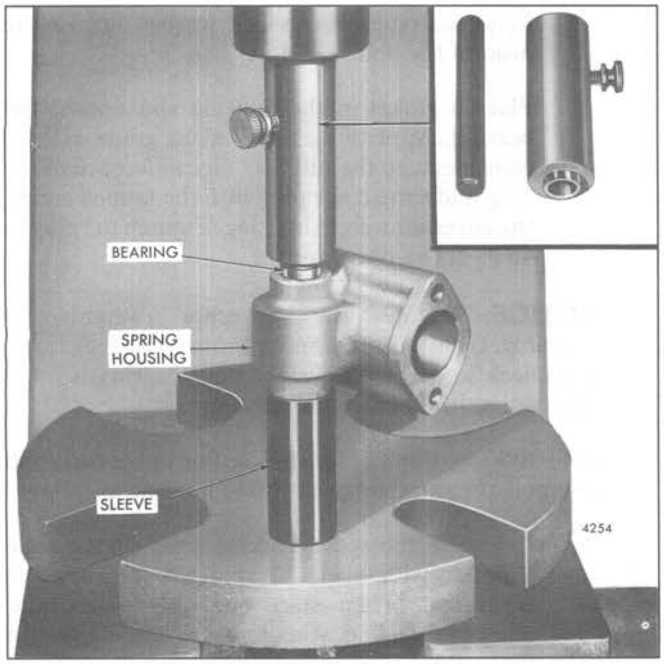


Fig. 22 – Installing Speed Control Shaft Bearings in Spring Housing using Tool J 9196

NOTICE: When the shoulder on the installer body contacts the housing, the bearing will be properly positioned in the housing.

d. Install the 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.

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. 6), single or double lever type, 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 in 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. 22. Then press the bearing in the housing until the shoulder on the installer contacts the housing.

k. 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.

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 N•m) 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 spring housing.

n. 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.

o. 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.

p. 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.

q. If removed, thread the lock nut on the idle speed adjusting screw. Then thread the idle speed adjusting screw into the spring housing approximately 1".

5. Refer to Figs. 1 and 21 and attach the variable speed spring plunger guide, plunger, retainer, shims, spring, stops and spring housing assembly to the governor housing as follows:

a. Clamp the flange of the governor housing in a vise equipped with soft jaws.

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 (Fig. 1).

d. Place the spring retainer solid stop in the counterbore of the governor housing.

e. 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.

f. 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.

NOTICE: Be sure to use shims with an 11/32" 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 3/4" I.D. However, do not use the 11/32" I.D. shims with a spring retainer which has only one air bleed hole.

g. 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. If a two spring assembly is used, insert the inner spring inside the outer spring.

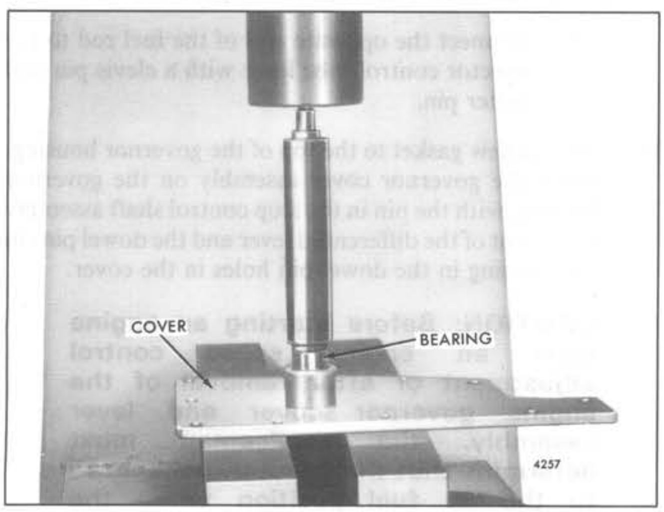


Fig. 23 – Installing Bearings in Governor Cover using Tool J 21068

h. Place the variable speed spring housing into position against the governor housing with the speed control lever facing the bottom of the governor (Fig. 2), and the variable speed spring over the end of the spring plunger (Fig. 1) inside the governor housing.

i. Install the two spring housing retaining bolts and lock washers. Tighten the bolts to 13–17 lb–ft (18–23 N•m) torque.

6. Refer to Figs. 4 and 17 for the location of the various parts and assemble the governor cover as follows:

a. If the stop lever bushing (Fig. 4) was removed from the cover, place the cover, inner face down, on two steel supports on the bed of an arbor press as shown in Fig. 23. 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 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. Place the stop shaft lever return spring over the stop shaft with the hooked end of the spring facing up. Install the stop lever on the shaft and secure it in place with the retaining bolt and lock washer.

Install Governor On Engine (6V and 8V Engines)

1. Affix a new gasket to the bolting flange of the fuel pump. Place the fuel pump against the governor housing in its original position and secure it in place with the three bolt and seal assemblies. Tighten the bolts to 13–17 lb–ft (18–23 N•m) torque.

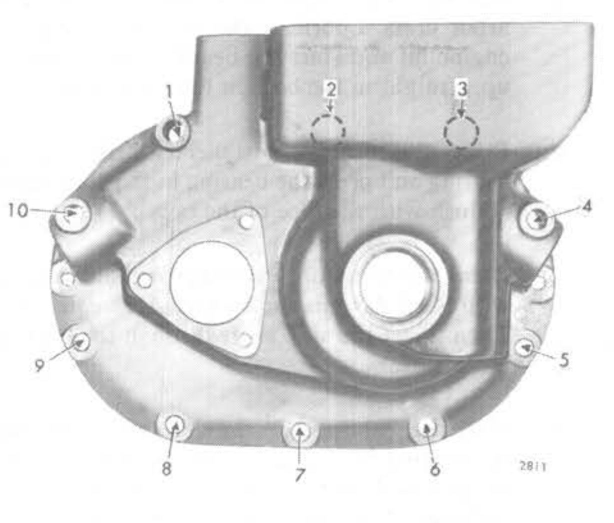
2. If removed, place a fuel rod cover tube hose and clamp on each fuel rod cover tube at each side of the governor housing.

3. Affix a new gasket to the forward face of the blower end plate.

4. Place the fuel pump drive fork on the fuel pump shaft. Position the governor and fuel pump assembly in front of the blower. Rotate the fuel pump fork until the prongs of the fork align with the slots in the drive disc. Rotate the weight shaft and align the splines on the shaft with the splines in the blower rotor.

5. Push the governor straight back over the dowels in the blower end plate and against the gasket.

6. Refer to Fig. 24 for the location and install the bolts, lock washers, copper washers and plain washer which secure the governor to the blower. Tighten the bolts to 13–17 lb–ft (18–23 N•m) torque.



Bolt Size	Washer:	Position:
5/16"–18 x 5 1/4"	Copper	4
5/16"–18 x 4"	Copper	10
5/16"–18 x 3 3/4"	Lock and Plain	1
5/16"–18 x 2 1/4"	Lock	2–3–5–6–7–8–9

Fig. 24 – Location and Size of Governor Retaining Bolts

7. Slide each fuel rod cover tube hose down on the cover tubes attached to the cylinder heads and tighten the hose clamps.

8. Install and connect the crossover fuel oil line to each cylinder head and connect the fuel oil lines to the fuel pump.

9. Place the water bypass tube between the two thermostat housings and slide the hoses part way on the thermostat housings. Position the bypass tube so it clears the governor, fuel pump and fuel oil lines. Then tighten the hose clamps.

10. Install the fuel rods between the cylinder heads and the governor as follows:

    a. Insert the lower end of the left–bank fuel rod down through the top of the governor housing and through the fuel rod cover tubes to the injector control tube lever.

    b. Raise the connecting pin up in the connecting link lever (Fig. 1). Insert the end of the fuel rod between the two bosses on the lever and insert the connecting pin through the fuel rod and into the lower boss.

    c. Connect the opposite end of the fuel rod to the injector control tube lever with a clevis pin and cotter pin.

    d. Insert the lower end of the right–bank fuel rod down through the top of the governor housing and through the fuel rod cover tubes to the injector control tube lever.

    e. Remove the short screw pin from the control link operating lever. Insert the end of the fuel rod between the two bosses on the lever and install the screw pin. Tighten the pin securely.

    f. Connect the opposite end of the fuel rod to the injector control tube lever with a clevis pin and cotter pin.

11. Affix a new gasket to the top of the governor housing. Place the governor cover assembly on the governor housing with the pin in the stop control shaft assembly in the slot of the differential lever and the dowel pins in the housing in the dowel pin holes in the cover.

CAUTION: 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 position when the governor stop lever is placed in the stop position. Engine overspeed will result if

the injector racks cannot be positioned at no fuel with the governor stop lever. An overspeeding engine can result in engine damage which could cause personal injury.

12. Refer to Fig. 2 for the location of the stop lever return spring special screw. Then install the eight governor cover attaching screws and lock washers. Tighten the screws securely.

    NOTICE: The short cover attaching screw with the drilled head goes in the corner hole next to the variable speed spring housing.

13. With the hooked end of the stop lever return spring in position on the lever, place the extending end of the spring behind the special cover attaching screw as shown in Fig. 2.

14. Attach the booster spring to the speed control lever and tighten the outer booster spring adjusting nut on the eyebolt (Fig. 2).

15. Install all of the accessories that were removed from the cylinder head, governor or the front end of the engine.

16. Connect the control linkage to the speed control and stop levers.

17. Close the drain cocks and fill the cooling system.

18. Perform the governor and injector rack control adjustment as outlined in Section 14.4.

Install Governor On Engine (12V and 16V Engines)

1. Affix a new governor housing gasket to the forward face of the blower end plate. Position the governor in front of the end plate. Align the splines of the weight shaft with the splines in the blower rotor. Then push the weight shaft in the rotor and slide the governor housing over the dowel pins in the end plate and against the gasket.

2. Refer to Fig. 24 for bolt location and install the bolts, lock washers, plain washer and copper washers which secure the governor to the blower. Tighten the bolts to 13–17 lb–ft (18–23 N•m) torque.

3. Affix a new blower housing gasket to the cylinder block with a good grade of gasket cement to prevent the gasket from shifting when the blower is lowered into position.

4. Thread eyebolts in diagonally opposite tapped holes in the top of the blower housing. Then attach a rope sling and chain hoist to the eyebolts.

5. Lift the blower and governor assembly, at a slight angle, and position it on top of the cylinder block, with the flange of the rear end plate cover inside the blower drive shaft cover hose.

6. Thread a 7/16"–14 x 8–1/4" bolt and special washer finger tight in the center hole of each blower end plate. Then install the 3/8"–16 x 5–1/2" bolts and retaining washers finger tight at each side of the blower housing.

   NOTICE: The lip at the beveled end of the bolt retaining washer goes in the small recess in the housing just above the bolt slot.

7. Tighten the bolts as follows:

   a. First, tighten the blower–to–block end plate bolts to 40–60 lb–ft (54–81 N•m) torque.

   b. Then tighten the blower housing–to–block side angle bolts uniformly to 30–35 lb–ft (41–47 N•m) torque in 5 lb–ft (7 N•m) increments.

   c. Recheck the blower–to–block end plate bolts.

8. Slide the blower drive support–to–blower hose (seal) and clamps into position and tighten the clamps.

9. Insert the blower drive shaft through the blower drive coupling and into the blower drive hub and install the retaining snap ring in the groove in the flexible coupling.

10. Affix a new gasket to the flywheel housing hole cover, then attach the cover to the flywheel housing with six bolts and lock washers.

On an engine equipped with a rear mounted battery–charging alternator, affix a new gasket to the alternator drive assembly. Place the alternator drive coupling on the drive hub, then place the drive assembly into position and align the slots in the drive coupling with the drive hub on the blower drive gear. Place the drive assembly against the flywheel housing and install the bolts, lock washers and alternator adjusting strap. Install the alternator drive pulley and drive belt.

On an engine equipped with a hydraulic oil pump, refer to *the "install oil pump" section in the manufacturer's service manual for the Marine Gear, Reduction Gear or Transmission used on the engine.*

11. Connect the blower drive support oil tube to the fitting in the blower drive support. Then tighten the two seal ring retaining plate bolts to 13–17 lb–ft (18–23 N•m) torque.

12. Affix a new gasket to the fuel pump flange, then install the fuel pump drive fork and fuel pump on the governor housing. Connect the fuel pump inlet and outlet tubes or hoses to the fuel pump.

13. Slide the governor housing–to–auxiliary control link housing hose and clamp into position between the two housings and tighten the hose clamp.

14. Slide the fuel rod cover hose down on the cover tube attached to the cylinder head at each side of the governor housing and tighten the hose clamps.

15. Place the control link operating lever connecting link in position in the governor and auxiliary housings and connect it to the ball joint studs in the control link operating levers.

16. Install the fuel rods between the cylinder heads and the governor as follows:

    a. Insert the lower end of the left–bank fuel rod down through the top of the governor housing and through the fuel rod cover tubes to the injector control tube lever.

    b. Raise the connecting pin up in the connecting link lever (Fig. 1). Insert the end of the fuel rod between the two bosses on the lever and insert the connecting pin through the fuel rod and into the lower boss.

    c. Connect the opposite end of the fuel rod to the injector control tube lever with a clevis pin and cotter pin.

    d. Insert the lower end of the right–bank fuel rod down through the top of the governor housing and through the fuel rod cover tubes to the injector control tube lever.

    e. Remove the short screw pin from the control link operating lever. Insert the end of the fuel rod between the two bosses on the lever and install the screw pin. Tighten the pin securely.

    f. Connect the opposite end of the fuel rod to the injector control tube lever with a clevis pin and cotter pin.

17. Place a new auxiliary control link housing cover gasket on the housing, then install the cover and secure it in place with screws and lock washers.

18. Place a new governor housing cover gasket on the housing, then install the cover and secure it in place with screws and lock washers.

19. If removed, attach the booster spring bracket to the cylinder head. Then attach the booster spring to the speed control lever (Fig. 3) and tighten the outer booster spring adjusting nut on the eyebolt.

CAUTION: 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 position when the governor stop lever is placed in the stop position. Engine overspeed will result if the injector racks cannot be positioned at no fuel with the governor stop lever. An overspeeding engine can result in engine damage which could cause personal injury.

20. Install the cylinder head rocker covers.

21. On a non–turbocharged engine, remove the cover from the top of the blower. Place the blower screen, wire side down, on top of the blower and install the air shutdown adaptor. Then attach the air shutdown housings and gaskets to the adaptors.

    On a turbocharged engine, remove the cover from the top of the blower. Place the blower screen, wire side down, and install the air shutdown adaptor and air shutdown housing as an assembly on the blower. Then attach the shutdown rod to the lever on the shutdown housing.

22. On a non–turbocharged engine, connect the air inlet tubes to the air shutdown housings.

    On a turbocharged engine, attach the air inlet tube to the rear air shutdown housing and the turbocharger.

    On a marine engine, install the air silencers on the air shutdown housings.

23. Connect the linkage to the governor speed control and stop levers.

24. Perform an engine tune–up as outlined in Section 14.4.1.

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 between 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 N•m) 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.

NOTICE: 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 governor (Fig. 1) is a hydraulic type with a speed droop stabilization mechanism. Hydraulic action is transmitted by oil admitted under pressure from the engine lubricating system to an auxiliary oil pump in the governor. The auxiliary pump then develops the oil pressure necessary to actuate the governor mechanism.

To stabilize the governor, a speed droop adjustment is incorporated in the governor mechanism. The speed droop is regulated by a droop adjusting bracket attached to the top of the terminal lever. To decrease the governor droop move the droop adjusting bracket IN and move it in the opposite direction to increase the governor droop.

The governor operates in such a manner that the amount of fuel supplied to the injectors is increased by the hydraulically operated power piston and decreased by action of the fuel rod spring.

The governor is located at the front of the 6 and 8V engines (Fig. 5) and at the center of the 12V and 16V engines (Fig. 6). It is mounted on the governor drive housing which also serves as the blower front cover (rear blower on the 12V and 16V engine).

The governor is driven by one of the blower rotors through a horizontal drive shaft and bevel gear and a vertical driven sleeve and bevel gear, both mounted on ball bearings and retained in the governor drive housing.

The injector control tubes are actuated by the governor through a linkage consisting of the fuel rods, vertical link, and levers, connected as shown in Fig. 2 in Section 2.8.3.

Two pairs of fuel rods are used on the 12V and 16V engines. Each pair of rods is connected to a shaft and lever assembly. The two shaft and lever assemblies, mounted on self-aligning bearings, are connected to a common lever to which the vertical link is attached.

When starting a cold engine, time is required to develop sufficient oil pressure to operate the governor and thus move the injector control racks to the full-fuel position so the engine can start. Since this delay is undesirable, the starting time can be shortened by moving the governor operating lever to the full-fuel position, to take control of the injector racks away from the governor. On certain installations, an oil reservoir is provided to supply the governor with sufficient oil to overcome the delay in governor operation upon starting the engine.

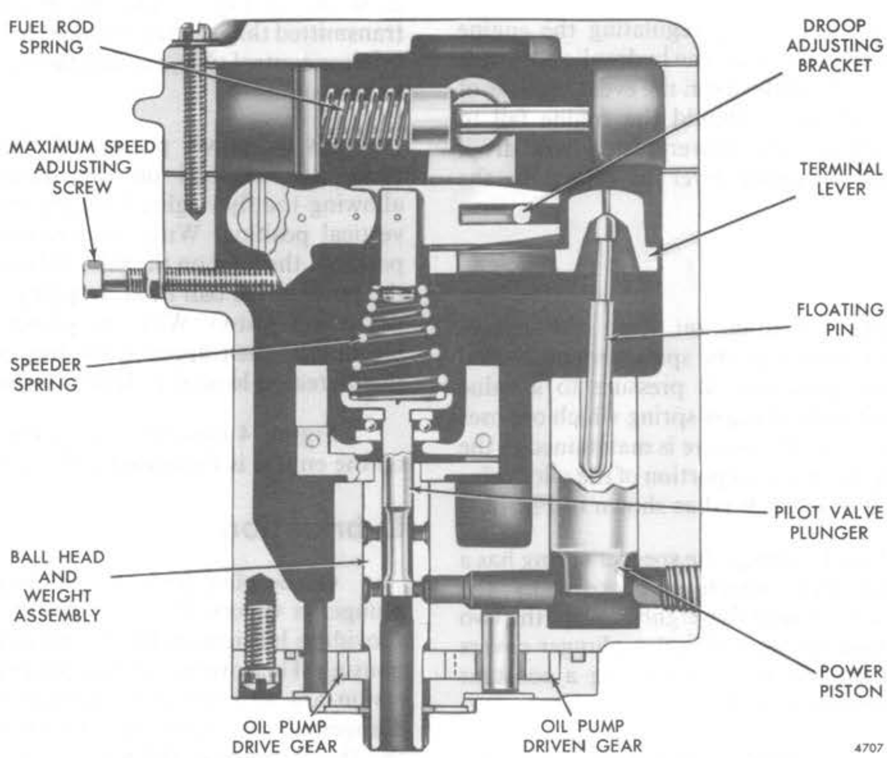


Fig. 1 – Hydraulic Governor Assembly

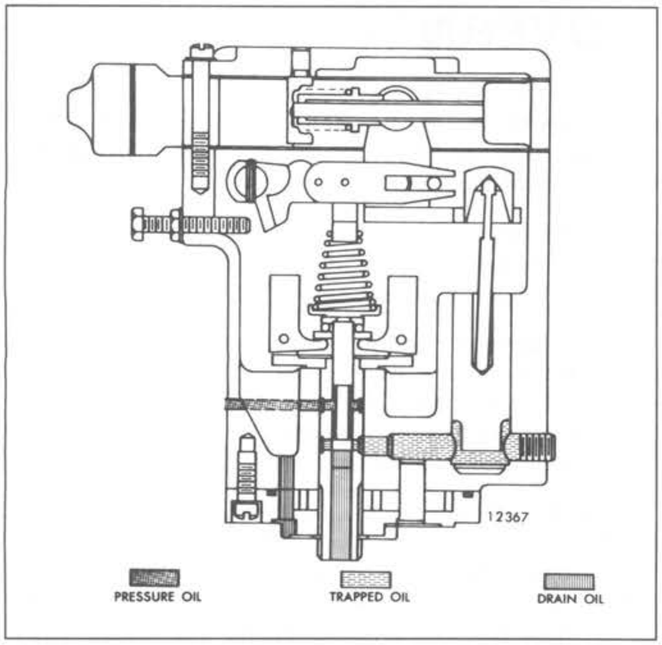


Fig. 2 – Position of Governor Mechanism when Load is Constant

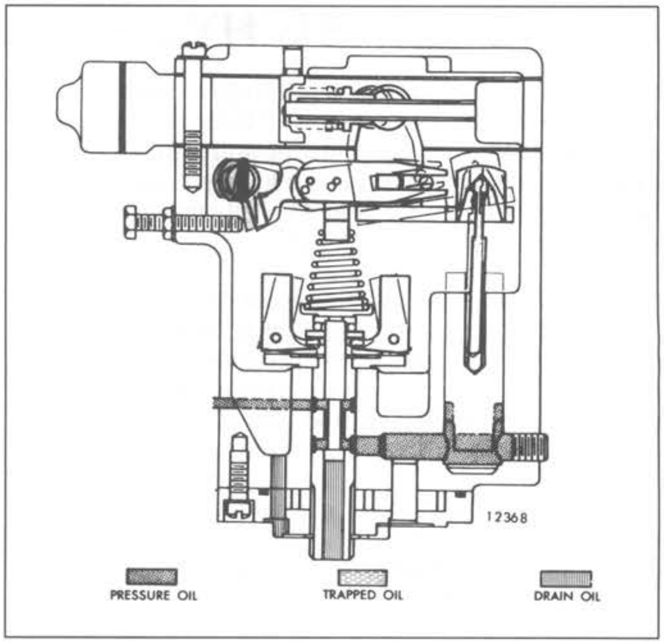


Fig. 3 – Position of Governor Mechanism as Load Increases and Engine Speed Tends to Decrease

The engine can be stopped, regardless of the governor, by moving the governor operating lever to the no–fuel position.

In addition to its function of regulating the engine speed under varying load conditions, the hydraulic governor acts as an automatic shutdown device in the event of a loss of engine lubricating oil pressure. Should the engine fail to supply oil to the governor, the power piston will drop, allowing the governor operating lever to return to the no–fuel position.

Operation

With the engine operating, oil from the engine lubrication system is admitted to the space around the oil pump gears. The gears raise the oil pressure to a value determined by the relief valve plunger spring which opposes the relief valve plunger. The oil pressure is maintained in the annular space between the undercut portion of the pilot valve plunger and the bore in the ball head as shown in Fig. 2.

For any given throttle setting, the speeder spring has a definite compressional force which is opposed by the centrifugal force of the revolving flyweights. When the two forces are equal, the land on the pilot valve plunger covers the lower opening in the ball head, producing a constant speed condition as shown in Fig. 2.

When the load on an engine is increased, the engine speed will drop momentarily and the governor weights will be forced inward by the speeder spring permitting the pilot valve plunger to uncover the lower port in the ball head. With this port uncovered, oil, under pressure of the governor pump, will be admitted to the cavity at lower end of the power piston and force the piston and floating lever upward as shown in Fig. 3. The upward motion of the piston is transmitted through the terminal lever and the fuel rod to the injector control tube, causing the fuel setting of the engine to be increased.

As the power piston and the floating lever rise, the compressional load on the speeder spring is reduced, allowing the flyweights to again 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 ball head, 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 4 illustrates the governor reaction as the load on the engine is decreased and the engine speed increases.

Lubrication

Oil seeping past the power piston and pilot valve plunger is vaporized by the revolving governor flyweights, providing lubrication for the moving parts in the governor housing. The governor pump, pilot valve plunger, and power piston are all exposed to pressurized oil. The pilot valve plunger has two oil holes to provide additional lubrication to the thrust bearing. Oil which collects on the floor of the governor housing passes through a passage into the governor drive housing, providing lubrication for the governor drive and driven shaft beveled gears and their bearings.

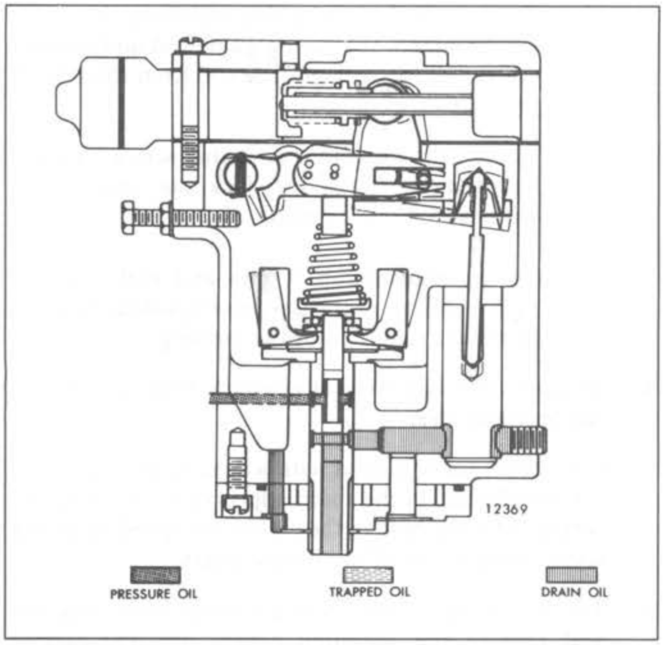


Fig. 4 – Position of Governor Mechanism as Load Decreases and Engine Speed Tends to Increase

Remove Governor

Refer to Figs. 5 and 6 and remove the governor as follows:

1. Remove the nut, lock washer and bolt securing the speed control lever to the speed adjusting shaft. Then, pull the lever with link assembly attached from the shaft.

2. Mark the position of the governor operating lever on the terminal lever shaft. Loosen the bolt securing the lever to the shaft then pull the lever with link assembly attached from the shaft.

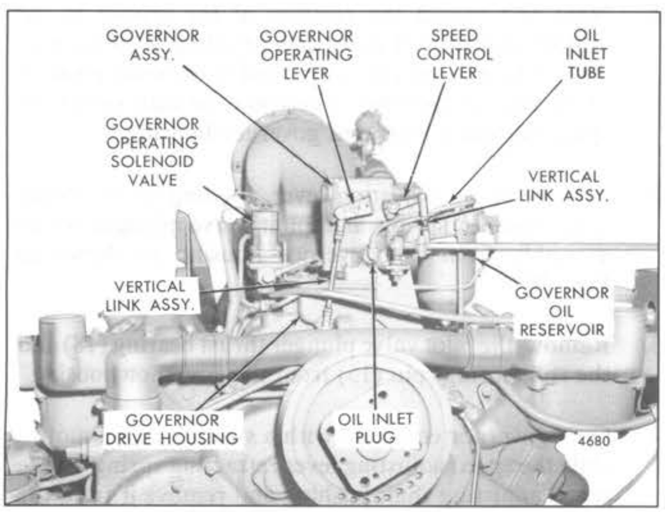


Fig. 5 – Typical Hydraulic Governor Mounting

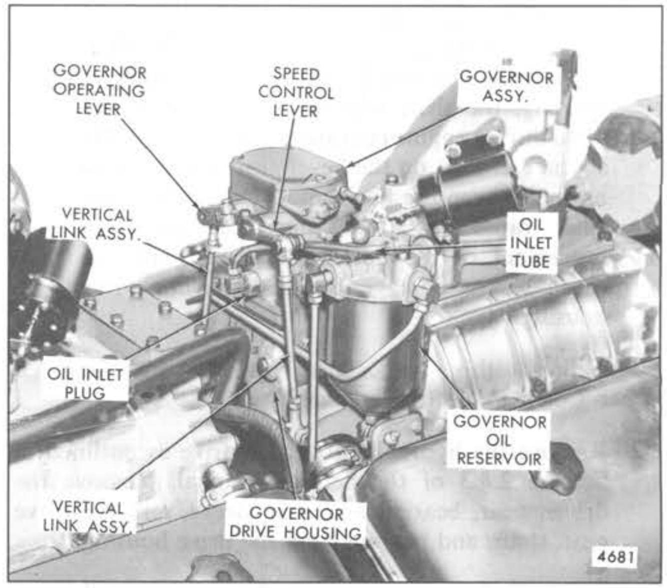


Fig. 6 – Hydraulic Governor Mounted on 16V Engine

The surplus oil returns to the engine crankcase through connecting drilled passages in the blower end plate and cylinder block.

3. If the governor is equipped with a governor operating solenoid valve assembly, disconnect and remove the oil tube from the valve assembly and governor housing.

4. Disconnect and remove the oil inlet tube assembly from the governor oil inlet elbow, and the governor oil reservoir if used.

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 or housing cover. Then lift the governor away from the drive housing or cover and remove the gasket.

- *Before a Barber–Coleman electronic governor is installed on an engine previously equipped with a hydraulic governor, the vertical driven gear, bearing, and gear sleeve and the horizontal drive gear, shaft, and bearing must be removed form the governor drive housing.*

These components serve no useful purpose when the hydraulic governor is replaced by the electronic governor and *will cause severe engine damage if not removed.* Because the horizontal drive shaft is splined to the blower rotor shaft, both governor shafts will continue to rotate when the engine is operated. However, with the hydraulic governor removed, the horizontal and vertical shafts and bearings will no longer receive adequate support or lubrication and will quickly wear out.

NOTICE: Do not remove only the vertical shaft and bearing. If the horizontal drive shaft and bearing assembly is left in the governor drive housing, the shaft will move freely back and forth during engine operation. This is due to the absence of load on the bevel gear which would normally keep the horizontal shaft in position. The rapid rotation and back-and-forth movement of the horizontal drive shaft can cause severe damage to the governor drive housing.

Follow this procedure before installing a Barber–Coleman electronic governor:

1. Remove the hydraulic governor drive as outlined in Section 2.8.3 of the Service Manual. Remove the driven gear, bearing and gear sleeve, and the drive gear, shaft, and bearing from the drive housing.
2. Reinstall the governor drive housing and all parts previously removed, except the drive and driven gears and related components, following procedures in Section 2.8.3 of the Service Manual.
3. Install the Barber–Coleman electronic governor per the manufacturer's instructions, and perform the engine tune-up as outlined in Section 14 of the Service Manual.

Disassemble Governor

Before removing any parts from the governor, wash it thoroughly in clean fuel oil and dry it with compressed air.

Governor disassembly need be carried out only as far as necessary to correct the difficulties which interfere with proper governor operation.

Refer to Figs. 1 and 12 for the location of the various parts and disassemble as follows:

1. Clamp the governor housing and base assembly in a bench vise equipped with soft jaws (Fig. 9).
2. If necessary, remove the oil inlet elbow or fitting from the oil inlet plug.
3. Remove the three cover screws, then remove the cover and gasket from the housing.
4. To facilitate the removal of the governor subcap, disassemble the subcap before removal from the governor housing. Refer to Figs. 7 and 8 and proceed as follows:
   a. Remove the two screws and lock washers securing the spring pad cover to the subcap, then remove the cover from the spring guide rod. Remove the cover gasket.
   b. Remove the fuel rod spring and the spring guide rod seat from the spring guide rod and subcap. Then pull the spring guide rod from the subcap with a pair of pliers.
   c. Loosen the load limit adjusting screw lock nut and remove the screw, lock nut and copper washer from the subcap.
5. Remove the two subcap screws and lock washers securing the subcap to the governor housing. Remove the subcap and gasket from the housing.
6. Remove the terminal lever cross pin from the arms of the terminal lever.
7. 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.
8. Loosen the maximum speed adjusting screw lock nut and remove the adjusting screw, nut and copper washer from the governor housing.

   NOTICE: If the maximum speed adjusting screw is not removed, the speed adjusting lever roll (spring) pin will hit the screw when it is being removed from the speed adjusting lever and shaft.

9. Remove the speed droop adjusting bracket screw lock washer and plain washer from the terminal lever, then remove the droop adjusting bracket from the floating lever and the terminal lever.
10. 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. 9.
11. 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 governor housing.
12. 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. 10.
13. Remove the pilot valve plunger thrust bearing (18) and the roll (spring) pin (15) from the governor housing.
14. On a governor equipped with a synchronizing motor, slide the speed adjusting lever retracting spring off the speed adjusting shaft bushing and remove it from the housing.

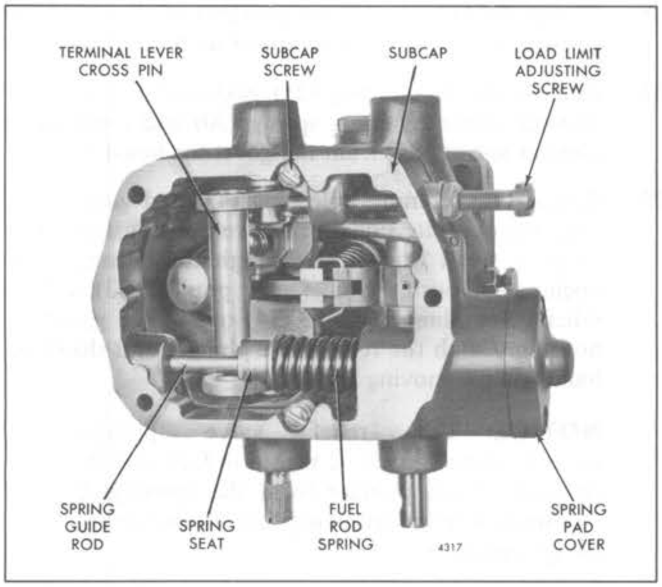


Fig. 7 – Top View of Governor with Cover Removed

15. If necessary, the speed adjusting lever (16), floating lever (55), spring fork (53), speeder spring (52) and pilot valve plunger and spring seat assembly, may be disassembled as follows:

   a. Straighten the bent end of the wire pin (54) securing the speed adjusting lever and spring fork to the speed adjusting floating lever.

   b. Pull the pin out of the speed adjusting lever, 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.

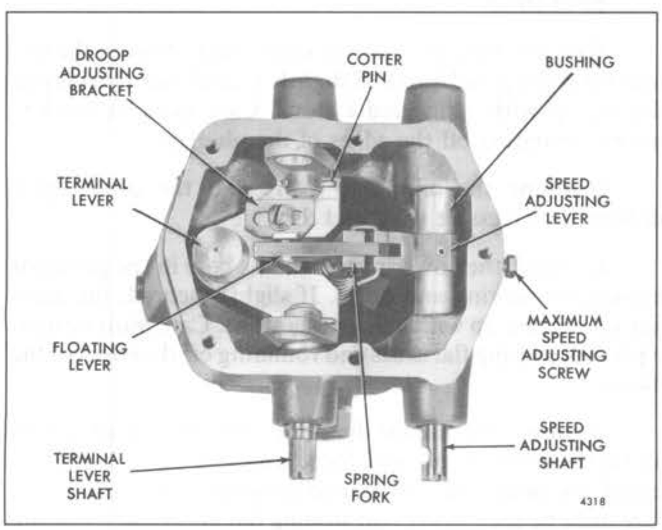


Fig. 8 – Top View of Governor with Subcap Removed

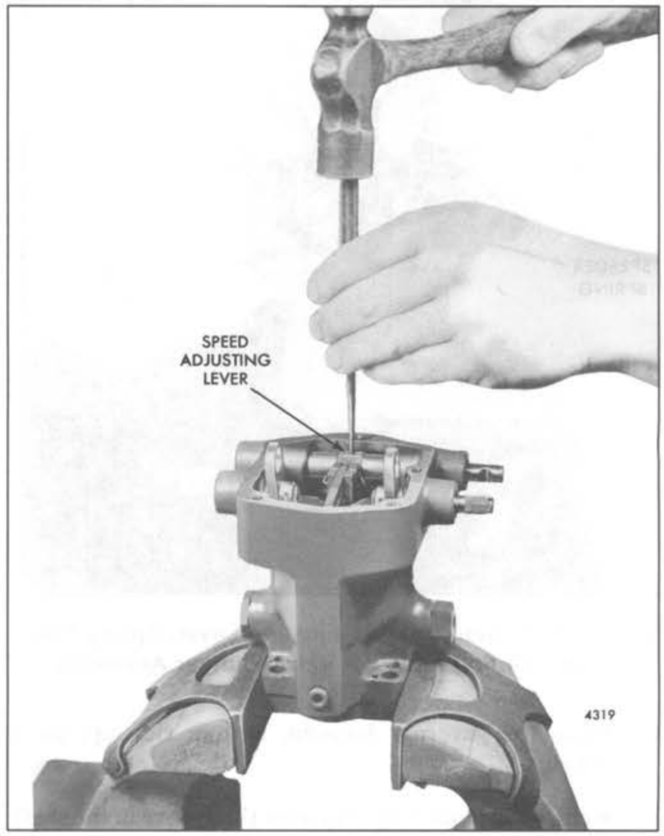


Fig. 9 – Removing Speed Adjusting Lever Roll Pin

   d. Work a small screw driver under the speeder spring and remove the spring from the pilot valve plunger and spring seat assembly.

16. Remove the two cotter pins securing the terminal lever to the terminal lever shafts. Then pull the long terminal lever shaft from the terminal lever and the governor housing.

17. Place a 1/4" brass rod approximately 5" long through the terminal lever shaft opening in the governor housing and terminal lever and against the inner end of the second terminal lever shaft. Then drive the governor housing cup plug out of the housing boss as shown in Fig. 11.

18. Push the terminal lever shaft out of the terminal lever and housing with the brass rod. Remove the brass rod and lift the terminal lever out of the housing.

19. Remove the terminal lever–to–power piston pin (47) 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.

NOTICE: 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.

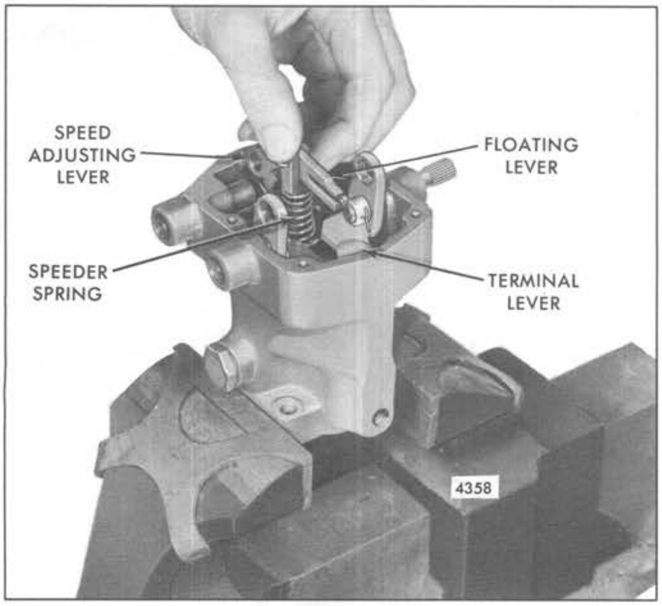


Fig. 10 – Removing Speed Adjusting Lever, Spring Fork, Speeder Spring and Pilot Valve Plunger Assembly

21. Place the governor housing, bottom side up, on a bench.

22. Remove the lock ring (41) from the groove in the shaft of the ball head (22) with a pair of snap ring pliers, then remove the ball head and flyweight assembly from the housing.

23. Remove the three screws (42) securing the governor base (40) 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 (38) and (63) from the governor base or housing.

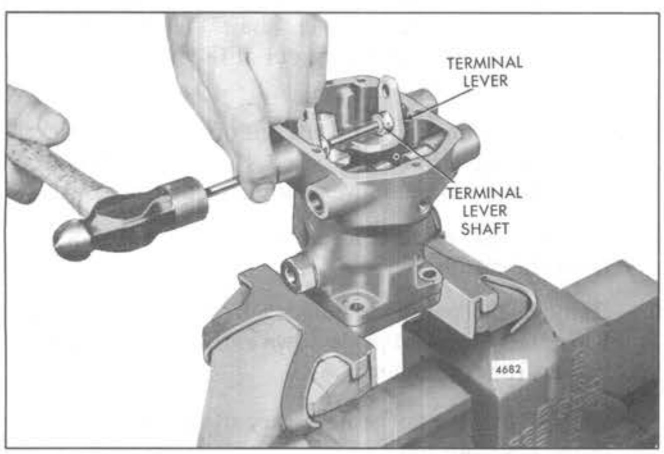


Fig. 11 – Removing Cup Plug from Governor Housing

26. Clamp the bottom (square portion) of the governor housing in a bench vise equipped with soft jaws.

27. Remove the oil inlet plug (28), gasket (29), relief valve plunger sleeve retaining spring (30) and relief valve plunger spring (34) from the governor housing.

28. Remove the dummy hole plug (43) and gasket (44) 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 (33) and the relief valve plunger sleeve (34) out of the governor housing. Catch the relief valve plunger and sleeve by hand when removing them.

NOTICE: 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 pipe plug in the forward face of the governor housing.

30. 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 boss with a hammer.

31. Inspect the speed adjusting lever shaft and terminal lever shaft oil seals and, if necessary, remove them from the governor housing.

Inspection

Wash all of the governor parts in clean fuel oil, dry them with compressed air and inspect.

CAUTION:To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.

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 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 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 stoning flat areas and rounding off the edges of the ball head.

NOTICE: The pilot valve plunger power piston and ball head assembly must operate freely in their respective bores.

Examine the pilot valve plunger 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 supports for satisfactory governor operation.

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.

Inspect the speed adjusting lever shaft and terminal lever shaft oil seals in the governor housing for excessive wear.

Inspect the speed adjusting lever shaft and terminal lever shaft bushing in the governor housing for excessive wear.

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 current plunger incorporates four relief holes and is slightly larger than the former plunger. The current sleeve assembly has the washer affixed to the sleeve. When it is necessary to replace either the former plunger or the sleeve and washer a plunger kit must be used which includes the current plunger and a sleeve assembly. Also, examine the plunger and sleeve springs for fractured coils.

Examine the fuel rod spring for fractured coils.

Examine the face of the spring guide rod seat where it contacts the terminal lever cross pin for scoring and wear.

Replace all of the governor parts that are excessively worn or damaged.

Assemble Governor

Refer to Figs. 1 and 12 and assemble the governor as follows:

1. If removed, install new speed adjusting lever and terminal lever shaft bushings in the governor housing to the specified dimensions shown in Fig. 13.
2. If removed, install the pipe plug (83) in the governor housing.
3. Lubricate the two oil pump gears (38) and (63) with engine oil and place them in their respective positions in the governor base (40).
4. Place a new seal ring (39) in the groove in the governor base, with the wide side of the seal down in the groove.
5. Set the governor housing (45) 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.
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 (42) 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 rotates freely.

If a bind exists, loosen the three 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.

8. Install the ball head lock ring (41) in the groove in the ball head shaft with a pair of snap ring pliers.
9. Refer to Fig. 14 and install the relief valve plunger, plunger sleeve, plunger spring, sleeve retaining spring, oil inlet plug and dummy hole 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 the plunger sleeve.
   b. Insert the relief valve plunger and sleeve assembly straight into the opening in the right–hand side of the governor housing, when viewed from the power piston side, 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 and base assembly between the soft jaws of a bench vise. Then tighten the oil inlet plug and the dummy hole plug securely.

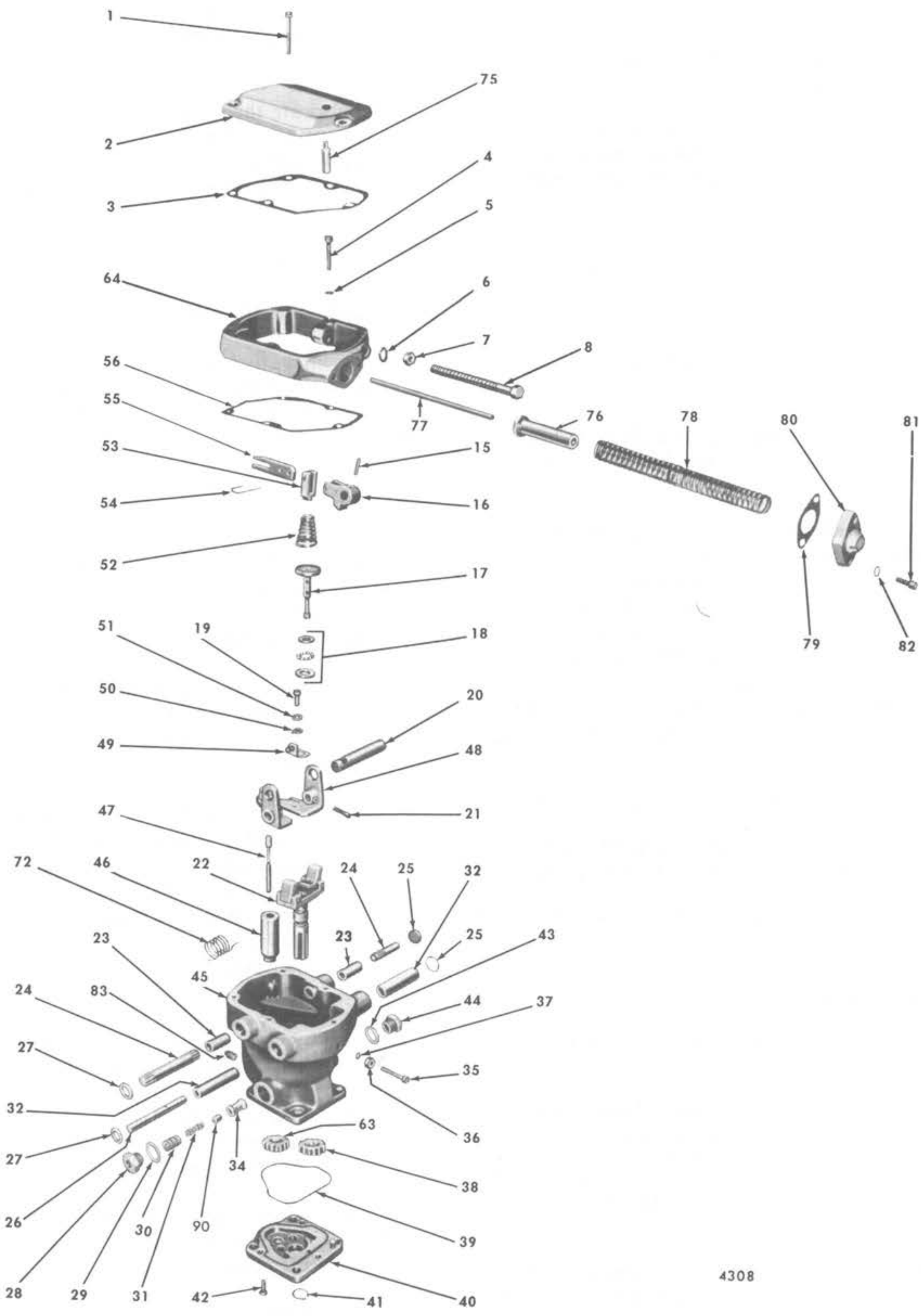


Fig. 12 – Hydraulic Governor Details and Relative Location of Parts

1. Screw—Governor Cover
2. Cover—Governor
3. Gasket—Governor Cover
4. Screw—Subcap-to-Housing
5. Lock Washer
6. Washer—Copper
7. Lock Nut
8. Screw—Load Limit Adjusting
15. Pin—Roll
16. Lever—Speed Adjusting
17. Plunger—Pilot Valve
18. Bearing—Pilot Valve Plunger Thrust
19. Screw—Droop Adjusting Bracket
20. Pin—Terminal Lever Cross
21. Cotter Pin
22. Ball-Head Assembly
23. Bushing—Terminal Lever
24. Shaft—Terminal Lever
25. Plug—Cap
26. Shaft—Speed Adjusting Lever
27. Oil Seal
28. Plug—Governor Oil Inlet
29. Gasket—Relief Valve
30. Spring—Sleeve Retaining
31. Spring—Relief Valve
32. Bushing—Speed Adjusting Lever Shaft
33. Valve—Relief
34. Sleeve—Relief Valve
35. Screw—Maximum Speed Adjusting
36. Lock Nut
37. Washer—Copper
38. Gear—Oil Pump Drive
39. Ring—Housing-to-Base Seal
40. Base—Governor
41. Lock Ring
42. Screw—Governor Base
43. Gasket—Spacer Cap
44. Plug—Dummy Hole
45. Housing—Governor
46. Piston—Power
47. Pin—Floating
48. Lever—Terminal
49. Bracket—Speed Droop Adjusting
50. Plain Washer
51. Lock Washer
52. Spring—Speeder
53. Fork—Adjusting Linkage Spring
54. Pin—Spring Fork
55. Lever—Speed Adjusting Floating
56. Gasket—Subcap-to-Housing
63. Gear—Oil Pump Driven
64. Subcap—Governor
72. Spring—Torsion (Syn. Motor Only)
75. Screw—Low Speed Stop
76. Seat—Guide Rod Spring
77. Rod—Spring Guide
78. Spring—Terminal Lever Return
79. Gasket
80. Cover—Spring Pad
81. Screw—Spring Pad
82. Washer—Internal Lock
83. Plug—Housing

Fig. 12 – Hydraulic Governor Details and Relative Location of Parts

10. Lubricate the power piston (46) 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.

11. Install the terminal lever (48), terminal lever shafts (24), cotter pins (21), cup plug (25) and oil seal (27) in the governor housing as follows:

    a. Apply a thin coat of sealing compound to the outside diameter of a new terminal lever shaft oil seal. Start the seal, with the lip of the seal facing down, straight into the terminal lever shaft opening in the oil inlet plug side of the housing, then press the seal in flush with the outside face of the boss.

    b. Clamp the bottom (square portion) of the governor housing and base assembly between the soft jaws of a bench vise.

    c. Lubricate the long terminal lever shaft with engine oil. Place the terminal lever in between the ends of the two bushings inside the governor housing. Then insert the serrated end (with the cotter pin hole) of the shaft through the oil seal and 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.

    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 housing 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 governor housing cup plug (25). Start the plug, open end out, straight into the terminal lever shaft opening in the housing. Then press the plug in flush with the outside face of the housing boss.

12. Apply a thin coat of sealing compound to the outside diameter of a new speed adjusting lever shaft oil seal. Start the seal, with the lip of the seal facing down, straight into the speed adjusting lever shaft opening in the oil inlet plug side of the housing. Then press the seal in flush with the outside face of the boss.

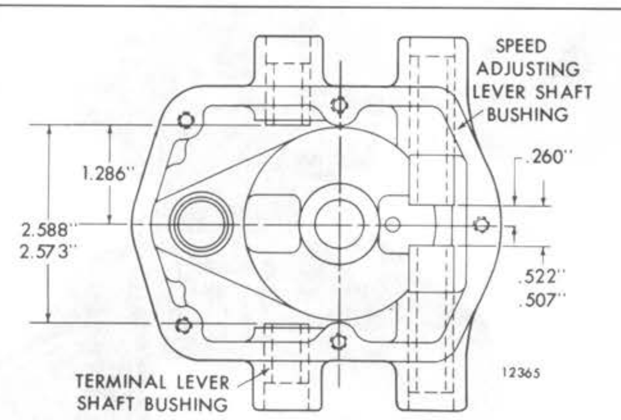


Fig. 13 – Location of Speed Adjusting Lever and Terminal Lever Shaft Bushings in Governor Housing

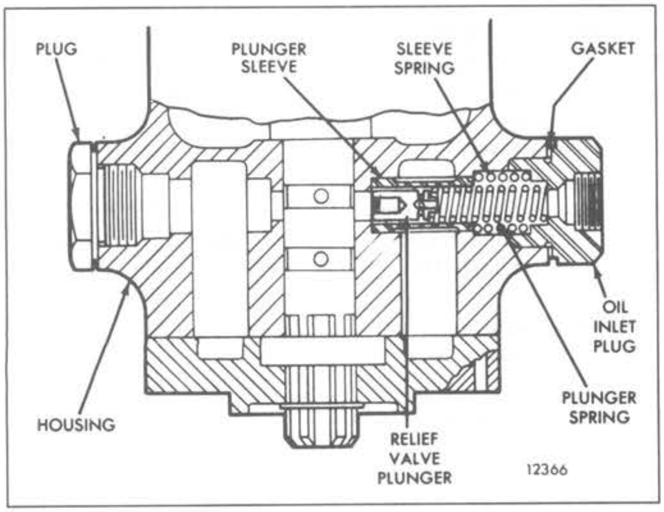


Fig. 14 – Location of Oil Relief Valve Plunger, Plunger Sleeve, Springs, Oil Inlet Plug and Dummy Plug

13. Apply a thin coat of sealing compound to the outside diameter of a new governor housing cup plug (25). Start the plug, open end out, straight into the speed adjusting lever shaft opening in the housing. Then press the plug in flush with the outside face of the housing boss.

14. Lubricate the terminal lever–to–power piston pin (47) 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.

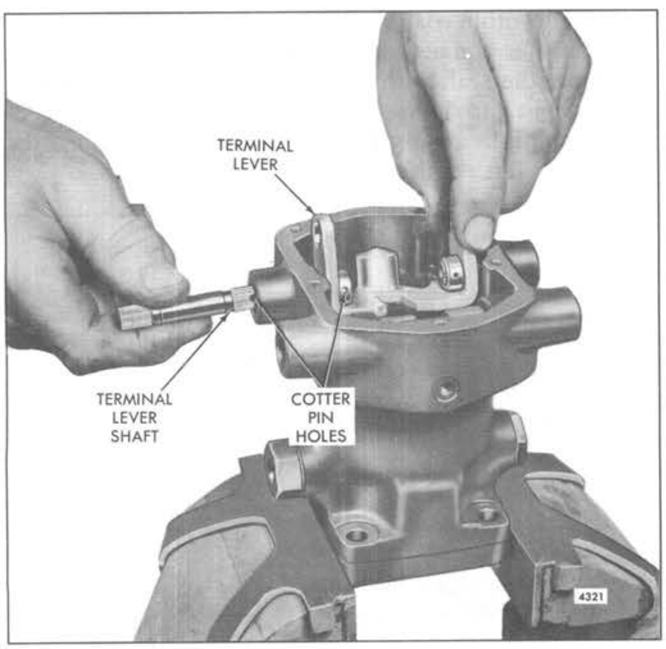


Fig. 15 – Installing Terminal Lever Shaft in Governor Housing and Terminal Lever

15. If disassembled, the speed adjusting lever (16), floating lever (55), spring fork (53), speeder spring (52) and pilot valve plunger (17) may be assembled as follows:

   a. Place the non–slotted end of the speed adjusting floating lever in the slot of the speed adjusting lever, (Fig. 1) 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 (Fig. 17).

   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 floating lever.

   d. Push the wire pin in against the speed adjusting lever and spring fork and bend the protruding end of the wire 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.

16. 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 over the slot between the two bushings.

17. Place the governor housing on its side, oil inlet plug side up, on a bench with the top of the housing facing out.

18. 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 (Fig. 1).

19. 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 in the housing (Fig. 16). 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 (Fig. 1).

20. Install the speed adjusting lever shaft (26) and roll (spring) pin (15) 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 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, from the oil inlet plug side, with the roll pin hole in the shaft and lever in alignment as shown in 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.

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.

d. Start the speed adjusting lever roll (spring) pin (15) straight in 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 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.

21. Place the speed droop adjusting bracket in position against the top face of the terminal lever, with the pin in the bracket in the slot of the speed adjusting floating lever (Fig. 8) and secure it to the lever with a flat washer, lock washer and screw.

22. If removed, thread the lock nut on the maximum speed adjusting screw (35). Place the copper washer on the adjusting screw, then thread the screw approximately halfway in the governor housing (Fig. 1).

23. Install the terminal lever cross pin through the pin holes in the terminal lever as shown in Fig. 7, with the spring guide rod slot in the pin facing up.

24. Affix a new governor subcap gasket (56) to the top of the governor housing.

25. Place the governor subcap (64) on top of the gasket and housing with the fuel rod spring opening in the subcap facing the maximum speed adjusting screw side of the governor housing (Fig. 1). Install the two subcap screws and lock washers and tighten them securely.

26. Refer to Figs. 1, 7 and 12 and install the spring guide rod (77), spring guide rod seat (76), fuel rod spring (21), spring pad cover (80) and the load limit adjusting screw (8) in the governor subcap as follows:

a. Lubricate the spring guide rod with engine oil, then insert the end of the rod through the opening in the subcap, through the slot in the terminal lever cross pin and into the hole at the opposite end of the subcap.

b. Place the spring guide rod seat, large diameter end first, over the end of the spring guide rod and push it forward over the rod and into the notch in the terminal lever cross pin with the flat on the side of the seat adjacent to the terminal lever cross pin support.

c. Insert the end of the fuel rod spring over the end of the spring guide rod, through the opening in the subcap and ove the end of the spring guide rod seat.

d. Affix a new gasket (79) to the flat face of the spring pad cover (80).

e. Place the spring pad cover against the end of the fuel rod spring. Push in on the cover to compress the spring and at the same time, pilot the end of the spring guide rod in the hole in the flat face of the cover. Install the two screws and lock washers and tighten them securely.

f. If removed, thread the lock nut (7) on the load limit adjusting screw (8). Place the copper washer (6) over the end of the load limit adjusting screw, then thread the screw into the subcap until the end protrudes approximately 1/8" through the second boss inside the subcap (Fig. 5).

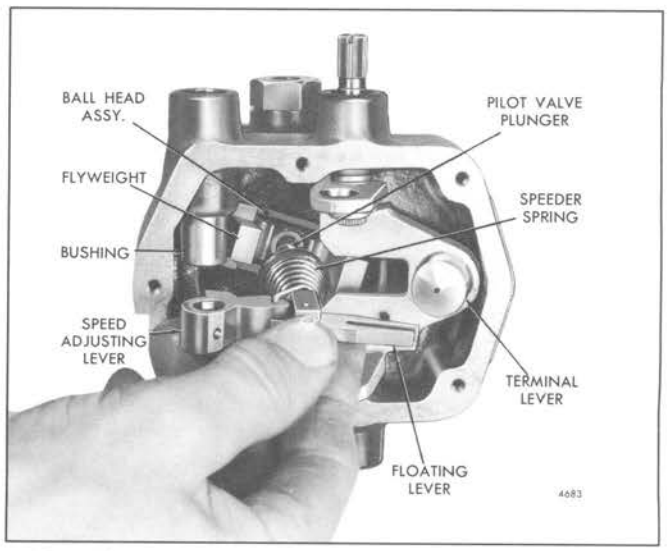


Fig. 16 – Installing Speed Adjusting Lever, Floating Lever, Speeder Spring and Pilot Valve Plunger Assembly

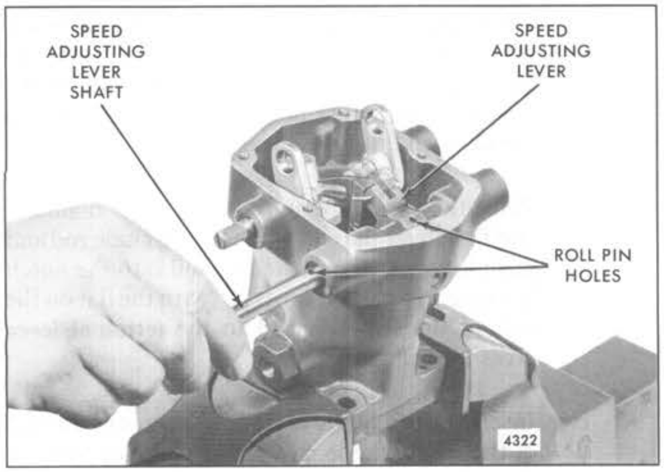


Fig. 17 – Installing Speed Adjusting Lever Shaft in Governor Housing and Adjusting Lever

27. Affix a new gasket (3) to the top face of the governor subcap, then place the governor cover on top of the gasket and install the three screws with lock washers. Tighten the screws securely.

28. If removed, install the oil inlet elbow or fitting in the oil inlet plug.

Install Governor

Refer to Figs. 5 and 6 and proceed as follows:

1. Affix a new gasket to the top of the governor drive housing or housing cover.

2. Position the governor over the governor drive housing or housing cover with the ends of the terminal lever and speed adjusting lever shafts facing the front end of the engine. Turn the ball head assembly slightly to align the splines of the ball head shaft with the splines in the driven shaft sleeve, then enter the shaft straight in the sleeve and set the governor on the gasket and drive housing or cover.

3. Install the four governor to drive housing bolts and lock washers. Tighten the bolts to 13–17 lb–ft (18–23 Nm) torque.

4. Install and connect the oil inlet tube assembly to governor oil reservoir or oil supply valve (if used) and the oil inlet elbow or fitting.

5. If the governor is equipped with a governor operating solenoid valve assembly, install and connect the oil tube to the valve assembly and the governor housing.

6. On a governor equipped with a synchronizing motor, connect the wires to the motor.

7. Place the governor operating lever, with link assembly attached, on the 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 (10–12 Nm) torque.

8. Place the speed control lever, with link assembly attached, on the speed adjusting lever shaft and install the bolt, lock washer and nut. Tighten the bolt nut to 8–10 lb–ft (11–14 Nm) torque.

9. Position the injector control racks and make the final governor adjustments as outlined under *Engine Tune–Up Procedures* in Section 14.

PSG HYDRAULIC GOVERNOR

The governor is located at the front of the engine (Fig. 1) and is mounted on the governor drive housing which also serves as the blower front cover.

The governor is driven by one of the blower rotors through a horizontal drive shaft and bevel gear and a vertical driven shaft and bevel gear. Both shafts are mounted on ball bearings and are retained in the governor drive housing. The injector control tubes are actuated by the governor through a linkage consisting of the fuel rods, vertical link and levers connected as shown in Fig. 2.

The governor is an isochronous hydraulic type with a speed droop stabilization mechanism. Hydraulic action is transmitted by filtered oil admitted under pressure from the engine lubricating system to an auxiliary oil pump in the governor. The auxiliary pump then develops the oil pressure necessary to actuate the governor mechanism.

The isochronous feature of this governor is its ability, at zero droop, to hold the engine at a constant speed regardless of the load, provided the load is within the capacity of the unit.

The governor operates in such a manner that the amount of fuel supplied to the injectors is increased by the hydraulically operated servo–motor piston and decreased by action of the terminal lever return spring.

When starting a cold engine, time is required to develop sufficient oil pressure to operate the governor and thus move the injector control racks to the full–fuel position so the engine can start. Since this delay is undesirable, the starting time can be shortened by moving the governor operating lever to the full–fuel position, to take control of the injector racks away from the governor. The engine can be stopped, regardless of the governor, by moving the governor operating lever to the no–fuel position.

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 the event of a loss of engine lubricating oil pressure. Should the engine fail to supply oil to the governor, the servo–motor piston will drop, thus allowing the governor operating lever to return to the no–fuel position.

Operation

With the engine operating, oil from the engine lubricating system is admitted to the space around the governor pump gears. The pump gears raise the oil pressure to a value determined by the spring in the relief valve which opposes the relief valve plunger. The oil pressure is maintained in the annular space between the undercut portion of the pilot valve plunger and the bore in the pilot valve bushing (Fig. 3).

For any given throttle setting, the speeder spring exerts a definite force which is opposed by the centrifugal force of the revolving flyweights. When the two forces are equal, the control land on the pilot valve plunger covers the lower ports in the pilot valve bushing.

Under these conditions, equal oil pressures are maintained on both sides of the buffer piston and tension on the two buffer springs in equal. The oil pressure is also equal on both sides of the receiving compensating land of the pilot valve plunger, due to oil passing through the compensating needle valve. Thus the hydraulic system is in balance and the engine speed remains constant.

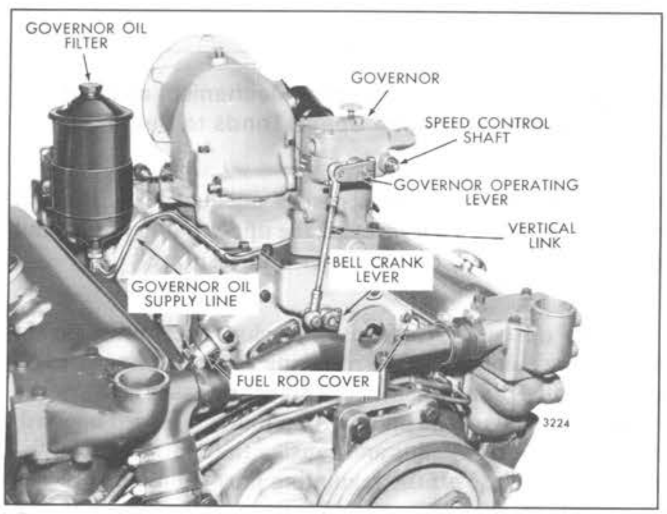


Fig. 1 – PSG Hydraulic Governor Mounting

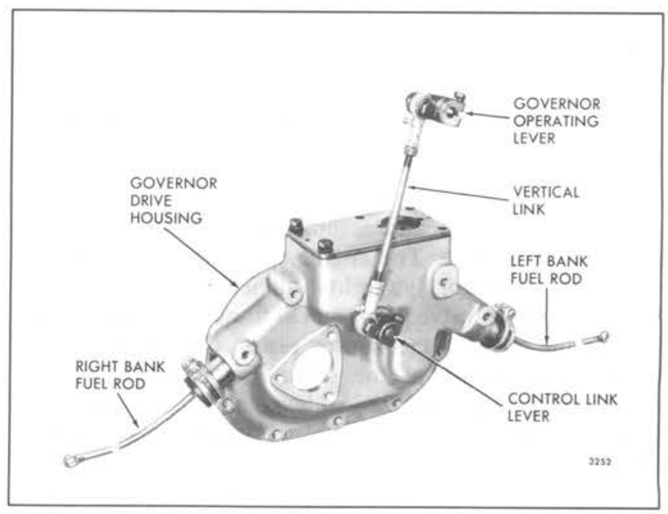
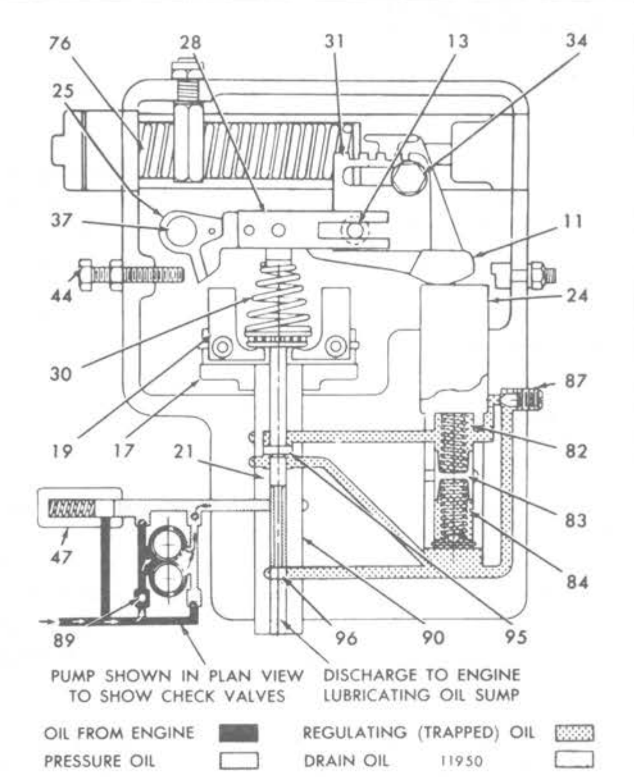
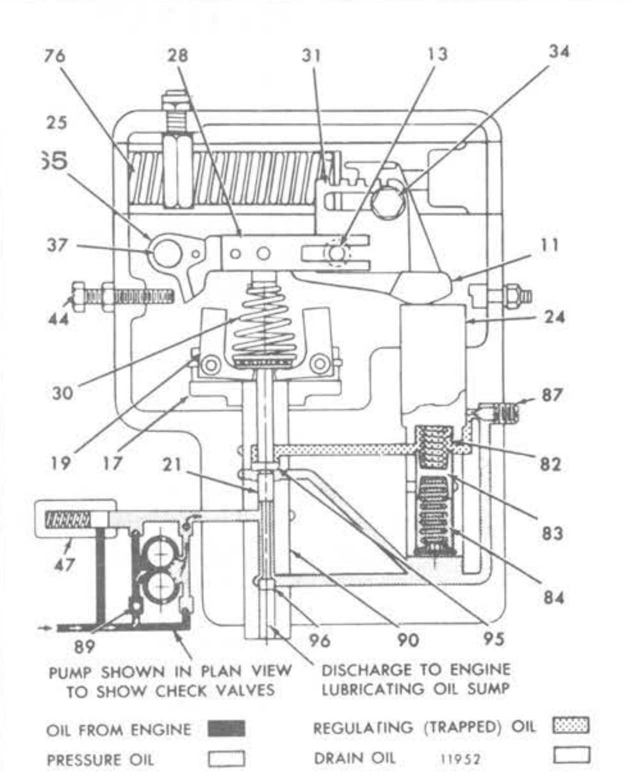


Fig. 2 – Enclosed Type Governor–to–Injector Rack Control Linkage



11. Lever—Terminal
13. Shaft—Terminal (long)
17. Ball Head Assy.
19. Flyweight
21. Plunger—Pilot Valve
24. Piston—Servo-Motor
25. Lever—Speed Adjusting
28. Lever—Floating
30. Spring—Speeder
31. Bracket—Droop Adjusting
34. Bolt—Droop Adjusting
37. Shaft—Speed Adjusting
44. Screw—Maximum Speed Adjusting
47. Valve—Relief
76. Spring—Terminal Lever Return
82. Spring—Buffer (upper)
83. Piston—Buffer
84. Spring—Buffer (lower)
87. Valve—Compensating Needle
89. Valve—Check
90. Bushing—Pilot Valve
95. Land—Receiving Compensating
96. Land—Pilot Valve Control

Fig. 3 – Stable position of Governor When Load on Engine is Constant



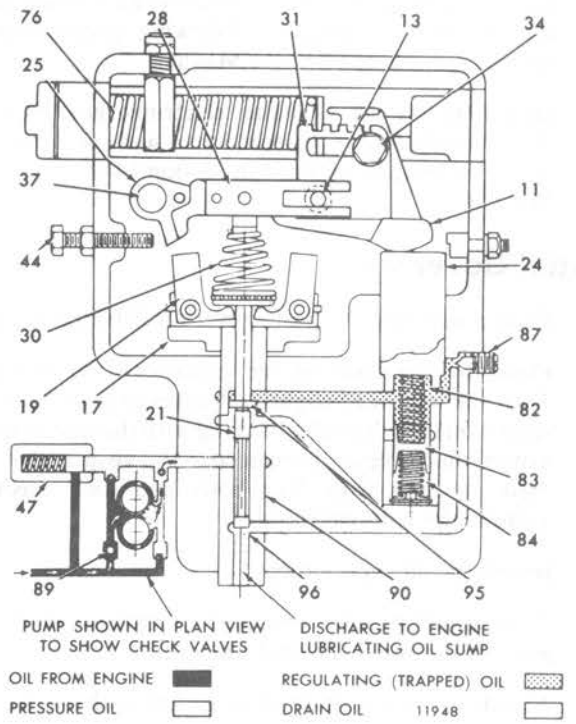
11. Lever—Terminal
13. Shaft—Terminal (long)
17. Ball Head Assy.
19. Flyweight
21. Plunger—Pilot Valve
24. Piston—Servo-Motor
25. Lever—Speed Adjusting
28. Lever—Floating
30. Spring—Speeder
31. Bracket—Droop Adjusting
34. Bolt—Droop Adjusting
37. Shaft—Speed Adjusting
44. Screw—Maximum Speed Adjusting
47. Valve—Relief
76. Spring—Terminal Lever Return
82. Spring—Buffer (upper)
83. Piston—Buffer
84. Spring—Buffer (lower)
87. Valve—Compensating Needle
89. Valve—Check
90. Bushing—Pilot Valve
95. Land—Receiving Compensating
96. Land—Pilot Valve Control

Fig. 4 – Position of Governor Mechanism as Load Increases and Engine Speed Tends to Decrease

Refer to Fig. 4 and assume that a load increase is applied to the engine. The engine speed will momentarily drop and the governor flyweights will be forced inward, thus lowering the pilot valve plunger. Oil under pressure will be admitted under the servo–motor piston causing it to rise. This upward motion of the servo–motor piston will be transmitted through the terminal lever and the linkage to the injector control tubes, causing the fuel setting of the engine to be increased.

The oil which forces the servo–motor piston upward also forces the buffer piston upward because the oil pressure at each side of the buffer piston is unequal. This upward motion of the piston compressed the upper buffer spring and relieves the pressure on the lower buffer spring.

The oil cavities above and below the buffer piston (Fig. 4) are common to the receiving compensating land on the pilot valve plunger. Since the higher pressure is below the compensating land, the pilot valve plunger is forced upward, recentering the flyweights and causing the control land of the pilot valve to close off the regulating port. Thus the upward movement of the servo–motor piston stops when it has moved far enough to make the necessary fuel correction.



11. Lever—Terminal
13. Shaft—Terminal (long)
17. Ball Head Assy.
19. Flyweight
21. Plunger—Pilot Valve
24. Piston—Servo-Motor
25. Lever—Speed Adjusting
28. Lever—Floating
30. Spring—Speeder
31. Bracket—Droop Adjusting
34. Bolt—Droop Adjusting
37. Shaft—Speed Adjusting
44. Screw—Maximum Speed Adjusting
47. Valve—Relief
76. Spring—Terminal Lever Return
82. Spring—Buffer (upper)
83. Piston—Buffer
84. Spring—Buffer (lower)
87. Valve—Compensating Needle
89. Valve—Check
90. Bushing—Pilot Valve
95. Land—Receiving Compensating
96. Land—Pilot Valve Control

Fig. 5 – Position of Governor Mechanism as Load Decreases and Engine Speed Tends to Increase

Oil passing through the compensating needle valve equalizes the pressure above and below the buffer piston, thus allowing the piston to return to its center position which, in turn, equalizes the pressure above and below the receiving compensating land. The pilot valve plunger then moves to its central position and the engine speed returns to its original setting because there is no longer any excessive outward force on the flyweights.

Figure 5 illustrates the governor reaction as the load on the engine is decreased and the engine speed returns to normal. With a decrease in the load, the engine speed will momentarily increase and the flyweights will move outward, thus raising the pilot valve plunger.

This allows the oil below the buffer piston (and below the receiving compensating land) to flow to the drain passage, thus reducing the pressure on the lower side of the buffer piston and on the lower side of the receiving compensating land. This allows a downward movement of the servo–motor piston which is transmitted through the terminal lever and linkage to the injector control tubes, causing the fuel setting of the engine to be decreased.

The compensating mechanism produces stable engine operation by permitting the governor to move instantaneously in response to a load change and to make the necessary fuel adjustment to maintain the initial engine speed.

The speed changes previously described were the result of load changes. Similar governor movements occur through movement of the governor speed control lever. Movement of the speed control lever (through the vernier control and connecting linkage) changes the tension on the speeder spring, thus causing the pilot valve plunger to raise or lower.

Lubrication

Oil passes up through a drilled passage in the pilot valve plunger and is directed at the thrust bearing from where it is thrown onto the moving parts in the governor housing by the revolving flyweights. The governor pump gears, pilot valve plunger, servo–motor ppiston and buffer piston are all exposed to pressurized oil. Oil which collects on the floor of the governor housing passes through a drilled passage into the governor drive housing, thus libricating the governor drive and driven gears and shafts and their bearings. Surplus oil returns to the engine crankcase through connecting drilled passages in the blower end plate and cylinder block.

Remove Governor

Refer to Fig. 1 and remove the governor as follows:

1. Disconnect any linkage which may be attached to the governor speed control lever.
2. Drain the governor oil filter.
3. Disconnect the oil supply tube between the governor and the filter.
4. Remove the oil filter element and clean the filter housing. Install a new filter element.
5. Disconnect the vertical link assembly from the governor operating lever.
6. Disconnect the wires to the synchronizing motor, if used. Tag the wires to facilitate reassembly.
7. Remove the four bolts and lock washers that attach the governor to the governor drive housing cover. Lift the governor away from the drive housing. Remove the gasket.

• *Before a Barber–Coleman electronic governor is installed on an engine previously equipped with a hydraulic governor, the vertical driven gear, bearing, and gear sleeve and the horizontal drive gear, shaft, and bearing must be removed form the governor drive housing.*

These components serve no useful purpose when the hydraulic governor is replaced by the electronic governor and *will cause severe engine damage if not removed.* Because the horizontal drive shaft is splined to the blower rotor shaft, both governor shafts will continue to rotate when the engine is operated. However, with the hydraulic governor removed, the horizontal and vertical shafts and bearings will no longer receive adequate support or lubrication and will quickly wear out.

NOTICE: Do not remove only the vertical shaft and bearing. If the horizontal drive shaft and bearing assembly is left in the governor drive housing, the shaft will move freely back and forth during engine operation. This is due to the absence of load on the bevel gear which would normally keep the horizontal shaft in position. The rapid rotation and back-and-forth movement of the horizontal drive shaft can cause severe damage to the governor drive housing.

Follow this procedure before installing a Barber–Coleman electronic governor:

1. Remove the hydraulic governor drive as outlined in Section 2.8.3 of the Service Manual. Remove the driven gear, bearing and gear sleeve, and the drive gear, shaft, and bearing from the drive housing.
2. Reinstall the governor drive housing and all parts previously removed, except the drive and driven gears and related components, following procedures in Section 2.8.3 of the Service Manual.
3. Install the Barber–Coleman electronic governor per the manufacturer's instructions, and perform the engine tune-up as outlined in Section 14 of the Service Manual.

Install Governor

1. Place a new gasket on the governor drive housing.
2. Place the governor on the governor drive housing. Turn the ball head slightly, if necessary, to align the splines on the pilot valve bushing with the splines in the driven shaft sleeve. Then secure the governor to the drive housing with four bolts and lock washers. Tighten the bolts uniformly.
3. Install the oil supply tube.
4. Pour approximately one pint of engine oil in the governor to provide initial lubrication.
5. Attach a new governor cover gasket to the subcap.
6. If previously removed, install the speed adjusting lever stop on the underside of the governor cover. Secure the lever stop to the cover with a lock nut and copper washer.
7. Before installing the governor cover or connecting the governor linkage, perform a complete engine tune–up as outlined in Section 14.

HYDRAULIC GOVERNOR DRIVE

6V AND 8V–92 ENGINES

The governor is driven by one of the blower rotors through a horizontal drive shaft and drive (bevel) gear and an integral vertical driven (bevel) gear (Fig. 1). Each gear is mounted on a ball bearing and is contained in a drive housing that also serves as the blower front cover.

Splines on the horizontal drive shaft engage the splines in the blower rotor shaft that provides the drive. Splines on the lower end of the governor ball head register with the splines in the upper end of a sleeve that is pressed on the vertical driven gear.

The fuel rod from each injector control tube is connected to a common control link lever which is enclosed in the governor drive housing.

The governor is connected to the fuel rods by a vertical link attached to the control link lever and the governor operating lever (Fig. 2).

Naturally aspirated engine drive assemblies include a reduction gear assembly.

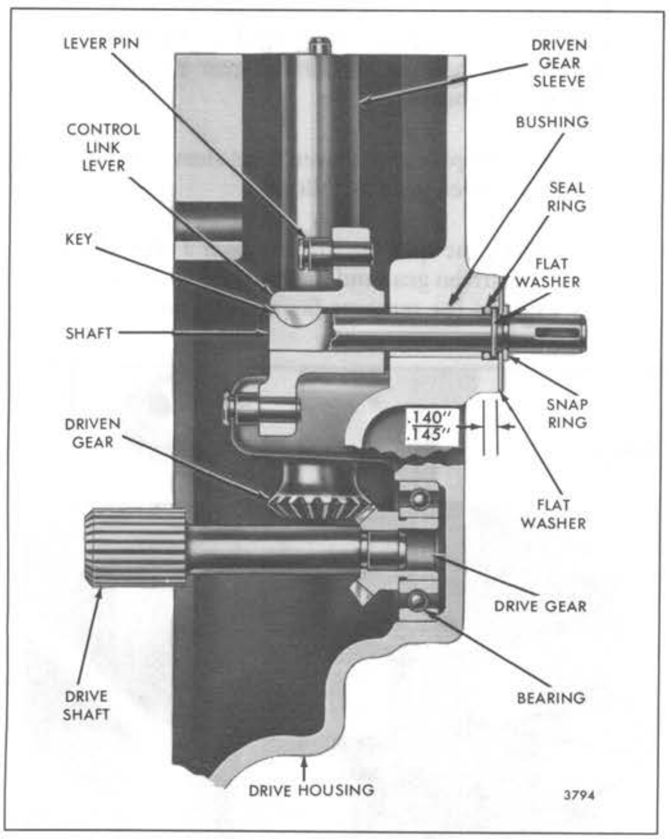


Fig. 1 – Governor Drive Assembly

Lubrication

The gears and bearings of the governor drive assembly are lubricated by surplus oil from the governor, which spills over the moving parts. The oil then returns to the engine crankcase through drilled passages in the blower end plate and cylinder block.

The rod end bearings of the vertical link assembly are lubricated with grease through the fittings provided.

Remove Governor Drive

If the governor fails to control the engine speed properly, the fault may lie in the governor drive. To function properly, there must be approximately .001" to .003" clearance between the governor drive and driven gears.

Remove the governor drive assembly, if necessary, as follows:

1. Disconnect the throttle control linkage to the governor speed control lever.

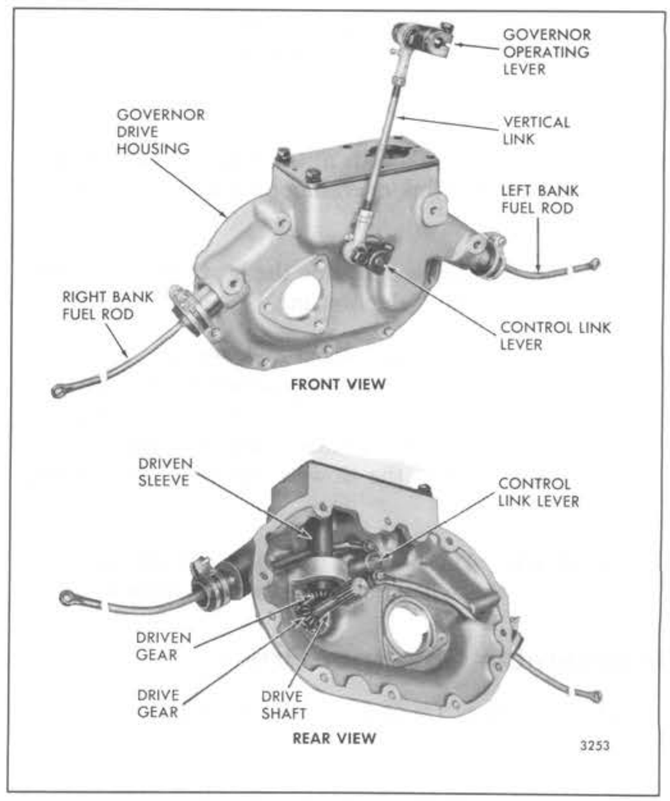


Fig. 2 – Hydraulic Governor Drive

2. Remove the bolts and lock washers that attach the vertical link assembly to the governor operating lever and the control link operating lever. Remove the link assembly.

3. If the engine is equipped with a governor oil reservoir, disconnect and remove the oil inlet, outlet and return tubes from the reservoir, governor and drive housing. Then remove the oil reservoir from the drive housing.

4. If equipped with a governor operating solenoid, disconnect and remove the oil inlet and outlet tubes from the solenoid, governor and drive housing. Tag and remove the electrical wires from the top of the solenoid. Remove the solenoid from the drive housing.

5. If the governor is equipped with a synchronizing motor, tag and remove the electrical wires from the motor terminals.

6. Remove the four bolts and lock washers securing the governor to the governor drive housing. Lift the governor from the drive housing cover and remove the governor gasket.

7. Remove the housing cover and gasket.

8. Drain the cooling system. Remove the water by–pass tube between the two thermostat housings.

9. Disconnect and remove the fuel oil inlet and outlet pipes from the fuel pump, then remove the fuel pump, gasket and drive coupling fork from the drive housing.

10. Remove the valve rocker covers.

11. Disconnect the fuel rods at the injector control tubes and the control link operating lever and withdraw the fuel rods.

12. Loosen the clamps and slide the hoses up on the fuel rod cover tubes of the housing.

13. Remove the ten bolts, seven lock washers and three copper washers securing the governor drive housing to the blower end plate. Tap the edge of the housing lightly with a plastic hammer to loosen it, then remove the housing from the dowels. Remove the housing gasket.

   NOTICE: Do not pry the housing off the dowels as this will damage the finished surfaces.

Disassemble Governor Drive

Refer to Figs. 1 and 2 and disassemble the governor drive assembly as follows:

1. Loosen the bolt securing the control link shaft lever to the shaft, then remove the lever and key from the shaft.

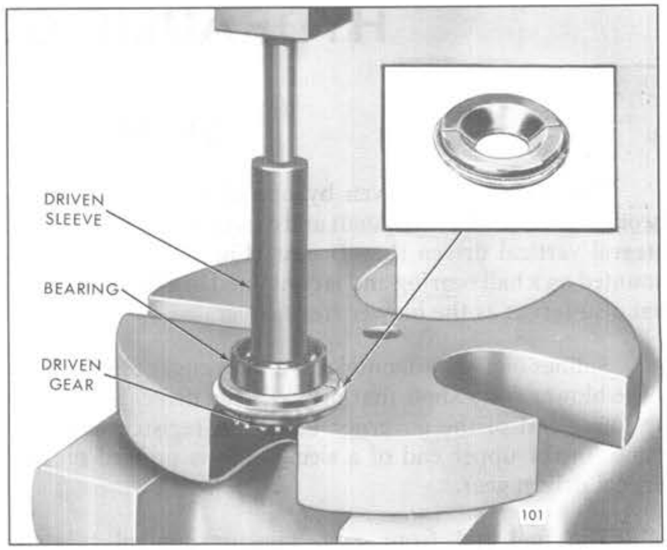


Fig. 3 – Removing Driven Sleeve and Bearing from Driven Gear

2. Remove the snap ring and flat washer that retains the control link lever and shaft assembly in the drive housing, then pull the lever and shaft assembly from the housing. Remove the small flat washer and seal ring from the bushing bore in the housing.

3. Remove the snap ring securing the governor driven gear bearing in the drive housing (Fig. 6), then pull the driven gear, bearing and driven gear sleeve from the bore in the housing.

4. Remove the governor driven gear sleeve and bearing from the driven gear as follows:

   a. Place the split bearing remover J 4685 between the driven gear and the bearing, with the beveled side of the remover facing the gear.

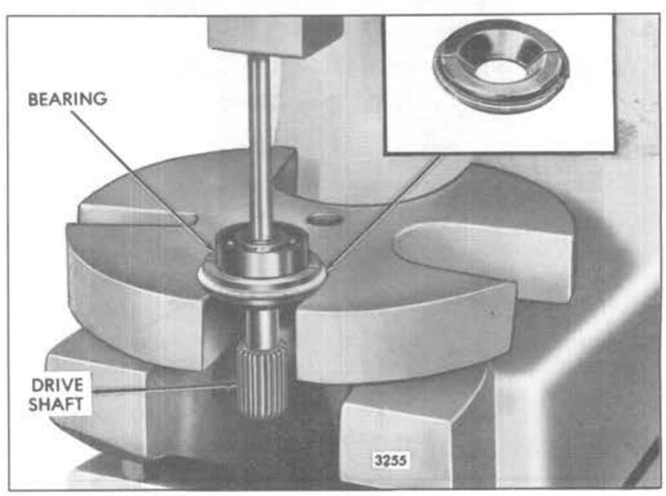


Fig. 4 – Removing Bearing from Drive Gear

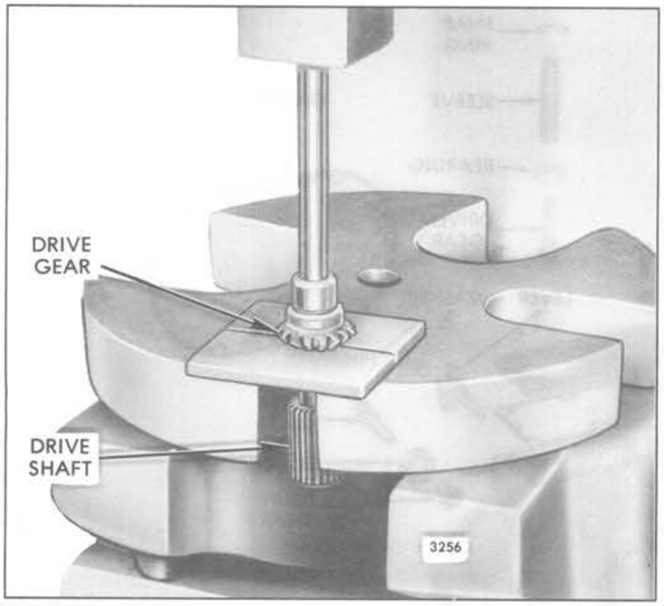


Fig. 5 – Removing Drive Gear from Drive Shaft

b. Support the driven gear assembly and remover on the bed of an arbor press (Fig. 3). Place a brass rod inside the sleeve against the end of the driven gear, then press the driven gear from the sleeve and bearing. Catch the driven gear by hand when pressed from the bearing.

5. Remove the governor drive gear, drive shaft and bearing assembly by pulling it straight out of the bore in the housing.

6. Remove the governor drive gear shaft bearing and drive gear from the drive shaft as follows:

   a. Place the split bearing remover J 4685 between the drive gear and the bearing, with the beveled side of the remover facing the gear.

   b. Support the drive gear assembly and remover on the bed of an arbor press (Fig. 4). Place a brass rod on the end of the drive shaft, then press the drive gear and shaft assembly from the bearing. Catch the drive gear and shaft by hand when pressed from the bearing.

   c. Place two split brass plates beneath the teeth of the drive gear, then support the assembly on the bed of an arbor press (Fig. 5). Place a brass rod on the end of the drive shaft, then press the drive shaft from the drive gear.

Inspection

Wash all of the parts in clean fuel oil and dry them with compressed air.

CAUTION: To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.

Inspect the teeth of the drive and driven bevel gears for chipping, scoring or wear. Remove any slight score marks with a stone. If the teeth are severely scored or worn, replace the gears.

Examine the drive shaft and the driven shaft sleeve for worn splines. Also check the mating parts for wear.

Check each ball bearing for indications of corrosion or pitting. Lubricate the bearing with light engine oil. Then, while holding the inner race, revolve the outer race slowly by hand. Any rough spot in the bearing is sufficient cause for rejection.

Inspect the control link operating shaft and its bushing in the governor drive housing for wear. If a new bushing is to be installed, press it in the drive housing so it will be .140" to .145" below the outside face of the housing to provide space for the seal ring (Fig. 1).

Examine the fuel rod cover hoses for damage. Replace them if necessary.

Check the fuel rod pins in the control link lever for wear and scoring.

Replace all of the governor drive parts that are excessively worn or damaged.

Assemble Governor Drive

Refer to Figs. 1 and 6 for the location of the various parts and assemble the governor drive as outlined below:

1. Install the governor drive shaft bearing and drive gear on the drive shaft as follows:

   a. Lubricate the drive shaft bearing with engine oil, then start the bearing, numbered side up, straight on the end of the drive gear.

   b. Place the beveled end of the drive gear on the bearing installer J 4683 and place the assembly on the bed of an arbor press as shown in Fig. 7. Then place a sleeve on the inner race of the bearing and press the bearing tight against the shoulder on the drive gear.

   c. Lubricate the small end of the governor drive shaft with engine oil, then start the drive gear straight on the shaft with the gear teeth facing the splined end of the shaft.

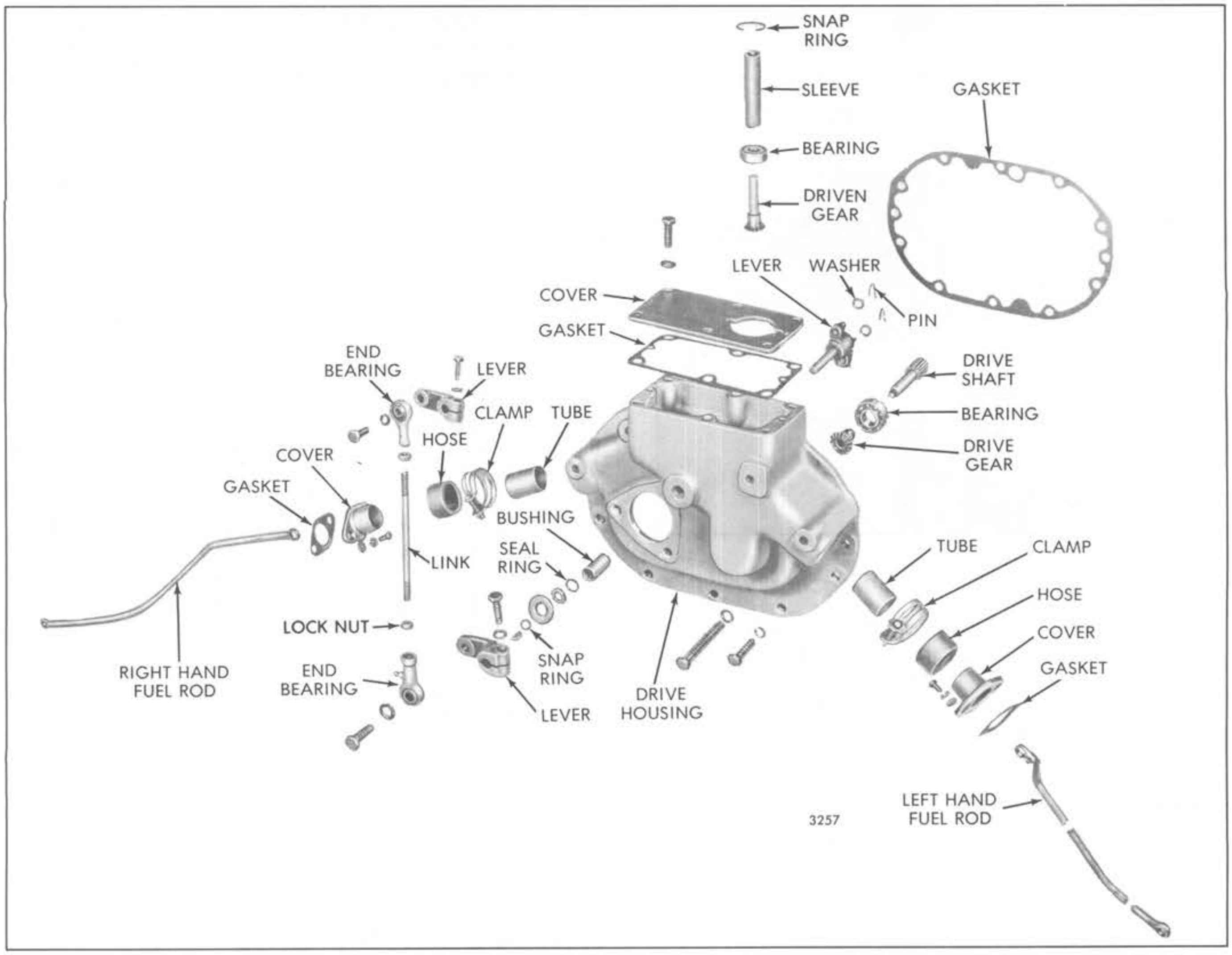


Fig. 6 – Details of Hydraulic Governor Drive and Relative Location of Parts

d. Place the drive shaft, gear and bearing assembly on the bed of an arbor press with the bearing and gear end up (Fig. 8). Then place a sleeve or a round brass bar on the inner race of the bearing and press the drive gear tight against the shoulder on the shaft.

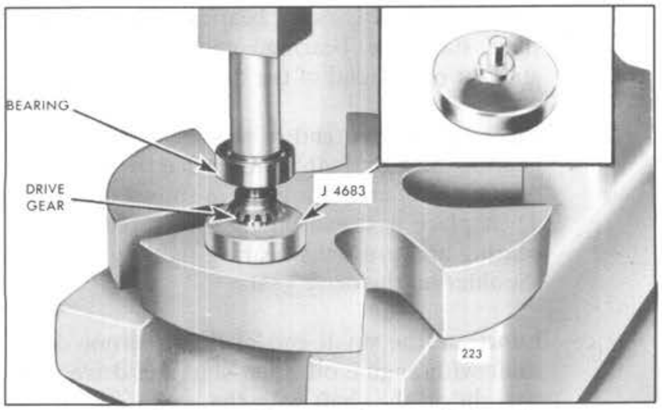


Fig. 7 – Installing Bearing on Drive Gear

2. Lubricate the governor drive shaft bearing with engine oil, then insert the drive shaft, drive gear and bearing assembly straight into the bearing bore in the drive housing (Fig. 1).

3. Install the governor driven gear bearing and sleeve on the driven gear as follows:

   a. Lubricate the driven gear bearing with engine oil, then start the bearing, numbered end up, straight on the driven gear.

   b. Lubricate the inside diameter of the driven gear sleeve with engine oil, then start the sleeve, splined end up, straight on the end of the driven gear.

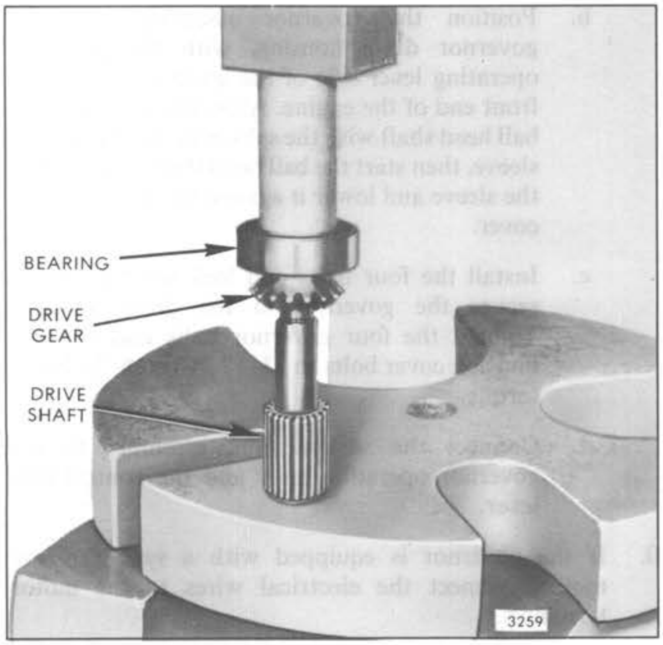


Fig. 8 – Installing Drive Gear and Bearing on Drive Shaft

c. Place the driven gear, bearing and sleeve assembly on the bed of an arbor press, with a spacer under the gear (Fig. 9) to support the gear teeth above the bed of the press. Then press the sleeve and bearing tight against the shoulder on the driven gear.

4. Lubricate the driven gear bearing with engine oil, then insert the driven gear, bearing and sleeve assembly through the top of the drive housing and start the bearing straight into the bearing bore in the housing. Push the driven gear assembly down in the housing until the teeth of the driven gear mesh with the drive gear (if necessary, rotate one of the gears slightly to align the gear teeth) and the bearing rests on the shoulder in the housing.

5. Install the snap ring in the groove in the housing next to the bearing.

6. Rotate the drive and driven gears and check for freeness and clearance between the gear teeth. The clearance should be .001" to .003".

7. Install the governor control link lever and shaft assembly in the drive housing as follows:

   a. Lubricate the control link lever shaft with engine oil, then slide the shaft through the bushing from the inner side of the housing (Fig. 1).

   b. Place a new seal ring over the shaft and slide it into the housing against the bushing, then place the small flat washer over the shaft and slide it in against the seal ring. Place the large flat washer over the shaft and slide it against the housing, then install the snap ring in the groove in the shaft.

   c. Install the Woodruff key in the keyway in the shaft, then slide the control link shaft lever over the shaft and key and secure it in place with a bolt and lock washer.

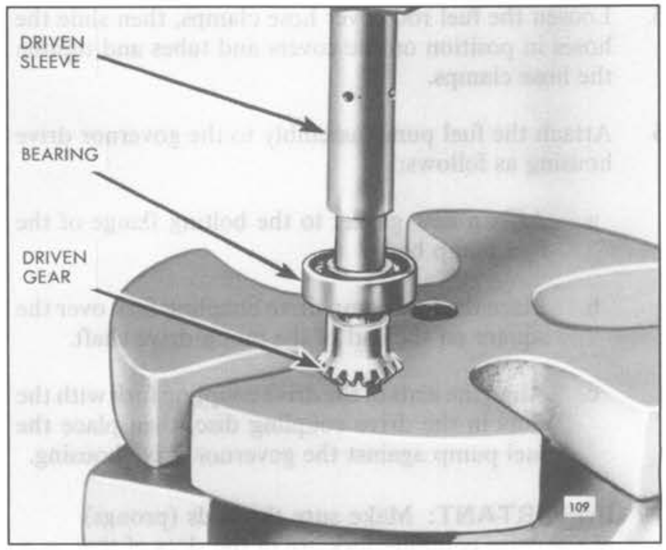


Fig. 9 – Installing Bearing and Driven Sleeve on Driven Gear

Install Governor Drive

After the governor drive is assembled, attach it to the blower, then attach the governor to the drive housing as outlined below:

1. Place a fuel rod cover hose and clamp on each of the fuel rod tubes in the drive housing, then tighten the hose clamp screws to retain the clamps on the hoses.

2. Affix a new gasket to the blower end plate. Then, with the splines of the governor drive shaft and the blower rotor shaft in alignment, insert the drive shaft into the rotor shaft and slide the drive housing on the dowels and against the gasket.

3. Install the ten bolts, seven lock washers and three copper washers which secure the drive housing to the blower end plate. Tighten the bolts to 13–17 lb-ft (18–23 N•m) torque.

   NOTICE: The three copper washers are used on the three long bolts which are exposed to the oil inside the drive housing.

4. Insert the fuel rods through the opening in the top of the drive housing, then connect them to their injector control tube levers and to the control link lever inside the housing.

5. Loosen the fuel rod cover hose clamps, then slide the hoses in position on the covers and tubes and tighten the hose clamps.

6. Attach the fuel pump assembly to the governor drive housing as follows:

   a. Affix a new gasket to the bolting flange of the fuel pump body.

   b. Place the fuel pump drive coupling fork over the square on the end of the pump drive shaft.

   c. Align the ends of the drive coupling fork with the slots in the drive coupling disc, then place the fuel pump against the governor drive housing.

   IMPORTANT: Make sure the ends (prongs) of the drive coupling fork are in the slots of the drive disc before installing and tightening the attaching bolts.

   d. Install the three bolt and seal assemblies and tighten the bolts to 13–17 lb–ft (18–23 N•m) torque.

7. Connect the fuel oil inlet and outlet pipes to the fuel pump.

8. Affix a new gasket to the top face of the governor drive housing, then place the housing cover on top of the gasket with the governor opening in the cover over the governor driven gear sleeve. Install two bolts and lock washers in the end holes, opposite the governor opening. Do not tighten the bolts at this time.

9. Attach the governor assembly to the drive housing as follows:

   a. Affix a new governor gasket to the top face of the housing cover.

   b. Position the governor assembly over the governor drive housing, with the governor operating lever side of the governor facing the front end of the engine. Align the splines of the ball head shaft with the splines in the driven gear sleeve, then start the ball head shaft straight into the sleeve and lower it against the gasket on the cover.

   c. Install the four bolts and lock washers which secure the governor to the drive housing. Tighten the four governor bolts and the two housing cover bolts to 13–17 lb–ft (18–23 N•m) torque.

   d. Connect the vertical link assembly to the governor operating lever and the control link lever.

10. If the governor is equipped with a synchronizing motor, connect the electrical wires to the motor terminals.

11. If a governor operating solenoid is used, attach the solenoid to the drive housing, then connect the oil inlet and outlet tubes to the solenoid, governor and drive housing. Also connect the electrical wires to the solenoid terminals.

12. If an oil reservoir is used, attach the reservoir to the drive housing, then connect the oil inlet, outlet and return tubes to the oil reservoir, governor and drive housing.

13. Connect the throttle control linkage to the speed control lever.

14. Lubricate the governor control linkage end bearings with grease through the fittings provided.

15. If drained, refill the cooling system.

16. Perform an engine tune–up as outlined in Section 14.

GOVERNOR DRIVE FOR 12V AND 16V–92 ENGINE

The governor is driven by one of the blower rotors through a horizontal drive shaft and drive (bevel) gear and an integral driven (bevel) gear (Fig. 10). Each gear is mounted on a ball bearing and is contained in a drive housing that also serves as a front cover for the rear blower.

Splines on the horizontal drive shaft engage the splines in the blower rotor shaft that provides the drive. Splines on the lower end of the governor ball head register with the splines in the upper end of a sleeve that is pressed on the vertical driven gear.

The fuel rod from each injector control tube is connected to a pair of control link levers. One is enclosed in the governor drive housing (front cover of rear blower) and the other is enclosed in the governor control housing (rear cover of front blower).

The shafts of the two control link levers (Fig. 10) are connected together by means of a common lever and cap assembly.

The variable speed hydraulic governor is connected to the fuel rods by a vertical link attached to a common lever and cap assembly and the operating lever on the governor terminal lever shaft.

Naturally aspirated engine drive assembly includes a reduction gear assembly.

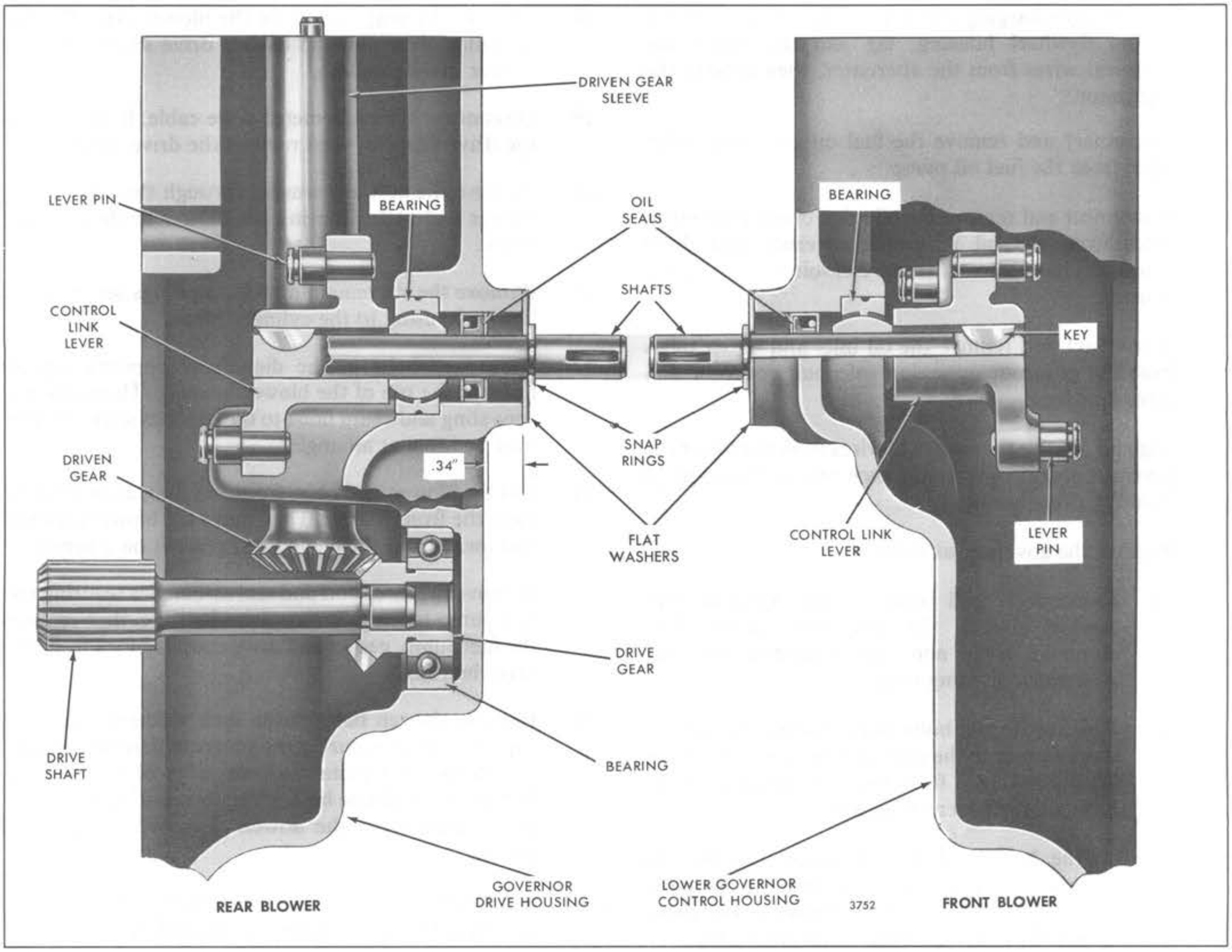


Fig. 10 – Governor Drive and Control Housing Assembly

Lubrication

The gears and bearings of the governor drive assembly are lubricated by surplus oil from the governor, which spills over the moving parts. The oil then returns to the engine crankcase through drilled passages in the blower end plate and cylinder block.

The rod end bearings of the external vertical link assembly are lubricated with grease through the fittings provided.

Remove Governor Drive

If the governor fails to control the engine speed properly, the fault may lie in the governor drive.

To function properly, there must be approximately .001" to .003" clearance between the governor drive bevel gears.

Due to the clearance between the front and rear blower assemblies, it will be necessary to remove one of the blowers in order to remove the governor drive housing or the governor control housing on the front blower.

Remove the governor drive assembly, if necessary, as follows:

1. Disconnect the throttle control linkage to the governor speed control lever.
2. Remove the air inlet pipe between the air cleaner, or turbocharger, and the air shutdown housing on the rear blower.
3. Remove the air shutdown housing from the blower, then cover the top of the blower to prevent entry of foreign material.

4. If a battery–charging alternator is attached to the top of the flywheel housing, tag and disconnect the electrical wires from the alternator, then remove the alternator.

5. Disconnect and remove the fuel oil inlet and outlet pipes from the fuel oil pump.

6. Disconnect and remove the oil inlet, outlet and return tubes from the oil reservoir, governor and drive housing. Then remove the oil reservoir from the drive housing.

7. Disconnect and remove the oil inlet and outlet tubes from the governor operating solenoid, governor and drive housing.

8. Tag and remove the electrical wires from the top of the governor operating solenoid, then remove the solenoid from the drive housing.

9. Remove the governor as follows:

   a. Disconnect and remove the vertical link assembly from the governor control link common lever and cap assembly and the governor operating lever.

   b. Remove the four bolts and lock washers securing the governor to the governor drive housing, then lift the governor from the drive housing cover. Remove the governor gasket.

10. Remove the bolts and lock washers securing the governor control link common lever and cap assembly to the control link lever shafts between the drive housing and the lower governor control housing.

11. Remove the valve rocker covers from the rear of the engine.

12. Remove the governor drive housing cover and gasket from the top of the drive housing.

13. Disconnect the fuel rods at the injector control tube levers and the control link lever inside the governor drive housing, then withdraw the fuel rods.

14. Loosen the fuel rod hose clamps and slide the hoses up on the fuel rod cover tubes in the drive housing.

15. Disconnect the blower oil pressure tube from the fitting in the blower drive support, then slide the tube forward into the blower end plate.

16. Loosen the hose clamp on the blower drive support to blower seal.

17. Remove the flywheel housing cover in back of the blower drive support.

18. Remove the snap ring from the blower drive flexible coupling, then pull the blower drive shaft from the blower drive coupling.

19. Disconnect the tachometer drive cable, if used, from the drive adaptor, then remove the drive adaptor.

20. Remove the bolt and washer through the top of each blower end plate securing the blower to the cylinder block.

21. Remove the six remaining bolts and lugs securing the blower housing to the cylinder block.

22. Thread eyebolts in the diagonally opposite tapped holes in the top of the blower housing. Then attach a rope sling and chain hoist to the eyebolts so the blower may be lifted at an angle.

23. Lift the blower assembly, front end first, at an angle to clear the front blower. Then move the blower forward and away from the engine and place it on a bench.

24. Remove the three bolt and seal assemblies securing the fuel pump to the governor drive housing, then remove the fuel pump, gasket and drive coupling fork from the drive housing.

25. Remove the ten bolts, seven lock washers and three copper washers securing the governor drive housing to the blower end plate. Tap the edge of the housing lightly with a plastic hammer to loosen it, then remove the housing from the dowels. Remove the housing gasket.

    NOTICE: Do not pry the housing off the dowels as this will damage the finished surfaces.

26. If necessary, the governor control housing may be removed from the engine front blower, at this time, by following the procedure outlined in steps 11, 12, 13, 14 and 25 above.

    NOTICE: The cover must be removed from the governor control housing in order to disconnect the fuel rods from the control link lever in the housing.

Disassemble Governor Drive

Refer to Figs. 10 and 15 and disassemble the governor drive assembly as follows:

1. Remove the Woodruff key from the keyway of the governor control link lever shaft.

2. Remove the snap ring and flat washer that retains the control link lever, shaft and bearing assembly in the drive housing, then remove the lever, shaft and bearing assembly from the housing.

NOTICE: The two governor control link lever, shaft and bearing assemblies in the governor drive housing and governor control housing are identical, except for the location of the keyway in the outer end of the shaft. If both control link lever, shaft and bearing assemblies are to be removed, be sure and tag one or both of the lever assemblies so they may be reinstalled in their respective housings.

3. If necessary, remove the control link lever shaft bearing from the shaft as follows:

   a. Support the inner end of the control link lever on a sleeve, on the bed of an arbor press, then press the shaft approximately 1/4 inch out of the lower end of the lever.

   b. Support the opposite end of the lever, next to the bearing, on the bed of an arbor press. Do not put the support under the bearing. Then press the shaft back in flush with the end of the lever.

   NOTICE: This will leave approximately 1/4 inch space between the bearing and the lever.

   c. Place two split plates between the bearing and the lever, then support the split plates, lever, shaft and bearing assembly on the bed of an arbor press as shown in Fig. 11. Press the shaft from the bearing.

   NOTICE: The hole in the split plates should be the same diameter as the shaft so the inner race of the bearing will rest on the plates when in place.

   d. If necessary, the control link lever shaft may be pressed from the control link lever.

4. Inspect the control link lever shaft oil seal for wear and damage. If necessary, the oil seal may be replaced in the governor drive housing without removing the drive and driven gear assemblies. Replace the oil seal as follows:

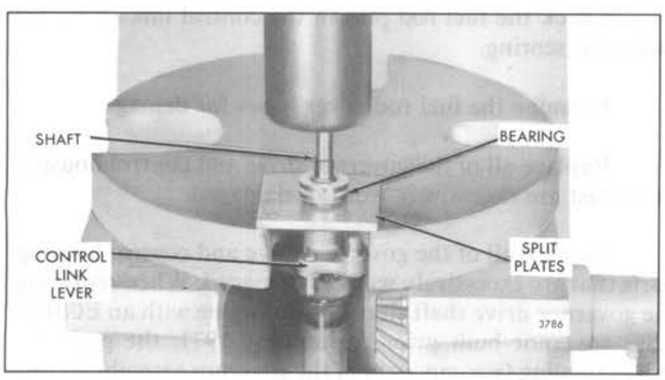


Fig. 11 – Removing Bearing from Control Link Lever Shaft

   a. Support the inner face of the drive housing on two wood blocks approximately 2" thick. Then place a short piece of 3/4" round bar stock on top of the oil seal and tap it out of the housing with a hammer.

   b. Apply a thin coat of sealing compound to the outside diameter of the new oil seal casing, then start the oil seal with the lip of the seal facing down, straight into the bore in the housing.

   c. Support the inner face of the drive housing on two wood blocks on the bed of an arbor press. Place the 3/4" round bar stock on top of the oil seal and under the ram of the press, then press the oil seal into the housing until it is .340" below the outer face of the housing (Fig. 10).

5. Remove the snap ring securing the governor driven gear bearing in the drive housing, then pull the driven gear, bearing and driven gear sleeve from the bore in the housing.

6. Remove the governor driven gear sleeve and bearing from the driven gear as follows:

   a. Place the split bearing remover J 4685 between the driven gear and the bearing, with the beveled side of the remover facing the gear.

   b. Support the driven gear assembly and remover on the bed of an arbor press (Fig. 12). Place a brass rod inside the sleeve, against the end of the driven gear, then press the driven gear from the sleeve and bearing. Catch the driven gear by hand when pressed from the bearing.

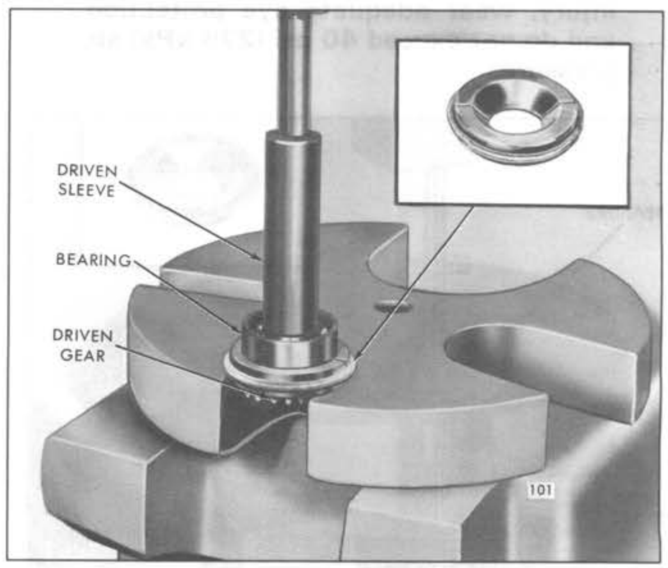


Fig. 12 – Removing Driven Sleeve and Bearing from Driven Gear

7. Remove the governor drive gear, drive shaft and bearing assembly by pulling it straight out of the bore in the housing.

8. Remove the governor drive shaft bearing and drive gear from the drive shaft as follows:

   a. Place the split bearing remover J 4685 between the drive gear and the bearing, with the beveled side of the remover facing the gear.

   b. Support the drive gear assembly and remover on the bed of an arbor press (Fig. 13). Place a brass rod on the end of the drive shaft, then press the drive gear and shaft assembly from the bearing. Catch the drive gear and shaft by hand when pressed from the bearing.

   c. Place two split brass plates beneath the teeth of the drive gear, then support the assembly on the bed of an arbor press (Fig. 14). Place a brass rod on the end of the drive shaft, then press the drive shaft from the drive gear. Catch the drive shaft by hand when pressed from the drive gear.

9. If necessary, the governor control link lever assembly and oil seal may be removed from the governor control housing and the bearing removed from the control link lever shaft by following the procedure outlined in Steps 1 through 4 above.

Inspection

Wash all of the parts in clean fuel oil and dry them with compressed air.

CAUTION:To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.

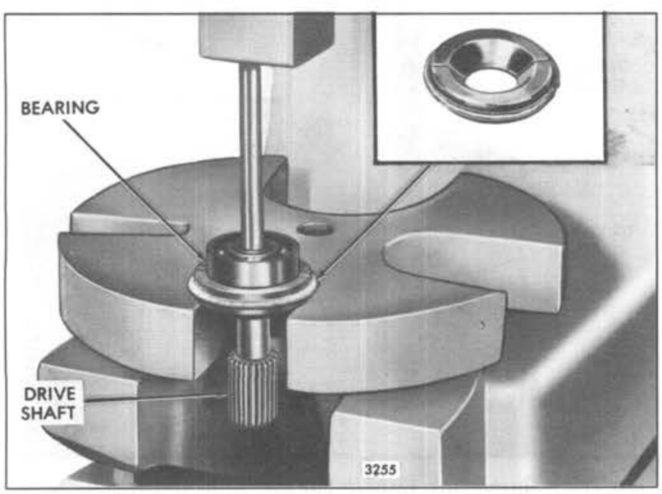


Fig. 13 – Removing Bearing from Drive Gear

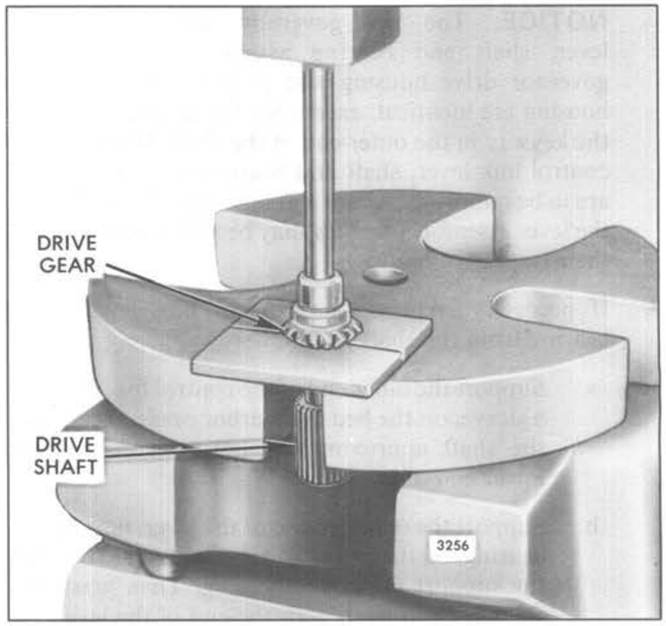


Fig. 14 – Removing Drive Gear from Drive Shaft

Inspect the teeth of the drive and driven bevel gears for chipping, scoring or wear. Remove any slight score marks with a stone. If the teeth are severely scored or worn, replace the gears.

Examine the drive shaft and the driven shaft sleeve for worn splines. Also, check the mating parts for wear.

Check each ball bearing for indications of corrosion or pitting. Lubricate the bearing with light engine oil. Then, while holding the inner race, revolve the outer race slowly by hand. Any rough spot in the bearing is sufficient cause for rejection.

Check the control link lever shaft and vertical link spherical bearings for free movement on their inner race. Also examine the control link lever shaft oil seals for wear, cracks or other damage.

Check the fuel rod pins in the control link levers for wear and scoring.

Examine the fuel rod cover hoses for damage.

Replace all of the governor drive and control housing parts that are excessively worn or damaged.

Replace all of the governor drive and control housing parts that are excessively worn or damaged. When replacing the governor drive shaft sleeve on an engine with an EGB or LSG governor built prior to January, 1971, the governor drive coupling (a component of the governor assembly) must be removed. The current governor drive shaft sleeve is 1.290" longer than the former sleeve to offset the drive coupling.

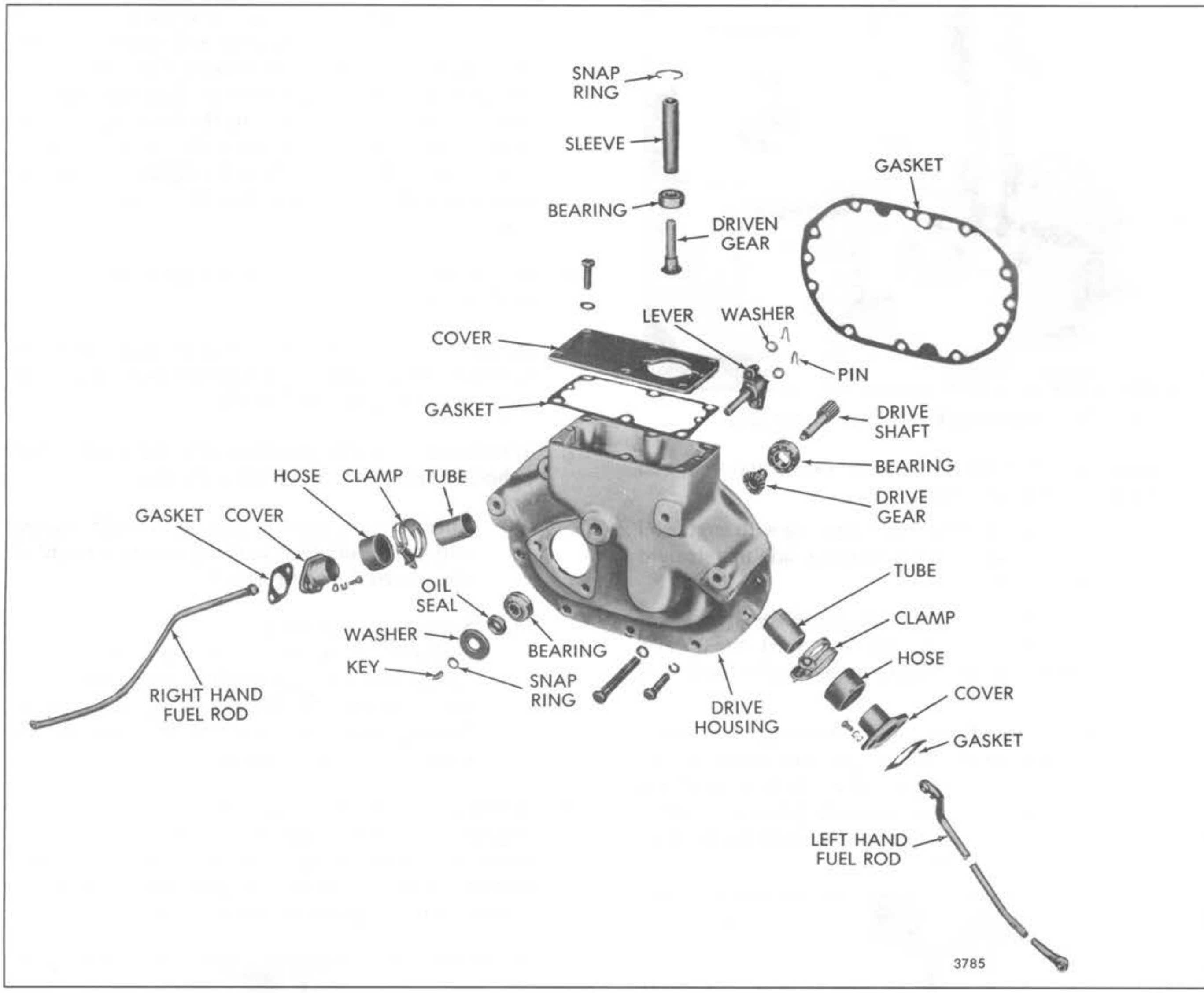


Fig. 15 – Details of Enclosed Linkage Type Hydraulic Governor Drive and Relative Location of Parts

Assemble Governor Drive

Refer to Figs. 10 and 15 for the location of the various parts and assemble the governor drive as outlined below:

1. Install the governor drive shaft bearing and drive gear on the drive shaft as follows:
   a. Lubricate the drive shaft bearing with engine oil and start the bearing, numbered side up, straight on the end of the drive gear.
   b. Place the beveled end of the drive gear on the bearing installer J 4683 and place the assembly on the bed of an arbor press as shown in Fig. 16. Then place a sleeve on the inner race of the bearing and press the bearing tight against the shoulder on the drive gear.
   c. Lubricate the small end of the governor drive shaft with engine oil, then start the drive gear straight on the shaft with the gear teeth facing the splined end of the shaft.
   d. Place the drive shaft, gear and bearing assembly on the bed of an arbor press, with the bearing and gear end up (Fig. 17). Then place a sleeve or a brass rod on the inner race of the bearing and press the drive gear tight against the shoulder on the shaft.
2. Lubricate the governor drive shaft bearing with engine oil, then insert the drive shaft, drive gear and bearing assembly straight into the bearing bore in the drive housing (Fig. 10).

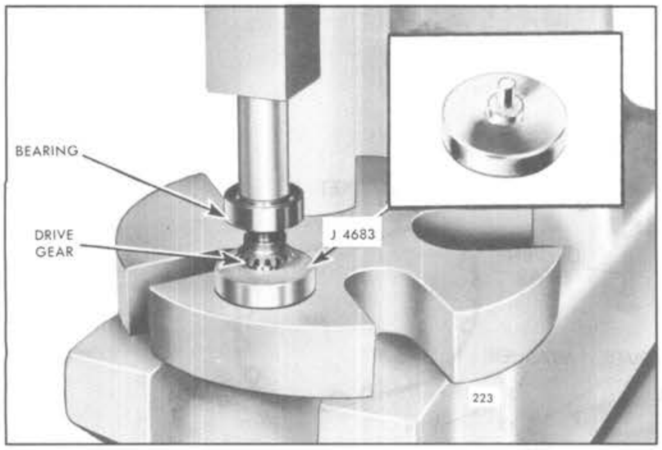


Fig. 16 – Installing Bearing on Drive Gear

3. Install the governor driven gear bearing and sleeve on the driven gear as follows:
    a. Lubricate the driven gear bearing with engine oil and start the bearing, number side up, straight on the driven gear.
    b. Lubricate the inside diameter of the driven gear sleeve with engine oil and start the sleeve, splined end up, straight on the end of the driven gear.
    c. Place the driven gear, bearing and sleeve assembly on the bed of an arbor press, with a spacer under the gear (Fig. 18) to support the gear teeth above the bed of the press. Then press the sleeve and bearing tight against the shoulder on the driven gear.

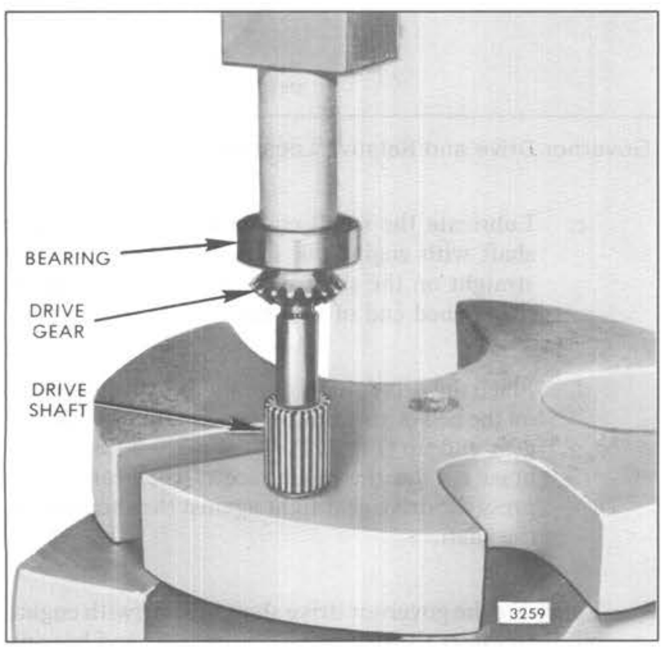


Fig. 17 – Installing Drive Gear and Bearing on Drive Shaft

4. Lubricate the driven gear bearing with engine oil, then insert the driven gear, bearing and sleeve assembly through the top of the drive housing. Start the bearing straight into the bearing bore in the housing. Push the driven gear assembly down in the housing until the teeth of the driven gear mesh with the drive gear (if necessary, rotate one of the gears slightly to align the gear teeth) and the bearing rests on the shoulder in the housing.

5. Install the snap ring in the groove in the housing next to the bearing.

6. Rotate the drive and driven gears and check for freeness and clearance between the gear teeth. The clearance should be .001" to .003".

7. If removed, install the governor control link lever shaft spherical bearing on the shaft as follows:
    a. Lubricate the control link lever shaft bearing with engine oil, then start the bearing straight on the control link lever shaft.
    b. Support the control link lever, shaft and bearing assembly on the bed of an arbor press, with a spacer under the control link lever and shaft as shown in Fig. 19. Place a sleeve on top of the bearing inner race, then press the bearing tight against the control link lever.

8. Lubricate the control link lever shaft bearing with engine oil, then start the control link lever, shaft and bearing assembly straight into the bore in the drive housing (Fig. 10). Push the assembly in until the bearing is tight against the shoulder in the housing.

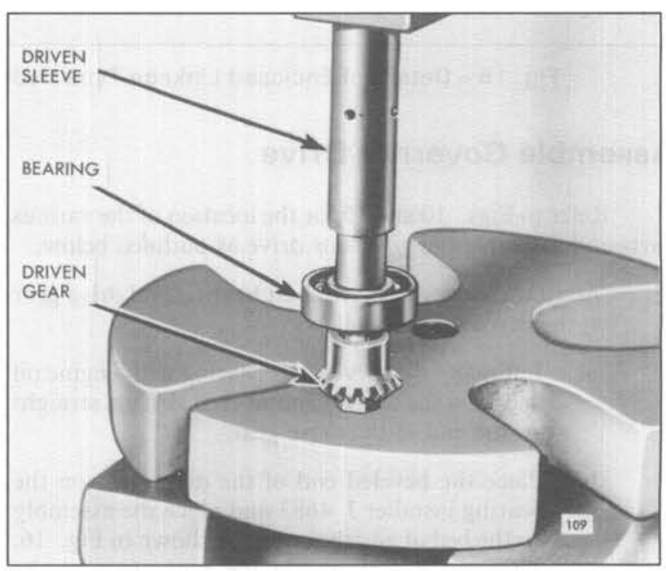


Fig. 18 – Installing Bearing and Driven Sleeve on Driven Gear

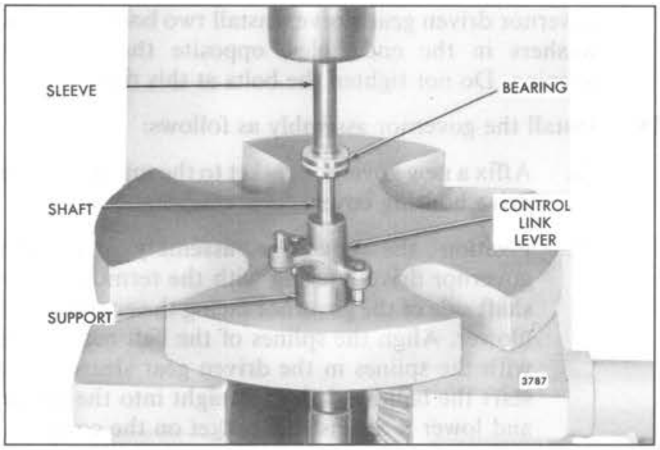


Fig. 19 – Installing Bearing on Governor Control Link Lever Shaft

Be sure to install the proper control link lever, shaft and bearing assembly in the governor drive housing. Refer to Fig. 10 and **NOTE** in Step 2 under *Disassemble Governor Drive.* When the control link lever, shaft and bearing assemblies are correctly installed, the keyway in the outer end of each shaft will face the right–hand side of the engine, as viewed from the rear, when the blower assemblies are attached to the cylinder block.

9. Install the governor control link lever shaft oil seal in the governor drive housing as follows:

   a. Wrap a thin layer of cellulose tape over the snap ring groove and keyway in the outer end of the control link lever shaft to protect the oil seal lip.

   b. Support the governor drive housing on the bed of an arbor press, with a spacer under the end of the control link lever to prevent the bearing from slipping out of the housing (Fig. 20).

   c. Apply a thin coat of sealing compound on the outside diameter of the new oil seal casing, then place the oil seal, with the lip of the seal facing down, over the end of the shaft and start it straight into the bore in the housing. Be careful not to damage the oil seal lip.

   d. Place a 23/32" outside diameter sleeve over the end of the shaft and rest it on top of the seal, then press the oil seal into the housing until it is .340" below the outer face of the housing (Fig. 10).

   e. Remove the tape from the shaft, then place the flat washer over the shaft against the housing and install the snap ring in the groove in the shaft. Install the Woodruff key in the keyway in the shaft.

Install Governor Drive

After the governor drive is assembled, it may be attached to the rear blower, the blower assembly installed on the cylinder block, and the governor attached to the drive housing by following the procedure outlined below:

1. Affix a new gasket to the rear blower front end plate. Then, with the splines of the governor drive shaft and the blower rotor shaft in alignment, insert the drive shaft into the rotor shaft and slide the drive housing on the dowels.

2. Install the ten bolts, seven lock washers and three copper washers which secure the drive housing to the blower end plate. Tighten the bolts to 13–17 lb–ft (18–23 N•m) torque.

   NOTICE: The three copper washers are used on the three long bolts which are exposed to the oil inside the drive housing.

3. Attach the fuel pump assembly to the governor drive housing as follows:

   a. Affix a new gasket to the bolting flange of the fuel pump body.

   b. Place the fuel pump drive coupling fork over the square on the end of the pump drive shaft.

   c. Align the ends of the drive coupling fork with the slots in the drive coupling disc, then place the fuel pump against the governor drive housing with the openings in the fuel pump inlet and outlet elbows facing up.

Make sure the ends (prongs) of the drive coupling fork are in the slots of the drive disc before installing and tightening the attaching bolts.

   d. Install the three bolt and seal assemblies and tighten the bolts to 13–17 lb–ft (18–23 N•m) torque.

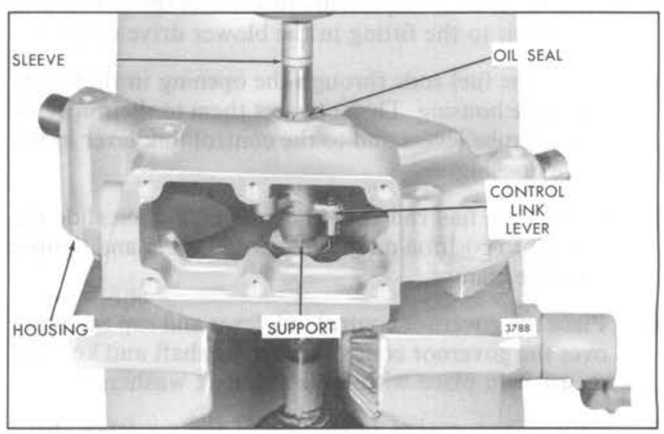


Fig. 20 – Installing Control Link Lever Shaft Oil Seal in Governor Drive

4. Place a hose and clamp on each of the fuel rod tubes in the governor drive housing, then tighten the clamp screws to retain the clamps on the hoses.
5. Affix a new blower housing gasket to the top of the cylinder block. Use a good grade of non–hardening cement to prevent the gasket from shifting when the blower is installed.
6. Thread eyebolts in diagonally opposite tapped holes in the top of the blower housing. Then attach a rope sling and chain hoist to the eyebolts so the blower may be lifted at an angle.
7. Lift the blower assembly, front end first, at an angle and position it over the top of the cylinder block. Lower the blower and start the blower seal on the rear blower end plate cover over the blower drive support. Then move the blower back and lower it against the gasket on the cylinder block.
8. Secure the blower to the cylinder block with bolts, retaining lugs and flat washers and tighten the blower side angle bolts uniformly to 30–35 lb–ft (41–47 N•m) torque in 5 lb–ft (7 N•m) increments. Tighten the blower–to–block end plate bolts to 40–45 lb–ft (54–61 N•m) torque.
9. Attach the tachometer drive adaptor, if used, to the blower, then connect the tachometer drive cable to the drive adaptor.
10. Insert the blower drive shaft through the blower drive flexible coupling and into the blower drive coupling. Then install the snap ring in blower drive flexible coupling.
11. Affix a new gasket to the flywheel housing cover, then attach the cover to the flywheel housing with bolts and lock washers.
12. Place the lower seal clamp in position on the seal and tighten the clamp screw.
13. Slide the blower oil pressure tube out of the blower and connect it to the fitting in the blower drive support.
14. Insert the fuel rods through the opening in the top of the drive housing. Then connect them to their injector control tube levers and to the control link lever in the drive housing.
15. Loosen the fuel rod cover hose clamps, then slide the hoses into position on the covers and tubes and tighten the hose clamps.
16. Place the governor control link lever and cap assembly over the governor control link lever shaft and key and secure it in place with bolts and lock washers.
17. Affix a new gasket to the top of the governor drive housing, then place the housing cover on top of the gasket with the governor opening in the cover over the governor driven gear sleeve. Install two bolts and lock washers in the end holes, opposite the governor opening. Do not tighten the bolts at this time.
18. Install the governor assembly as follows:
    a. Affix a new governor gasket to the top face of the drive housing cover.
    b. Position the governor assembly over the governor drive housing with the terminal lever shaft side of the governor facing the engine front blower. Align the splines of the ball head shaft with the splines in the driven gear sleeve, then start the ball head shaft straight into the sleeve and lower it against the gasket on the cover.
    c. Install the four bolts and lock washers which secure the governor assembly to the drive housing cover. Tighten the bolts to 13–17 lb–ft (18–23 N•m) torque.
    d. If removed, install the governor operating lever on the terminal lever shaft, then connect the vertical control link assembly to the operating lever and the governor control link common lever and cap assembly.
19. Attach the governor operating solenoid to the governor drive housing, then connect the electrical wires to the solenoid terminals.
20. Connect the oil inlet and outlet tubes to the governor operating solenoid, governor and drive housing.
21. Attach the governor oil reservoir to the governor drive housing, then connect the oil inlet, outlet and return tubes to the oil reservoir, governor and drive housing.
22. Connect the fuel oil inlet and outlet pipes to the fuel oil pump.
23. Attach the battery charging alternator to the engine flywheel housing, then connect the electrical wires to the alternator.
24. Attach the air shutdown housing to the top of the blower.
25. On industrial units, install the air inlet pipe between the air cleaner, or turbocharger, and the air shutdown housing on the rear blower.
26. On marine units, install the air inlet pipe between the air cleaner and the air shutdown housing on the rear blower.
27. Connect the throttle control linkage to the governor speed control lever.
28. Perform an engine tune–up as outlined in Section 14.

Refer to Shop Notes (section 2.0) before installing a Barber–Coleman electronic governor on an engine previously equipped with a hydraulic governor.

HYDRAULIC GOVERNOR SYNCHRONIZING MOTOR

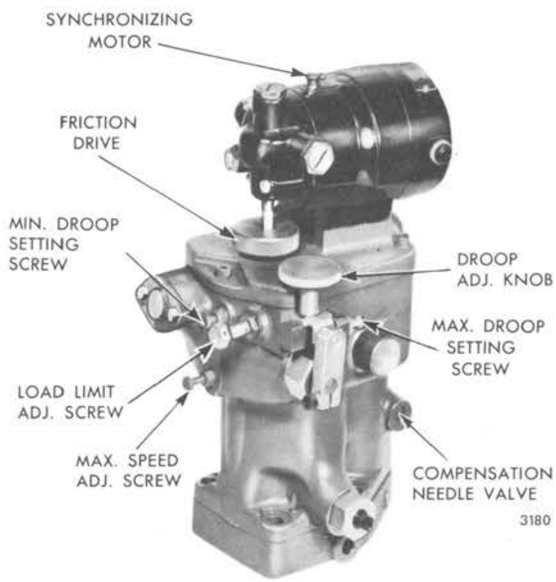


Fig. 1 – Synchronizing Motor Mounting

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.

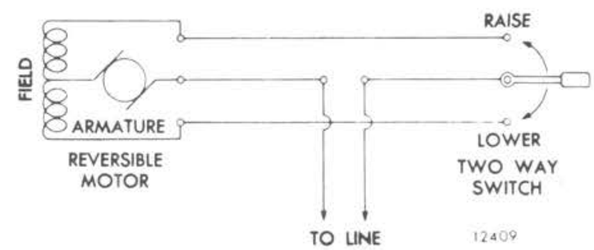


Fig. 2 – Synchronizing Motor Wiring Diagram

When the two–way control switch on the control panel is closed, the motor shaft turns the governor speed adjusting shaft by means of the reduction gear and friction drive. The direction of rotation (clockwise or counterclockwise) is dependent upon the position of the switch. When the desired engine speed is indicated on a tachometer or frequency meter on the control panel, the switch is returned to the *off* position by the operator.

If the switch is held in the *lower* speed position too long, the synchronizing motor will continue to lower the engine speed until it ultimately shuts the engine down. If the switch is held too long in the *raise* speed position, the motor will turn the governor speed adjusting shaft until it strikes the maximum speed adjusting screw, after which the friction drive will slip and the motor will continue to run at a slightly reduced speed without further effect.

Service

The synchronizing motor is constructed to render long satisfactory service. However, if the motor is damaged or fails to operate, replace the entire motor as an assembly.

The spring washer of the friction drive must be strong enough to permit the motor to carry the speed adjusting lever up against the maximum speed adjusting screw without slipping, yet it must be loose enough to slip after the lever contacts the screw.

FUEL INJECTOR CONTROL TUBE

The fuel injector control tube assemblies are mounted on the left and right bank cylinder heads of an engine and consist 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 each cylinder head (Fig. 1).

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 spring–loaded injector control tube assemblies (Fig. 2), similar to the above except they have a yield spring at each injector rack control lever and only one screw and lock nut 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.

NOTICE: 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 shut down 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.

CAUTION:To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.

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.

Assemble Injector Control Tube

With all of the parts cleaned and inspected and the necessary new parts on hand, refer to Fig. 1 or 2 and assemble as follows:

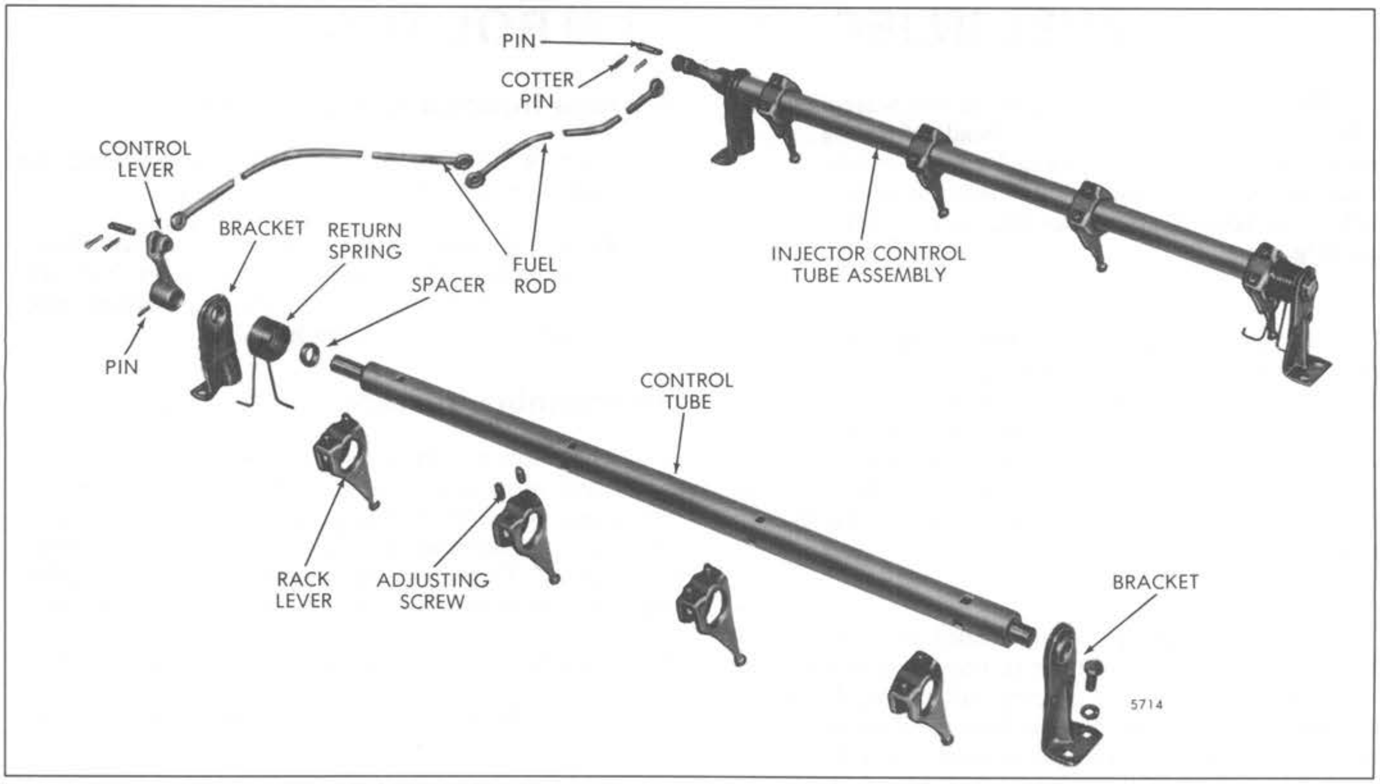


Fig. 1 – Injector Control Tube Assemblies (Non–Spring Loaded)

LEFT BANK 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 the 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. On both designs, attach the curled end of the control tube return spring to the rack control lever and the extended end of the spring behind the front bracket.

4. On both designs, install the rear bracket on the end of the injector control tube.

RIGHT BANK 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 rear 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 rear bracket.

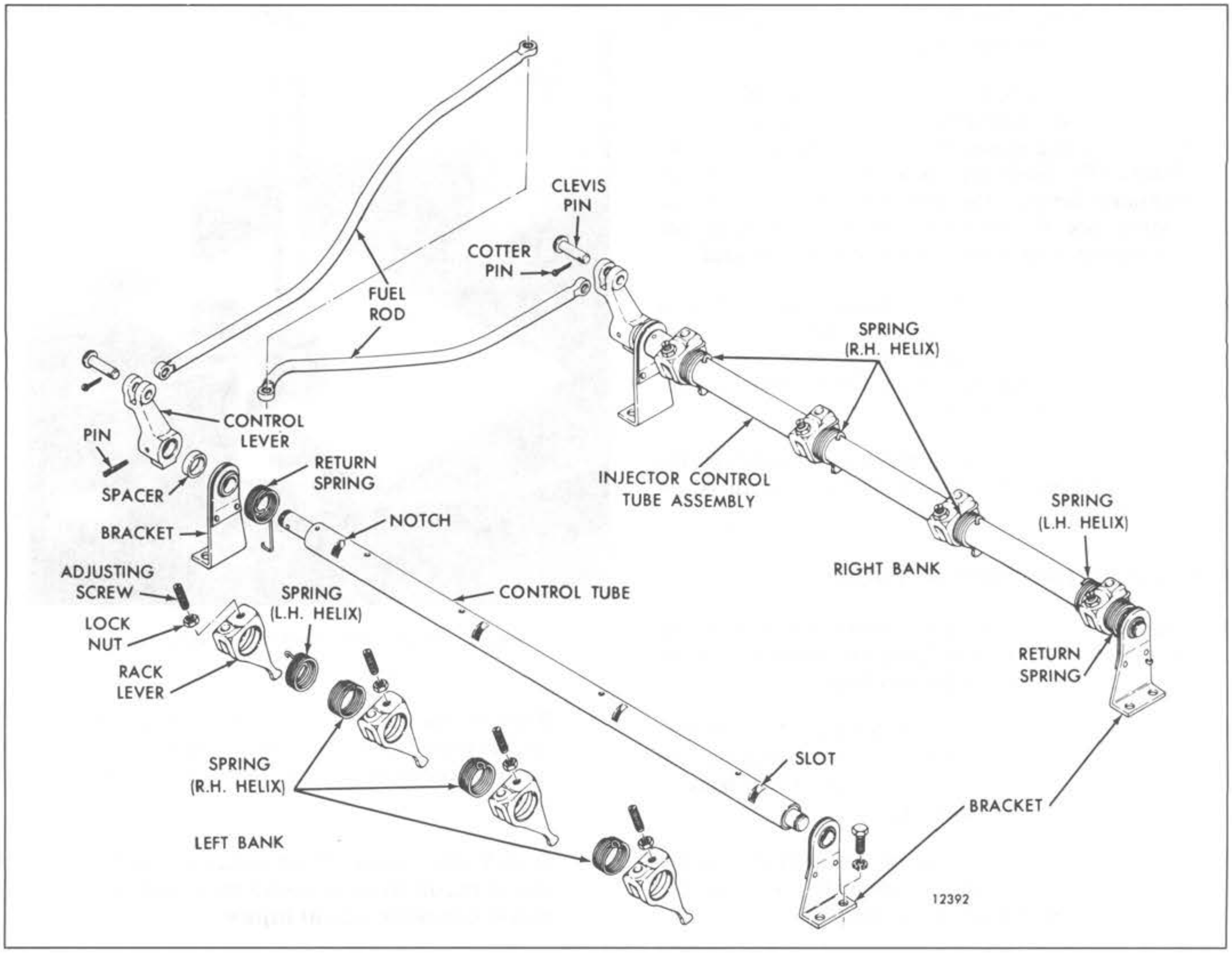


Fig. 2 – Injector Control Tube Assemblies (Spring-Loaded)

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.
2. Fabricate an indexing bracket from a 5" long piece of 1/2" wide, 1/8" thick bar stock (Fig. 3). Secure the indexing bracket to the control tube with a hose clamp (Fig. 4).
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.

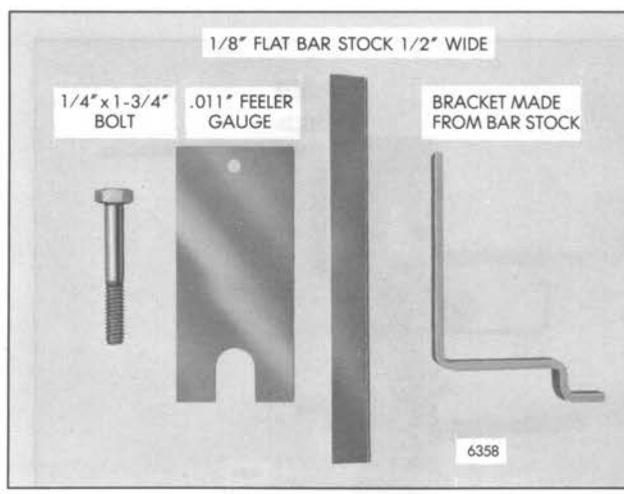


Fig. 3 – Fabricate Indexing Bracket

4. Remove the pin from the control lever and press the old lever off the control tube (Fig. 5).

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 with the bolt resting against the indexing bracket (Fig. 6). 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. (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.

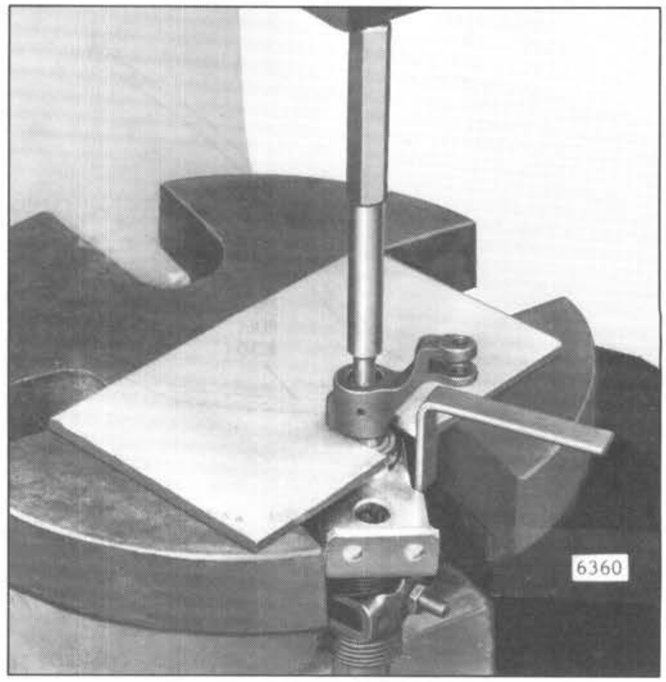


Fig. 5 – Press Old Lever off Control Tube

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 N•m) 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.

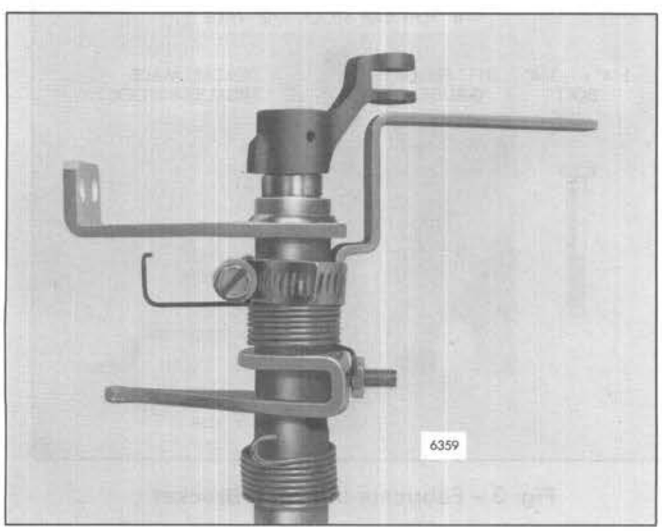


Fig. 4 – Secure Indexing Bracket to Control Tube

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.

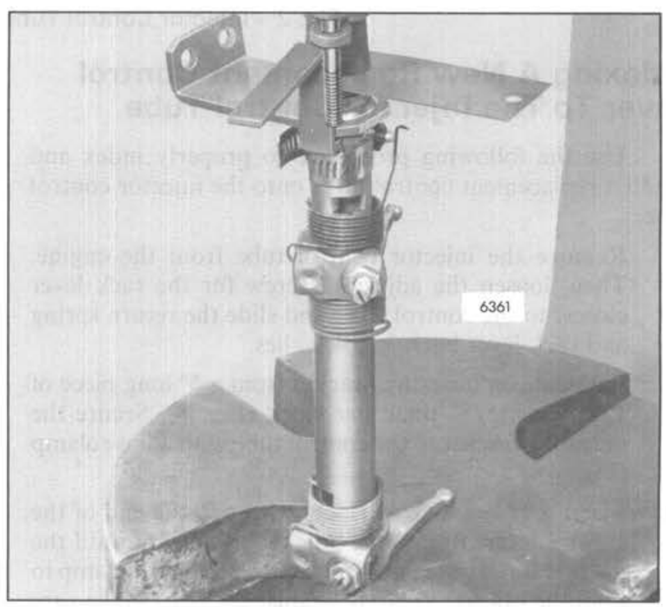


Fig. 6 – Installing New Lever

SHOP NOTES - TROUBLESHOOTING SPECIFICATIONS - SERVICE TOOLS

SHOP NOTES

INJECTOR TESTER J 23010-A

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.

Use injector test oil J 26400 in the injector tester.

Installing Fuel Injector In Tester

1. Select the proper clamping head (Fig. 1). Position it on the clamping post and tighten the thumb screw into the lower detent position (Fig. 2).
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. 1).
6. Swing the mounted injector and adaptor plate inward until they contact the stop pin at the rear of the support bracket.

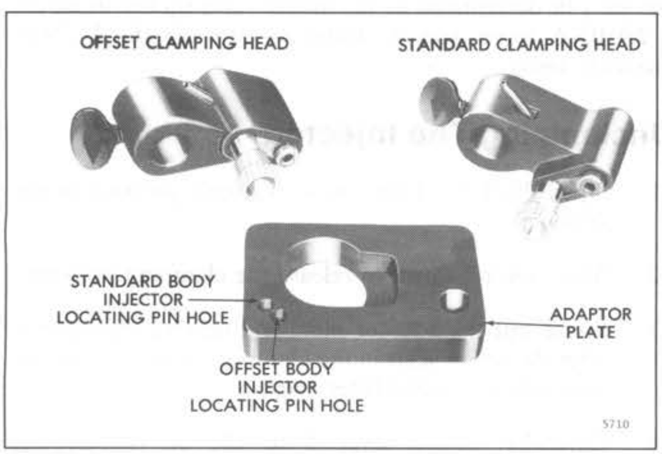


Fig. 1 - Injector Tester J 23010-A Clamping Heads

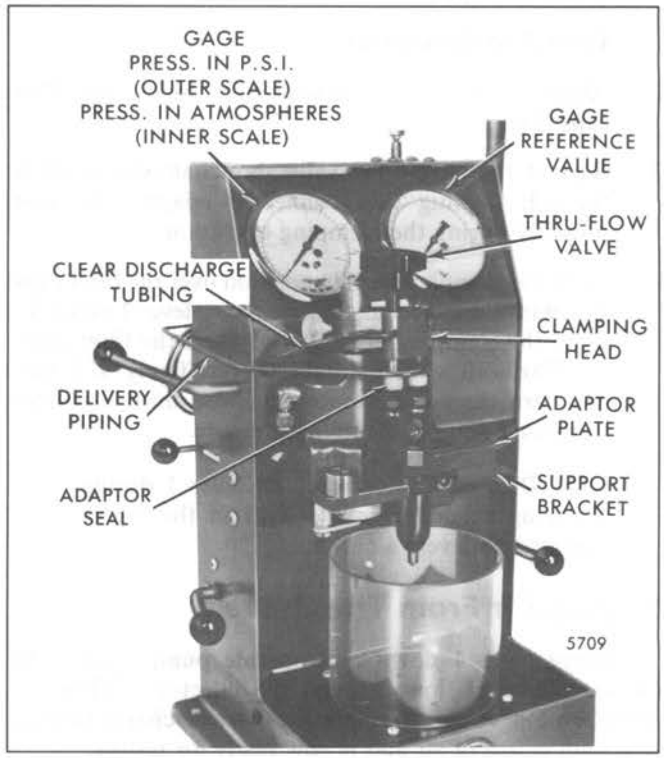


Fig. 2 - Injector Installed in Tester J 23010-A with Clamping Head

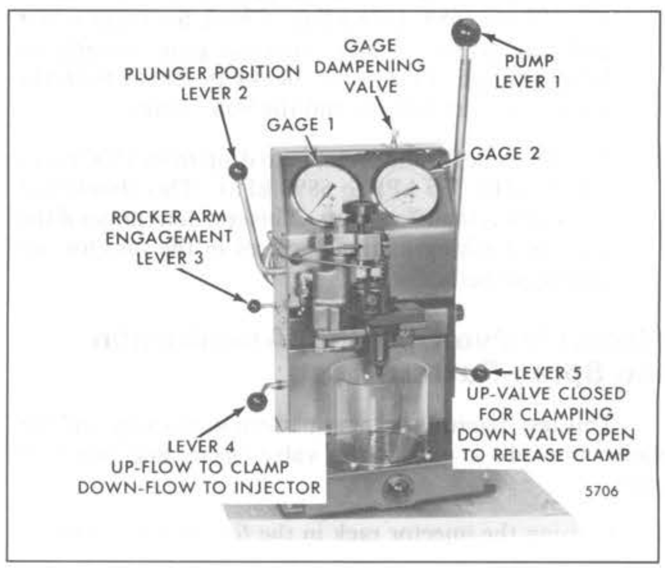


Fig. 3 - Injector in Position for Testing with J 23010-A

Clamping The Fuel Injector

1. Refer to Fig. 3 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 seals over the injector filter caps (Fig. 2).

3. Back off the Thru–Flow valve about half–way to allow the self–aligning fuel connector adaptors 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.

   NOTICE: 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.

Check the injector for leaks as follows:

1. Operate pump lever 1 until gage 1 slowly reaches 100–200 psi (689–1378 kPa). Check for injector nut seal ring leaks. Then, increase gage reading to 1500–2000 psi (10 335–13 780 kPa). Check for leaks at the filter cap gaskets and the body plugs.

2. Note the time for the pressure to drop from 1500 psi to 1000 psi (10 335 kPa to 6890 kPa). This should not occur in less than 7 seconds. This test determines if the body–to–bushing mating surfaces in the injector are sealing properly.

Injector Valve Opening, Atomization And Spray Pattern Test

This test determines spray pattern uniformity and the relative pressure at which the valve opens and injection begins.

1. Position the injector rack in the *full–fuel* position.

2. Place pump lever in the *vertical* position.

3. Move the rocker arm engagement lever to the forward detent (Fig. 4).

4. Turn the gage damping valve knob (Fig. 3) clockwise to the *closed* position, then open the vlave slightly to control the rate of return of the gage hand. This valve is deleted on the current testers.

5. Operate the pump lever uniformly and observe the spray pattern produced.

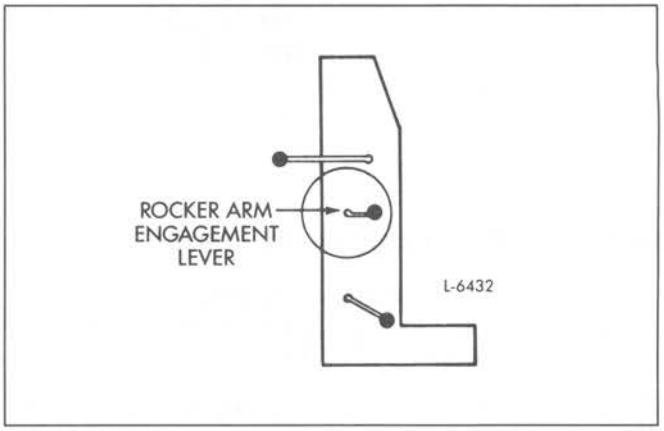


Fig. 4 – Position of Rocker Arm Engagement Lever

Some experimentation may be necessary to determine the most effective rate at which the injector should be stroked. The correct rate is the one that produces the highest gage reading, too fast or too slow will give low readings.

The highest pressure indication will be reached just before injection ends. Use the following reference values to determine the relative acceptability of the injector (138 Min. – 162 Max.).

The reference values obtained when pop testing the needle valve injectors are to be used as a troubleshooting 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 the J 23010–A tester and tip tester adaptor on the J 22640 auxiliary tester.

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.

CHECKING INJECTOR TESTER J 23010–A OR J 9787

The injector tester J 23010–A 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–A 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 holding pressure test.

If it is suspected that the lines have been altered, i.e. by shortening or replacing with a longer line, check the accuracy of the tester with a master injector on which the pressure holding time is known. If the pressure holding time does not agree with that recorded for the master injector, replace the lines.

INJECTOR SPRAY TIP TESTER (J 22640–A)

Valve Opening, Spray Pattern and Atomization.

1. Operate the pump handle until a clear flow of test oil is obtained at the tip mounting pedestal.
2. Place the tip assembly, valve spring with cage and check valve cage on top of the pedestal. Tighten the injector nut (Fig. 5).

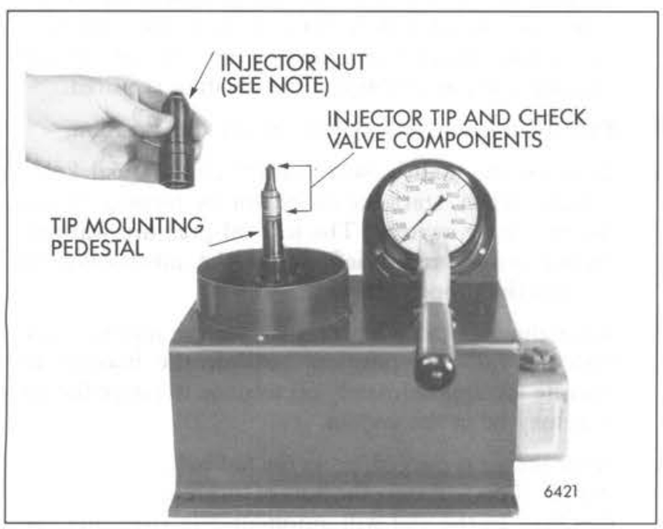


Fig. 5 – Installing Injector Nut

3. Place the shield on the tester and operate the pump handle until the needle valve has opened several times to purge air from the system (Fig. 6).

CAUTION: Do not operate the tester without the shield. The fuel spray 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.

4. Operate the pump lever 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 needle valve and spring which should open between 1700 and 2300 psi (11 713 and 15 847 kPa). When using the high V.O.P. spring, the oil delivery will occur at 2900–3900 psi (19 981–26 871 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 the minimum specified limits or atomization is poor, the cause is usually a weak valve spring or poor needle valve seat.

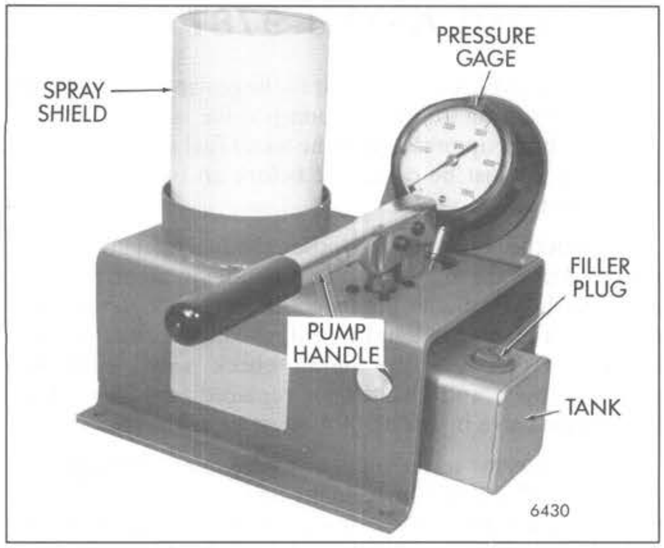


Fig. 6 – Tester J 22640–A with Shield Installed

If the valve opening pressure is within specified limits, proceed to check for spray tip leakage as follows:

When testing for spray tip leakage, 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.

Field Modification Kit (J 22640–51) consists of a pump and reservoir with hardware which is used to convert auxiliary tester J 22640 to J 22640–A. Tester J 22640 was previously connected to the pump of the pop stand.

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.

Field Modification Kit (J 25600–103) upgrades plunger and bushing/tip flow gage J 25600 to J 25600–A. The kit includes adaptors for Series 53 plunger and bushings. A newly designed spray tip receiver/holder is included with the kit along with instruction decals to be applied to the tester. This kit greatly upgrades the function of J 25600 by improving operation and repeatability.

CHECK INJECTOR OUTPUT

Perform the injector fuel output test in calibrator J 22410–A (Fig. 7).

1. Before testing injector output, be sure calibrator test oil is supplied to the injector fitting located over the rack. To change the flow from the calibrator, exchange the positions of the braided and the clear fuel lines (Fig. 8).
2. Place the cam shaft index wheel and fuel flow lever in their respective positions. Turn on the test fuel oil heater switch to preheat the test oil to 95–105°F (35–40°C).
3. 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.
4. Place the injector seat J 22410–226 into the permanent seat (cradle handle in the *vertical* position). Clamp the injector into position by operating the injector clamp–up valve.

   Set the counter (Fig. 9) at the appropriate number of strokes, 500 or 1,000. If for any reason this setting has been altered, reset the counter for the correct number of strokes. Calibrators with Serial No. 1175 or lower were manufactured as 1,000 stroke machines, but may have been converted to 500 stroke machines with a conversion kit (J 22410–516). Refer to the calibrator instruction manual for information on setting the counter and any additional information required.
5. Pull the injector rack out to the *no–fuel* position.
6. Turn on the main power control circuit (vial light) switch. Then, start the calibrator by turning on the motor starter switch. The low oil pressure warning buzzer will sound briefly until the lubricating oil reaches the proper pressure.
7. 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.
8. After the air is purged, press the red button on the test switch. This will start the flow of fuel into the vial. The fuel flow to the vial will automatically stop after the correct number of preset strokes are counted.

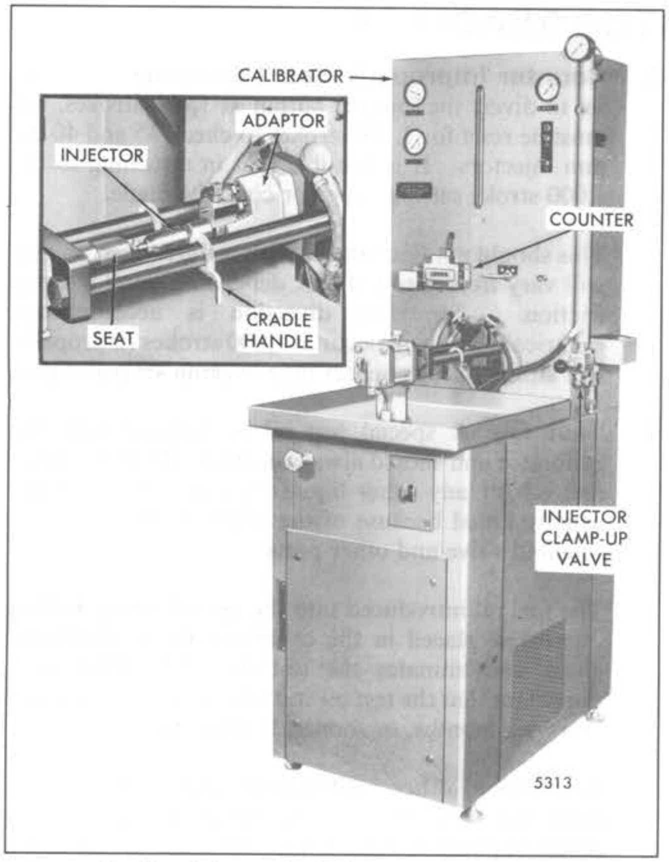


Fig. 7 – Injector in Calibrator J 22410–A

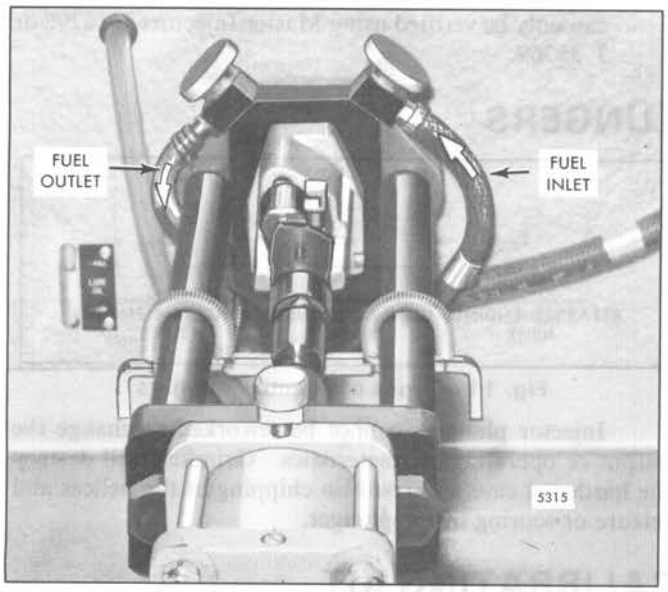


Fig. 8 – Position of Calibrator Fuel Flow Pipes

9. Shut the calibrator off when two consecutive tests show the same output. Usually, 3 tests are sufficient.

10. Observe the vial readings and refer to Table 1 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 *Troubleshooting Chart 3* for the cause and remedy. See *Injector Calibrator Readings* for different factors that may affect the injector calibrator output reading.

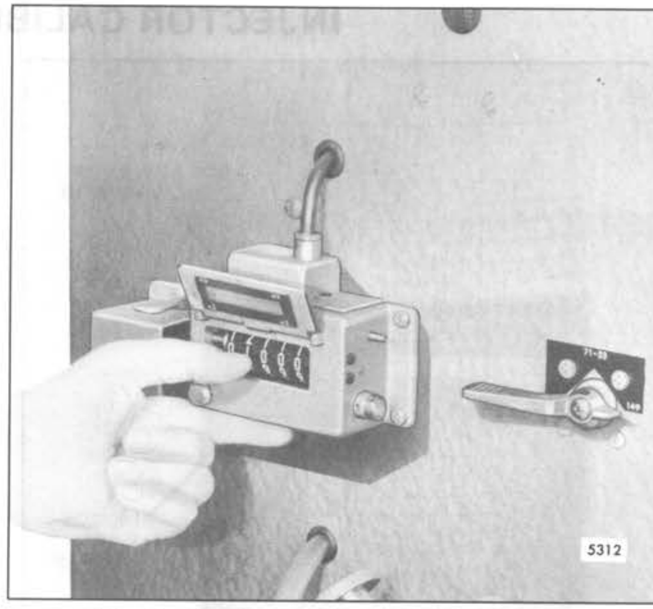


Fig. 9 – Setting Calibrator Stroke Counter

INJECTOR	MIN.	MAX.	INJECTOR	MIN.	MAX.
9270	65	75	9B90	85	91
9275	70	76	9C70	65	71
9280	75	81	9C75	70	76
9285	80	86	9C80	75	81
9290	85	91	9C90	85	91
9295	90	96	9E65	70	75
9200	95	101	9E70	75	80
9215	110	116			
9225	118	126			
9A80	75	81	9F90	85	91
9A85	80	86	7G65	67	72
9A90	85	91	7G70	72	77
9B70	65	71	7G75	77	82
9B75	70	76			
9B80	75	81			
9B85	80	86			

TABLE 1

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.

INJECTOR CALIBRATOR READINGS

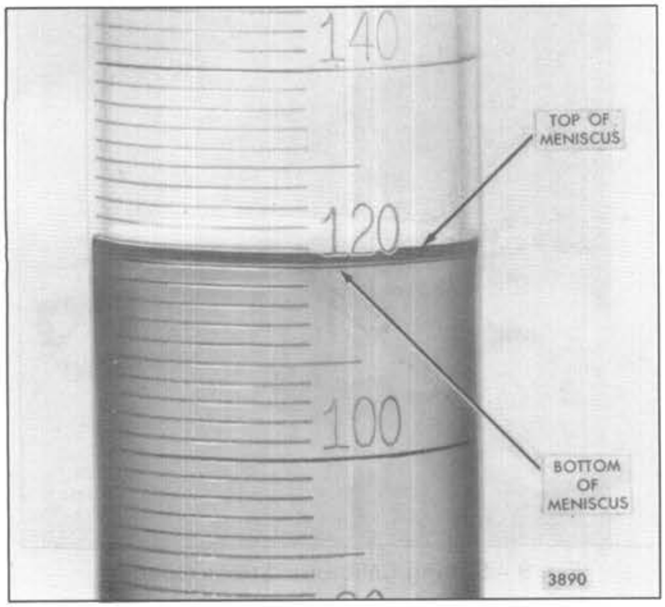


Fig. 10 – Checking Fuel Output

Several factors affect the injector calibrator output readings. The four major items are:

1. **OperatorErrors:** 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. 10.
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. Calibrator accuracy can only be verified using Master Injectors J 26298 or J 35369.

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. 11. 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.

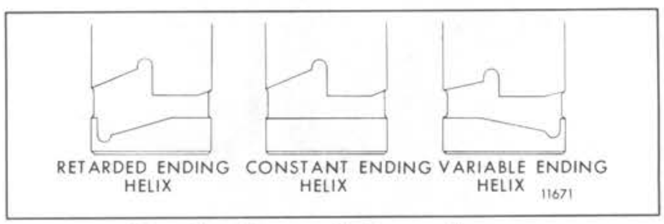


Fig. 11 – Types of Injector Plungers

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 or J 35369 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.

PLUNGER/BUSHING AND TIP FLOW GAGE

The injector fuel output is largely dependent upon the combined output of its plunger/bushing and spray tip assemblies. To assist in the rebuilding of fuel injectors that will calibrate within specified limits, it is desirable to preselect and match plunger/bushings and tips according to their output prior to assembly into the injector.

The J 25600–A Plunger/Bushing and Tip Flow Tester, using low pressure air, has the capabilities to measure the output of plunger/bushing and spray tip assemblies. The flow (output) of the spray tip can be correlated to high pressure fuel flow during calibration however, used spray tips because of the worn condition of their spray holes will often flow higher then indicated on a low pressure air tester.

Records should be maintained which indicate the output values of both plunger/bushing and spray tip assemblies being matched with resultent calibration in order to develop a useful matching chart.

Installation

Place the flow gage unit in a clean well lighted area that has an air supply of 40 psi (276 kPa), but not more than 150 psi (1034 kPa). Turn off the air supply valve (on the rear of the flow gage) and connect your air line. Familiarize yourself with the various components on the unit (Fig. 12).

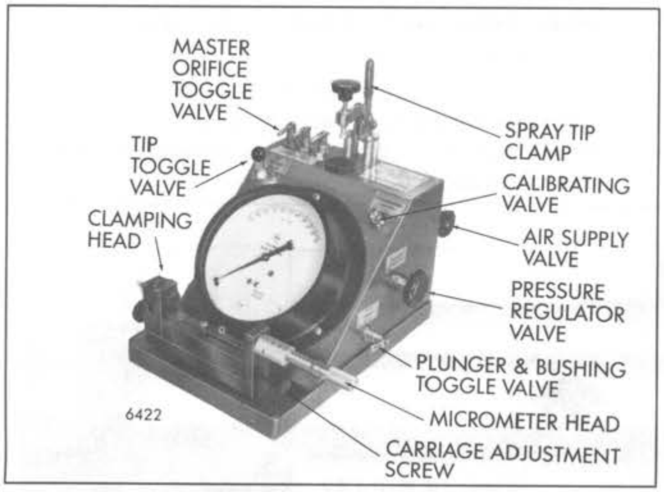


Fig. 12 – Plunger/Bushing and Tip Flow Gage J 25600–A

Regulated Pressure Adjustment

1. Set all toggle valves in the *closed* position (Fig. 12).
2. Open the calibrating valve approximately 4 turns.

NOTICE: DO NOT use this valve as an air shutoff. Tight closing of this valve may result in valve seat damage.

3. Turn the pressure regulator knob in a counterclockwise direction until it spins freely.
4. Open the air supply valve approximately 3 turns. The pressure regulator is a constant bleed type (.04 cubic feet per minute), the air supply valve is provided as a convenient shutoff to avoid compressed air waste when the flow gage is not in use.
5. Adjust the pressure regulator by rotating the knob in a clockwise direction until the gage needle is aligned exactly on the regulated pressure mark.

Calibration To Master Orifice

When no air is leaking through a master orifice, injector tip or plunger/bushing, the gage needle will go to the regulated pressure mark. The master orifices (A, B and C) are provided as controlled air leak passages. Flow tests are conducted comparing an injector tip or a plunger/bushing, to an air leak through a master orifice.

1. Be sure all toggle valves are in the *off* position. The gage needle will be at the regulated pressure mark.
2. Open master orifice valve A. The gage needle will move away from the regulated pressure mark.
3. Adjust the calibrating valve, so that the gage needle is exactly at the "set line" (Fig. 13).
4. Close the master orifice toggle valve (needle will return to the regulated pressure mark).
5. You are now ready to perform a flow measurement.

Measuring Spray Tip Flow

1. Clean all spray tips thoroughly (correct flow rate is dependent on a clean spray tip).
2. Observe the number and size of the spray tip holes marked on the narrow end of the spray tip and calibrate to orifice A. Refer to the Chart for the flow values.
3. Remove the needle valve, if installed, and clamp the spray tip on the unit (Fig. 14).
4. Open the tip toggle valve and observe the gage reading.
5. The tip can now be compared to the specification sheet and sorted into groups; high, low, mean, etc.

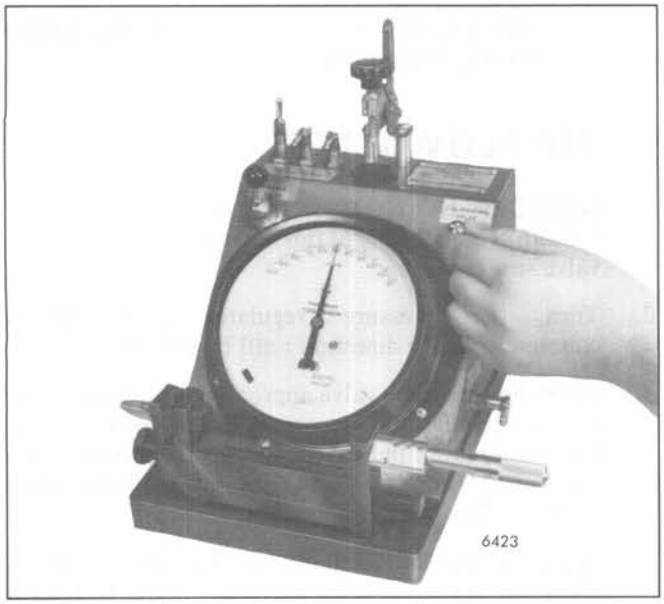


Fig. 13 – Adjusting the Calibrating Valve

TIP STAMP	NOMINAL FLOW VALUE	MASTER ORIFICE CALIBRATION
6–.006	22	A
7–.006	69	
8–.0055	26	
8–.006	48	
9–.0055	48	
9–.0058	69	

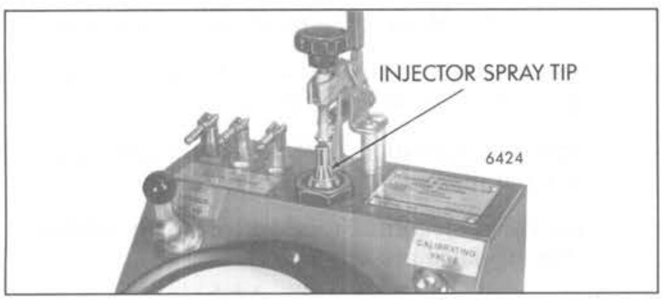


Fig. 14 – Spray Tip Installed in Tester

Plunger/Bushing Effective Stroke Measurement

The reason for measuring the flow thru the plunger/bushing assemblies is to measure the effective stroke (port closing to opening), in thousandths of an inch. To find the closing and opening points a controlled air leak is used ("A" master orifice is used as reference). When the plunger is moved close to the port *closed* position, the gage needle will be at the set line. At this position, the air leaking out the bushing port matches the air that would leak out the "A" orifice.

As the plunger is moved inward, the leak stops and the gage needle goes to the regulated pressure mark. When the

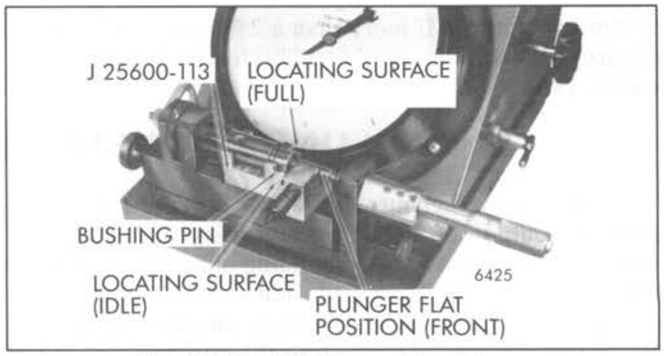


Fig. 15 Cradle Mounted on Fixture

plunger is moved further, air begins to leak again. The gage needle moves away from the regulated pressure mark and moves toward the set line. When the plunger is moved far enough to read the effective stroke, the gage needle will be at the set line again. The distance the plunger has moved as indicated on the micrometer, is the effective stroke. This stroke is measured while the plunger/bushing is held in the *full–fuel* position.

1. Select the proper cradle for the plunger/bushing to be tested and mount on the fixture (Fig. 15).
2. Calibrate to the "A" orifice, see "Calibration to Master Orifice". All plunger/bushing tests use the "A" orifice as reference.
3. Close all toggle valves, gage needle will be at the regulated pressure mark.
4. Adjust the micrometer to zero reading (all zeros).
5. Place the plunger/bushing in the cradle. Be sure the plunger flat and locating pin or slot is properly positioned (Fig. 15). To check in *full–fuel* position, rotate bushing until the bushing pin contacts the rear locating surface.
6. Adjust spring loaded button until enough force is exerted on the plunger flat to hold the plunger steady, but not enough to restrict sliding movement when air pressure is applied.

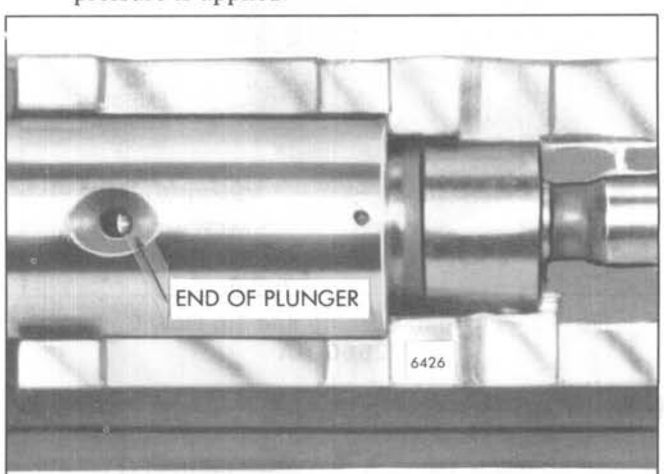


Fig. 16 – End of Plunger Shown in Port

7. Hold the plunger against the micrometer and rotate the carriage adjustment screw until the plunger almost closes the port (Fig. 16).
8. Open the plunger and bushing toggle valve.
9. If the plunger has not closed the port far enough, an air leak will be heard and the gage needle will be left of the set line. If it has closed the port too far, it will be to the right of the set line, toward or at the regulated pressure mark.
10. Turn the carriage adjustment screw until the gage needle is at approximately 20.
11. Turn the carriage adjustment screw clockwise very slowly until the gage needle is exactly at the set line. Always adjust in this manner, with the needle moving from approximately 20 to the set line.
12. Turn the micrometer thimble clockwise. The gage needle will move toward, and go to the regulated pressure mark. Very little air will be heard leaking.
13. Continue turning clockwise until the gage needle begins to move away from the regulated pressure mark (air from the bushing will again be heard leaking). Turn very slowly until the gage needle reaches the set line.
14. Observe and record the micrometer reading. The number shown is the effective stroke in thousandths of an inch.
15. Turn the micrometer back to zero. Gage needle should return to or very near the set line.
16. Turn off the plunger/bushing test toggle valve.
17. Loosen the clamping knob and remove the plunger/bushing.
18. Only minor carriage adjustment will be required for other plunger/bushing of the same type.
19. Chart the stroke readings and compare to the specifications. Sort into groups, high strokes, low strokes and mean strokes.

REFINISH LAPPING BLOCKS

As the continued use of the lapping blocks will cause worn or low spots to develop in their lapping surfaces, they should be refinished from time to time.

It is 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. 17). 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.

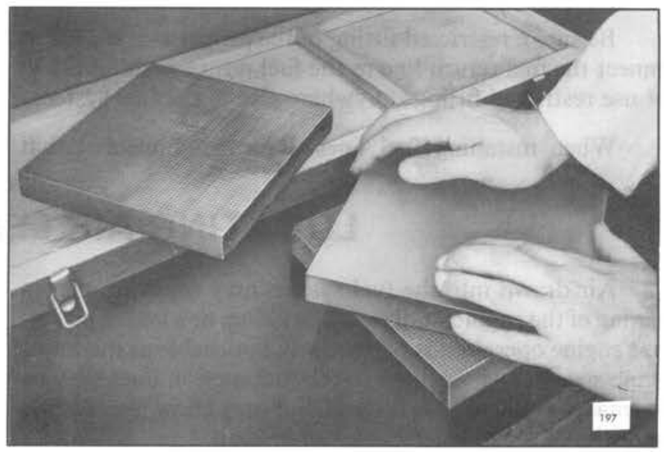


Fig. 17 – Refinishing Lapping Blocks

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

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.

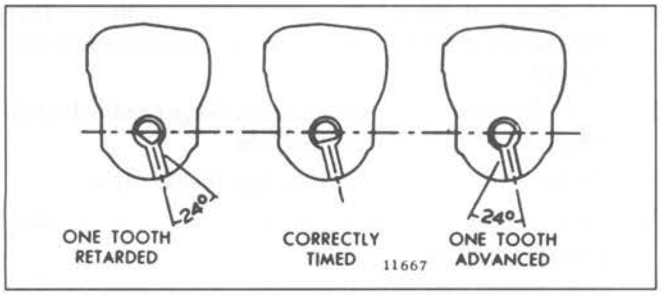


Fig. 18 – Injector Rack–to–Gear Timing

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. 18) and appears in the "advanced" or "retarded" position, disassemble the injector and correct the rack–to–gear timing.

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 fifteen (15) to twenty (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 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.

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 ten to twenty 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.

NOTICE: 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 cavities in the injector are subjected to the high test pressure, fuel is forced past the plunger into the rack and gear cavity. 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 lubricating 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 (118 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 DDC 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 DDC guidlines for pressure holding test (see Section 2.1.1) and the specification for lube oil dilution (2.5).

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.

FUEL JUMPER LINE MAINTENANCE AND REUSE

Maintenance and service personnel should be aware that severe engine damage could result from fuel oil leakage into the lubricating oil and should therefore, follow proper procedures when removing, handling and installing fuel jumper lines (fuel pipes).

The fuel jumper lines which carry fuel to and form the fuel injectors must be handled and installed very carefully to prevent line damage that can result in severe engine damage. Severe fuel leakage, if not detected, can also result in an over–filled crankcase (oil pan) which can cause an abnormal amount of fuel and lubricating oil vapor to escape from the engine and crankcase breathers. An abnormal concentration of fuel and lube oil vapors is flammable and could ignite in a closed engine compartment.

The following are some of the conditions that can result in fuel jumper line leakage:

1. Improper handling and storage of jumper lines when servicing the engine can result in physical damage and contamination.
2. Careless use of special tool (socket) J 8932–01 during removal or installation can cause a jumper line to bend and be permanently distorted.
3. Reuse of a bent or distorted jumper line can result in excessive stress and cause the line to crack or fracture at or above the flared ends of the jumper line. A fuel leak will ultimately result.
4. Excessive tightening of the jumper line nut will distort and fracture the flared end of the jumper line, resulting in a fuel leak.

NOTICE: DDC recommends that the original fuel pipes not be reused. New flared end fuel pipes should be installed. When installing flared end fuel pipes, use fuel pipe nut wrench J 8932–01 and "clicker" type torque wrench J 24405 (calibrated in inch– pounds) to apply proper torque and avoid damaging the fuel pipes. Refer to the chart for torque specifications. Fuel leakage from damaged or improperly installed fuel pipes can cause lube oil dilution, which may result in serious engine damage.

To help insure more consistent fastening, tighten fuel pipe nuts on jumper lines to the single torque values shown below. Use fuel line nut wrench J 8932–01 and "clicker" type torque wrench J 24405 (calibrated in inch–pounds).

NOTICE: Because of their low friction surface, Endurion®–coated nuts on fuel jumper lines must be tightened to 130 lb–in (14.69 N•m) torque, instead of the 160 lb–in (18.3 N•m) required with uncoated nuts. To avoid possible confusion when tightening jumper line nuts, do not mix lines with uncoated and Endurion®–coated nuts on the same cylinder head.

Jacobs brake jumper lines and jumper lines used with load–limiting devices do not have coated nuts. Tighten these to the values shown on the Chart.

NOTICE: When installing fuel jumper lines, *Do Not Overtighten.* Damage to the jumper line flares and connector seats can result from excessive tightening, causing fuel leakage into the lubricating oil.

Jumper Line Usage	Torque
Endurion®-coated	130 lb-in. (14.69 N·m)
Uncoated	160 lb-in. (18.3 N·m)
Jacobs Brakes*	120 lb-in. (13.6 N·m)
Load limiting devices	160 lb-in. (18.3 N·m)
DDEC Engines	145 lb-in. (15.6 N·m)

**Not serviced. Available from Jacobs Manufacturing Company.*

Jumper Line Nut Torque

5. Damaged threads and flare seats on the injector and cylinder head jumper line connectors can also result in fuel leakage.
6. Leaks can also occur at injector filter nut gaskets and/or cylinder head connector washers due to distortion, damage or incorrect torque.

The following troubleshooting procedure is recommended after installation of fuel jumper lines and/or connectors to determine if fuel leakage is present.

Checking For Fuel Leaks

Always check the fuel system for leaks after injector or fuel jumper line replacement and any time the fuel connections under the rocker cover are suspected of leaking. Failure to correct a fuel leak in this area can lead to dilution of the lube oil. Use one of the following methods to check for leaks.

METHOD A

Use when the engine has been operating 20–30 minutes. After operating the engine, shut it off and remove the rocker cover(s). Discard the gasket(s). Inspect the lube oil puddles that normally form where the fuel connectors join the cylinder head and where the fuel jumper lines join the fuel line 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 B

Use when the engine is not operating such as during or after repairs. Remove the rocker cover(s). Discard the gasket(s). Pour clean lube oil over the fuel jumper lines 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 A. Plug the fuel return line at a convenient location (cylinder head or fuel tank, for example). Disconnect the fuel pump supply line at the inlet of the secondary filter. Connect an external source of pressurized fuel (60–80 psi or 414–552 kPa) to the inlet of the secondary filter cover. Install a pressure gage (0–100 psi or 0–689 kPa) at the outlet of the filter cover. Gage installation can be accomplished by installing a "T" fitting between the filter cover and outlet line or by removing the pipe plug at the outlet in the cover. Use of a gage will allow ready reference to the fuel pressure being maintained for this test. Severe leaks are immediately visible and minor leaks take longer to appear. It may be necessary to maintain fuel pressure for a period of 20 to 30 minutes in order to find minor leaks. Leaks may be repaired by replacing damaged parts or determining if the part is loose and below torque specifications. Test and reinspect.

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 B. Injectors should be removed from the engine and high pressure tested as outlined in Section 2.1 or 2.1.1.

METHOD C

Use while the engine is operating at 400–600 rpm. Apply an outside fuel source capable of 60–80 psi (414–552 kPa) to the outlet side of the secondary filter. Pour lube oil over the fuel jumper lines and connectors so that oil puddles form where jumper 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 60–80 psi (414–552 kPa). After 10–20 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.

Slightly worn injector 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 exist.

METHOD D

Fluorescent dye fuel leak testing. When testing an engine that has been in service, it will be preferable to use the fluorescent dye and black light method of testing. Proceed as follows:

1. Mix 4 oz. of fluorescent additive J 28431 with 4 gallons (15 liters) of clean diesel fuel (#1 or #2) in a clean container. The container should be marked "Test Fuel" and be resealable so that it won't be contaminated when not being used.

2. Isolate the engine fuel system so that the supply and return fuel lines are connected only to the test fuel container. It will be necessary to intermittently check the fuel level to maintain an adequate supply.

3. Warm up the engine by operating it at maximum no–load speed for approximately 15 minutes.

4. With the engine idling and the rocker cover removed, shine the black light over the head assembly. The lube oil will show a dull blue. If a fuel leak is present, the fuel with the fluorescent dye will glow a bright yellow.

5. After the cause of the fuel leak has been determined and corrected, wipe the area and fuel connections clean and recheck with the black light. When no leaks are present, reassemble the unit with the original fuel lines and normal fuel source. It is not necessary to change the fuel filters. Run the engine to purge the air from the fuel system.

With the engine at rest, all injectors will leak to some extent when pressurized. The leakage occurs because there is no other place for the pressurized fuel to go. When the low and high pressure cavities in the injector are subjected to the high test pressure, fuel is forced past the plunger into the rack and gear cavity. Result: Droplets of fuel form at the rack and drip off. Special consideration must be given to this weepage. If considered to be excessive, the injector should be removed and tested for pressure holding capabilities.

NOTICE: 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.

Use new gasket(s) and reinstall the valve rocker cover(s).

POINTS TO REMEMBER

1. Lube oil puddle inspection is one method of testing the fuel system for internal leaks. The missing puddles show where the leaks are. This test can be performed any time the rocker covers are removed, after the fuel jumper lines and connectors have been splashed with clean lube oil and there is normal fuel pressure in the system.

2. All leakage or spillage of fuel during leak detection testing further dilutes the lube oil.

3. The final step in maintenance of this type should include lube oil filter changes if a fuel leak is detected.

4. Oil level above the dipstick "full" mark or a decrease in lube oil consumption may indicate internal fuel leaks.

5. Improper storage, handling or installation of jumper lines can cause fuel leakage, resulting in lube oil dilutuion and severe engine damage.

TAMPER–RESISTANT GOVERNOR FOR HIGHWAY VEHICLE ENGINES

A tamper–resistant double–weight limiting speed governor is provided for highway vehicle engines.

This governor incorporates an adaptable high–speed spring housing to make unauthorized speed setting changes extremely difficult.

The new governor spring housing has one inch of additional metal resembling two bosses cast on the bolt head of the housing (Figs. 20 and 21). These bosses are counterbored to accept the two bolts which hold the spring housing on the governor housing and to allow for the installation of plugs over the bolt heads. The plugs are secured in the counterbores by tapered pins which, when driven in place, cannot be removed when the governor is mounted on the blower. In order to remove the pins to get to the spring housing retainer bolts, the complete governor must be removed from the blower.

The governor is not tamper–resistant as furnished on an engine by the factory. The spring housing retainer bolts are removable to permit governor adjustments that may be necessary before the engine is placed in service following delivery. To make the governor tamper–resistant after initial engine start–up, two plugs, two tapered pins and the gap adjusting screw and spring cover must be added to the governor as follows:

1. Disassemble the governor spring housing and spring assemblies as follows:
   a. Remove the two bolts and washers securing the high–speed spring housing to the governor housing and withdraw the housing.
   b. Loosen the high–speed spring retainer locknut with a spanner wrench. Then, remove the high–speed spring retainer, idle speed adjusting pin and set screw, high–speed spring, spring plunger, low–speed spring, spring seat and spring cap as an assembly. Remove the gasket.
2. Remove the governor housing cover and lever assembly. Remove and discard the spring housing bolt retainer which should be lying loose in the governor housing.
3. Refer to Figs. 20 and 21 and install the gap adjusting pin and set screw and spring cover and spring assemblies in the governor housing as follows:
   a. On the current tamper–resistant governor, insert the 1–1/4" Allen head retaining screw through the unthreaded clearance hole in the gap adjusting screw and spring cover (Fig. 21) and secure the cover to the inside of the governor housing. The retaining screw sets into a counterbore in the current cover. Turn the retaining screw into the housing until the cover is secure.
   b. On the former tamper–resistant governor, place the gap adjusting screw and spring cover (Fig. 20) in the governor housing with the threaded bolt hole up and in position to receive the spring and plunger assembly.

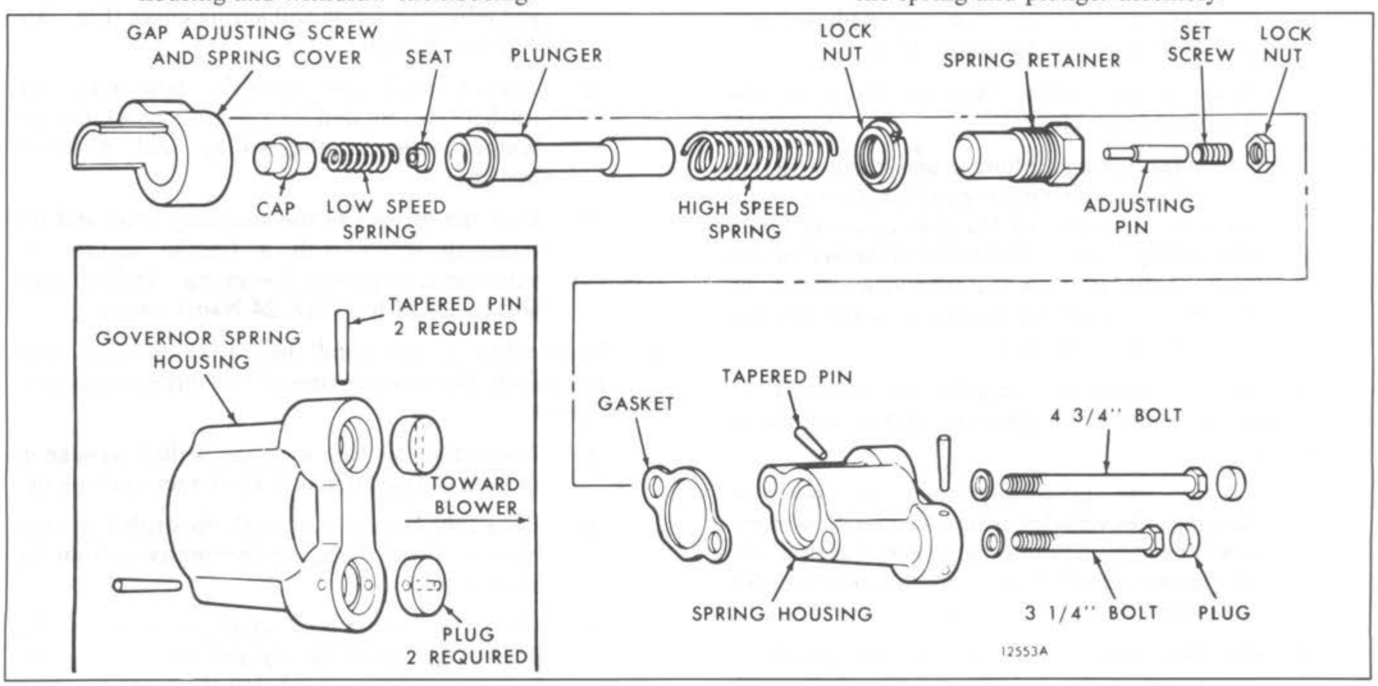


Fig. 20 – Tamper–Resistant Governor Components (Former)

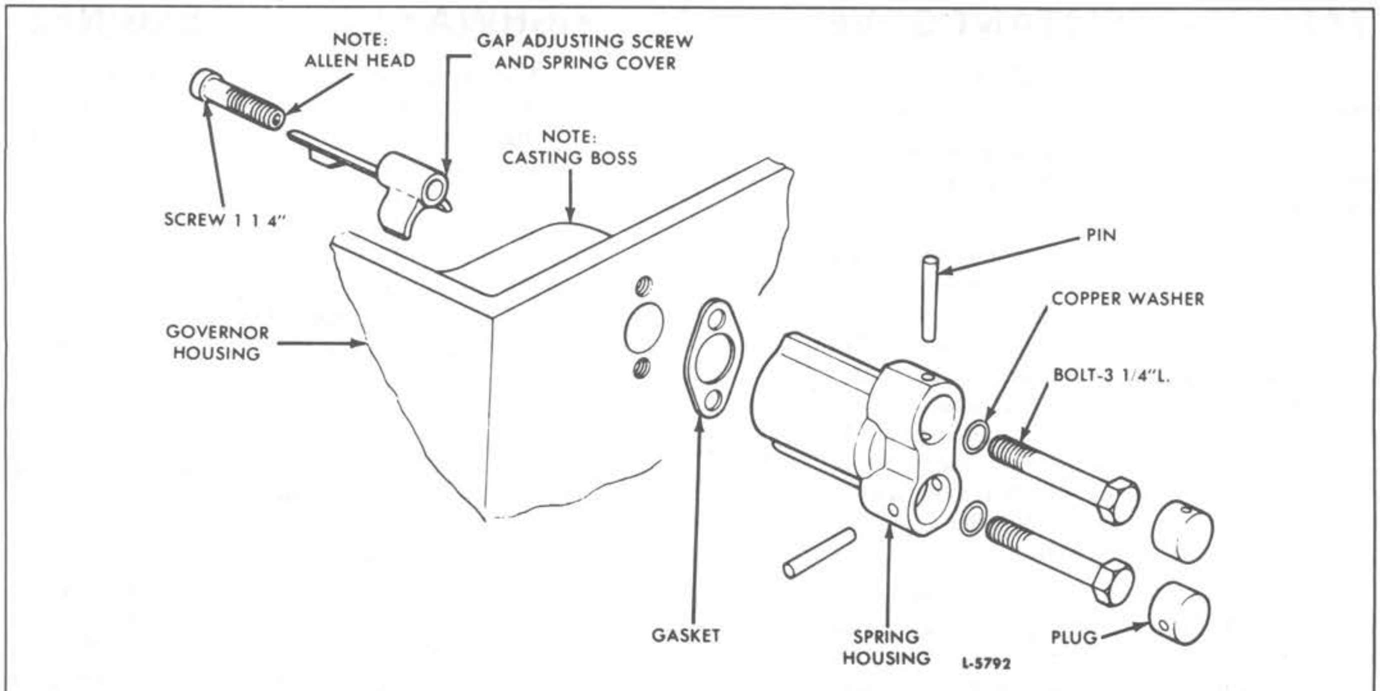


Fig. 21 – Tamper–Resistant Governor Components (Current)

c. Insert the high–speed spring and plunger assembly in the high–speed spring retainer. Thread the idle speed adjusting screw into the threaded end of the plunger approximately 1/2". Then, thread the locknut on the idle speed adjusting screw.

d. Insert the low–speed spring seat, spring and cap assembly into the high–speed spring plunger and over the idle speed adjusting screw.

e. Affix a new spring housing gasket to the governor housing.

f. Insert the springs, plunger and retainer as an assembly into the opening in the governor and through the center of the gap adjusting screw and spring cover. The inner diameter of the cover should pilot on the outer diameter of the retainer. Thread the retainer into the housing approximately one inch.

4. Perform the governor adjustments outlined in Section 14.3. Install the governor spring housing as follows:

   a. Position the spring housing on the governor housing. On vehicles using a frontal air system, it will be necessary to remove material from the air cleaner adaptor boss to provide clearance for the governor spring housing.

   b. On the current tamper–resistant governor, insert one of the 3–1/4" attaching bolts with copper washer through the top bolt hole in the spring housing and thread it into the top hole on the outside of the governor housing. Tighten the bolt.

   c. On the former tamper–resistant governor, insert the 4–3/4" attaching bolt with copper washer through the top bolt hole in the spring housing and thread it into the threaded hole in the former gap adjusting screw and spring cover (Fig. 20). Tighten the bolt.

   d. Thread the 3–1/4" attaching bolt with lock washer (current and former governors) into the bottom hole in the spring and governor housings.

   e. Coat the threads of the attaching bolts and the retaining screw with a Loctite sealant, or equivalent, to prevent loosening. Tighten each bolt to 13–17 lb–ft (18–24 N•m) torque.

5. Refer to Fig. 20 and install the tamper–resistant plugs and pins in the counterbores of the spring housing as follows:

   a. Install the top plug with the drilled passage in the *vertical* position and the larger opening up.

   b. Install the bottom plug with the drilled passage horizontal and the larger opening away from the blower.

   c. Drive the tapered pins, small end first, into the drilled passages in the top and side of the spring housing until the pin is below flush and firmly in place.

Most limiting speed governors on engines already in service can be converted to the tamper–resistant setup as follows:

1. Disassemble the governor spring housing and spring assemblies as outlined under Step 1, Items a and b above.

2. Remove the governor housing cover and lever assembly. Drill out the 5/16"–18 tapped hole in the governor housing at the spring housing top retaining bolt position to 11/32" diameter. Remove all drilled particles from the inside of the governor housing following the drilling operation.

3. Refer to Fig. 21 and install the current gap adjusting screw and spring cover and the high and low–speed spring assemblies, replacing the original retainer with the new longer retainer in the governor housing as outlined under Step 3, Items a through f above.

4. Perform the governor adjustments outlined in Section 14.3. Replace the original spring housing with the new spring housing and install the new housing and governor housing cover on the governor housing as outlined under Step 4, Items a through e above.

5. Refer to Figs. 20 or 21 and install the tamper–resistant plugs and pins in the counterbores of the spring housing as outlined under Step 5, Items a through c above.

NOTICE: If the spring housing of a former tamper–resistant governor (Fig. 20) is removed for any reason, the gap adjusting screw and spring cover will fall into the governor housing. Therefore, it is important to remove the governor cover and lever assembly and check to make sure that the gap adjusting screw and spring cover is secured by the 5/16"–18 x 4–3/4" bolt after the spring housing is reinstalled.

MODIFICATION OF GOVERNOR HOUSING TO ACCEPT CURRENT TAMPER–RESISTANT GAP ADJUSTING SCREW AND SPRING COVER

A former governor housing can be reworked to accept the new tamper–resistant gap adjusting screw and spring cover. Kent–Moore Master Thread Repair Kit J 26520 can be used.

With this procedure, two threaded inserts are installed in the governor housing, one from the inside and one from the outside. This will allow the new retaining screw to be installed on the inside of the governor housing and the new spring housing upper 3–1/4" bolt to be installed from the outside (Fig. 21).

1. Remove the governor cover, high–speed spring housing and spring pack.

2. Apply a thick coat of grease to the inside of the housing. Fit an oil soaked rag through the spring pack hole, using the grease as a seal between the housing and the rag.

3. Drill the upper high–speed spring housing bolt hole to 13/32" and tap the hole with a 7/16"–14 tap.

4. Remove the rag, making sure all of the chips are out of the housing. Then wipe the grease from the housing.

5. Thread a 5/16"–18 insert by hand from each side until the lock tabs bottom. The inserts and tab tools can be part of J 26520 master thread repair kit. The 5/16"–18 insert kit is J 26520–312 containing 20 inserts. The tab tool is J 26520–311. Then, use the 5/16" tab driver to drive the lock tabs in until flush. This will lock the insert in place. On the inside insert, use the same driver and a brass rod.

The inside of the governor housing cast boss, where the drill breaks through, may need to be filed flat. This is to prevent the gap adjusting screw and spring cover from tilting out of position when the retaining screw is tighten.

REWORK GOVERNOR HOUSING

The V–92 engine mechanical governor housing can be reworked when wear occurs at the boss that holds either the upper or lower end of the operating lever shaft.

Repair can be made by adding a bushing to the worn boss as follows (Fig. 22):

1. Refer to the drawing and bore out the hole so that the repair bushing fits tight (.4990"–.5005" diameter).

2. Shorten the bushing to a length of .380".

3. Press the bushing in the hole flush to .010" below the surface of the housing boss.

4. Ream the bushing to .3757–.3766" diameter, using a 3/8" reamer.

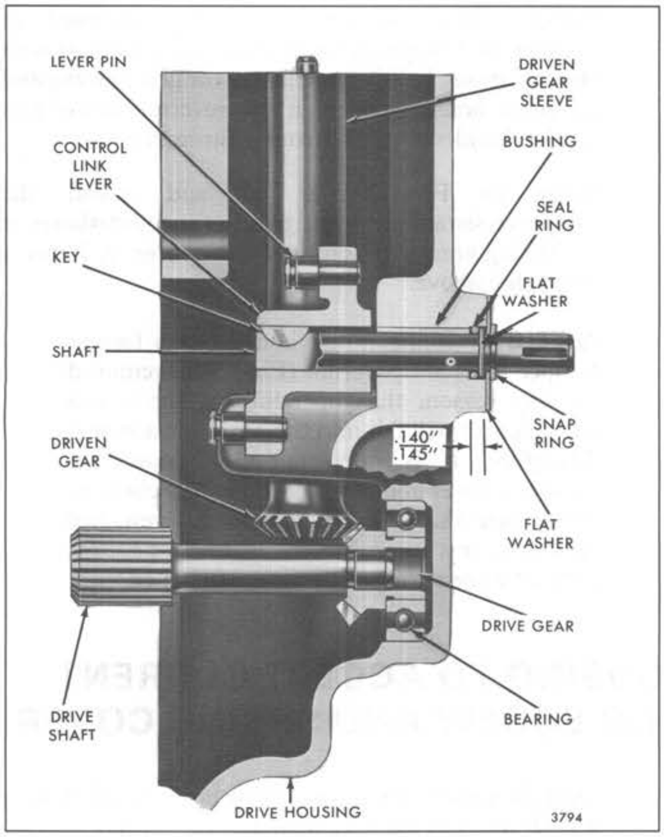


Fig. 22 – Governor Drive Assembly

After assembly of the governor, check for shaft freeness.

Careful workmanship is a must when making this repair to maintain proper geometry and fit within the governor.

Before Installing A Barber–Coleman Electronic Governor

Before a Barber–Coleman electronic governor is installed on an engine previously equipped with a hydraulic governor, the vertical driven gear, bearing, and gear sleeve and the horizontal drive gear, shaft and bearing must be removed from the governor drive housing (see Fig. 22).

These components serve no useful purpose when the hydraulic governor is replaced by the electronic governor and **will cause severe engine damage if not removed.** Because the horizontal drive shaft is splined to the blower rotor shaft, both governor shafts will continue to rotate when the engine is operated. However, with the hydraulic governor removed, the horizontal and vertical shafts and bearings will no longer receive adequate support or lubrication and will quickly wear out.

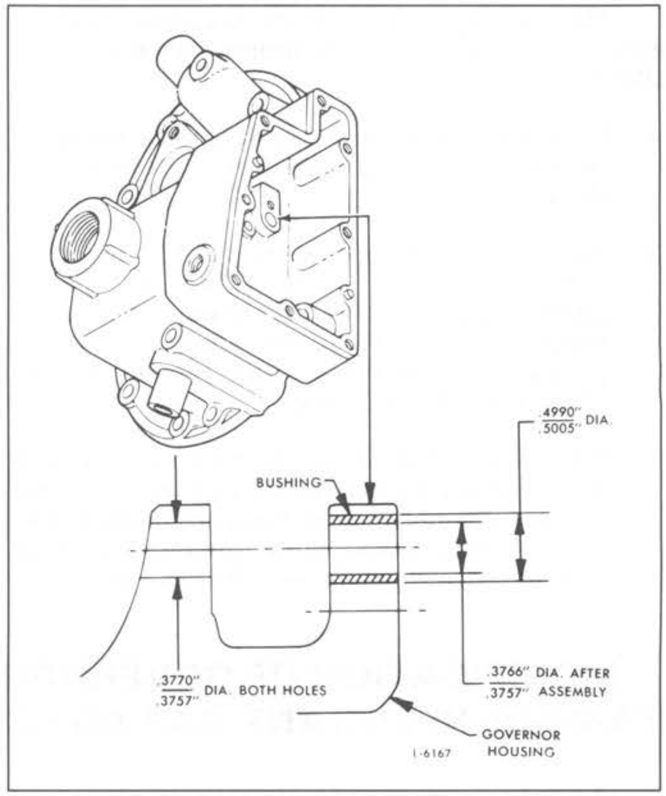


Fig. 23 – Reworking Governor Housing

NOTICE: Do not remove only the vertical shaft and bearing. If the horizontal drive shaft and bearing assembly is left in the governor drive housing, the shaft will move freely back and forth during engine operation. This is due to the absence of load on the bevel gear which would normally keep the horizontal shaft in position. The rapid rotation and back–and–forth movement of the horizontal drive shaft can cause severe damage to the governor drive housing.

Following this procedure before installing a Barber–Coleman electronic governor:

1. Remove the hydraulic governor drive as outlined in Section 2.8.3 of the Service Manual. Remove the driven gear, bearing and gear sleeve, and the drive gear, shaft and bearing from the drive housing.

2. Reinstall the governor drive housing and all parts previously removed, except the drive and driven gears and related components, following procedures in Section 2.8.3 of the Service Manual.

3. Install the Barber–Coleman electronic governor per the manufacturer's instructions and perform the engine tune–up as outlined in Section 14 of the Service Manual.

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 one of the pump flange drain holes, then crank the engine momentarily and note if 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 stick in a *fully open or partially open* position due to a small amount of grit or foreign material lodged between the relief valve and its bore or seat. This permits the fuel to circulate within the pump rather than being forced through the fuel system.

Therefore, if the fuel pump is not functioning properly, remove the fuel pump from the engine. Then, 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 in the pump.

After the relief valve has been checked and the fuel pump reinstalled on the engine, 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 line from the fitting at the fuel tank and hold the open end in a convenient receptacle (Fig. 23).

2. Start and run the engine at 1200 rpm or 1800 rpm and measure the fuel flow. Refer to Section 13.2 for the specified quantity per minute.

3. Immerse the end of the fuel line 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

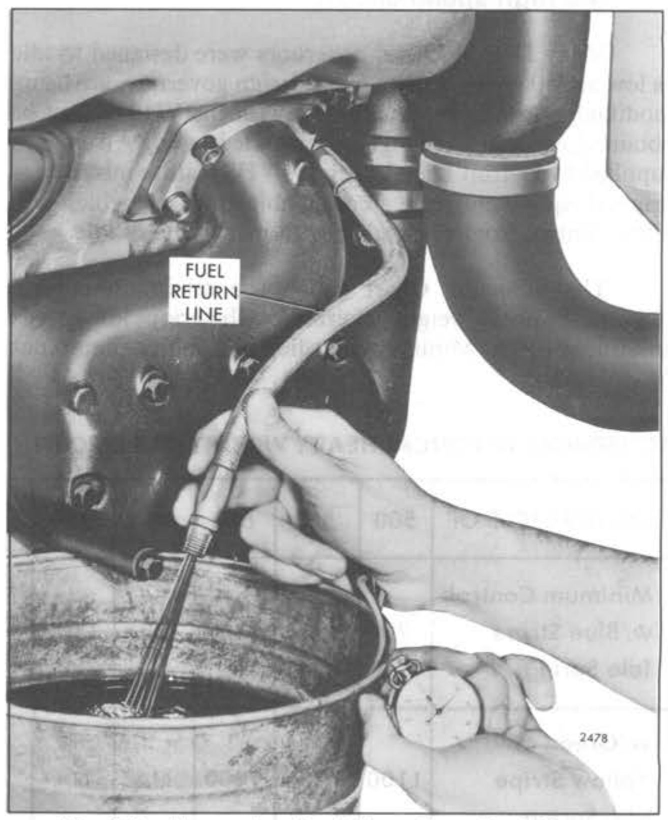


Fig. 23 – Measuring Fuel Flow From Fuel Return Manifold

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 92 engines require 70 psi (483 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 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 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.

The following Chart shows the minimum control speed of the heavy weight governors with various idle speeds and idle springs. Minimum certified idle values should not be violated.

GOVERNORS W/TYPICAL HEAVY WEIGHT IDLE CIRCUIT

NORMAL IDLE OF	500	550	600	650	750
Minimum Control w/Blue Stripe Idle Spring	700	900	1100	1375	1500
w/Green or Yellow Stripe Idle Spring	1100	1225	1400	NA	NA

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. Temporary engine overspeed

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 *overspeed*, the variable orifice is installed in the supply line to the throttle lock.

In case of *underspeed*, 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.

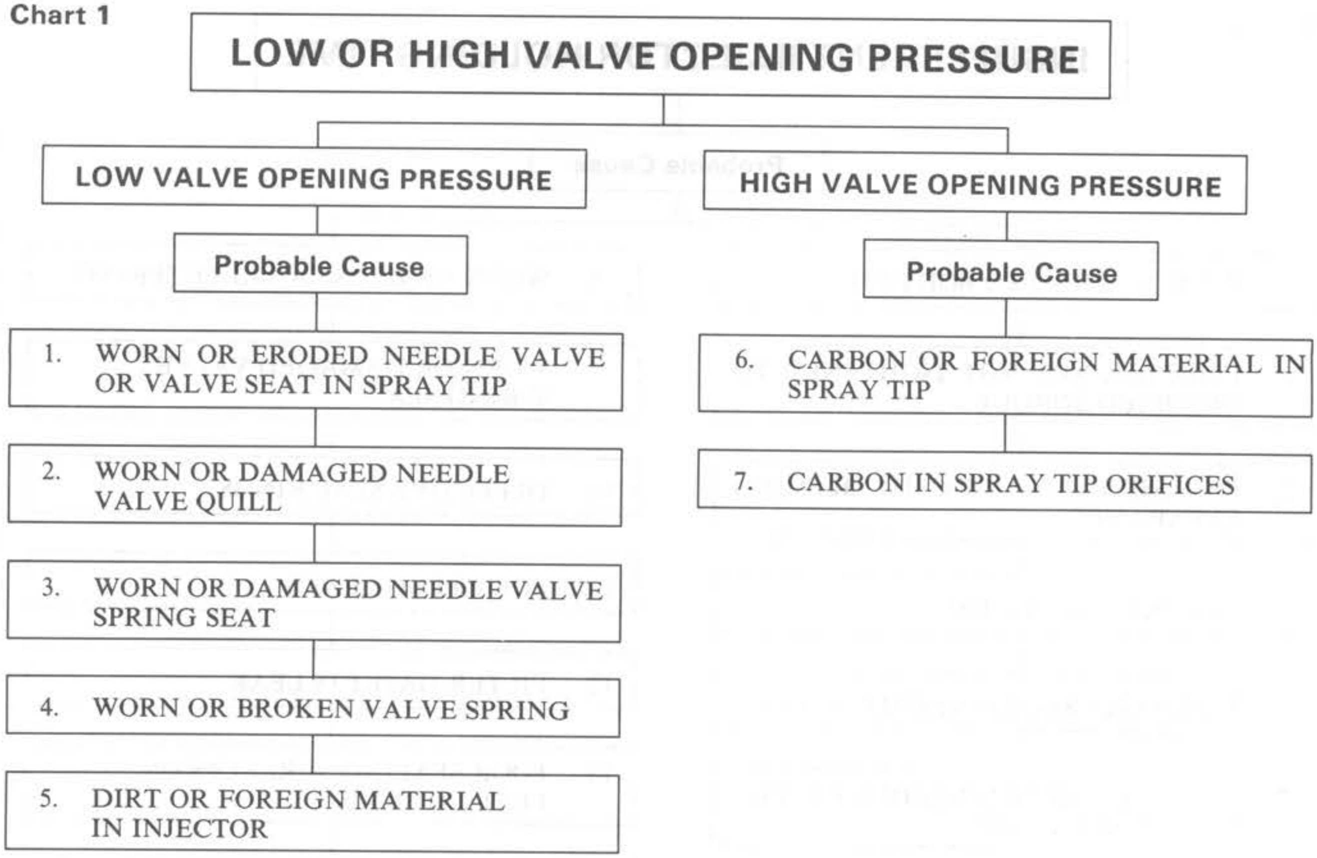
The elastic stop nut is screwed in too tight, pulling the high speed plunger off its seat. This will cause low power but no change in the no–load rpm. Readjust the elastic stop–nut.

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.

NEEDLE VALVE INJECTORS

Chart 1



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.

NEEDLE VALVE INJECTORS

Chart 2

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 N•m) 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 N•m) 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.

NEEDLE VALVE INJECTORS

Chart 3

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 GAGE, 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.

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)	260M BOLTS TORQUE N•m	THREAD SIZE	280M OR BETTER TORQUE (lb–ft)	280M OR BETTER TORQUE N•m
1/4–20	5–7	7–9	1/4–20	7–9	10–12
1/4–28	6–8	8–11	1/4–28	8–10	11–14
5/16–18	10–13	14–18	5/16–18	13–17	18–23
5/16–24	11–14	15–19	5/16–24	15–19	20–26
3/8–16	23–26	31–35	3/8–16	30–35	41–47
3/8–24	26–29	35–40	3/8–24	35–39	47–53
7/16–14	35–38	47–51	7/16–14	46–50	62–68
7/16–20	43–46	58–62	7/16–20	57–61	77–83
1/2–13	53–56	72–76	1/2–13	71–75	96–102
1/2–20	62–70	84–95	1/2–20	83–93	113–126
9/16–12	68–75	92–102	9/16–12	90–100	122–136
9/16–18	80–88	109–119	9/16–18	107–117	146–159
5/8–11	103–110	140–149	5/8–11	137–147	186–200
5/8–18	126–134	171–181	5/8–18	168–178	228–242
3/4–10	180–188	244–254	3/4–10	240–250	325–339
3/4–16	218–225	295–305	3/4–16	290–300	393–407
7/8–9	308–315	417–427	7/8–9	410–420	556–569
7/8–14	356–364	483–494	7/8–14	475–485	644–657
1–8	435–443	590–600	1–8	580–590	786–800
1–14	514–521	697–705	1–14	685–695	928–942

Grade identification markings are normally stamped on the heads of the bolts. To aid identification of the various bolts used in Detroit Diesel engines, refer to the following chart.

Grade Identification Marking on Bolt Head	GM Number	SAE Grade Designation	Nominal Size Diameter (inch)	Tensile Strength Min. (psi)
None	GM 255-M	1	No. 6 thru 1 1/2	60,000
None	GM 260-M	2	No. 6 thru 3/4 over 3/4 to 1 1/2	74,000 60,000
Bolts and Screws	GM 280-M	5	No. 6 thru 1 over 1 to 1 1/2	120,000 105,000
Hex Head Sems Only	GM 275-M	5.1	No. 6 thru 3/8	120,000
Bolts and Screws	GM 290-M	7	1/4 thru 1 1/2	133,000
Bolts and Screws	GM 300-M	8	1/4 thru 1 1/2	150,000
Bolts and Screws	GM 455-M	None	No. 6 thru 1 1/2	55,000

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BOLT IDENTIFICATION CHART

EXCEPTIONS TO STANDARD BOLT AND NUT TORQUE SPECIFICATIONS

APPLICATION	THREAD	(lb–ft)	(lb–in)	(N•m)
Control Tube Bracket Bolts	1/4–20	10–12		14–16
Governor Weight Shaft Bearing Retaining Bolt	5/16–24	15–19		20–26
Variable Speed Spring Lever Set Screw	5/16–24	12–15		16–20
Air Inlet Housing Adaptor–to–Blower Housing Bolt	3/8–16	16–20		22–27
Air Inlet Housing–to–Adaptor Bolt	3/8–16	16–20		22–27
Injector Clamp Bolt	3/8–16	20–25		27–34
•Fuel pipe nut (Endurion® coated)	3/8–24		130 lb–in	14.69
•Fuel pipe nut (uncoated)	3/8–24		160 lb–in	18.3
•Fuel pipe nut (load limiting device)	3/8–24		160 lb–in	18.3
•Fuel pipe nut (Jacobs Brake)	3/8–24		120 lb–in	13.6
Blower End Plate–to–Cylinder Block Bolts	7/16–24	40–45		54–61
*Rocker Arm Bracket Bolts	1/2–13	90–100		122–136
Injector Filter Caps	5/8–24	65–75		88–102
Injector Nut	15/16–24	75–85		102–115

*75–85 lb–ft (102–115 N•m) torque on the two bolts attaching a load limit or power control screw bracket (if used) to the rocker arm shaft brackets.

SERVICE TOOLS

TOOL NAME	TOOL NO.
INJECTOR	
Buffing Wheel (brass wire)	J 7944
Fuel Pipe Socket	J 8932–B
Fuel System Primer	J 5956
Injector Auxiliary Tester	J 22640–A
Injector Body Reamer	J 21089
Injector Calibrator	J 22410
Injector Carbon Remover Set	J 9418
Injector Holding Fixture	J 22396
Injector Nut Seal Ring Installer	J 29197
Injector Service Tool Set	J 23435–C
Body Brush	J 8152
Nut Socket Wrench	J 4983–01
Rack Hole Brush	J 8150
Spray Hole Cleaner Vise	J 4298–1
Spray Tip Carbon Remover (High Sack)	J 9464–01
Spray Tip Carbon Remover (Low Sack)	J 24838
Spray Tip Driver and Bushing Cleaner	J 129101
Wire Sharpening Stone	J 8170
Injector Tag Remover and Installer	J 24767
Injector Test Oil (5, 10, 30 and 55 gal.)	J 26400
Injector Tester	J 23010–B
DDEC Injector Adapter Kit	J 23010–500
Lapping Block Set	J 22090–A
Master Injector Calibrating Kit	J 35369
Neddle Valve Lift Gage	J 9462–02
Polishing Compound	J 23038
Polishing Stick Set	J 22964
Spray Tip Cleaning Wire (.007" dia. holes)	J 21462–01
Spray Tip Flow Gage	J 25600–B
Field Modification Kit	J 25600–103
Spring Tester	J 29196
Tip Conc. Gage & Rack Freeness Tester	J 29584
INJECTOR TUBE	
Cylinder Head Holding Plate Set	J 3087–01
Cylinder Liner Depth Gage	J 22273–01
Injector Protrusion Gage	J 25521
Injector Tube Service Tool Set	J 22525–B
Injector Tube Swaging Tool	J 28611–A

TOOL NAME	TOOL NO.
FUEL PUMP	
Fuel Pump Tool Set	J 1508–E
Fuel Pump Wrench	J 4242
Fuel System Primer	J 5956
MECHANICAL GOVERNOR	
Control Link Operating Lever Bearing Remover and Installer	J 8985
Governor Cover Bearing Installer	J 21068
Governor Cover Bearing Remover and Installer	J 21967–01
High Speed Spring Retainer and Installer	J 5345–12
Governor Weight Shaft Retaining Ring Installer	J 36840

SECTION 3

AIR INTAKE SYSTEM

CONTENTS

AIR INTAKE SYSTEM

In the scavenging process employed in the V–92 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 Fig. 1. 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.

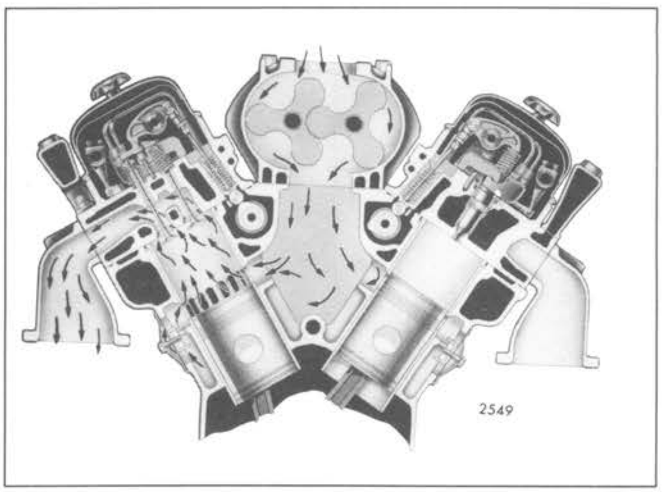


Fig. 1 – Air Flow Through Blower and Engine

OIL BATH TYPE AIR CLEANER

The oil bath type air cleaners used on the V–92 engines are 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–laden 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 air cleaners are mounted on brackets attached to the flywheel housing and the cleaner outlet is connected to the air inlet housing by means of a hose and clamp. A "Y" shaped air inlet housing is used on installations with two air cleaners which are mounted side by side at the rear of the unit (Fig. 1).

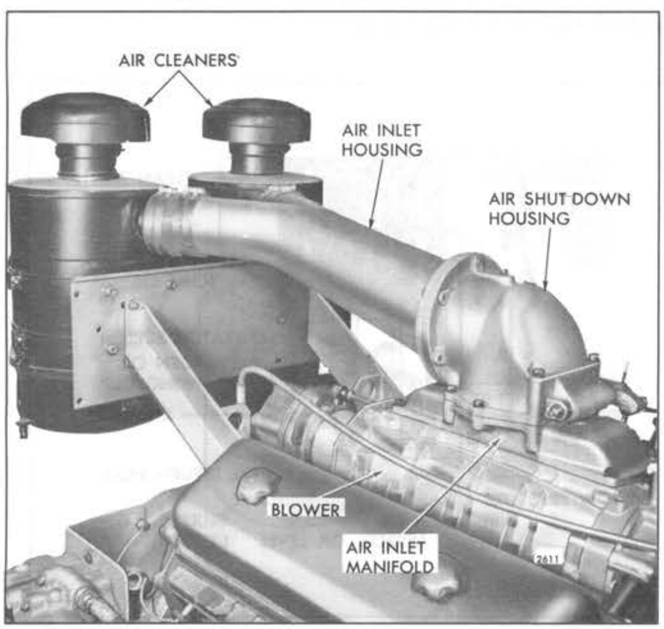


Fig. 1 – Typical Oil Bath Air Cleaner Mounting

Air Cleaner Maintenance

Although air cleaners are highly efficient, this efficiency depends upon proper maintenance and periodic servicing. If the cleaners are not properly maintained, the oil sump will become filled with sludge and the screens or elements will not remove dust properly. This will result in dust and dirty oil entering the engine and also increase the restriction to air flow through the cleaner.

Should dust in the air supply enter the engine, it would be carried directly into the cylinders and, due to its abrasive properties, cause premature wear of moving parts, which would materially shorten engine life. Should the air flow through the cleaner be restricted, it would eventually be impossible for the engine to burn all of the fuel injected into its cylinders and carbon formation would progress at a greatly increased rate.

The efficiency of the air cleaner may be offset by leaks in the duct work, loose hose connections or damaged gaskets which permit dust–laden air to completely bypass the cleaner and enter the engine directly.

The following maintenance procedure will assure efficient air cleaner operation:

1. Keep air cleaner tight on air intake to engine.

2. Keep air cleaner properly assembled so joints are strictly oil and air tight.

3. In case of damage to the air cleaner, intake or connections, repair at once.

4. In dusty areas, inspect the air cleaner frequently for dirt deposits in the oil bath or thickened oil.

   Thoroughly clean the oil bath cleaner often enough to prevent oil from becoming excessively thick with sludge, and be sure to use the proper kind and quantity of oil. Keep the oil at the level mark in the cup. When replacing the cup, be sure it fits snugly to form a tight joint.

5. Where rubber hose from cleaner to blower is employed, remove hose connections and cement them in place. Use new hose and clamps, if necessary, to obtain an air–tight connection.

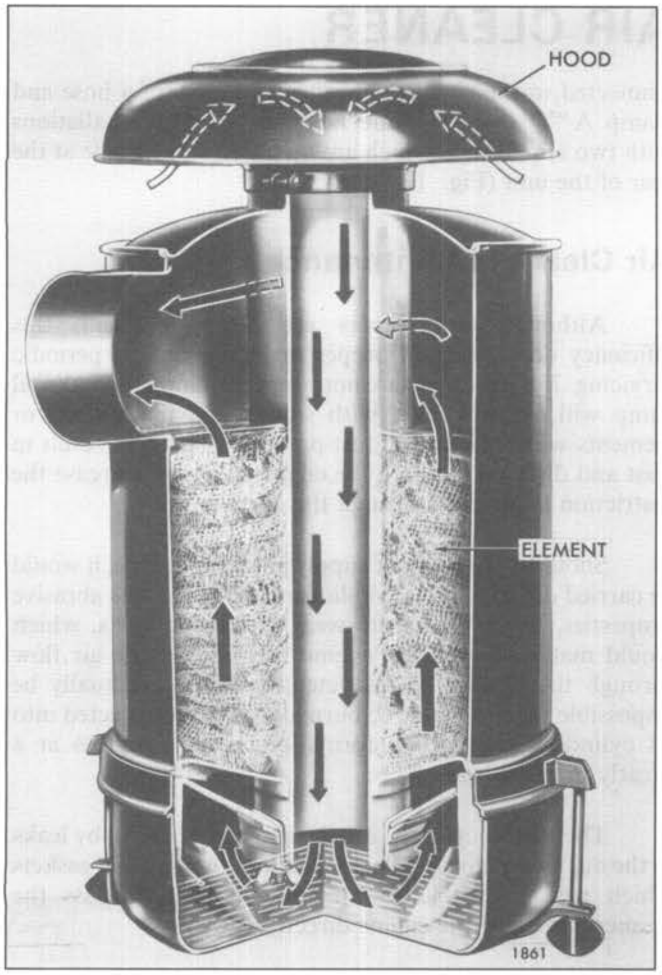


Fig. 2 – Typical Oil Bath Air Cleaner (Industrial Engines)

6. After servicing the air cleaner, remove air inlet housing and clean accumulated dirt deposits from blower screen and air inlet housing. Make sure all air intake passages and air box are kept clean.

7. Make careful periodic inspection of entire air system. Enough dust–laden air will pass through an almost invisible crack to eventually cause serious damage to an engine.

No hard fast rule for servicing any air cleaner can be given since it depends upon the type of cleaner, air conditions and type of application. A cleaner operating in severe dust conditions will require more frequent service than a cleaner operating in clean air. The most satisfactory service period should be determined by frequently inspecting the cleaners, under normal operation, then setting the service period to best suit the requirements of the application.

In air cleaners having an oil bath, use the same viscosity oil as that being used in the engine crankcase. The oil level should not be above that indicated on the air cleaner sump. If too much oil is used, it may be pulled through the element and into the engine, thus carrying dirt into the cylinders and also resulting in excessive speed.

Oil Bath Type Air Cleaner(Industrial Engines)

In the oil bath air cleaners used on industrial units (Fig. 2), the air is drawn through the air inlet hood and down through the center tube. 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 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 oil cup. The clean air then leaves the cleaner through a tube at the side and enters the blower through the air inlet housing.

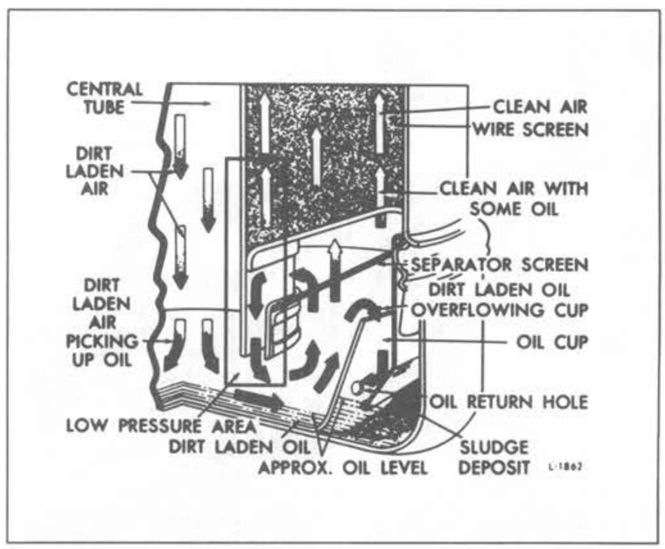


Fig. 3 – Air Flow Through Oil Bath Air Cleaner

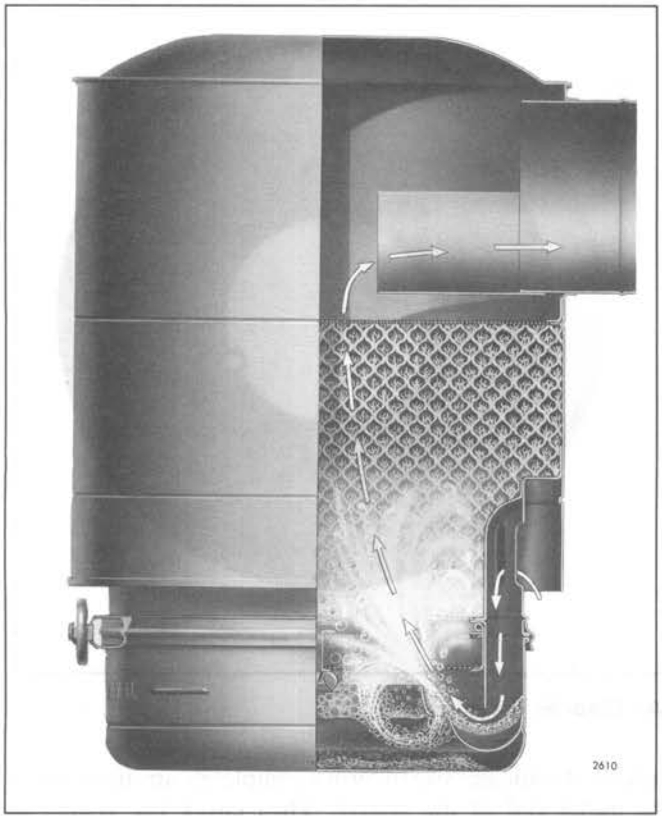


Fig. 4 – Typical Oil Bath Air Cleaner (Marine Engines)

An air inlet hood must be used with the air cleaner. The inlet hood normally requires cleaning more frequently than the main air cleaner. The air inlet hood serves only to prevent rain, rags, paper, leaves, etc., from entering the air cleaner. Air enters the hood through a heavy screen which forms the lower portion of the hood, and the air flow 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 a clamp. The openings in the hood should be kept clear to prevent excessive restriction to air flow.

Oil Bath Type Air Cleaner(Marine Engines)

In the oil bath air cleaners used on marine units (Fig. 4), the air is drawn into the cleaner through a series of slots around the perimeter of the cleaner body just above the oil cup assembly. The air passes over the oil and is than directed upwards by baffles and then passes through a removable screen assembly. During this change in the direction of flow, the larger particles of foreign matter such as lint, chaff, leaves, etc., are removed from the air by the oil and the screen assembly and settles in the oil cup sump. The air continues upward through metal–wool elements where finer particles such as dust and the entrained oil are removed. The clean air is then discharged through a side outlet near the top of the cleaner body and flows through the air inlet housing to the intake side of the blower assembly.

Air Cleaner Service

The air inlet hoods used on industrial engine 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.

The oil sump should be checked for dirt accumulation. Loosen the wing nuts and pull the side rod assemblies away from their forked retaining brackets to remove the oil cup(s). Empty the oil from the cup(s) and clean with fuel oil to remove all sediment.

A tray type screen is used on the industrial engine air cleaners. A lip on the tray fits over the edge of the oil cup of the cleaner. One rubber seal ring fits over the lower edge of the cleaner body to form an air tight seal between the cleaner body and tray. Another seal ring fits around the tray and forms an air and oil seal between the tray and the oil cup.

The efficiency of the tray type oil bath air cleaner will 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 and blow out with compressed air (Fig. 5). An even pattern of light should be visible through the screens when a clean tray is held up to the light (Fig. 5). 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.

Check for dirt accumulation in the 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.

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 the element to dry thoroughly before installing the cleaner on the engine. If the fixed elements require too frequent cleaning, it is advisable to relocate the air intake to provide a cleaner air supply.

The air cleaner used on marine engines is serviced in a similar manner. However, a replaceable screen element is used in place of the tray type screen. The element is attached to the cleaner body by means of a wing nut. The cleaner does not have a center air passage.

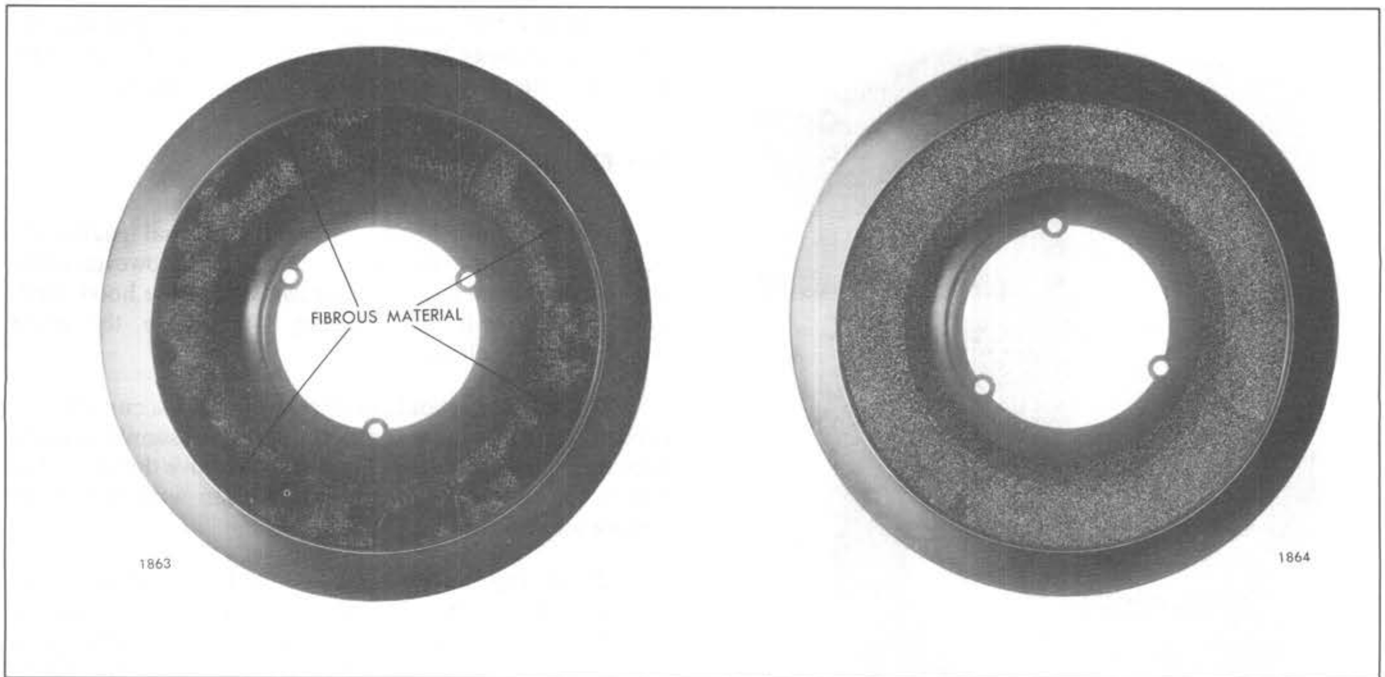


Fig. 5 – Comparison of Air Cleaner Trays

When all of the components have been cleaned, the cleaner is ready for assembly. The removable screen or tray should be installed. Replace the rubber seal rings if necessary. The oil cup(s) should be filled with clean engine oil of the same viscosity and grade as used in the engine crankcase. Fill the cup(s) to the indicated oil level and install 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 (14 kPa) 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.

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 soap–suds 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 soap–suds solution. All leaks thus discovered should be remedied to ensure an air–tight system.

6. Remove the plugs and install the air inlet hood.

DRY TYPE AIR CLEANER

TWO–STAGE AIR CLEANER

The dry type air cleaner is designed to provide highly efficient air filtration under all operating conditions and is not affected by engine speed (Fig. 6). The cleaner assembly consists of a centrifugal air cleaner in series with a replaceable impregnated paper filter element. The dust collected in the centrifugal cleaner is exhausted by connecting the dust bin to an exhaust gas aspirator. The centrifugal cleaner and replaceable filter element are held together in a steel housing. Positive sealing between the two elements and the housing is provided by rubber gaskets. The steel housing incorporates filter fasteners, mounting flanges and an outlet for the filtered air.

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 through an exhaust gas aspirator (Fig. 7).

The exhaust gas aspirator is connected into the exhaust system of the engine (Fig. 8). A flexible hose carries the dust particles from the cleaner dust bin to the aspirator where the waste energy of the exhaust gases draws the dust–laden bleed–off air out and discharges it into the atmosphere along with the engine exhaust gases. Approximately 90% of the total dust load is disposed of in this manner. The centrifugal air cleaner is fully effective at either high or low velocities.

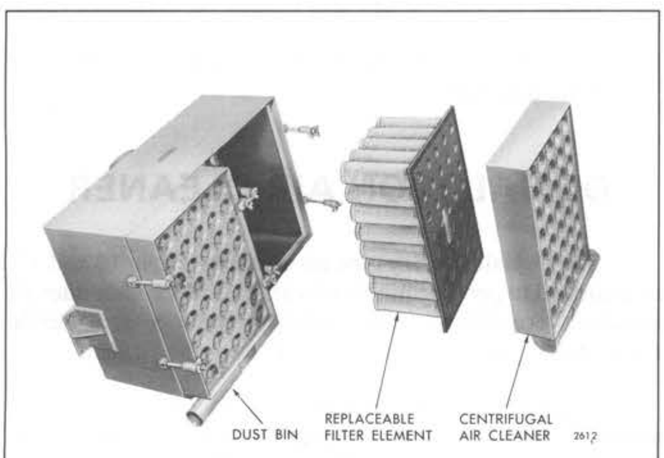


Fig. 6 – Dry Type Air Cleaner

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.

An air cleaner restriction indicator may be attached near the outlet side of the cleaner (Fig. 8). As the restriction in the cleaner increases, suction created will pull the indicator plunger upward. A brightly colored card, attached to the plunger and visible through a small window in the indicator, will indicate the relative amount of air restriction in the cleaner. When the card is fully visible, the air cleaner should be cleaned and the indicator reset by pushing the plunger all the way up and then releasing it.

The air cleaner restriction indicator is equipped with a safety fitting. The fitting incorporates an internal filter in one end and does not require any service. When replacing the safety fitting thread the open end of the fitting in the indicator and the screen end in the air cleaner.

Service

The first stage centrifugal air cleaner tends to be self–cleaning due to the action of the exhaust gas aspirator. 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.

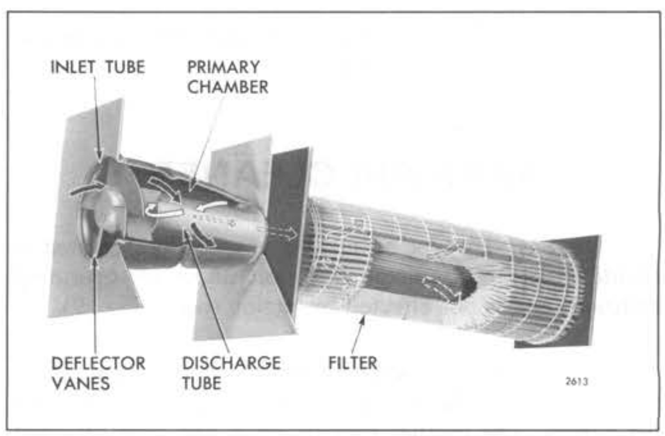


Fig. 7 – Flow of Air Through Dry Type Air Cleaner

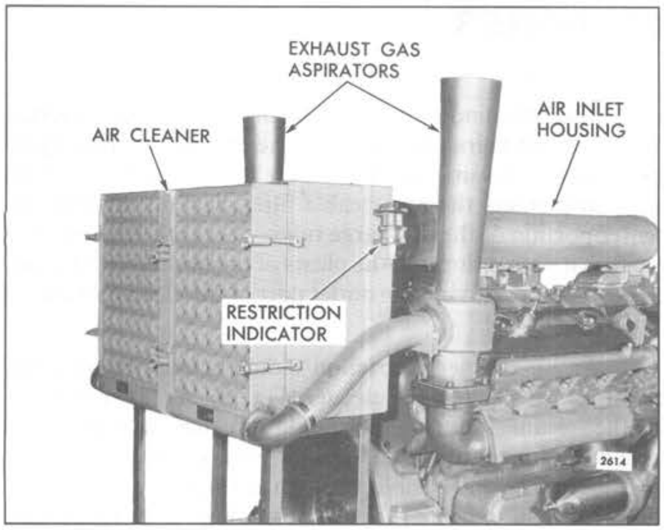


Fig. 8 – Typical Dry Type Air Cleaner Mounting

The filter element may be replaced as follows:

1. Disconnect the flexible aspirator hose at the dust bin of the air cleaner.

2. Loosen the wing nuts on the filter fasteners and swing the retaining bolts away from the cleaner.

3. Lift the cleaner away from the housing and inspect it. Clean out any accumulated foreign material.

4. Withdraw the paper filter element and discard it.

5. Install a new filter element. New sealing gaskets are provided with the element to insure positive air seal at all times.

6. Install the cleaner and secure it in place with the fasteners.

7. Connect the aspirator hose to the dust bin making sure the connection is air tight.

FARR AIR CLEANER

The Farr dry type air cleaner is specially designed to provide highly efficient air filtration under all operating conditions and is not affected by engine speed (Fig. 9).

The air cleaner assembly consists of a plenum pan, a replaceable Dynacell air filter element, holding straps and a inlet screen. The cleaner mounts on a pan type air inlet manifold shutdown assembly.

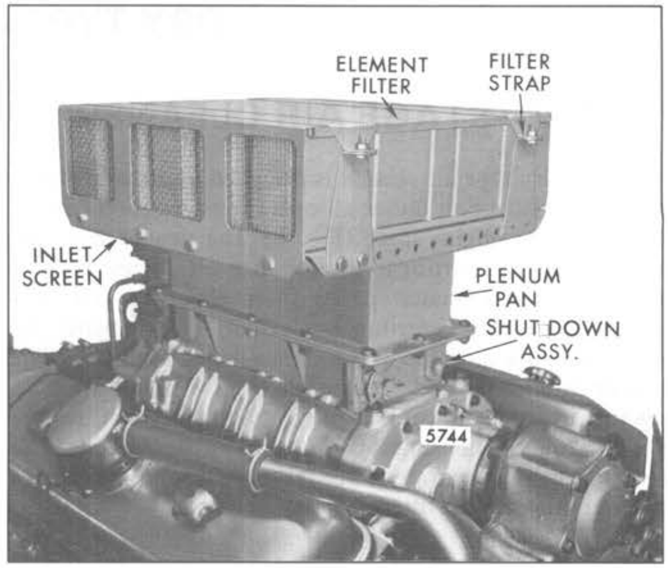


Fig. 9 – Farr Dry Type Air Cleaner

Service

The air cleaner 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 attaching bolts and remove the inlet screen.

2. Loosen the attaching bolts and remove the filter straps.

3. Remove and discard the paper filter element.

4. Install a new Dynacell air filter element.

5. Install the filter straps and tighten the attaching bolts.

6. Clean and/or replace the inlet screen and tighten the attaching bolts.

DONALDSON AIR CLEANER

The Donaldson dry type air cleaners (Figs. 10 and 11) 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.

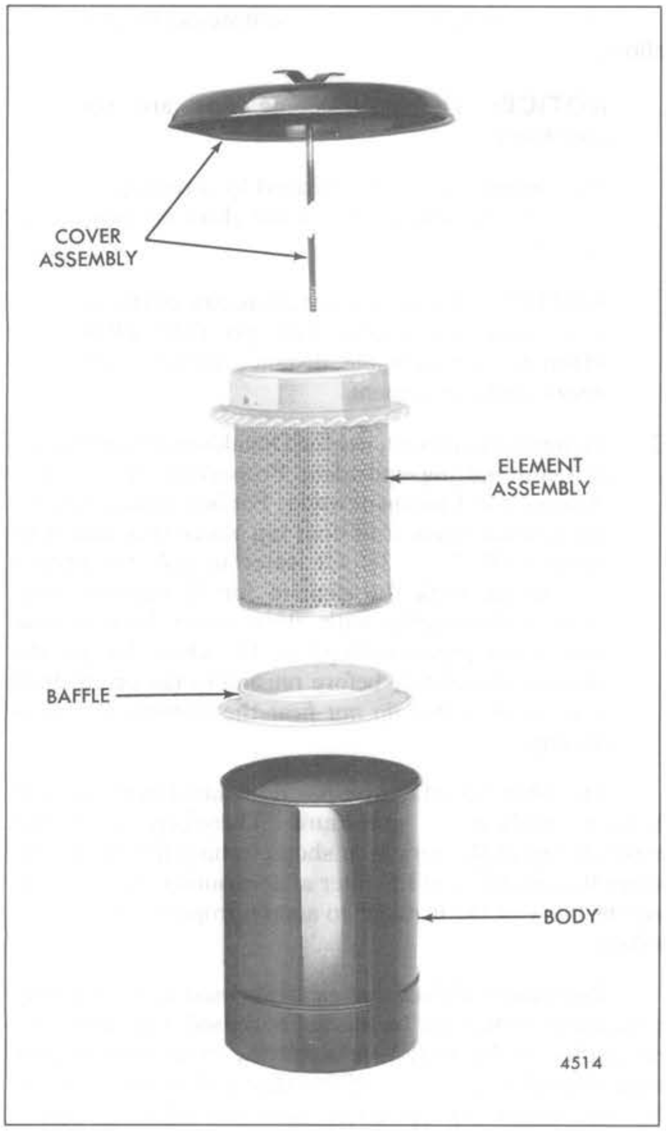


Fig. 10 – Dry Type Air Cleaner

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.

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.

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

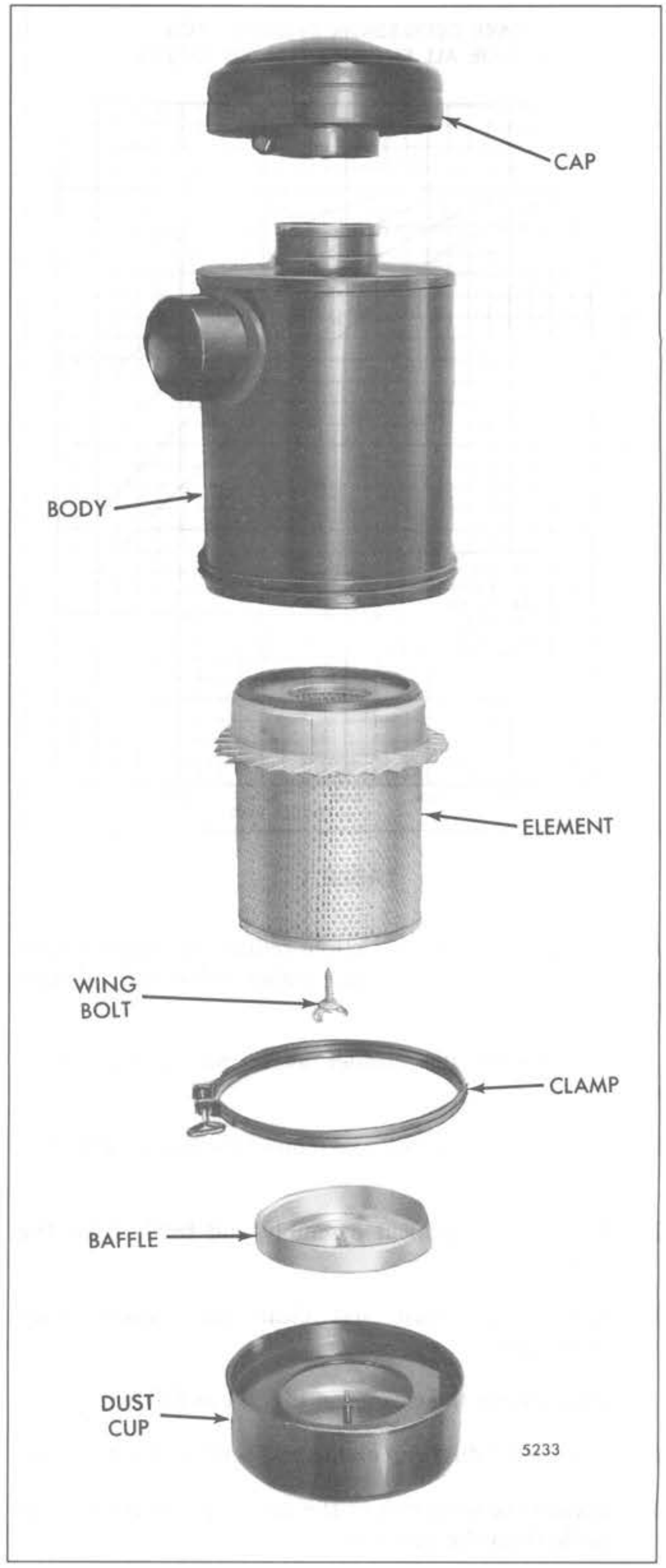


Fig. 11 – Dry Type Air Cleaner (Heavy Duty)

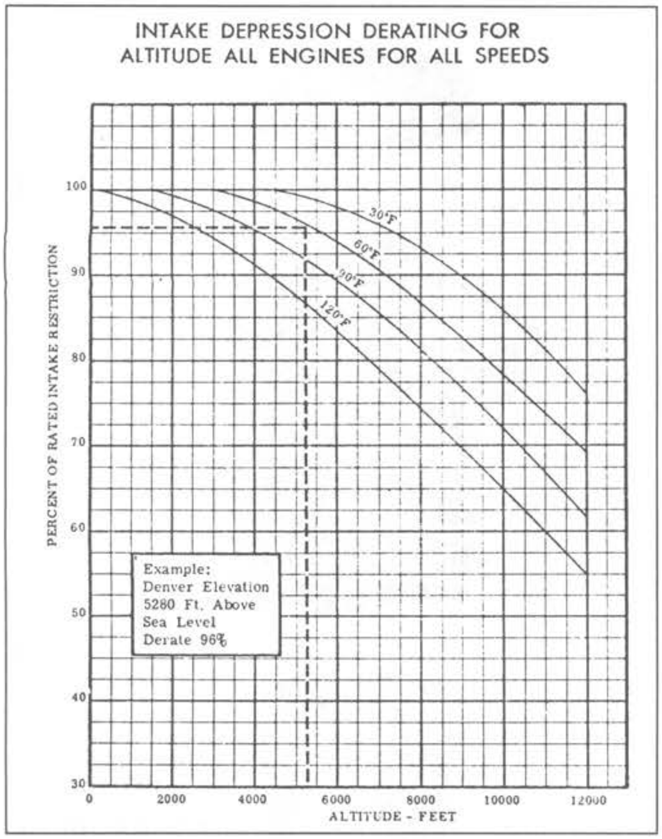


TABLE 1

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. 10 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.
3. Remove the dust and clean the cleaner body thoroughly.

Disassemble the cleaner in Fig. 11 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:

NOTICE: 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.

NOTICE: 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.

NOTICE: 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.

AIR SILENCER (Turbocharger)

The air silencer is attached at the air outlet end to the turbocharger with a hose and clamps and is supported by a bracket attached to the flywheel housing. An air filter element of polyurethane foam is used on the air silencer inlet screen.

Remove Air Silencer

While no servicing is required on the air silencer, it will be necessary to remove it to perform other service operations.

1. Remove the air filter element.
2. Loosen the clamps and slide the hose back on the turbocharger.
3. Loosen the nut and bolt securing the silencer mounting band to the support bracket. Remove the silencer.
4. If necessary, remove the mounting band from the support bracket and the bracket from the flywheel housing.

Install Air Silencer

1. If removed, attach the support bracket to the flywheel housing with two 7/16"–14 x 1–1/4" bolts and washers. Tighten the bolts.
2. If removed, attach the silencer band to the support bracket with a 5/16"–18 x 1" bolt, plain washer, lock washer and nut. Do not tighten the nut at this time.
3. Align the silencer with the turbocharger and slide the hose in place and tighten the clamps. Then tighten the band bolt.
4. Slide the air filter element over the silencer air inlet screen.

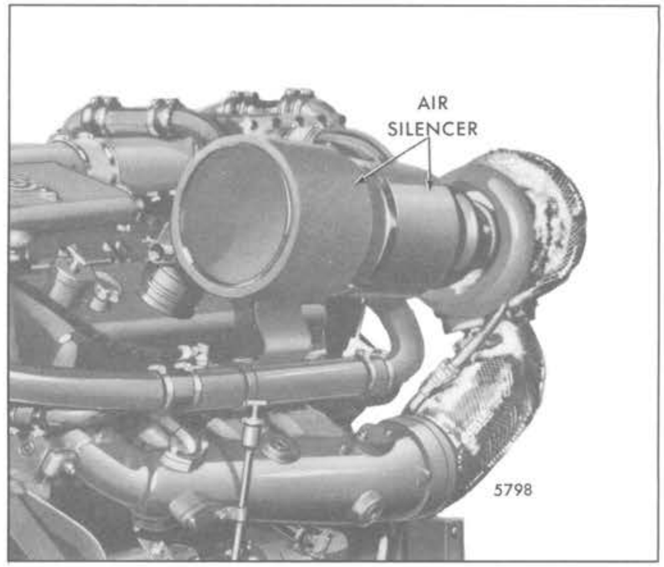


Fig. 1 – Air Silencer Mounted on 6V–92TA Engine

AIR SHUTDOWN HOUSING

The air shutdown housing is mounted on the blower (Fig. 1). A valve mounted inside of the housing may be closed to shut off the air supply and stop the engine when abnormal operating conditions require an emergency shut down.

Remove Air Shutdown Housing

1. On naturally aspirated engines, disconnect and remove the air inlet housing between the air cleaner(s) and the air shutdown housing. On turbocharged engines (Fig. 1), loosen the hose clamp and slide the hose between the air shutdown housing and the turbocharger back on the turbocharger.
2. Disconnect the control wire from the air shutoff cam pin handle.
3. Remove the bolts and lock washers which attach the air shutdown housing to the adaptor. Then, remove the housing and gasket.
4. Remove the bolts and washers which attach the housing adaptor to the blower. Then, remove the adaptor and the blower screen.

Disassemble Air Shutdown Housing

1. Remove the pin from the end of the shutdown shaft. Then, remove the spacer from the shaft and the seal ring from the housing.
2. Remove the two pins that secure the shutdown valve to the shaft.
3. Remove the bolt, lock washer and plain washer which attach the latch to the housing. Then, remove the latch, latch spring and spacer.

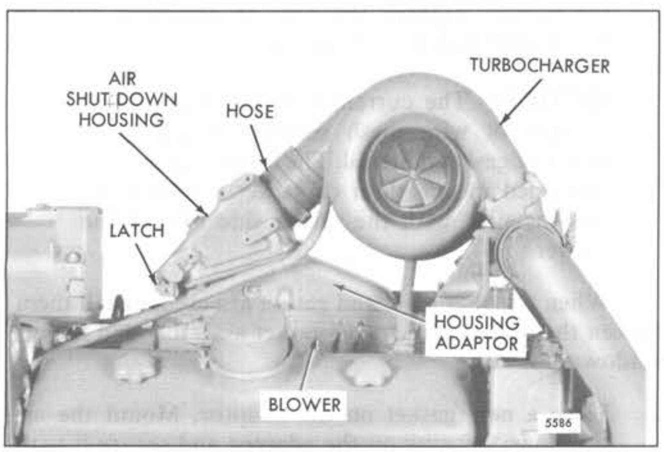


Fig. 1 – Typical Air Shutdown Housing Mounting (Turbocharged Engine)

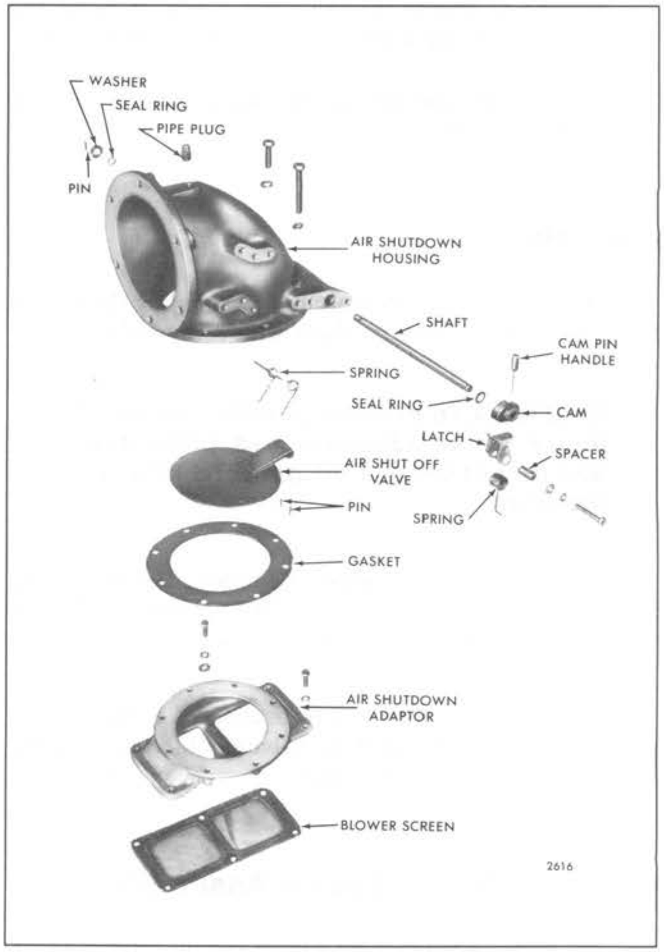


Fig. 2 – Air Shutdown Housing Details and Relative Location of Parts (Non–turbocharged Engines)

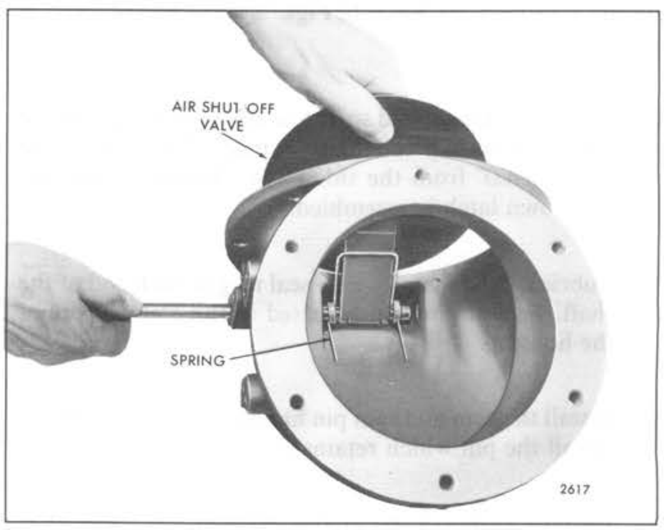


Fig. 3 – Installing Air Shutdown Valve Spring and Valve

4. Note the position of the air shutdown valve spring and valve (Fig. 3), then withdraw the shaft from the housing to release the valve and spring. Remove the valve and spring and the seal ring from the housing.

5. Remove the cam pin handle and withdraw the cam *from* the shaft.

Inspection

Clean all of the parts thoroughly, including the blower screen, with fuel oil and dry them with compressed air.

CAUTION:To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.

Inspect the parts for wear or damage. The face of the shutdown valve must be perfectly flat to assure a tight seal when it is in the shutdown position.

The 8V–92 and 16V–92 turbocharged engines use a nylon bushing at each end of the valve shaft. Examine them for wear and replace, if necessary.

Assemble Air Shutdown Assembly

The holes for the cam pin handle and the retaining pins must be drilled, using a 1/8" diameter drill, at the time a new service shaft or shutdown valve(s) are assembled (see *Shop Notes* in Section 3.0 for procedure). The valve(s) must be in the same plane within .030" when in the stop position (flush with the housing face). Refer to Figs. 2 and 4 and proceed as follows:

1. Place the valve(s) and spring in position in the housing (Fig. 3) and slip the shaft in place. The shaft must extend .700" from the side of the housing where the shutdown latch is assembled.

2. Lubricate and install a new seal ring at each end of the shaft. Be sure the seal is seated in the counterbore of the housing.

3. Install the cam and cam pin handle on the shaft. Then, install the pin which retains the cam to the shaft.

4. Install a washer or spacer and retaining pin at the other end of the shaft.

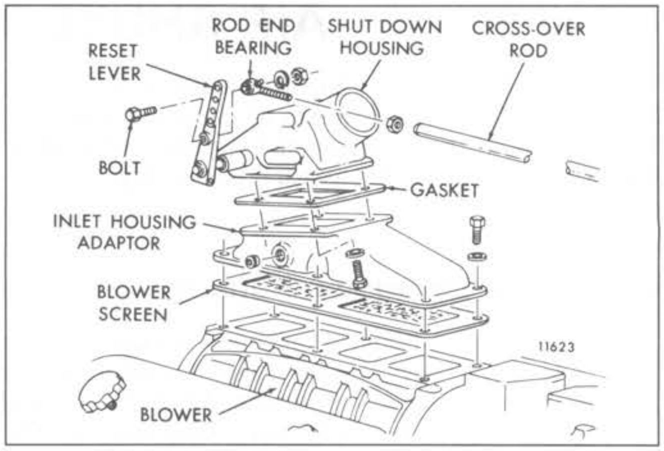


Fig. 4 – Air Shutdown Housing Details and Relative Location of Parts (Rear of Dual Mounting – Turbocharged Engines)

5. Assemble the spacer, spring and latch to the shutdown housing with the 1/4"–20 bolt, lock washer and plain washer.

   a. Align the notch on the cam with the notch on the latch and lock the cam in this position.

   b. Install the pins in the valve(s) to retain it to the shaft with the cam release latch set and the valve(s) in the *run* position.

   c. Level the valve(s) in the shutdown position.

   d. Adjust the cam so the valve(s) contact the housing when the cam release latch is set.

Install Air Shutdown Housing

1. Place the blower screen and gasket assembly, if used, in position and install the shutdown housing adaptor on the blower. Tighten the 3/8"–16 attaching bolts to 16–20 lb-ft (22–27 N•m) torque.

   NOTICE: The current blower screen gasket consists of wire mesh secured between two sheets of gasket material. The former screen was imbedded in one sheet of gasket material and was installed with the screen side toward the blower.

When a striker plate and gasket are used, install them between the blower screen and gasket assembly and the air shutdown housing.

2. Place a new gasket on the adaptor. Mount the air shutdown housing on the adaptor and secure it with 3/8"–16 bolts and lock washers. Tighten the bolts to 16–20 lb-ft (22–27 N•m) torque.

3. On naturally aspirated engines, install the air ducts from the air cleaner to the air shutdown housing. Use a new gasket at the housing. Be sure all connections are air tight. On turbocharged engines, slide the hose in place between the shutdown housing and the turbocharger and tighten the clamps.

4. When dual air shutdown housings (Fig. 4) have been installed, position the crossover rod between the shutdown housings at the reset lever and the shutdown lever.

   NOTICE: Before securing the couplings (non–turbocharged engines), close the valves in both of the shutdown housings and center the couplings on the housing shafts with the aid of new roll pins. On turbocharged engines, secure the rod end bearings at the levers with 5/16"–24 x 1 1/8" bolts. Tighten the bolts to 15–19 lb–ft (20–26 N•m) torque.

5. Reset the air shutdown latch in the *run* position.

6. Start and run the engine at idle speed and no load. Trip the air shutdown latch. If the engine does not stop, check it for air leakage between the valves and the air inlet housing adaptor. If necessary, reposition the valves.

7. After this test has been satisfactorily performed, drill and pin the couplings (non–turbocharged engines) to the shafts with a roll pin for each coupling, using a 1/8" diameter drill.

BLOWER

The *large bearing* blower, designed especially for efficient diesel operation, supplies the fresh air needed for combustion and scavenging. Its operation is similar to that of a gear–type oil pump. Two hollow three–lobe rotors revolve with very close clearances in a housing bolted to the top deck of the cylinder block, between the two banks of cylinders. To provide continuous and uniform displacement of air, the rotor lobes are made with a helical (spiral) form (Fig. 1).

Currently two basic types of large bearing blowers are now being used. The regular type blower is shown in Fig. 1. This blower has six mounting holes in the top of the blower housing and also has regular end plates. The OTM (optional turbocharger mounting) type blower has additional outboard holes for mounting the turbocharger adaptor (6 and 8V blowers). One of the end plates includes two oil drain holes with seal rings for the turbocharger return oil drain back (refer to *Lubrication*, Section 3.5).

The blower used on naturally aspirated engines has a 2.60:1 ratio blower–to–engine speed. The blower used on turbocharged engines has a 2.05:1 ratio blower–to–engine speed. Certain 6V turbocharged aftercooled, 12V turbocharged and 16V turbocharged aftercooled engines have a 1.95:1 ratio blower–to–engine speed.

Two timing gears, located on the drive end of the rotor shafts, space the rotor lobes with a close tolerance. Therefore, as the lobes of the two rotors do not touch at any time, no lubrication is required.

Lip type oil seals are installed in the end plates of blowers on the naturally aspirated engines. Metal ring–type oil seals were formerly used in the blowers on turbocharged engines (inset in Fig. 1). Each ring–type oil seal consisted of a carrier pressed on the rotor shaft, a collar pressed into the end plate and a seal ring contained in a groove of the carrier. The outside diameter of the seal ring rode against the collar to prevent leakage of air or oil.

These 3–piece seals were replaced by double lip Teflon oil seals in 1986.

Each rotor is supported in the doweled end plates of the blower housing by a roller bearing at the front end and a double–row radial and thrust ball bearing at the gear end.

The right–hand helix rotor of the blower is driven by the blower drive shaft. The blower drive shaft is splined at one end to a drive hub attached to the blower drive gear and at the other end to a drive hub attached to the right–hand helix blower timing gear. The mating left–hand helix timing gear drives the left–hand helix rotor.

The basic blower parts for the 6 and 8 cylinder engines are identical and interchangeable with the exception of the housing and rotors which differ in length. Two 6V blowers are mounted on the top deck of the 12–cylinder engines while two 8V blowers are mounted on the top deck of the 16–cylinder engines. Both 12V and 16V blowers are driven by the gear trains at each end of the engine.

The blower rotors are timed by the two rotor gears at the rear end of the rotor shafts. This timing must be correct, otherwise the required clearance between the rotor lobes will not be maintained. A change in rotor timing is obtained by the use of shims between the gears and the bearings.

Normal gear wear causes a decrease of rotor–to–rotor clearance between the leading edge of the right–hand helix (drive) rotor and the trailing edge of the left–hand helix (driven) rotor. Clearance between the opposite sides of the rotor lobes is increased correspondingly.

While the rotor lobe clearance may be corrected by adjustment, gear backlash cannot be corrected. When gears have worn to the point where the backlash exceeds .004", replace the gears.

A coarse spline, 29–tooth blower drive system has replaced the 48–tooth system. The shafts are carbon–nitride hardened and the spline length of the front hub and turbo rear hub has been increased. The new 29 and 29/48 drive shafts are drilled to accept a .24" diameter spring. This spring is pressed into the front of the blower drive shaft nad helps reduce spline wear by limiting the axial (back and forth) movement of the drive shaft. New blower drive supports with a 1/32" oil passage for additional lubrication are being used on turbocharged engines only. The former 48–tooth and the new 29–tooth blower drive shafts, hubs, couplings and supports and the former and new snap rings are not interchangeable.

Two special 29/48–tooth blower drive shaft assemblies have been released to service large bearing blower engines having the former 48–tooth blower drive systems. The new shafts have 29 coarse splines on the blower drive support (rear) end and 48 splines on the blower timing gear (front) end. The new shaft assemblies are to be used only when the 48–tooth shaft and rear hub require replacement. If the blower assembly or front hub requires replacement or at time of major engine overhaul, a complete 29–tooth blower drive system should be installed.

A blower drive coupling spring pack is used in 6V–92 TA coach engines to prevent the transfer of torque fluctuations to the blower and reduce blower drive shaft spline wear. The spring pack is installed with the retainer groove in the cam facing the gear.

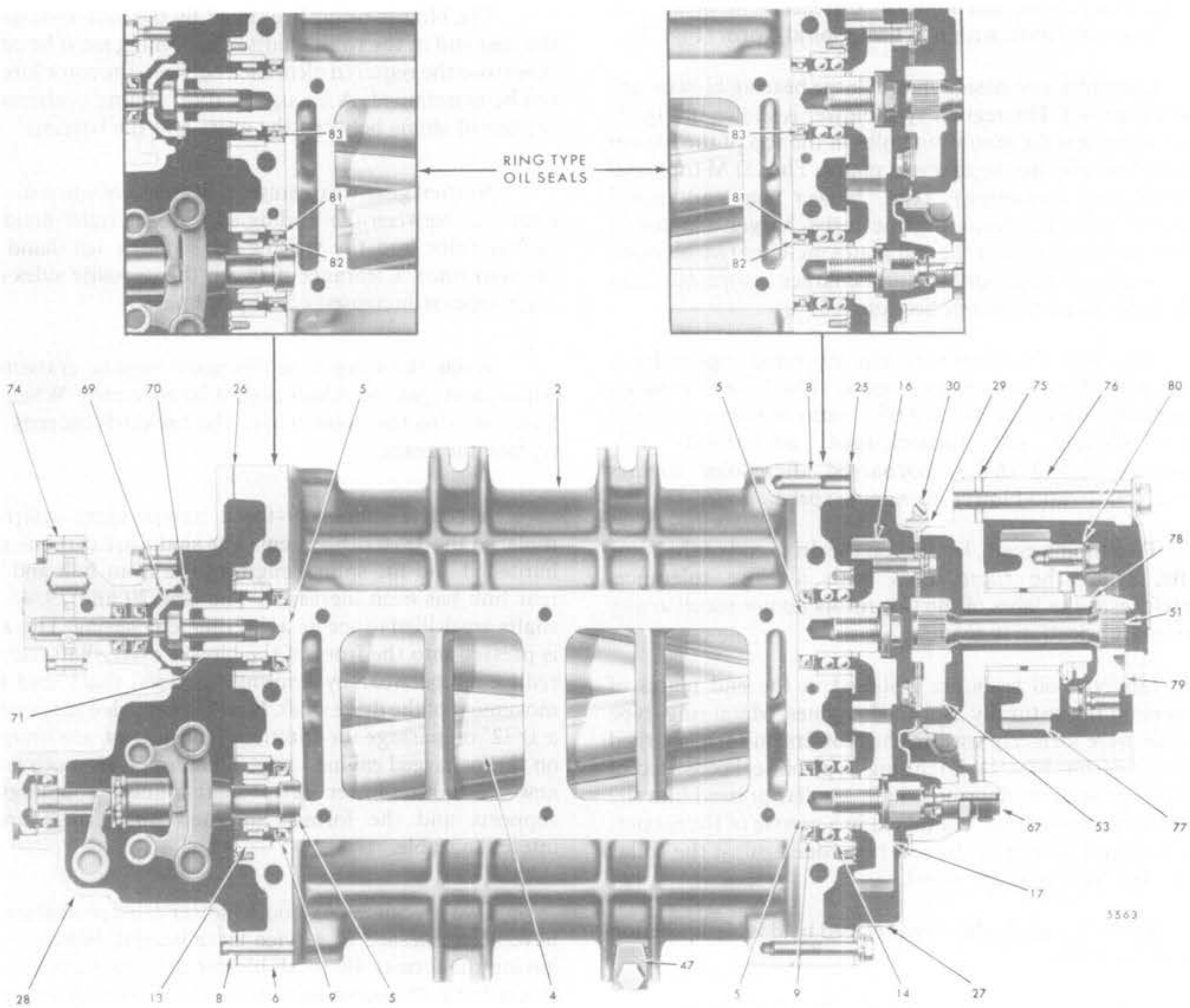


Fig. 1 – Blower and Drive Assembly and Accessories Attached to Blower

2.	Housing—Blower	25.	Gasket—Rear End Plate Cover	51.	Shaft—Blower Drive	76.	Housing—Flywheel
4.	Rotor Assy.—Blower	26.	Gasket—Front End Plate Cover	53.	Hub—Drive	77.	Gear—Blower Drive
5.	Shaft—Rotor	27.	Cover—Rear End Plate	67.	Fitting—Tachometer Drive Adaptor	78.	Support—Blower Drive
6.	Plate—Blower End	28.	Housing—Governor (Front End Plate Cover)	69.	Fork—Fuel Pump Drive	79.	Coupling—Blower Drive Flexible
8.	Pin—Dowel	29.	Seal—Rear End Plate Cover	70.	Disc—Fuel Pump Drive	80.	Plate—Blower Drive Flexible Coupling
9.	Seal—Oil	30.	Clamp—Rear End Plate Cover Seal	71.	Spacer—Fuel Pump Drive Disc	81.	Collar—Blower End Plate
13.	Bearing—Front (Roller)	47.	Lug—Mounting Bolt	74.	Pump Assy.—Fuel	82.	Carrier—Seal Ring
14.	Bearing—Rear (Ball)			75.	Plate—Cylinder Block Rear End	83.	Ring—Seal (Piston Type)
16.	Gear—Rotor Drive						
17.	Gear—Rotor Driven						

Fig. 1 – Blower and Drive Assembly and Accessories Attached to Blower

NOTICE: The shaft bore of the former blower drive supports installed in pre–1979 production engines cannot be rebored to the increased diameter of the current blower drive supports. Therefore, on engines built before 1979, new blower drive supports must be used when converting from a 48–tooth to a complete 29–tooth blower drive system.

Mini–Bypass Blower (6V And 8V Automotive Engines)

Effective with engine serial numbers 6VF–096295 and 8VF–079550, mini–bypass blowers have been released for 6V and 8V–92 Federal–certified and 8V–92 California–certified automotive engines equipped with front blower–mounted and real bracket–mounted turbochargers. Coach engines are not included in this change.

The mini–bypass blower was developed to increase fuel efficiency by reducing the amount of engine power required to operate the blower.

A spring–loaded bypass relief valve (Fig. 2) is positioned in a passage in the rear blower end plate of the turbocharged 6V and 8V–92 automotive engines indicated. This valve is closed at start–up and during low rpm/light load operation. However, as engine speed and load increase, turbocharger speed also increases until the turbocharger provides sufficient boost pressure for scavenging and charging the engine cylinders. At 12" Hg (41 kPa) airbox pressure the valve in the passage opens (Fig. 3). With the valve in the open position, incoming air is allowed to flow through the lobes of the blower and through the rear end plate to the airbox. The blower continues to operate with the valve open, but requires less engine power because the pressure rise across the blower is greatly reduced. This results in decreased brake specific fuel consumption and increased fuel economy.

The mini–bypass valve is externally vented back into the crankcase by means of a small vent hose and tube through the rear blower end plate. A very small amount of air bleeds past the valve and passes through the hose to help keep the valve clean and functioning properly. This has no effect on crankcase pressure.

• With the advent of the mini–bypass blower end plate and valve, one of the blower end plate cover bolts is eliminated and a new end plate cover reinforcing plate has been released. A new composition gasket is also being used to ensure proper sealing of the blower–to–end plate cover joint. An end plate cover reinforcing plate is used on 6V and 12V–92 midi–bypass blowers, effective with units manufactured March, 1986.

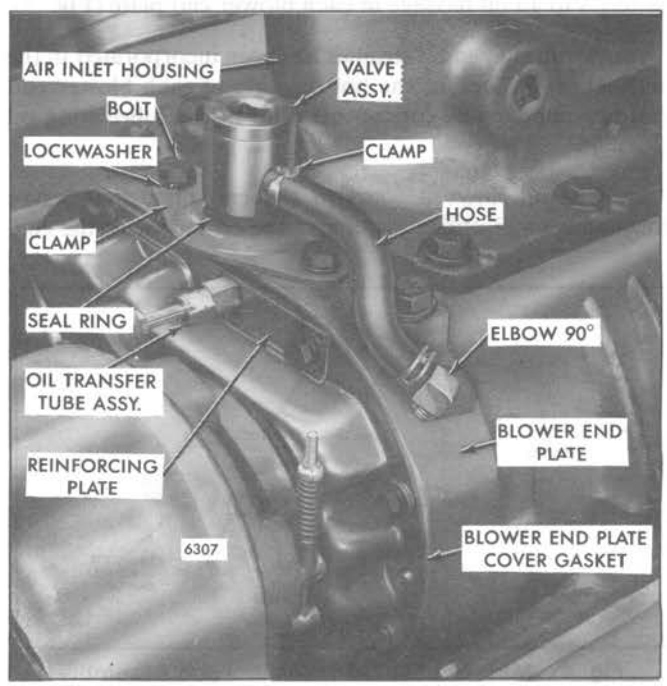


Fig. 2 – Typical Mini–Bypass Blower (6V–92)

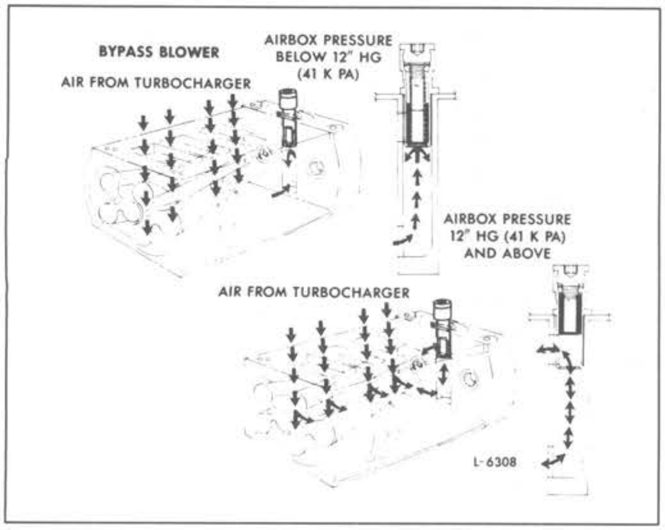


Fig. 3 – Mini–Bypass Blower Air Flow

Due to the size and location of the mini–bypass valve, new oil supply fittings (Fig. 4) are being used between the blower and the blower drive support, and new air inlet housings have been released. The blower assemblies formerly used on 6V and 8V–92 automotive engines equipped with front blower–mounted turbochargers or rear bracket–mounted turbochargers will continue to be serviced.

Lubrication

The blower bearings, timing gears, governor drive and fuel pump drive are pressure lubricated by oil passages in the top deck of the cylinder block which lead from the main oil galleries to an oil passage in each blower end plate (Fig. 5).

A cup shaped oil strainer has been incorporated in the vertical oil passage at the bottom side of each blower end plate to remove any foreign material in the lubricating oil (Fig. 5).

The oil flows upward in the end plate and leaves through a small orifice just above the centerline of the end plate. The oil is ejected from this orifice against the timing gears at the rear and the governor weights at the front of the blower and is then carried by splash to the bearings. Oil which collects at the bottom of each end plate overflows into two drain passages which lead back to the crankcase via oil passages in the cylinder block.

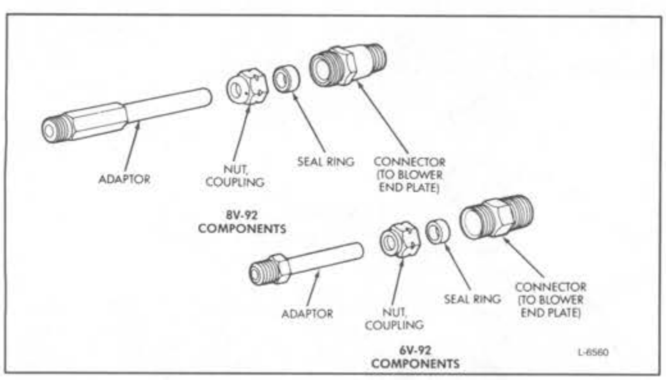


Fig. 4 – Mini–Bypass Oil Transfer Tube Assembly Components

NOTICE: The OTM (optional turbocharger mounting) type blower does not include an oil orifice in the end plate since the blower bearings are lubricated by the drain oil from the turbocharger.

The blower drive support bearings receive oil under pressure from a tube which connects the oil passage in the rear end plate to passages in the blower drive support. Excess oil drains back to the crankcase by way of the gear train.

Inspection

The blower may be inspected for any of the following conditions without being removed from the engine. However, the air silencer and adaptor, or the air inlet housing, air shutdown housing and adaptor must first be removed. The turbocharger and adaptor must also be removed on engines equipped with the OTM blower.

CAUTION: When inspecting a blower on an engine with the engine running, keep fingers and clothing away from moving parts of the blower and run the engine at low speeds only.

1. Dirt or chips, drawn through the blower, will make deep scratches in the rotors and housing and throw up burrs around such abrasions. If burrs cause interference between the rotors or between the rotors and the housing, remove the blower from the engine and "dress" the parts to eliminate interference, or replace the rotors if they are badly scored.

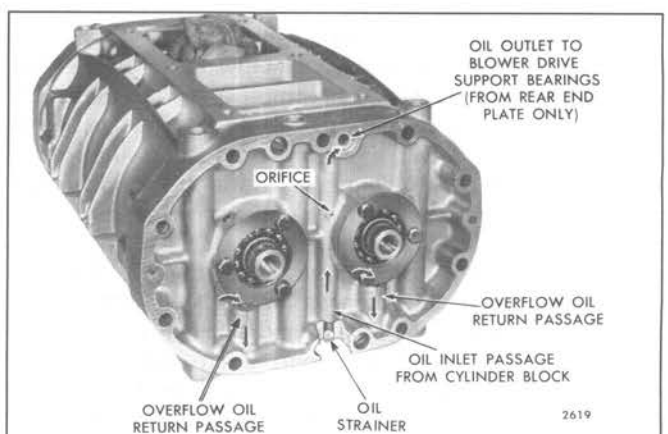


Fig. 5 – Blower Lubrication (Except OTM Blower)

2. Leaky oil seals are usually manifest by the presence of oil on the blower rotors or inside surfaces of the housing. This condition may be checked by running the engine at low speed and directing a light into the rotor compartment at the end plates and the oil seals. A thin film of oil radiating away from the seals toward the inlet of the blower is indicative of leaking seals.

3. Loose rotor shafts or damaged bearings will cause rubbing and scoring between the crowns of the rotor lobes and the mating rotor roots, between the rotors and the end plates, or between the rotors and the housing. Generally, a combination of these conditions exists. Worn or damaged bearings will cause rubbing between mating rotor lobes at some point or perhaps allow the rotor assemblies to rub the blower housing or the end plates. This condition will usually show up at the end where the bearings have failed.

4. Excessive backlash between the blower timing gears usually results in the rotor lobes rubbing throughout their entire length. This usually is on the trailing (close clearance) side.

5. Inspect the blower inlet screen, periodically, if used, as noted in Section 15.1, for an accumulation of dirt which, after prolonged operation, may affect the air flow. Servicing of the screen consists of thoroughly washing it in fuel oil and cleaning with a stiff brush until the screen is free of all dirt deposits. If broken wires are found in the blower screen, replace the screen.

6. Check the lubricating oil connection between the blower and the blower drive support for excessive oil leakage. If oil leakage exists, retighten or replace the fittings or seal rings.

7. Check the rubber seal ring used between the blower end plate cover and the blower drive support for oil leakage. If oil leakage exists, retighten the seal clamp or replace the seal ring. Some engines use a seal ring (.740" wide) that incorporates two raised edges which provide a groove to retain the clamp. To replace a seal ring without removing the blower, refer to Section 3.0.

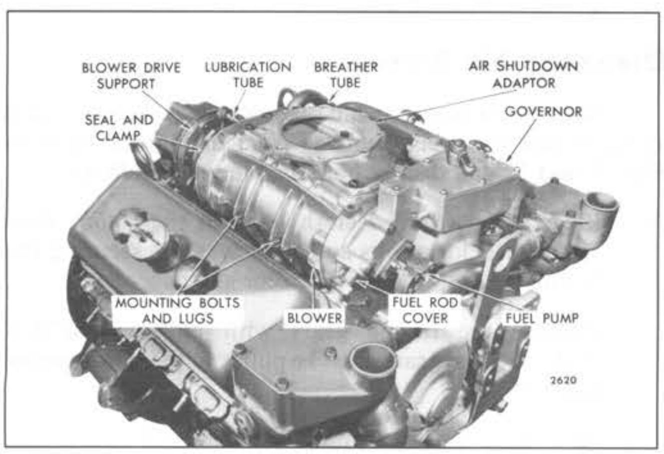


Fig. 6 – Typical Blower Mounting (Single Blower)

To correct any of the conditions cited in Items 1 through 6, the blower must be removed from the engine and either repaired or replaced.

Remove Blower From Engine

The engine governor components are assembled in a combination governor housing and blower front end plate cover. The fuel pump is also attached to the front end of the blower. Therefore, when removing the blower assembly from the engine, the governor and fuel pump will also be removed at the same time. Refer to Fig. 6 and proceed as follows:

1. Disconnect the air cleaner to air shutdown housing, or turbocharger, tubing as required (Section 3.1 or 3.5).
2. Remove the turbocharger, if used, and attaching parts (Section 3.5).
3. Disconnect the shutdown wire assembly from the air shutoff cam pin handle.
4. Remove the air shutdown housing assembly and gasket (Section 3.3).
5. Remove the bolts and washers securing the air shutdown housing to the blower. Remove the adaptor and the blower screen (if used).
6. Loosen the oil pressure line fitting from the rear of the blower to the blower drive support and slide the fitting back on the tube.
7. Loosen the hose clamp on the blower drive support–to–blower seal.
8. Disconnect the tachometer drive cable from the adaptor at the rear of the blower.
9. Remove the flywheel housing cover at the blower drive support.
10. Remove the snap ring and withdraw the blower drive shaft from the blower.
11. Open the drain cocks and drain the engine cooling system.
12. Loosen the hose clamps and slide the hoses back on the bypass tube between the thermostat housings. Remove the bypass tube.
13. Remove the fuel inlet and outlet lines to the fuel pump. Also, remove the fuel return crossover tube between the cylinder heads.

14. Remove or disconnect the breather pipe at the top of the cylinder block.

15. Remove the front engine lifter bracket, if necessary.

16. Disconnect the throttle control rods from the governor.

17. Clean and remove the rocker cover from each cylinder head.

18. Remove the eight governor cover screws and lock washers and remove the governor cover.

19. Disconnect the fuel rods from both the injector control tube levers and the governor and remove the fuel rods.

20. Loosen the hose clamps on the fuel rod cover tube hoses next to each cylinder head and slide each hose and clamp up on the tube in the governor housing.

21 Remove the two bolts and washers through the top of each end plate which secures blower to the cylinder block.

22. Remove the blower–to–block bolts and retaining washers on each side of the blower.

23. Disconnect and remove any tubing or accessories which may interfere with removal of the blower.

24 On 12V and 16V engines, disconnect the governor linkage as outlined in Section 2.7.1. Remove the governor from the engine. Either blower may be removed without disturbing the other blower. Remove the governor to blower gasket.

25. Thread eyebolts in the diagonally opposite tapped holes in the top of the blower housing. Then, attach a rope sling and chain hoist to the eyebolts.

26. Lift the blower up slightly and move it forward to detach the blower from the seal at the drive end. Then, lift the blower up and away from the engine. Remove the blower gasket.

With the blower, fuel pump and governor assembly removed from the engine, cover the air inlet and outlet openings of the blower housing and install the governor cover. Wash the exterior of the blower and governor housing with clean fuel oil and dry them with compressed air.

Remove Blower Rear End Plate Cover

Remove the blower rear end plate cover, governor and fuel pump assembly from the blower as follows:

1. Remove the remaining bolts, lock washers and special washers securing the rear end plate cover to the end plate. Remove the cover and gasket from the end plate.

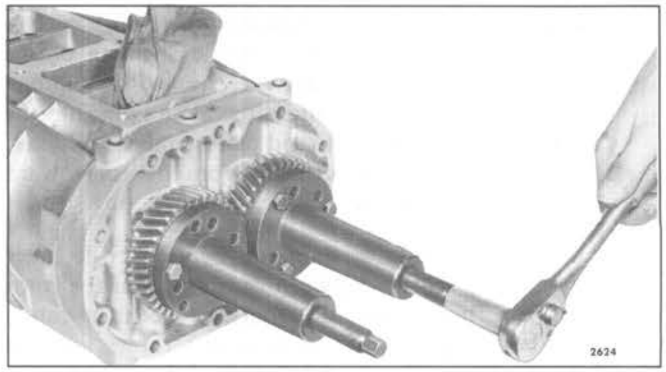


Fig. 7 – Removing Blower Gears with Tool J 6270–31

2. Remove the three bolts and washers or lock bolts securing the flex plates to the right–hand blower rotor gear. Remove the drive coupling from the gear.

   Some former engines are equipped with thin hub spacers. They are not readily accessible, and some mechanics may not be aware that they are behind the flex plate. Consequently, when working on the blower hub assemblies, remove the flex plate attaching bolts carefully to avoid dropping the thin hub spacers into the gear train. If spacers are inadvertently dropped into the gear train, removal of the engine flywheel housing and/or oil pan may be required to retrieve them.

3. Note the location of the two copper washers, one plain washer and eight lock washers on the governor–to–blower bolts before removing them. Then, remove the ten bolts and washers (two inside and eight outside) securing the governor and fuel pump assembly to the blower.

4. Tap the sides of the governor housing slightly with a plastic hammer to loosen the governor from the blower. Then, pull the governor and fuel pump assembly from the dowels in the blower end plate. Remove the fuel pump drive coupling fork and the governor housing gasket.

Disassemble Blower

With the blower rear end plate cover, blower drive hub and governor assembly removed from the blower, refer to Figs. 1 and 12 and disassemble the blower as follows:

1. Place a clean folded cloth between the rotors, then remove the lock bolts and thick washers securing the timing gears to the blower rotor shafts.

2. Remove the timing gears with pullers J 6270–1 (Fig. 7). Both gears must be pulled at the same time as follows:

   a. Back out the center screws of both pullers and place the flanges against the gear faces, aligning the flange holes with the tapped holes in the gears. Secure the pullers to the gears with 5/16"-24 x 1-1/2" bolts (two bolts on the L.H. helix gear and three bolts on the R.H. helix gear).

b. Turn the two puller screws uniformly clockwise and withdraw the gears from the rotor shafts (Fig. 7).

3. Remove the shims from the rotor shafts, after the gears have been removed, and note the number and thickness of shims on each rotor shaft to ensure identical replacement when reassembling the blower.

4. Remove the self locking screws securing the rotor shaft bearing retainers to the front and rear end plates. Remove the retainers.

5. Remove the blower rear end plate and ball bearing assembly from the blower housing and rotors with the two pullers J 6270-31 as follows:

a. Remove the two fillister head screws securing the rear end plate to the blower housing and loosen the two fillister head screws securing the front end plate to the housing approximately three turns.

b. Back out the center screws of the pullers far enough to permit the flange of each puller to lay flat on the face of the end plate.

c. Align the holes in each puller flange with the tapped holes in the end plate and secure the pullers to the end plate with six 1/4"-20 x 1-1/4" or longer bolts.

NOTICE: Be sure that the 1/4"-20 bolts are threaded all the way into the tapped holes in the end plate to provide maximum anchorage for the pullers and to eliminate possible damage to the end plate.

d. Turn the two puller screws uniformly clockwise and withdraw the end plate and bearings from the blower housing and rotors (Fig. 8).

6. Remove the blower front end plate and roller bearing assembly from the blower housing and rotors as follows:

a. Remove the fuel pump drive bolt, washer and spacer.

b. Remove the two fillister head screws securing the front end plate to the blower housing.

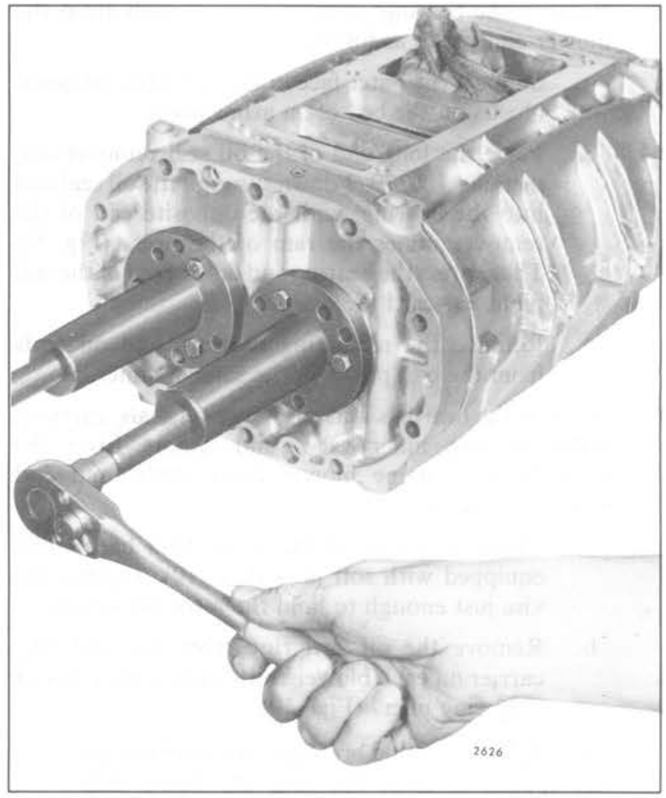


Fig. 8 – Removing Blower End Plate and Bearings from Housing and Rotors with Tool J 6270-31

c. Remove the front end plate and roller bearings from the housing and rotors.

NOTICE: The roller bearing inner races will remain on the shaft of the rotor and the lip type oil seals could be damaged.

7. Withdraw the blower rotors from the housing.

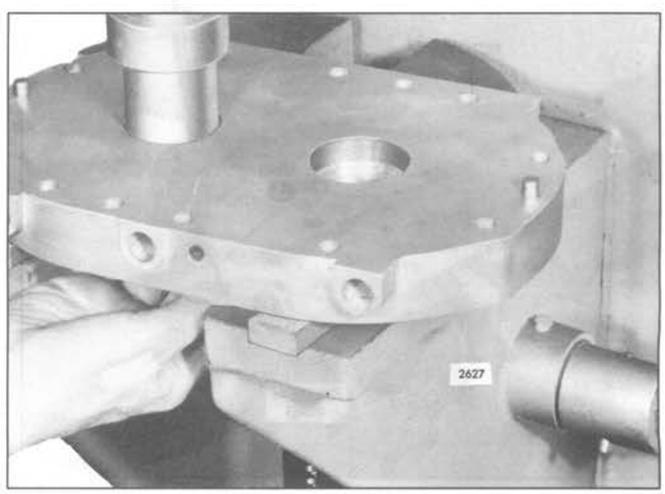


Fig. 9 – Removing Oil Seal (or Oil Seal Ring Collar) and Bearing from End Plate with Tool J 6270-3

8. Remove the bearings and *lip type* oil seals from the blower end plates as follows:

   a. Support the outer face of the end plate on wood blocks on the bed of an arbor press.

   b. Place the long end of the oil seal remover and installer J 6270–3 down through the oil seal and into the bearing, with the opposite end of the remover under the ram of the press (Fig. 9). Then, press the bearing and oil seal out of the end plate. Discard the oil seal.

   c. Remove the remaining bearings and oil seals from the end plates in the same manner.

9. Remove the bearings and *ring–type* oil seals, carriers, roller bearing inner races and collars from the turbocharged engine blower rotor shafts and end plates as follows:

   a. Clamp one lobe of the rotor in a bench vise equipped with soft jaws (Fig. 10). Tighten the vise just enough to hold the rotor stationary.

   b. Remove the oil seal ring from the seal ring carrier on each blower rotor shaft with a pair of snap ring pliers (Fig. 10).

   NOTICE: To avoid breakage or distortion, do not spread or twist the ring any more than necessary to remove it.

   c. Refer to Fig. 11 and place the seal ring carrier remover adaptor J 6270–2 over the carrier. Make sure the adaptor is seated in the groove of the carrier.

   d. Back out the center screw of puller J 6270–31 far enough to permit the puller flange to lay flat against the adaptor J 6270–2.

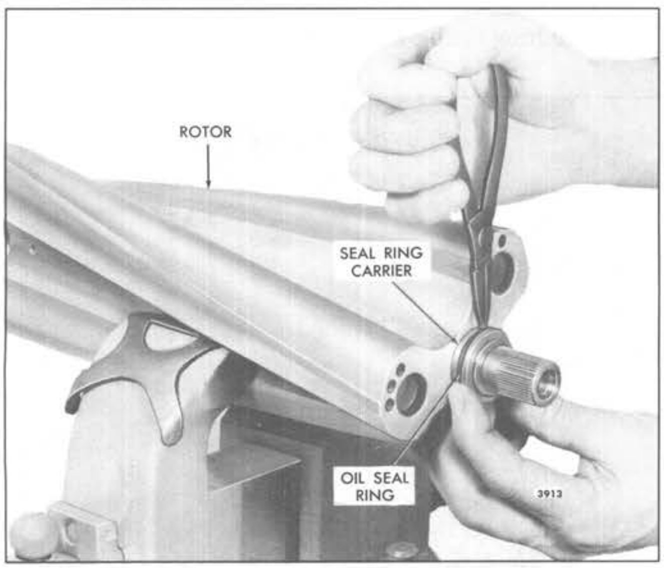


Fig. 10 – Removing Oil Seal Ring from Carrier (Turbocharged Engine Blowers)

   e. Place the puller over the end of the rotor shaft and against the adaptor on the oil seal ring carrier. Align the holes in the puller flange with the tapped holes in the adaptor, then secure the puller to the adaptor with two bolts.

   f. Turn the puller screw clockwise and pull the oil seal ring carrier and roller bearing inner race (front end of blower rotors only) from the rotor shaft (Fig. 11).

   g. Remove the remaining oil seal ring carriers from the rotor shafts in the same manner.

   h. Refer to Fig. 9 and support the outer face of the blower end plate on wood blocks on the bed of an arbor press.

   i. Place the long end of the oil seal remover and installer J 6270–3 down through the oil seal ring collar and into the bearing, with the opposite end of the remover under the ram of the press (Fig. 9). Then, press the bearing and oil seal ring collar out of the end plate.

   j. Remove the remaining bearings and oil seal ring collars from the end plates in the same manner.

The oil seal ring collar can be removed from the blower end plate with the bearing in place as follows:

   a. Insert J 6270–15 bushing ram (with the "O" ring) in the collar with the lip of the remover on the inside edge of the collar.

   b. Support the inner face of the blower end plate on wood blocks.

   c. Insert the small end of the driver handle J 6270–17 through the bearing and into the collar remover, spreading it tight in the collar.

   d. Press or tap on the driver handle to remove the collar.

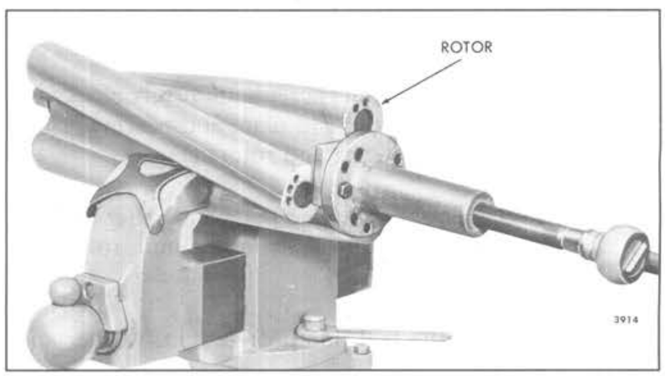


Fig. 11 – Removing Oil Seal Ring Carrier from Blower Rotor Shaft (Turbocharged Engine Blowers) using Tools J 6270–2 and J 6270–31

Inspection

Wash all of the blower parts in clean fuel oil and dry them with compressed air.

CAUTION:To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.

Examine the bearings for any indications of corrosion or pitting. Lubricate each ball bearing with light engine oil. Then, while holding the bearing inner race from turning, revolve the outer race slowly by hand and check for rough spots.

The double–row ball bearings are pre–loaded and have no end play. A new bearing will seem to have considerable resistance to motion when revolved by hand.

Check the oil seal rings, carriers and collars for wear or scoring. If worn excessively, they must be replaced. The current oil seal rings are chrome flashed and the carriers are liquid nitrided. When replacement of an oil seal ring or carrier is necessary, both parts must be replaced together.

Inspect the blower rotor lobes, especially the sealing ribs, for burrs or scoring. Rotors must be smooth for satisfactory operation of the blower. If the rotors are slightly scored or burred, they may be cleaned up with emery cloth.

Examine the rotor shaft serrations for wear, burrs or peening. Also inspect the bearing and oil seal contact surfaces of the shafts for wear or scoring.

Inspect the inside surface of the blower housing for burrs or scoring. The inside surface must be smooth for efficient operation of the blower. If the inside surface of the housing is slightly scored or burred, it may be cleaned up with emery cloth.

Check the finished ends of the blower housing for flatness or burrs. The end plates must set flat against the blower housing.

The finished inside face of each end plate must be smooth and flat. If the finished face is slightly scored or burred, it may be cleaned up with emery cloth.

NOTICE: Be careful not to remove metal at the joint face between the end plates and the housing. Air or oil leaks could develop after assembly.

Examine the serrations in the blower timing gears for wear or peening. Also, check the gear teeth for wear, chipping or other damage. If the gears are worn to the point where the backlash between the gears exceeds .004", or damaged sufficiently to require replacement, both gears must be replaced as a set.

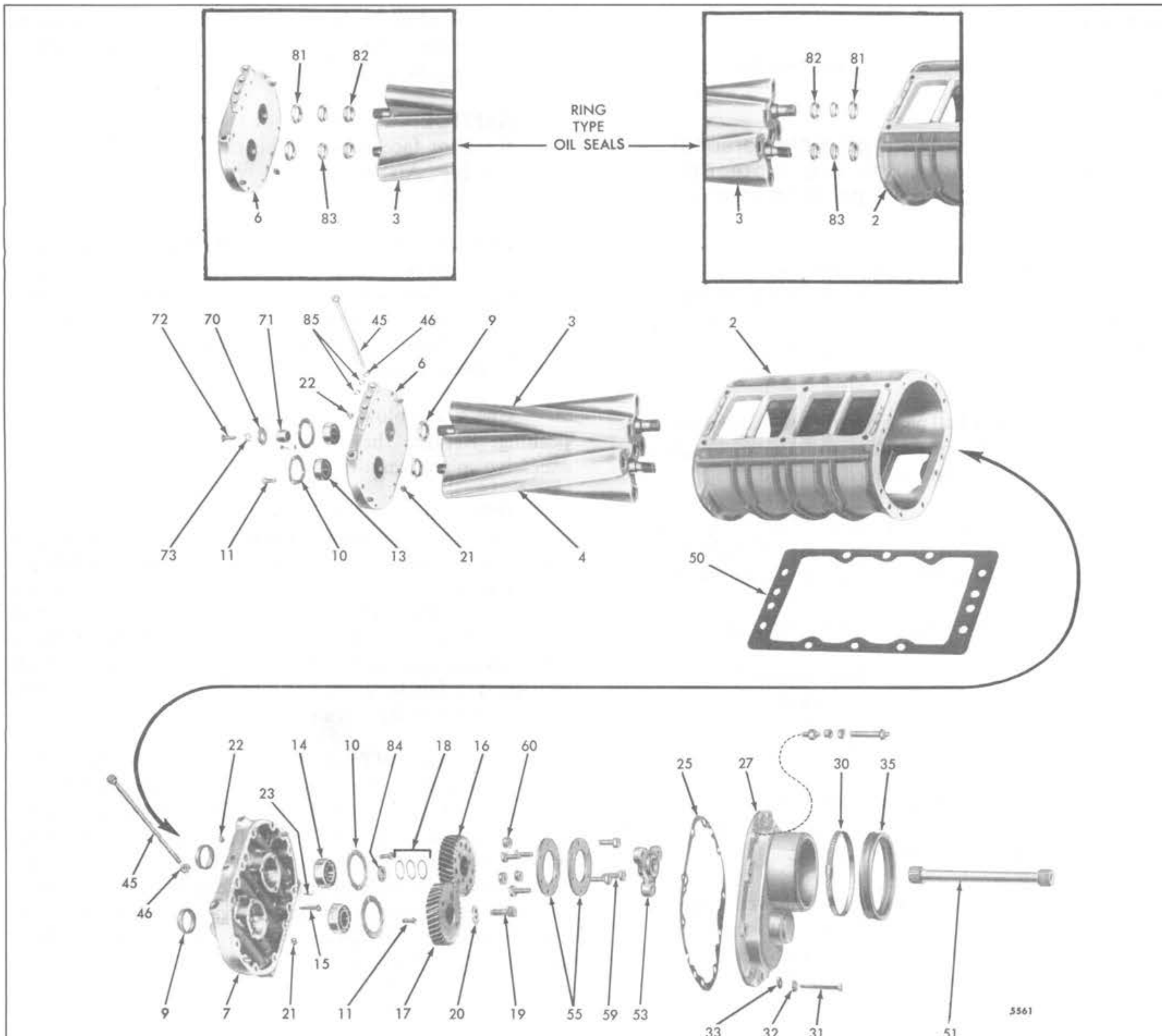
Check the blower drive shaft serrations for wear or peening. Replace the shaft if it is bent, cracked or has excessive spline wear.

Before installing a 29/48–tooth blower drive shaft, check the splines on the front hub for wear. During engine operation the splines on the front hub and the front hub end of the blower drive shaft normally wear at a slower rate than the rear hub splines. Before replacing the drive shaft and rear hub, install the new shaft and rotate it back and forth to determine the amount of front hub spline wear. If perceptible lash (wear) is felt, the front hub is badly worn, and a complete 29–tooth blower drive system should be installed.

The amount of front hub wear can also be determined by inspecting the corresponding splines on the used blower drive shaft. Minimal shaft spline wear indicates minimal hub spline wear, and the new 29–48–tooth drive shaft should provide satisfactory service until engine overhaul and complete system replacement. Conversely, significant shaft spline wear indicates significant front hub spline wear. In this event, the 48–tooth system should be replaced immediately with the 29–tooth system.

Replace all worn or excessively damaged blower parts.

Clean the oil strainer in the vertical oil passage at the bottom side of each blower end plate and blow out all oil passages with compressed air.



2. Housing—Blower
3. Rotor Assy.—R. H. Helix
4. Rotor Assy.—L. H. Helix
6. Plate—Blower Front End
7. Plate—Blower Rear End
9. Seal—Oil
10. Retainer—Blower Bearing
11. Retainer—Lock Screw
13. Bearing—Blower Rotor Front (Roller)
14. Bearing—Blower Rotor Rear (Ball)
15. Screw—Fillister Head
16. Gear—R. H. Helix Rotor
17. Gear—L. H. Helix Rotor
18. Shim—Blower Gear
19. Bolt—Blower Gear
20. Washer
21. Strainer—End Plate Oil Passage
22. Plug—Oil Passage
23. Orifice—Oil Passage
25. Gasket—Cover
27. Cover—Rear End Plate
30. Clamp—Hose
31. Bolt—Cover
32. Lock Washer
33. Washer—Special Flat
35. Hose—Blower Drive Cover
45. Bolt—Blower Mounting
46. Lock Washer
50. Gasket
51. Shaft—Blower Drive
53. Hub—Drive
55. Plate—Flexible
59. Bolt
60. Spacer
70. Disc—Fuel Pump Drive
71. Spacer—Fuel Pump Drive Disc
72. Bolt—Drive Disc
73. Lock Washer
81. Collar—Blower End Plate
82. Carrier—Seal Ring
83. Ring—Seal (Piston Type)
84. Spacer
85. Seal Ring

Fig. 12 – Blower Details and Relative Location of Parts

Assemble Blower

Several precautions are given below to assure proper assembly of the rotors and gears for correct blower timing.

1. The lobes on the *driving* blower rotor and the teeth on its gear form a right–hand helix while the lobes and teeth of the *driven* rotor and gear form a left–hand helix. Hence, a rotor with right–hand helix lobes must be used with a gear having right–hand helix teeth and vice versa.
2. One serration is omitted on the drive end of each blower rotor shaft and a corresponding serration is omitted in each gear. Assemble the gears on the rotor shafts with the serrations in alignment.
3. The rotors must be assembled in the blower housing with the omitted serrations in the rotor shafts aligned as shown in Fig. 24.

With these precautions in mind, proceed with the blower assembly, referring to Figs. 12 through 24 as directed in the text:

1. Install new *lip type* oil seals as follows:

   a. Support the blower end plate, finished surface facing up, on wood blocks on the bed of an arbor press.

NOTICE: If oversize oil seals are being used in the blower end plates, use installer J 6270–28 to install the oversize oil seal spacers on the rotor shafts.

   b. Start the oil seal straight into the bore in the end plate with the sealing edge facing down (toward the bearing bore).

   c. Place the short end of oil seal remover and installer J 6270–3 in the oil seal and press the oil seal into the end plate until the shoulder on the installer contacts the end plate (Fig. 13).

NOTICE: A step under the shoulder of the installer will position the oil seal approximately .005" below the finished face of the end plate. This is within the .002" to .008" specified.

   d. Install the remaining oil seals in the end plates in the same manner.

•2. Install *double–lip Teflon* oil seals as follows:

   a. Press the oversize oil seal spacer onto the rotor shaft with installer J 35787–1 until either the shoulder of the tool or the spacer contacts the rotor.

   b. Support the blower end plate, finished surface up, on wood blocks on the bed of an arbor press.

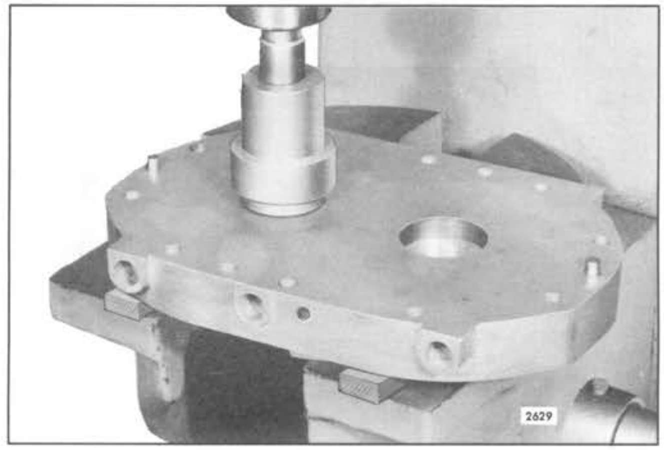


Fig. 13 – Installing Oil Seal (or Oil Seal Ring Collar) in End Plate using Tool J 6270–3

NOTICE: Do not lubricate the seals, spacers, or blower rotor shafts prior to seal installation. Teflon lip seals *must* be installed dry. This allows transfer of the Teflon to the spacer surface for proper sealing.

Double–lip Teflon seals are packaged around a special plastic sleeve which should not be removed prior to seal installation. The sleeve protects the lips of the seals during shipment and acts as a seal lip expander during blower assembly.

   c. With the part number on the seal facing the rotor, start the oil seal straight into the bore in the end plate.

   d. Using installer J 35787–2, press the double–lip oil seal below the surface of the end plate until the shoulder of the installer contacts the end plate.

   e. Install the remaining oil seals in the end plates in the same manner.

3. Install the *ring–type* oil seal carriers, collars, seal rings and roller bearing inner races (front end of blower rotors only) on the rotor shafts and in the end plates as follows:

   a. Support one of the rotor assemblies on wood blocks on the bed of an arbor press (Fig. 15).

   b. Lubricate the inside diameter of the oil seal ring carrier with engine oil. Then start the carrier straight over the end of the rotor shaft with the chamfered inside diameter end facing the rotor.

   c. Place the oil seal ring carrier installer J 6270–13 over the end of the rotor shaft and against the carrier with the end of the installer under the ram of the press. Then press the carrier down tight against the rotor.

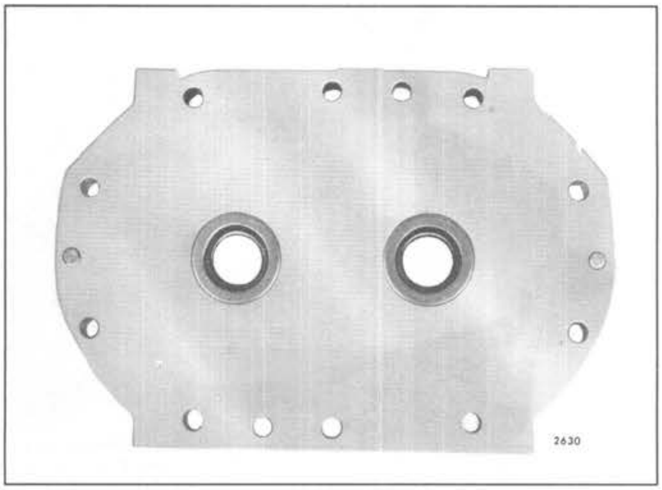


Fig. 14 – Location of Oil Seals in End Plate

d. Install the remaining oil seal ring carriers on the rotor shafts in the same manner.

e. Install an oil seal ring in the ring groove of each carrier with a pair of snap ring pliers in the same manner as shown in Fig. 10.

NOTICE: To avoid breaking the oil seal rings, do not spread them any more than necessary to place them over the end of the carrier. Do not twist the rings or possible distortion may result in loss of side contact area.

f. Support one of the blower end plates, inner face up, on wood blocks on the bed of an arbor press (Fig. 13).

g. Lubricate the outside diameter of a seal ring collar with engine oil. Then start the chamfered outside diameter end of the collar straight into the bore in the end plate.

h. Place the oil seal ring collar installer J 6270-3 on top of the seal ring collar and under the ram of the press (Fig. 13). Then, press the collar into the end plate until the shoulder on the installer contacts the end plate.

NOTICE: A step under the shoulder of the installer will position the collar approximately .005" below the finished face of the end plate. This is within the .002" to .008" specified.

i. Install the remaining oil seal ring collars in the end plates in the same manner.

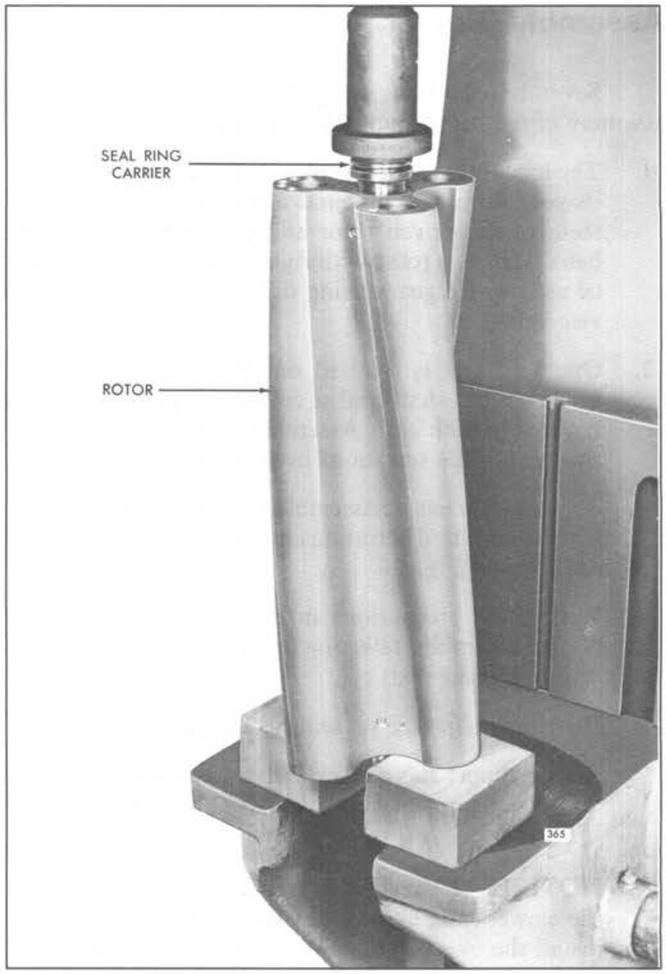


Fig. 15 – Installing Oil Seal Ring Carrier on Blower Rotor Shaft (V-92T Blowers) with Tool J 6270-4

Assemble Rotors And End Plates (Blower With Lip Type Oil Seals)

1. Install the blower front end plate.

The top of the end plate is readily identified by the two bolt holes and one oil hole, whereas the bottom side of the end plate has two bolt holes and three oil holes. Also, the front end plate is thinner than the rear end plate.

NOTICE: The horizontal oil passage in the top front face of the front end plate that intersects the vertical oil passage is plugged. Do not install this end plate on the rear end of the blower housing.

The front end plate should be attached to the front end of the blower housing first. The rear end plate is attached to the blower housing after the rotors are in place. Attach the front end plate to the blower housing as follows:

a. If removed, press a new oil strainer into the vertical oil passage at the bottom side of the end plate .150" below the bottom surface (Fig. 5). Then, install the pipe plug in the vertical oil passage at the top of the end plate.

b. Check the dowel pins. The dowel pins must project .320" from the flat inner face of the front end plate to assure proper alignment of the end plate with the housing.

c. If removed, press a new bolt guide sleeve (bushing) into one bolt hole in the bottom side of the end plate. Install the sleeve, with the three notches on the sleeve to the bottom side of the end plate and the center notch to the outside of the end plate, flush to .005" below the surface of the end plate.

NOTICE: When installed, the inside flats of the sleeve will be parallel to the center line of the housing.

d. Place the blower housing on a bench with the top side of the housing up and the front end of the housing facing the outside of the bench.

e. Apply a light coating of Permatex FORM-A-GASKET NO. 2 or an equivalent sealant to the mating surfaces of both the end plate and blower housing. Then, position the end plate in front of the blower housing with the top side of the end plate facing up. Start the dowel pins straight into the dowel pin holes in the housing. Push or tap the end plate against the housing. Note that no gaskets are used between the end plates and the housing. Therefore, the mating surfaces should be perfectly flat and smooth, however, caution must be used so that no sealant protrudes into the housing. Also, the sealant must not prevent the end plate from laying flat against the housing.

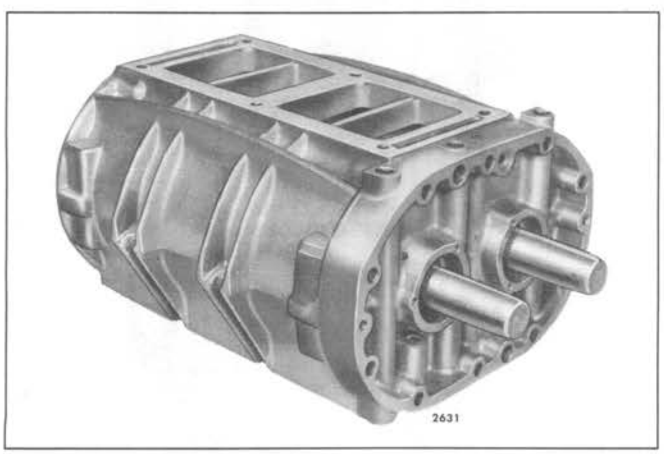


Fig. 16 – Assembling Blower Rotors in Housing and Front End Plate with Oil Seal Pilots (J 6270–5)

f. Insert the two fillister head screws through the end plate and thread them into the housing. Tighten the screws to 5–10 lb-ft (7–14 N•m) torque. Do not use lock washers on these screws.

2. Refer to Fig. 16 and install the blower rotors in the blower housing and end plate as follows:

a. Reverse the blower housing on the bench (open end of housing facing the outside of the bench).

b. Place the rotors in mesh with the omitted serrations in the rotor shafts in a horizontal position and facing to the left as viewed from the gear end. Note that the right–hand helix rotor is marked "GEAR END " on one end. The gear end of the left–hand rotor is that end which has the serrated shaft.

c. Install an oil seal pilot J 6270–5 over the opposite end of each rotor shaft.

NOTICE: When oversize oil seals are used in the blower end plate, use oil seal spacer installer J 6270–28 for the oil seal pilots in place of J 6270–5.

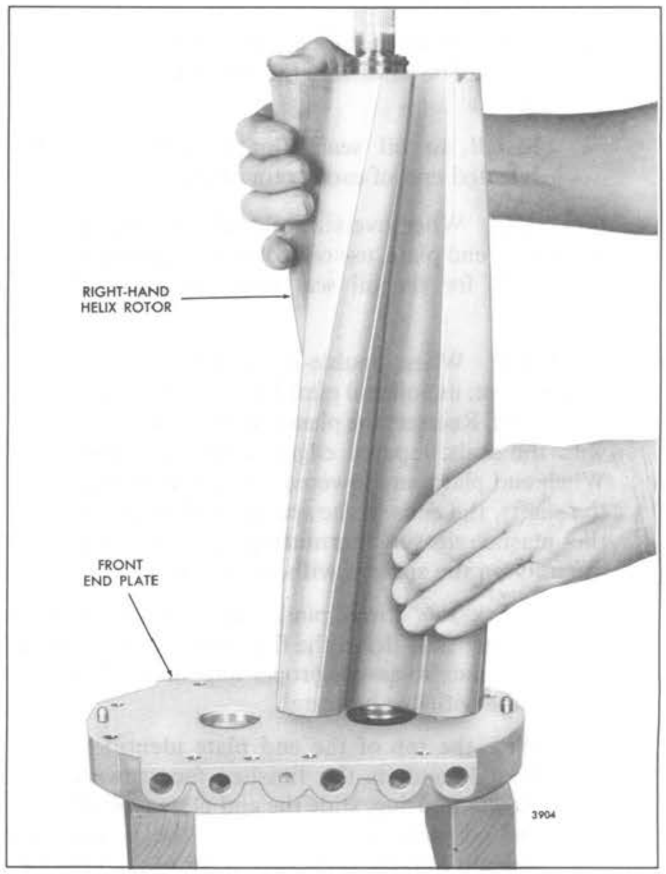


Fig. 17 – Installing Blower Rotor in Front End Plate (V–92T Blowers)

NOTICE: When double–lip Teflon oil seals are installed, use oil seal pilot J 6270–5 over each rotor shaft. Reinsert the plastic sleeves that came with the seals, tapered edges facing outboard. When end plates are lowered into position over the shafts, the ends of the spacers will push out the plastic sleeves, permitting seals to seat squarely on the spacers without damage.

d. Insert the rotors straight into the housing and through the front blower end plate.

e. Remove the oil seal pilots from the rotor shafts.

3. Install the blower rear end plate as follows:

a. If removed, press a new oil strainer into the vertical oil passage at the bottom side of the end plate .150" below the bottom surface (Fig. 5). Then, install the pipe plug in the vertical oil passage at the top of the end plate.

b. If removed, press a new bolt guide sleeve (bushing) into one bolt hole in the bottom side of the end plate. Install the sleeve, with the three notches on the sleeve to the bottom side of the end plate and the center notch to the outside of the end plate, flush to .005" below the surface of the end plate.

NOTICE: When installed, the inside flats of the sleeve will be parallel to the center line of the housing.

c. Install an oil seal pilot J 6270–5 over the serrated end of each rotor shaft.

NOTICE: When oversize oil seals are used in the blower end plate, use oil seal spacer installers J 6270–28 for the oil seal pilots in place of J 6270–5.

NOTICE: When double–lip Teflon oil seals are installed, use oil seal pilot J 6270–5 over each rotor shaft. Reinsert the plastic sleeves that came with the seals, tapered edges facing outboard. When end plates are lowered into position over the shafts, the ends of the spacers will push out the plastic sleeves, permitting seals to seat squarely on the spacers without damage.

d. Check the dowel pins. The dowel pins must project .320" from the flat inner face of the rear end plate to assure proper alignment of the end plate with the housing.

e. With the top of the end plate identified as in Step 1, and its flat finished face towards the blower housing, slide the end plate straight over the oil seal pilots and start the dowel pins straight into the dowel pin holes in the housing. Then, push or tap the end plate against the housing.

f. Insert the two fillister head screws through the end plate and thread them into the housing. Tighten the screws to 5–10 lb–ft (7–14 N•m) torque. Do not use lock washers on these screws.

g. Remove the oil seal pilots from the rotor shafts.

4. Check the relationship of the blower end plates to the housing at the cylinder block side of the blower assembly. The protrusion of the housing with respect to the end plates should not be more than .0005" above to .0065" below the end plate. Excessive protrusion could distort the housing when the end plate to cylinder block bolts are tightened and cause rotor to housing interference.

Assemble Rotors And End Plates (Blower With Ring–Type Oil Seals — Regular And OTM Blowers)

1. Install the blower rotors in the blower front end plate as outlined below.

a. Check the dowel pins. The dowel pins must project .320" from the flat inner face of the front end plate to assure proper alignment of the end plate with the housing.

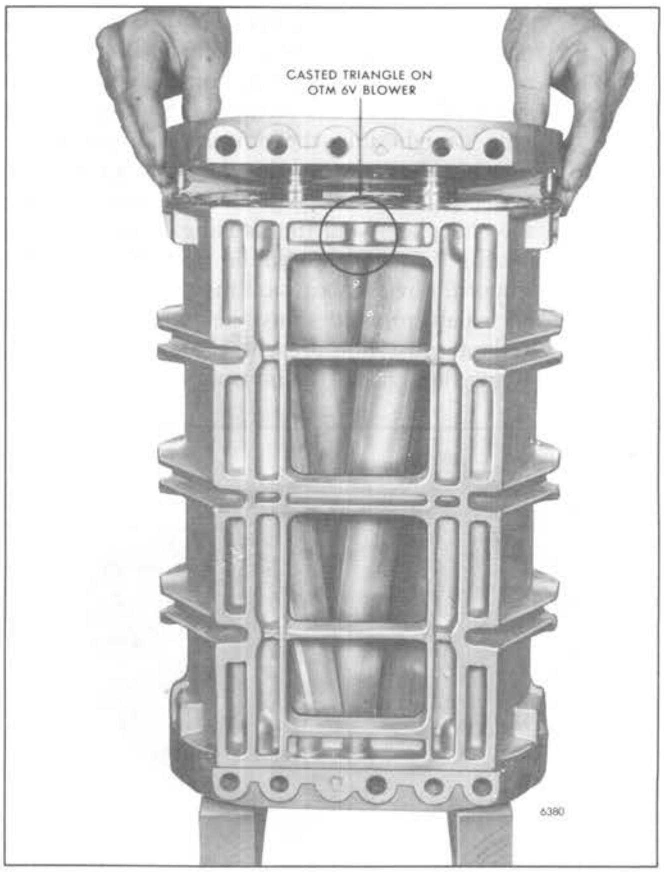


Fig. 18 – Installing Rear End Plate on Blower Rotors and Housing

b. If removed, press a new bolt guide sleeve (bushing) into one bolt hole in the bottom side of the end plate. Install the sleeve, with the three notches on the sleeve to the bottom side of the end plate and the center notch to the outside of the end plate, flush to .005" below the surface of the end plate.

NOTICE: When installed, the inside flats of the sleeve will be parallel to the center line of the housing.

c. Support the front end plate on two wood blocks approximately 4" high, with the inner face of the end plate facing up and the TOP side of the plate facing the serviceman's right (Fig. 17).

d. Lubricate the oil seal ring in the carrier on the front end of the right–hand helix rotor shaft with engine oil.

e. Hold the right–hand helix rotor in a vertical position (gear end up) and position the seal ring in the carrier so the ring protrudes from its groove the same amount on each side and the gap is facing away from the serviceman.

f. With the omitted serration in the splines of the shaft facing toward the top side of the end plate, start the end of the rotor shaft into the right–hand shaft opening in the end plate so that the gap portion of the seal ring is started into the ring collar (Fig. 17). Continue to lower the rotor and very carefully apply pressure to the seal ring approximately 180° from the gap while gently working the seal ring into the collar until the rotor contacts the end plate.

g. Perform Steps "d" and "e" above on the left–hand helix rotor.

h. Position the rotors so the lobes are in mesh and the omitted serrations in the splines of both rotor shafts are facing toward the top side of the end plate. Then install the left–hand helix rotor as in Step "f".

2. Install the blower housing over the rotors and attach it to the front end plate as follows:

NOTICE: When assembling an OTM *6V blower*, it must be determined which is the front end of the housing. For front mounted OTM vehicle engines, the housing must be installed with the stamped triangle end toward the front of the engine. With the rear mounted OTM vehicle engines, the housing is installed with the stamped triangle end toward the rear. On the 8V OTM vehicle engines, either end of the housing can face toward the front of the engine.

a. Position the blower housing over the top of the rotors so the bottom face of the housing faces the bottom side of the front end plate. Then lower the housing over the rotors until it contacts the dowel pins in the end plate.

b. Align the dowel pin holes in the housing with the dowel pins in the end plate. Then push the housing tight against the end plate. If necessary, tap the housing lightly with a plastic hammer.

c. Insert the two fillister head screws through the front end plate and thread them into the housing. Tighten the screws to 5–10 lb–ft (7–14 N•m) torque. Do not use lock washers on these screws.

3. Install the blower rear end plate on the rotor shafts and housing as follows:

a. Check the dowel pins. The dowel pins must project .320" from the flat inner face of the rear end plate to assure proper alignment of the end plate with the housing.

b. If removed, press a new bolt guide sleeve (bushing) into one bolt hole in the bottom side of the end plate. Install the sleeve, with the three notches on the sleeve to the bottom side of the end plate and the center notch to the outside of the end plate, flush to .005" below the surface of the end plate.

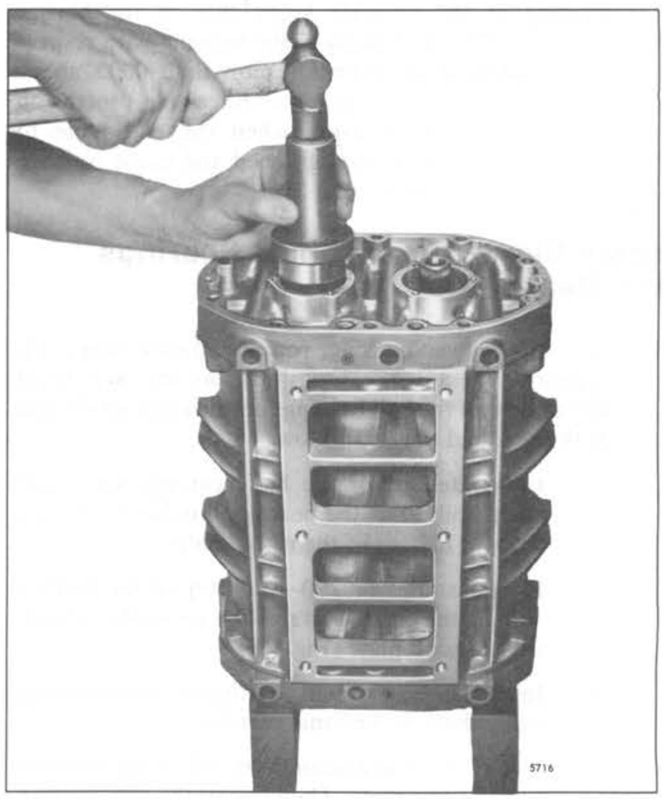


Fig. 19 – Installing Ball Bearings on Rotor Shaft and in Rear End Plate with Tool J 6270–13

NOTICE: When installed, the inside flats of the sleeve will be parallel to the center line of the housing.

c. Lubricate the oil seal rings in the carriers on the rotor shaft with engine oil.

d. Position the oil seal rings in the carriers so the ring protrudes from its groove the same amount on each side.

e. Position the rear end plate over the top of the rotor shafts with the inner face of the end plate facing the rotors and the TOP side of the end plate facing the top side of the blower housing.

f. Lower the end plate straight over the rotor shafts until the dowel pins in the end plate contact the blower housing (Fig. 18). Then, carefully work the dowel pins into the dowel pin holes in the housing and the oil seal rings into the collars. Push the end plate tight against the housing. If necessary, tap the end plate lightly with a plastic hammer.

g. Insert the two fillister head screws through the rear end plate and thread them into the housing. Tighten the screws to 5–10 lb-ft (7–14 N•m) torque. Do not use lock washers on these screws.

4. Check the relationship of the blower end plates to the housing at the cylinder block side of the blower assembly. The protrusion of the housing with respect to the end plates should not be more than .0005" above to .0065" below the end plate. Excessive protrusion could distort the housing when the end plate to cylinder block bolts are tightened and cause rotor to housing interference.

Install Blower Rotor Shaft Bearings And Gears

1. With the blower housing, rotors and end plates still supported in a vertical position on the two wood blocks, install the ball bearings on the rotor shafts and in the rear end plate as follows:

   a. Lubricate one of the ball bearings with light engine oil. Start the bearing, numbered end up, straight on one of the rotor shafts.

   b. Place installer J 6270–13 on top of the bearing and tap the bearing straight on the shaft and into the rear end plate (Fig. 19).

   c. Install the second ball bearing on the remaining rotor shaft in the same manner.

   d. Place the bearing retainers on top of the bearings and the end plate. Then install the self-locking screws. Tighten the screws to 7–9 lb-ft (9–12 N•m) torque.

2. Install the roller bearing inner races on the rotor shafts at the front end plate as follows:

   a. Reverse the position of the blower housing on the two wood blocks (Fig. 20).

   b. Position the roller bearing inner race over the front end of the rotor shaft and press the race on the shaft with tool J 6270–13 until the bearing contacts the shoulder on the shaft.

   c. Install the bearing inner race on the front end of the other rotor in the same manner.

3. Install the roller bearing outer race assemblies in the front end plate as follows:

   a. Lubricate one of the roller bearings with light engine oil. Start the bearing (shoulder side up) over the rotor shaft and bearing inner race and into the end plate.

   b. Place installer J 6270–13 on top of the bearing and tap the bearing straight on the inner race and into the front end plate (Fig. 20).

   c. Install the second roller bearing on the remaining rotor shaft in the same manner.

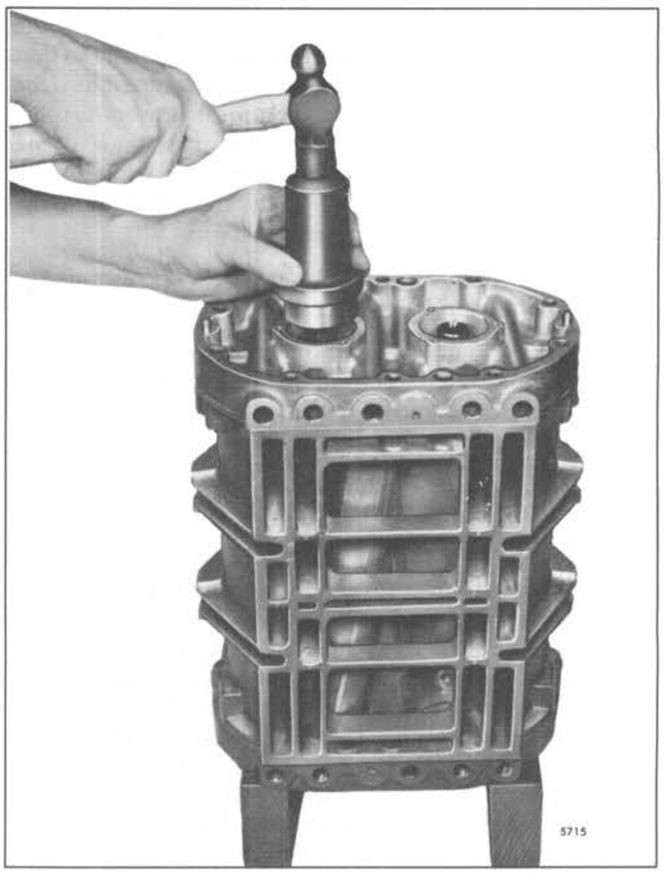


Fig. 20 – Installing Roller Bearings on Rotor Shafts and in Front End Plate with Tool J 6270–13

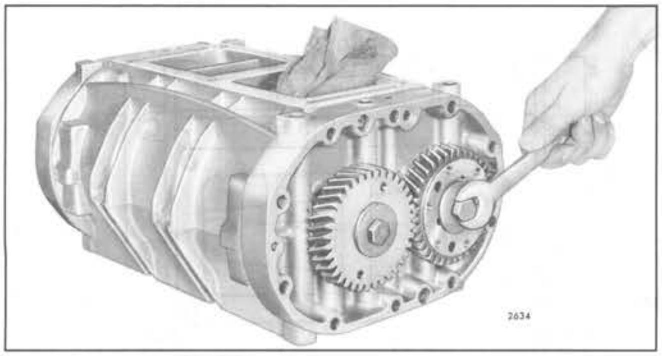


Fig. 21 – Installing Blower Rotor Timing Gears

d. Place the bearing retainers on top of the bearings and the end plate. Then install three self–locking retainer screws in each retainer. Tighten the screws to 7–9 lb–ft (9–12 N•m) torque.

4. Make a preliminary check of the rotor–to–end plate and rotor–to–housing clearances at this time with a feeler gage (Fig. 25). Refer to Fig. 23 for minimum blower clearances.

5. Before installing the blower rotor timing gears on the rotor shafts, observe precautions "2" and "3" relative to the rotor shaft and timing gear alignment under *Assemble Blower.*

The center punch mark in the end of each rotor shaft at the omitted serration will assist in aligning the gears on the shafts.

If shims were removed from the back side of the gears (between the inner race of the bearing and the gear), they should be replaced in their original positions before installing the gears on their respective shafts.

Install the blower timing gears as follows:

a. Place the blower assembly on the bench, with the top of the housing up and the rear end (serrated end of rotor shafts) of the blower facing the outside of the bench.

b. Rotate the rotors to bring the omitted serrations on the shafts in alignment and facing to the left.

c. Install a .140" thick gear spacer and the same number and thickness of shims on each rotor shaft that were removed at the time of disassembly.

d. Lubricate the serrations of the rotor shafts with light engine oil.

e. Place the teeth of the rotor gears in mesh so that the omitted serrations inside the gears are in alignment and facing the same direction as the serrations on the shafts.

f. Start both rotor gears straight on the rotor shafts with the right–hand helix gear on the right–hand helix rotor and the left–hand helix gear on the left–hand helix rotor, with the omitted serrations in the gears in line with the omitted serrations on the rotor shafts.

g. Thread a 1/2"–20 x 1–1/4" bolt with a thick washer into the end of each rotor shaft. Place a clean folded cloth between the lobes of the rotors to prevent the gears from turning (Fig. 21). Draw the gears into position tight against the spacers and shims and the bearing inner races (Fig. 21).

h. Remove the two bolts and washers that were used to draw the gears into position on the rotor shafts.

i. Lubricate the threads of the 1/2"–20 x 1–1/2" gear retaining bolts with engine oil. Place a spacer (.340" thick) on each of the bolts and thread the bolts into the rotor shafts. Tighten the bolts to 100–110 lb–ft (136–150 N•m) torque. Remove the cloth from the blower rotors.

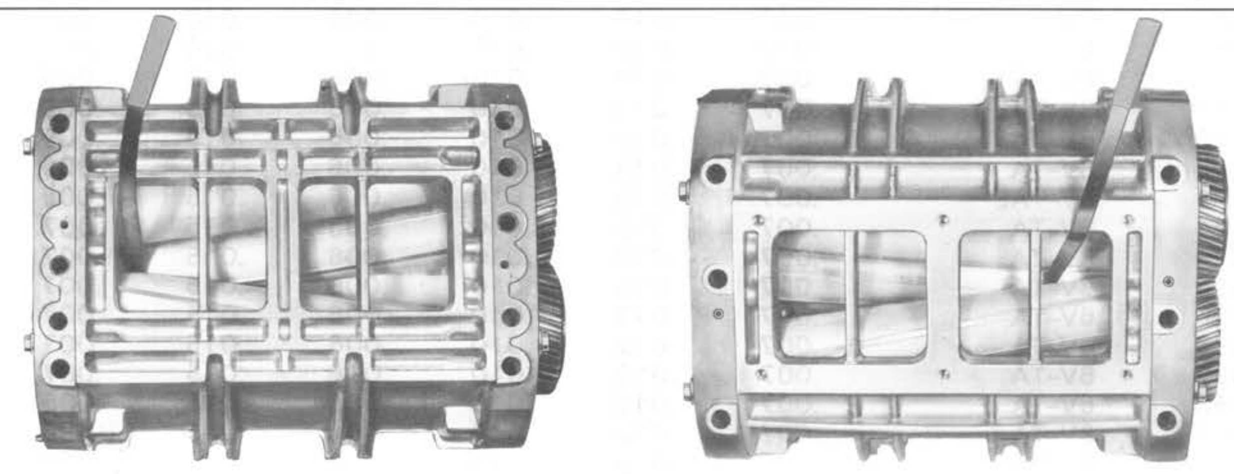


Fig. 22 – Measuring "CC" and "C" Clearance Between Blower Rotor Lobes

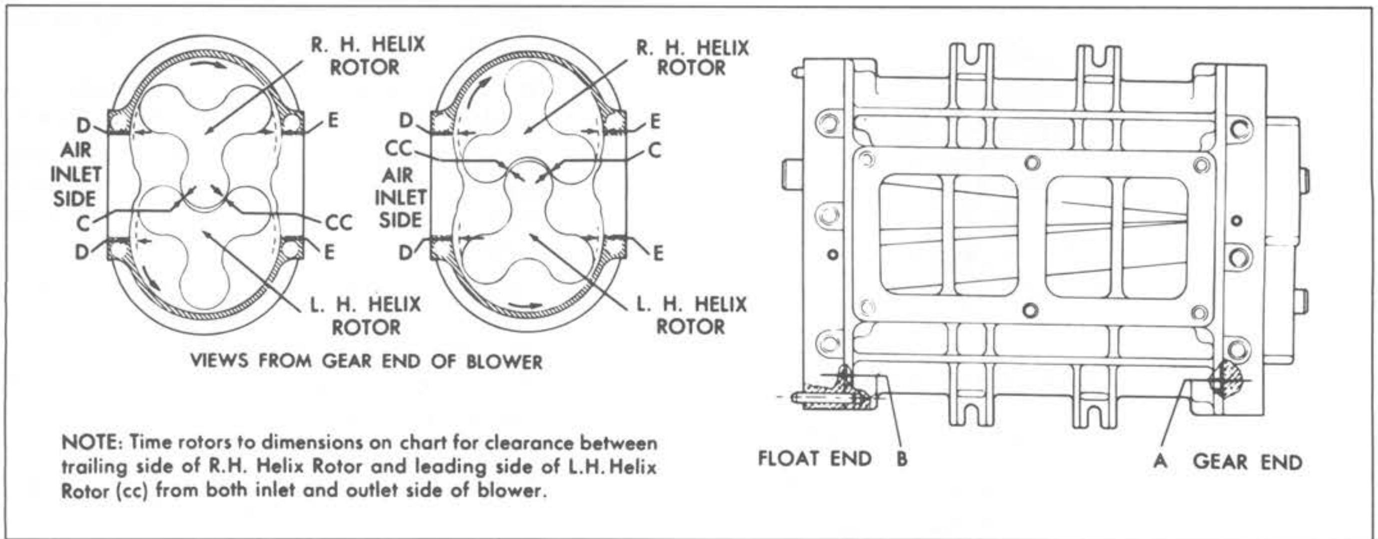


Fig. 23 – End View of Blower Rotor Clearances

CHART OF MINIMUM BLOWER CLEARANCES

Blower Part No.	Engine	CLEARANCES A	B	C	CC	D	E
5101483	8V–TA	.007	.019	.010	.006	.015	.005
5101484	8V–TAE	.007	.019	.010	.006	.015	.005
5101528	6V–TA	.007	.012	.010	.006	.015	.005
5103854	6V–TA	.007	.012	.010	.006	.015	.005
5104936	6V–T	.007	.012	.010	.006	.015	.005
5104937	8V	.007	.019	.010	.006	.015	.005
5144787	8V	.007	.014	.010	.006	.015	.005
5144893	8V	.007	.014	.010	.006	.015	.005
5146912	8V	.007	.012	.010	.006	.015	.005
5147152	8V	.012	.019	.010	.006	.030	.005
5147252	6V, 12V	.007	.012	.010	.006	.015	.005
8920613	8V–TAE	.007	.019	.010	.006	.015	.005
8920748	6V–TA	.007	.012	.010	.006	.015	.005
8921938	8V–TA	.007	.019	.010	.006	.015	.009
8923371	8V–TAE	.007	.019	.010	.006	.015	.005
8923474	8V–TA	.007	.019	.010	.006	.015	.007
8923475	8V–TA	.007	.019	.010	.006	.015	.007
8923476	8V–TA	.007	.019	.010	.006	.015	.007
8923495	6V–TA	.007	.012	.010	.006	.015	.007
8923496	6V–TA	.007	.012	.010	.006	.015	.007
8923497	6V–TA	.007	.012	.010	.006	.015	.007
8925153	6V–TA	.007	.012	.010	.006	.015	.005
8926407	8V–TA	.007	.012	.010	.006	.015	.005
8926408	8V–TA	.007	.019	.010	.006	.015	.005
8926615	6V–TA	.007	.012	.010	.006	.015	.005
8926616	8V–TA	.007	.019	.010	.006	.015	.005
8927037	8V–TA	.007	.019	.010	.006	.015	.007

CHART OF MINIMUM BLOWER CLEARANCES (Cont'd.)

Blower Part No.	Engine	CLEARANCES A	B	C	CC	D	E
8927039	6V–TA	.007	.012	.010	.006	.015	.005
8927041	8V–TA	.007	.019	.013	.013	.015	.009
8927043	8V–TA	.007	.019	.010	.006	.015	.007
8927156	6V–TA	.007	.012	.010	.006	.015	.005
8927468	8V–TA	.007	.019	.010	.006	.015	.009
8928984	12V	.007	.012	.010	.010	.015	.008
23501076	8V–TA	.007	.012	.010	.010	.015	.007
23501261	8V–TA	.007	.019	.010	.006	.015	.009
23501842	8V–TA	.007	.019	.010	.010	.015	.009
23502057	12V–TA	.010	.012	.020	.013	.015	.009
23502485	6V–TA	.007	.012	.010	.007	.015	.007
23502734	6V–TA	.007	.012	.010	.006	.015	.004
23503027	8V, 16V–TA	.010	.019	.025	.013	.015	.009
23503651	8V–TA	.007	.019	.013	.013	.015	.009

Timing Blower Rotors

After the blower rotors and timing gears are installed, the blower rotors must be timed.

> **NOTICE:** Before timing the blower, install four 5/16"–18 x 1–7/8" bolts with flat washers through four bolt holes in each end plate (top and bottom) and thread them into the blower housing (Fig. 14). Tighten the bolts to 13–17 lb–ft (18–23 N•m) torque. This will hold the end plates against the blower housing so the proper clearance between the rotors and the end plate can be obtained.

1. The blower rotors, when properly positioned in the housing, run with a slight clearance between the lobes. This clearance may be varied by moving one of the helical gears in or out on the shaft relative to the other gear.

2. If the right–hand helix gear is moved out, the right–hand helix rotor will turn counterclockwise when viewed from the gear end. If the left–hand helix gear is moved out, the left–hand helix rotor will turn clockwise when viewed from the gear end. This positioning of the gears, to obtain the proper clearance between the rotor lobes, is known as blower timing.

3. Moving the gears OUT or IN on the rotor shafts is accomplished by adding or removing shims between the gears and the bearings.

4. The clearance between the rotor lobes may be checked with 1/2" wide feeler gages in the manner shown in Fig. 22. When measuring clearances of more than .005", laminated feeler gages that are made up of .002", .003" or .005" feeler stock are more practical and suitable than a single feeler gage. A specially designed feeler gage set J 1698–02 for the blower clearance operation is available. Clearances should be measured from both the inlet and outlet sides of the blower.

5. Refer to Figs. 22 and 23 and time the rotors to the specified clearance between the *trailing* edge of the right–hand helix rotor and the *leading* edge of the left–hand helix rotor ("CC" clearance) measured from both the inlet and outlet sides. Then, check the clearance between the *leading* edge of the right–hand helix rotor and the *trailing* edge of the left–hand helix rotor ("C" clearance) for the minimum clearance. Rotor–to–rotor measurements should be taken 1" from each end and at the center of the blower.

6. After determining the amount one rotor must be revolved to obtain the proper clearance, add shims back of the proper gear to produce the desired result (Fig. 24). When more or less shims are required, both gears must be removed from the rotors. Placing a .003" shim in back of a rotor gear will revolve the rotor .001".

7. Install the required thickness of shims back of the proper gear and next to the .140" thick gear spacer which is against the bearing inner race and reinstall both gears. Recheck the clearances between the rotor lobes.

8. Determine the minimum clearances at points "A" and "B" (Fig. 23). Insert the feeler gages between the end plates and the ends of the rotors (Fig. 25). This operation must be performed at the ends of each lobe, making 12 measurements in all. Refer to Fig. 23 for the minimum clearances.

9. Check the clearance between each rotor lobe and the blower housing at both the inlet and outlet side — 12 measurements in all. Refer to Fig. 23 for the minimum clearances.

After the blower rotors are timed, complete assembly of the blower, as outlined below:

1. Place the fuel pump drive disc spacer over the forward end of the right–hand helix rotor shaft. Then place the special lock washer and the drive disc on the retaining bolt and thread the bolt into the rotor shaft against the spacer. Tighten the bolt to 55–65 lb–ft (75–88 N•m) torque. Bend one tang of the lock washer over into the slot in the drive disc and two tangs over against the flat sides of the bolt head.

2. Attach the two flex plates and spacers to the drive hub with three new type B hex lock bolts (Fig. 26). *Do Not attempt to reuse patch bolts.* Tighten the 5/16"–24 x .750" bolts to 25–30 lb–ft (34–41 N•m) torque.

NOTICE: Only the *new* flex plates and type B hex lock bolts should be used to service engines with large bearing blowers.

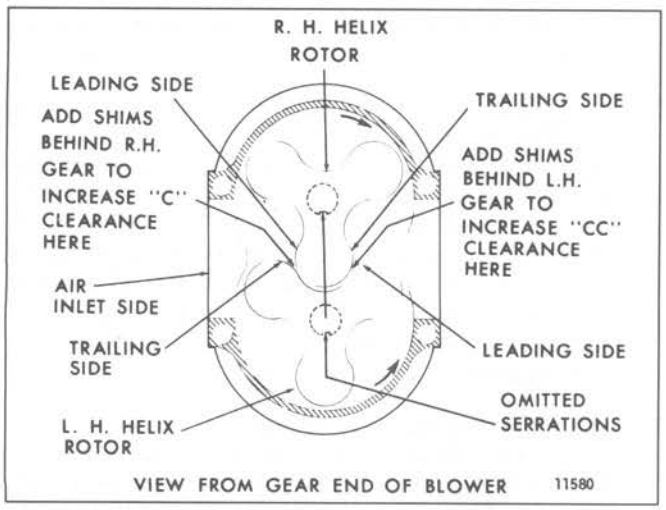


Fig. 24 – Diagram Showing Proper Location of Shims for Correct Rotor Lobe Clearances

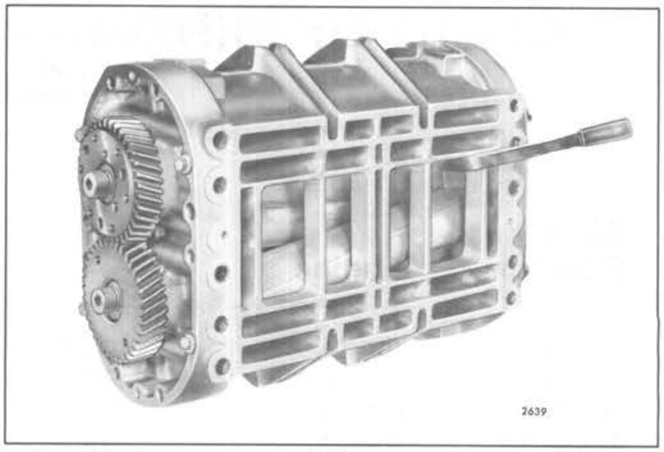


Fig. 25 – Measuring End Clearance Between Blower Rotors and End Plate

3. Attach the drive hub and spring plate assembly to the right–hand helix blower rotor timing gear with three spacers and three type B hex lock bolts (Fig. 26). Tighten the 5/16"–24 x 1" bolts to 25–30 lb–ft (34–41 N•m) torque.

NOTICE: When replacement of a blower drive hub becomes necessary, the new drive hub *plus* the new blower drive shaft flex plates, type B hex lock bolts and hub spacers *must* be used.

4. Affix a new gasket to the blower rear end plate cover. Place the cover over the gears and against the end plate, with the opening in the cover over the blower drive hub attached to the right–hand helix gear. Install the rear cover using ten 5/16"–18 x 2–1/4" bolts and lock washers. Tighten the bolts to 13–17 lb–ft (18–23 N•m) torque.

NOTICE: The tab on the gasket is to assure the gasket is in place.

5. On 6V and 12V engines, attach the adaptor and dry seal connector to the rear blower end plate when installing the blower on an engine.

6. On all 8V and 16V engines, attach the lubricating oil tube and dry seal connector to the rear blower end plate when installing the blower on the engine.

7. Attach the governor and fuel pump assembly to the blower as follows:

   a. Affix a new gasket to the forward face of the blower end plate.

   b. Place the fuel pump drive fork on the fuel pump shaft. Position the governor and fuel pump assembly in front of the blower. Rotate the fuel pump fork until the prongs of the fork align with the slots in the drive disc. Rotate the weight shaft and align the splines on the shaft with the splines in the blower rotor.

c. Push the governor straight on the dowel pins in the blower end plate and against the gasket.

d. Refer to Section 2.7.1 for the location and install the bolts, lock washers, copper washers and plain washer which secure the governor to the blower. Tighten the bolts to 13–17 lb-ft (18–23 N•m) torque.

Install Blower On Engine

On 12V and 16V engines, install the rear blower first if both blowers were removed.

Refer to Fig. 6 and install the blower assembly on the engine as follows:

1. Affix a new blower housing gasket to the cylinder block with Scotch Grip rubber adhesive No. 1300, or equivalent, to prevent the gasket from shifting when the blower is lowered into position.

2. If removed, place a fuel rod cover tube hose and clamp on each fuel rod cover tube at each side of the governor housing and tighten the clamps.

3. Place the blower end plate cover seal ring and clamp on the end of the blower drive support.

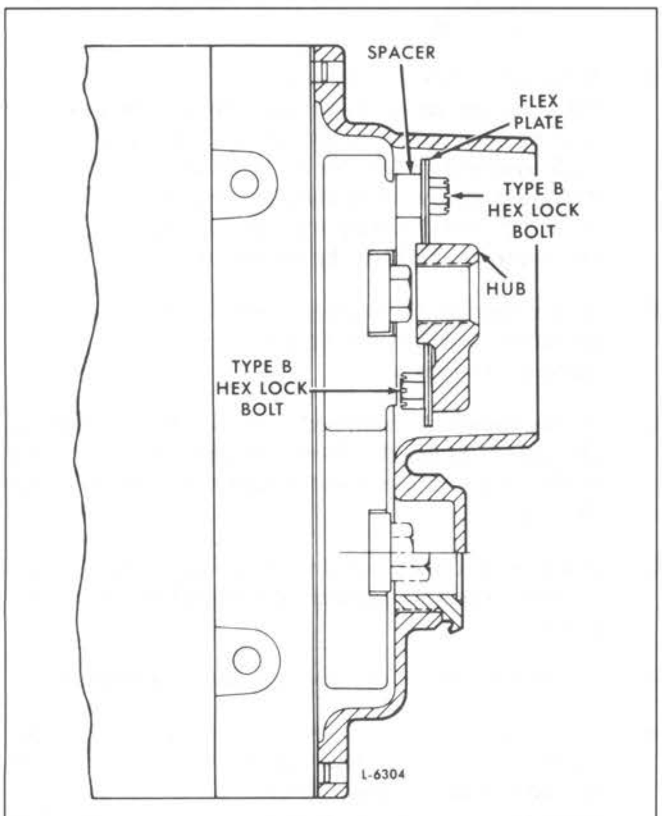


Fig. 26 – Front Hub Assembly – Large Bearing Blowers

4. Thread eyebolts in diagonally opposite tapped holes in the top of the blower housing. Then attach a rope sling and chain hoist to the eyebolts.

5. Lift the blower assembly at a slight angle and position it on top of the cylinder block, with the flange of the rear end plate cover inside the seal ring or hose.

6. Install loose the 7/16"–14 x 8–1/4" blower end plate bolts and special washers. Install loose the 3/8"–16 x 5–1/2" side angle bolts and retaining washers at each side of the blower housing.

NOTICE: The lip at the bevelled end of the bolt retaining washer goes in the small recess in the blower housing just above the bolt slot.

7. Slip the snap ring over the notched end of the alignment tool (J 33001) and thread the blower drive shaft onto the end. Install the alignment tool and position the blower so that the shaft can be removed and reinstalled easily without drag (Fig. 27).

8. Remove the shaft with the tool and rotate the lobes of the blower in 90° increments, reinserting the alignment tool and repositioning the blower, as necessary. Check the alignment at 90° increments through the full 360° of blower rotation.

9. If it is not possible to position the blower so that the tool can be removed and reinstalled without drag in all positions, repeat Step 8. However, this time try to achieve a condition in which the shaft can be removed with minimum drag in the two worst positions.

10. With the shaft in place and the blower properly aligned, tighten the bolts, as follows:

    a. Tighten the blower–to–block end plate bolts to 40–45 lb–ft (54–61 N•m) torque.

    b. Tighten the blower housing–to–block side angle bolts uniformly to 30–35 lb–ft (41–47 N•m) torque in 5 lb–ft (7 N•m) increments.

    c. Recheck the blower–to–block end plate bolts.

11. Install the snap ring. The notch in the tool provides sufficient clearance for the installation of the snap ring with a needle–nose pliers. Installing the snap ring with the alignment tool in place will prevent it from being inadvertently dropped into the engine gear train.

12. Remove the alignment tool from the blower drive shaft.

13. Place the blower rear end plate cover seal ring and hose clamp in position and tighten it. The former rubber seal ring (.740" wide) incorporates two raised edges which provide a groove to retain the clamp.

NOTICE: To retain seal load on the molded blower drive seal rings, a new 4.87" diameter spring loaded T–bolt style clamp is now being used.

After installing the new T–bolt style clamp on the blower drive seal, tighten the clamp nut on the bolt until the spring in the clamp is completely compressed.

14. Connect the lubricating oil tube to the fitting in the blower drive support.

15. Then, attach the flywheel housing cover to the flywheel housing.

NOTICE: If the spring has been removed in error, compress the spring and force it into the drilled hole opposite the tach drive square hole. This operation *must* be done on a press. To check for proper assembly, hold the spring and shaft assembly vertically by the spring. Weight of the shaft cannot allow the spring to come out of the drilled hole. A simple installation tool can be made from a .500" diameter piece of steel stock.

16. Attach the tachometer drive adaptor, if used, to the blower. Then, connect the tachometer drive cable to the drive adaptor.

17. Slide each fuel rod cover tube hose down on the cover tubes attached to the cylinder heads and tighten the hose clamps.

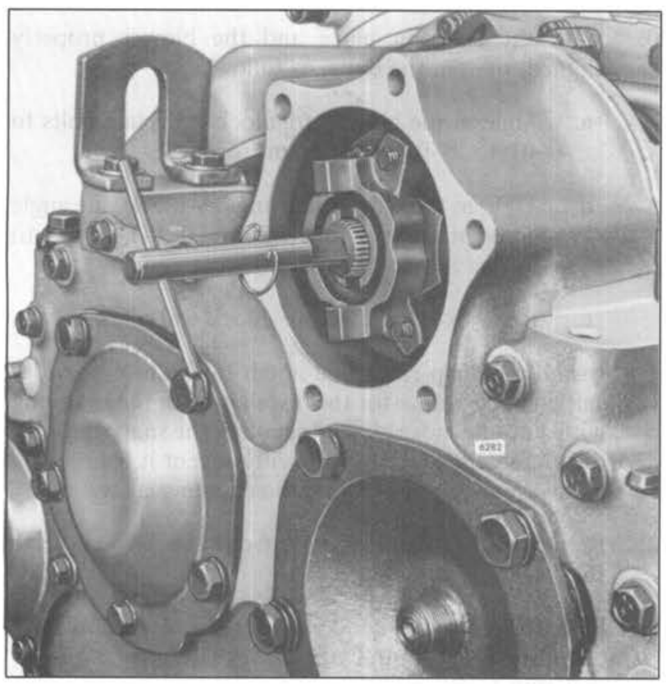


Fig. 27 – Aligning Blower with Tool J 33001

18. Install the fuel rods between the cylinder heads and governor, as follows:

    a. Insert the end of the left–bank fuel rod through the hole in the cylinder head and up through the fuel rod cover tube to the control link operating lever.

    b. Raise the connecting pin up in the connecting link lever. Insert the end of the fuel rod between the two bosses on the lever and insert the connecting pin through the fuel rod and into the lower boss.

    c. Connect the opposite end of the fuel rod to the injector control tube lever with a clevis pin and cotter pin.

    d. Insert the end of the right–bank fuel rod through the hole in the cylinder head and up through the fuel rod cover tube to the control link operating lever.

    e. Remove the short screw pin from the control link operating lever. Insert the end of the fuel rod between the two bosses on the lever and install the screw pin. Tighten the pin securely.

    f. Connect the opposite end of the fuel rod to the injector control tube lever with a clevis pin and cotter pin.

19. Affix a new gasket to the top of the governor housing. Place the governor cover assembly on the governor housing with the pin in the speed control or stop lever shaft assembly in the slot in the differential lever and the dowel pins in the housing in the dowel pin holes in the cover. Install the eight cover attaching screws and lock washers. Tighten the screws securely.

20. If the engine is equipped with a variable speed governor, attach the governor booster spring to the speed control lever.

21. If the engine is equipped with a battery–charging alternator, attach the alternator and support bracket to the cylinder head and connect the wires to the alternator.

22. Install and connect the crossover fuel oil line to each cylinder head and connect the fuel oil lines to the fuel pump.

23. If removed, install the front engine lifter bracket.

24. Place the water bypass tube between the two thermostat housings and slide the hoses part way on the thermostat housings. Position the bypass tube so it clears the governor, fuel pump and fuel oil lines. Then tighten the hose clamps.

25. Attach the air shutdown adaptor to the blower and the air shutdown housing assembly to the adaptor as outlined in Section 3.3.

26. Connect the shutdown wire assembly to the air shutoff cam pin handle at the side of the air shutdown housing.

27. Install the turbocharger and attaching parts, if used (Section 3.5).

28. Connect the air cleaner to shutdown housing, or turbocharger, tubing as required (Section 3.1 or 3.5).

29. Connect the throttle control rods to the speed control and stop levers on the governor.

30. Attach any other accessories to the engine that were removed.

31. Close the drain cocks and fill the engine cooling system.

32. Perform the governor and injector rack control adjustment, as outlined in Section 14. Check for and correct any coolant or oil leaks detected.

TURBOCHARGER (Airesearch)

The T18A40, T18A90, TV71, TV81 and T04B model turbochargers (Figs. 1 and 2) are designed to increase the over–all efficiency of the engine. Power to drive the turbocharger is extracted from the waste energy in the engine exhaust gas.

The turbocharger consists of a radial inward flow turbine wheel and shaft, a centrifugal compressor wheel, and a center housing which serves to support the rotating assembly, bearings, seals, turbine housing and compressor housing. The center housing has connections for oil inlet and oil outlet fittings.

The turbine wheel is located in the turbine housing and is mounted on one end of the turbine shaft. The compressor wheel is located in the compressor housing and is mounted on the opposite end of the turbine wheel shaft to form an integral rotating assembly.

The rotating assembly consists of a turbine wheel and shaft assembly, piston ring(s), thrust spacer or thrust collar, compressor wheel and wheel retaining nut. The rotating assembly is supported on two pressure lubricated bearings which are retained in the center housing by snap rings. Internal oil passages are drilled in the center housing to provide lubrication to the turbine wheel shaft bearings and the thrust bearing.

The turbine housing is a heat resistant alloy casting which encloses the turbine wheel and provides a flanged engine exhaust gas inlet and an axially–located turbocharger exhaust gas outlet. The T18A40, T18A90 and T04B turbine housing is bolted to the turbine end of the center housing while the TV71 and TV81 turbine housing is secured to the turbine end of the center housing with a "V" band coupling, thus providing a compact and vibration free assembly.

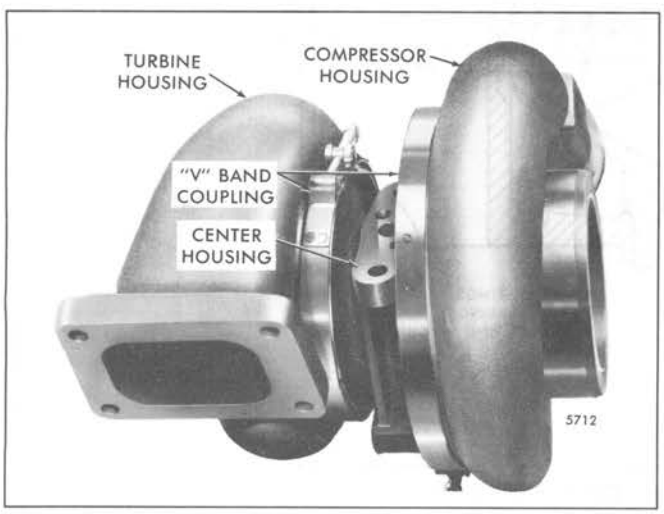


Fig. 1 – Typical Turbocharger Assembly

The compressor housing which encloses the compressor wheel provides an ambient air inlet and a compressed air discharge outlet. The T18A40, T18A90, TV71 and TV81 compressor housing is secured to the backplate assembly with a "V" band coupling. The T04B compressor housing is bolted to the backplate assembly. The backplate assembly is bolted to the compressor end of the center housing.

Operation

The turbocharger is mounted on the exhaust outlet flange of the engine exhaust manifold. After the engine is started, the exhaust gases flowing from the engine and through the turbine housing cause the turbine wheel and shaft to rotate (Fig. 3). The gases are discharged into the atmosphere after passing through the turbine housing.

The compressor wheel, which is mounted on the opposite end of the turbine wheel shaft, rotates with the turbine wheel. The compressor wheel draws in fresh air, compresses it and delivers high pressure air through the engine blower to the engine cylinders.

During operation, the turbocharger responds to the engine load demands by reacting to the flow of the engine exhaust gases. As the engine power output increases or decreases, the turbocharger responds to the engine's demand to deliver the required amount of air under all conditions.

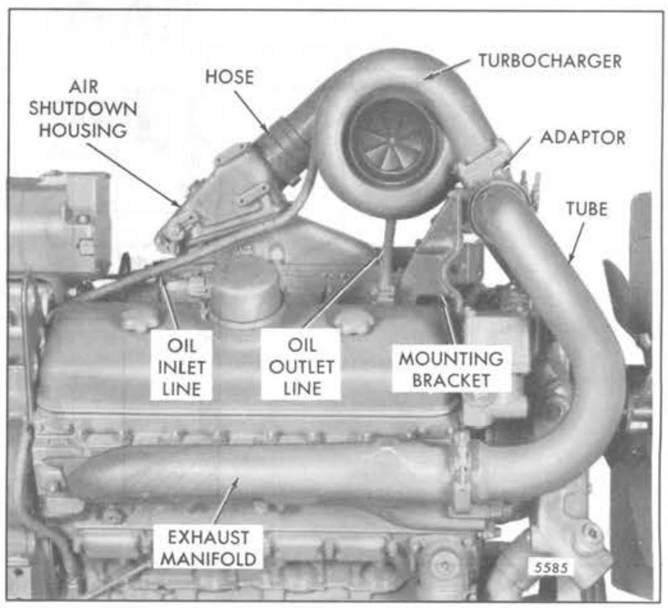


Fig. 2 – Typical Turbocharger Mounting

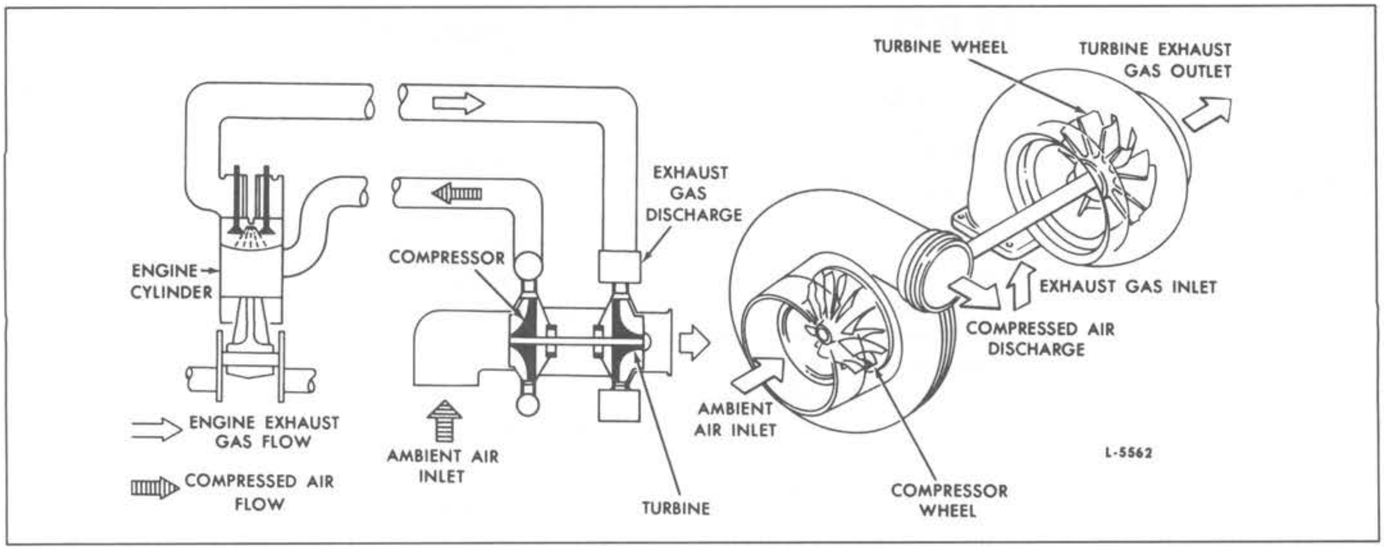


Fig. 3 – Schematic Air Flow Diagram

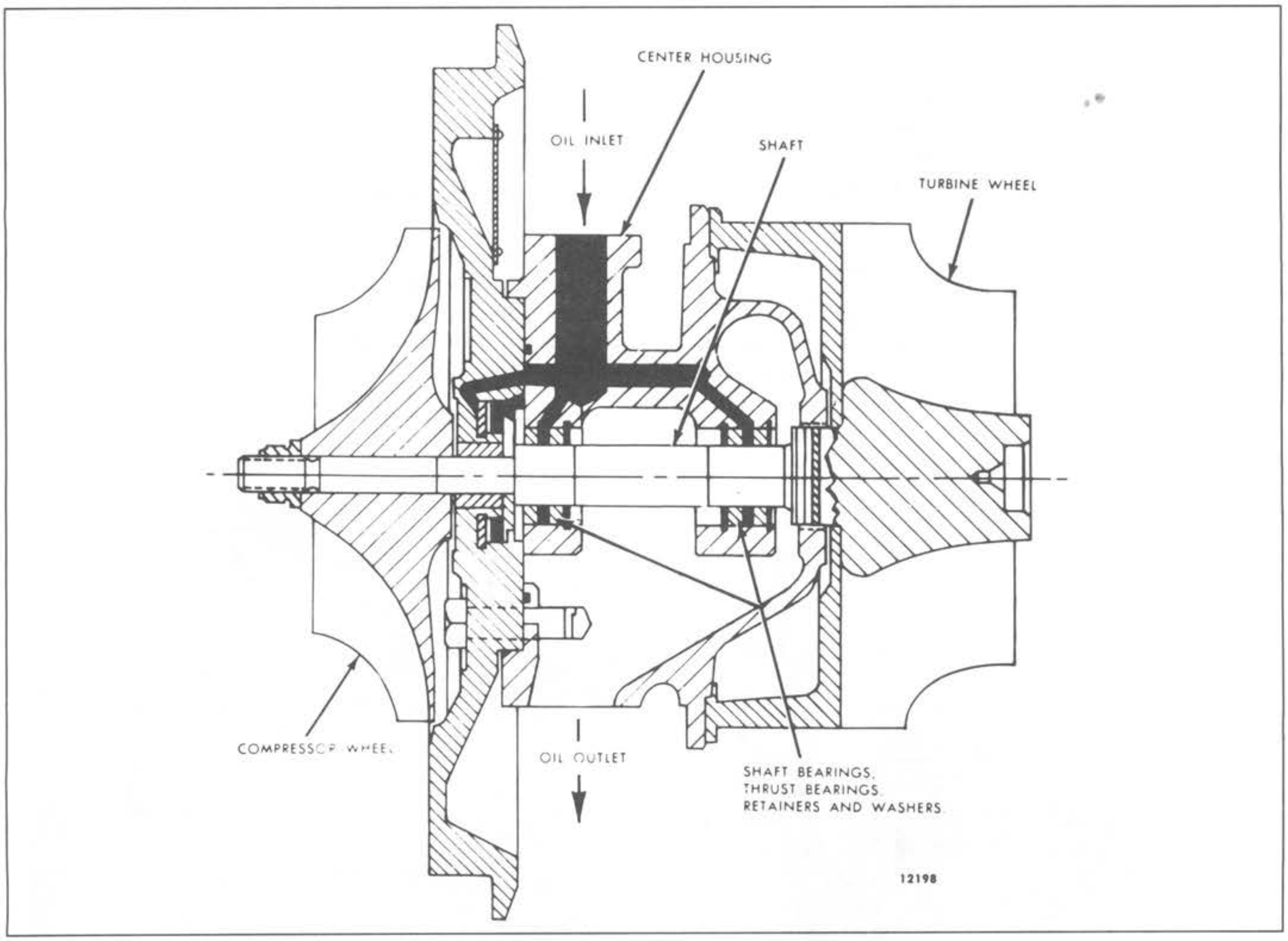


Fig. 4 – Typical Turbocharger Oil Flow Diagram

Certain engines are equipped with an aftercooler to cool the air going into the engine, after it passes through both the turbocharger and the engine blower (refer to Section 3.5.3). Certain marine engines are equipped with an intercooler to cool the air going into the engine, after it passes through both the turbocharger and engine blower (refer to Section 3.5.2).

Lubrication

Lubricating oil for the turbocharger is supplied under pressure through an external oil line extending from the engine cylinder block to the top of the center housing. From the oil inlet in the center housing, the oil flows through the drilled oil passages in the housing to the shaft bearings and thrust bearings (Fig. 4). The oil returns by gravity to the engine oil pan through an external oil line extending from the bottom of the turbocharger center housing to the cylinder block.

On OTM (optional turbocharger mounting) vehicle engines, the oil returns by gravity directly from the turbocharger through two drain holes in the blower end plate (front end plate for front mounted turbocharger or rear plate for rear mounted turbocharger) to lubricate the blower bearings and either the timing gears or the governor drive and fuel pump drive (refer to *Lubrication* in Section 3.4).

NOTICE: New service kits have been released to provide more durable rear lube oil supply lines for blower mounted turbochargers used on 6V and 8V-92 engines (Figs. 18 and 19). Each line must be positioned to prevent rubbing or chafing of the braided stainless steel hose cover against other hoses and/or engine components. The hose bracket (to air inlet housing) *must* be used to support the hose and tube assembly at the air inlet housing.

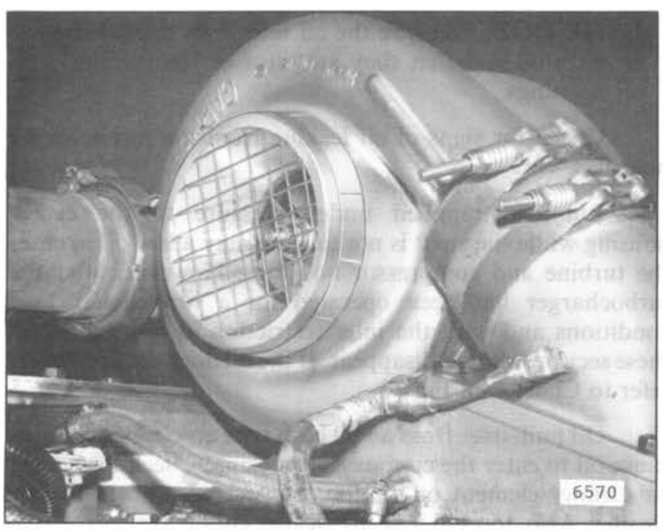


Fig. 5 - Turbo Compressor Inlet Guard Assembly

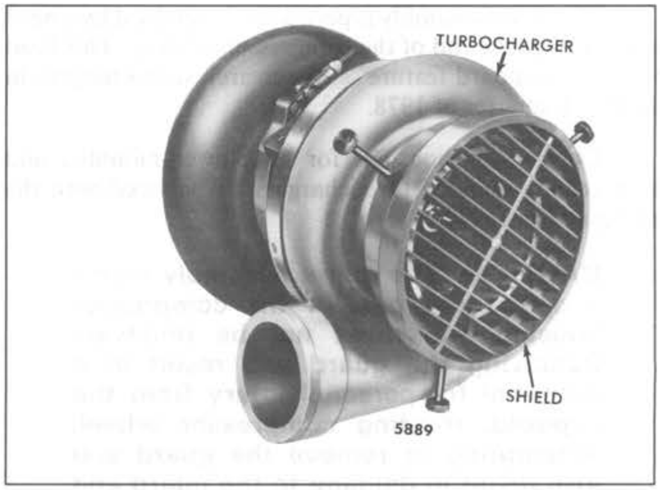


Fig. 5A - Inlet Shield (J 26554-A)

Front-mounted turbocharger lube oil supply line kits are now available to service 6V and 8V-71 engines equipped with blower mounted turbochargers. Marine engines are not included in this change. The new front-mounted turbocharger lines provide a shorter, more direct path for the turbocharger lube oil supply. To conform with the change to the front-mounted lube oil line, two tapped holes have been added to the front of current 6V and 8V-71 cylinder blocks. Refer to Section 3.0 for *Block Modifications* of former cylinder blocks. The right-bank hole is used for the turbocharger oil supply line. The left-bank hole may be used for an additional oil feed location, if desired.

NOTICE: On engines using a governor high idle cylinder, sufficient clearance *must* be provided between the turbo oil supply line and the high idle cylinder to avoid damage to the supply line.

Before the initial start, when a new or overhauled turbocharger is installed, the turbocharger must be pre-lubricated as outlined under *Install Turbocharger.*

NOTICE: Failure to perform the prelubrication procedure may result in premature bearing failure due to "oil lag" or lack of lubrication.

Turbocharger Safety

Effective February of 1988, a new guard assembly is installed over the compressor inlets of all blower-mounted and front center-mounted Airesearch turbochargers. The new two-piece assembly (Fig. 5) is intended to protect the service technician from the exposed turbocharger compressor wheel when the engine is operated with the air inlet piping removed from the compressor housing. The guard assembly also prevents foreign objects from being ingested by the turbocharger and causing damage.

The guard assembly is permanently retained by a bead machined on the end of the compressor housing. This bead became a standard feature on Airesearch turbochargers in the fourth quarter of 1978.

Compressor housings for all blower–mounted and front center–mounted turbochargers are serviced with the inlet guard installed.

CAUTION: The guard assembly forms a permanent part of the compressor housing and must not be removed. Removing the guard will result in a potential for personal injury from the exposed, rotating compressor wheel. Attempting to remove the guard will also result in damage to the guard and the housing. A damaged guard or housing cannot be reused.

Because of the added margin of safety provided by the inlet guard assembly, DDC recommends having the guard installed on early blower–mounted and front center–mounted turbochargers when the air inlet piping is removed for any reason.

CAUTION: The guard assembly cannot be installed on certain turbochargers because they have smaller (5.58") compressor inlet diameters. To avoid the potential for personal injury, shield J 26554–A (Fig. 5A) should be installed whenever the air inlet piping is removed from these turbochargers.

Periodic Inspection

Inadequate air filtering and excessive restrictions to air and exhaust flows will adversely affect turbocharger life and performance. Do not permit restriction levels to exceed the specified limits (refer to Section 13.2).

A periodic inspection of the turbocharger should be made along with an engine inspection.

CAUTION: To eliminate the possibility of personal injury when air inlet piping is removed, do not operate an engine with a blower–mounted or front center–mounted turbocharger unless the compressor inlet guard assembly (Fig. 5) or turbo inlet shield (Fig. 5A) is installed.

Inspect the turbocharger mountings and check all of the air ducting and connections for leaks. Make the inspection with the engine running and with it shut down. Check for leaks at the manifold connection, the turbine inlet and exhaust manifold gasket.

NOTICE: Do not operate the engine if leaks are found in the turbocharger ducting or if the air cleaner is not filtering efficiently. Dust leaking into the air ducting can damage the turbocharger and the engine.

Remove the inlet duct to the turbocharger compressor housing and check for carbon or dirt buildup on the impeller or in the housing. Excessive accumulations indicate either a leak in the ducting or a faulty air filtering system. Remove all such accumulations and determine and correct the cause. Refer to *Trouble Shooting Charts* (Fig. 6). Uneven deposits left on the compressor wheel can affect the balance and cause premature bearing failure.

NOTICE: Do not attempt to remove carbon or dirt buildup on the compressor or turbine wheels without removing the turbocharger from the engine. The blades on the wheels must be thoroughly cleaned. If chunks of carbon are left on the blades, an unbalanced condition would exist and subsequent failure of the bearings would result if the turbocharger is operated. However, it is not necessary to disassemble the turbocharger to remove dirt and dust buildup.

For proper operation, the turbocharger rotating assembly must turn freely. Whenever the exhaust ducting is removed, spin the turbine wheel by hand. If it does not spin freely, refer to Chart 1 of Fig. 6. Inspect the compressor and turbine wheels for nicks or loss of material. Both wheels are precision balanced. A broken or bent blade can throw the rotating assembly out of balance and shorten the life of the turbocharger.

Inspect the oil inlet and oil return lines to make certain all of the connections are tight and that the lines are not dented or looped so that oil flow to and from the center housing is restricted. Looping the oil return lines disrupts gravity flow of the oil back to the engine.

NOTICE: Be sure the oil inlet lines are filled with oil and that they are clear of the turbine housings.

Check for signs of oil leaking from the turbocharger housings.

Lubricant applied under pressure to the center housing while the shaft is not turning may allow oil to enter the turbine and compressor housings. However, after the turbocharger has been operated for a time under load conditions and with the inlet restriction at normal, oil in these sections should disappear. If the oil does not disappear, refer to Chart 2 of Fig. 6.

Oil pull–over from an oil bath type air cleaner can also cause oil to enter the compressor housing. Check for a dirty air cleaner element or for too low viscosity oil in the air cleaner. Also, too small an air cleaner could create excessive air flow velocity and result in oil pull–over.

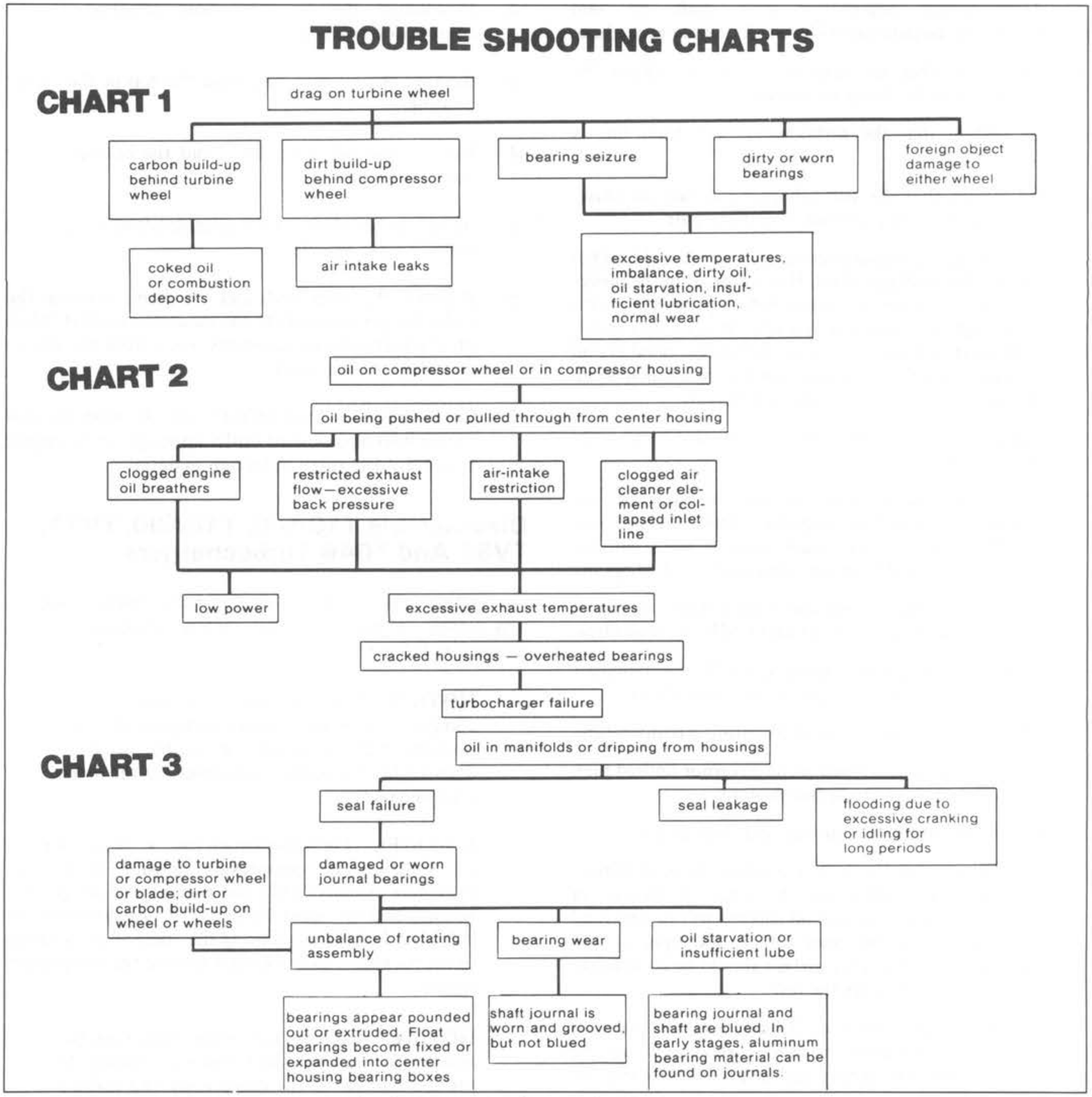


Fig. 6 – Inspection Checks for Turbocharger

Evidence of oil in the inlet or outlet ducts or dripping from either housing indicates a seal problem that will require overhaul of the turbocharger. Refer to Chart 3 of Fig. 6.

Tests show there are three conditions that contribute to oil seal leakage at the internal turbocharger oil seal.

1. A worn or defective oil seal, which must be replaced.
2. High air inlet restriction (above specified limits). This will cause oil to be pulled past the oil seal.
3. Long periods of operation where the engine is being motored (using the engine as a braking device when going down a long hill). This can also cause oil to pass by the oil seal.

To confirm oil leakage from one or more of these conditions, remove the compressor housing and inspect the backplate. If the surface is wet with oil, it indicates leakage.

If this test does not show leakage patterns, the oil seal assembly is good for normal operation.

Turbocharger compressor end shaft oil seal effectiveness can be determined by the following procedure:

1. Determine that air inlet restriction is within the maximum limit. Refer to Section 13.2.
2. Be certain that the turbocharger oil drain line is unrestricted.
3. Be certain that the turbocharger has not obviously been damaged and in need of major repair.
4. Remove the air intake ducting. Inspect the inside of the ducting for evidence of oil. If oil is found in the intake system, determine the source before proceeding with the compressor seal test and also thoroughly remove oil from the intake. Some external sources of oil are oil bath air cleaners, air compressor line, or a leak near an oil source such as an engine breather, etc.
5. Remove the compressor housing from the turbocharger.
6. Thoroughly clean the internal surfaces of the compressor housing, impeller cavity behind the impeller, and the backplate annulus with suitable solvent spray and then dry completely with shop air.
7. Spray the backplate annulus with a light coating of *Spot–Check* developer type SKD–MF, or equivalent.
8. Install the compressor housing on the turbocharger and reconnect the inlet and outlet connections.
9. Warm up the engine to normal operating temperature.
10. Operate engine at no load at the governor limited high speed for approximately five minutes.
11. Return the engine to low idle and then stop it.
12. Remove the intake duct and outlet hose and then remove the compressor housing. Evidence of compressor end shaft seal oil leakage will be observed as oil streaks in the *Spot–Check* developer on the backplate annulus. This surface should be completely free of oil streaks after the test.
13. If leakage is detected, and oil is positively not entering through the intake duct, then the turbocharger may be removed from the engine and inspected for damaged components.

Remove Turbocharger

1. Disconnect the exhaust manifold flange or adaptor attached to the turbine housing.

   NOTICE: When removing the left bank exhaust manifold to turbocharger tube on the blower mounted turbochargers, matchmark one end of the tube for ease of identification when reinstalling the tube.

2. Disconnect the air inlet hose attached to the compressor housing.
3. Remove the oil inlet line from the top of the center housing.
4. Remove the oil outlet line from the bottom of the center housing.
5. Attach a chain hoist and a suitable lifting sling to the turbocharger assembly.
6. Remove the nuts and lock washers securing the turbocharger assembly to the mounting bracket. Then lift the turbocharger assembly away from the engine and place it on a bench.
7. Cover the end of each oil inlet and oil outlet line and the air inlet and exhaust outlet openings on the engine to prevent the entry of foreign material.

Disassemble T18A40, T18A90, TV71, TV81 And T04B Turbochargers

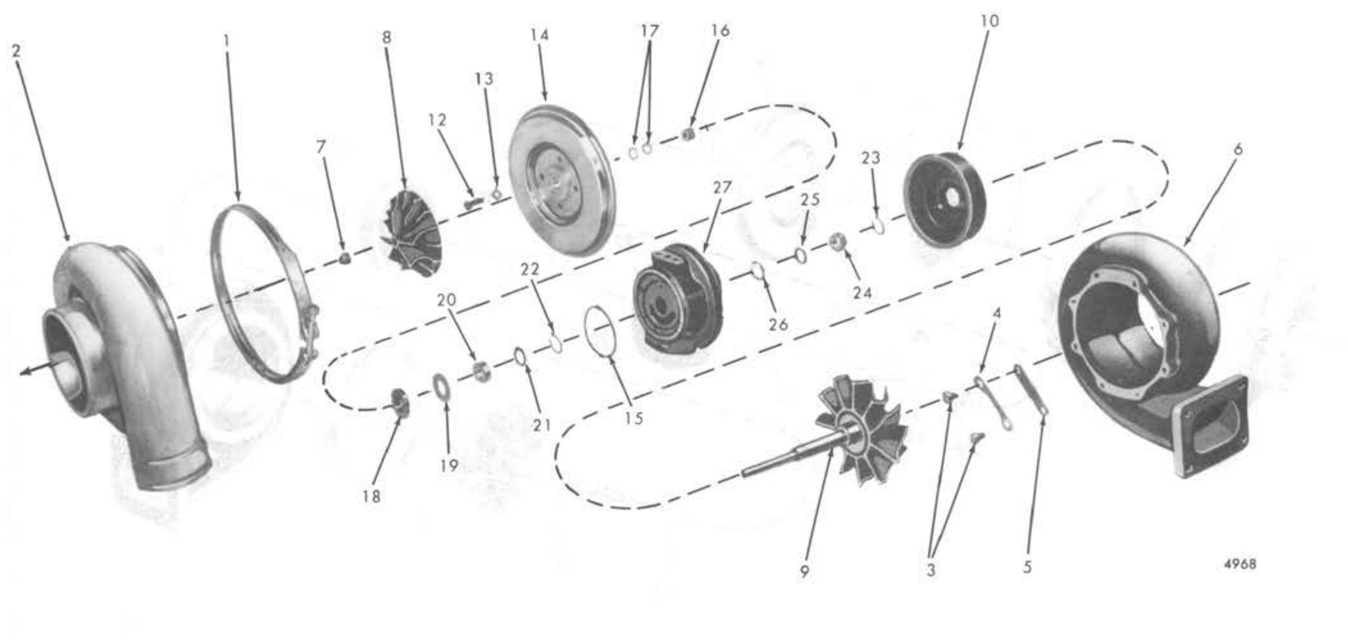
Clean the exterior of the turbocharger with a non–caustic cleaning solvent before disassembly and proceed as follows:

NOTICE: Mark related positions of the compressor housing, center housing and turbine housing with a punch or scribe prior to disassembly to assure reassembly in the same relative position.

1. Refer to Fig. 7 or 8 and loosen the "V" band coupling (1) securing the compressor housing (2) to the backplate assembly (14) and remove the compressor housing and "V" band. Refer to Fig. 9 and remove the bolts and lockplates securing the compressor housing to the backplate assembly and remove the compressor housing.

   NOTICE: Exercise care when removing the compressor housing and turbine housing to prevent damage to the compressor and turbine wheels.

2. With the T18A40, T18A90 and T04B turbochargers, bend down the ends of the lockplates (4) and remove the eight bolts (3) securing the four lockplates and turbine housing clamps (5) to the center housing (27) and turbine housing (6). With the TV71 and TV81 turbocharger, loosen the "V" band coupling (28) securing the turbine housing (6) to the center housing (27). Remove the turbine housing from the center housing.



1.	Coupling—"V" Band	8.	Wheel—Compressor	15.	Ring—Seal	21.	Washer—Bearing
2.	Housing—Compressor	9.	Shaft—Turbine Wheel Assembly	16.	Spacer—Thrust	22.	Ring—Snap
3.	Bolt			17.	Ring—Piston (Two for 18A90)	23.	Ring—Snap
4.	Lockplate	10.	Shroud—Turbine Wheel			24.	Bearing
5.	Clamp—Turbine Housing	12.	Bolt	18.	Collar—Thrust	25.	Washer—Bearing
6.	Housing—Turbine	13.	Lockplate	19.	Bearing—Inboard Thrust	26.	Ring—Snap
7.	Nut—Self-Locking	14.	Backplate Assembly	20.	Bearing	27.	Housing—Center

Fig. 7 – T18A40 and T18A90 Turbocharger Details and Relative Location of Parts

NOTICE: Tap the housing with a soft hammer if force is needed for removal.

3. Position the turbine wheel (9) of the center housing assembly in a suitable holding fixture (Fig. 10). Remove the wheel nut (7) from the shaft.

NOTICE: If a holding fixture is not available, clamp a suitable socket or box end wrench in a vise and place the extended hub on the shaft in the socket or wrench. Hold the center housing upright and remove the wheel nut from the shaft.

To prevent the possibility of bending the turbine wheel shaft, remove the compressor wheel nut from the shaft with a double universal socket and tee handle.

4. Lift or press the compressor wheel (8) from the wheel shaft assembly (9).

5. Withdraw the wheel shaft assembly (9) from the center housing. The wheel shroud (10), which is not retained, will fall free when the wheel shaft is removed.

6. With TV71, TV81 and T04B turbochargers, remove and discard the turbine piston ring (11) from the wheel shaft.

7. Bend down the lock tabs and remove the four bolts (12) and lockplates (13) securing the backplate assembly (14) to the center housing (27) and remove the backplate assembly. Do not disassemble the backplate assembly. Also, do not remove the pins from the center housing, unless it is necessary to replace the pins.

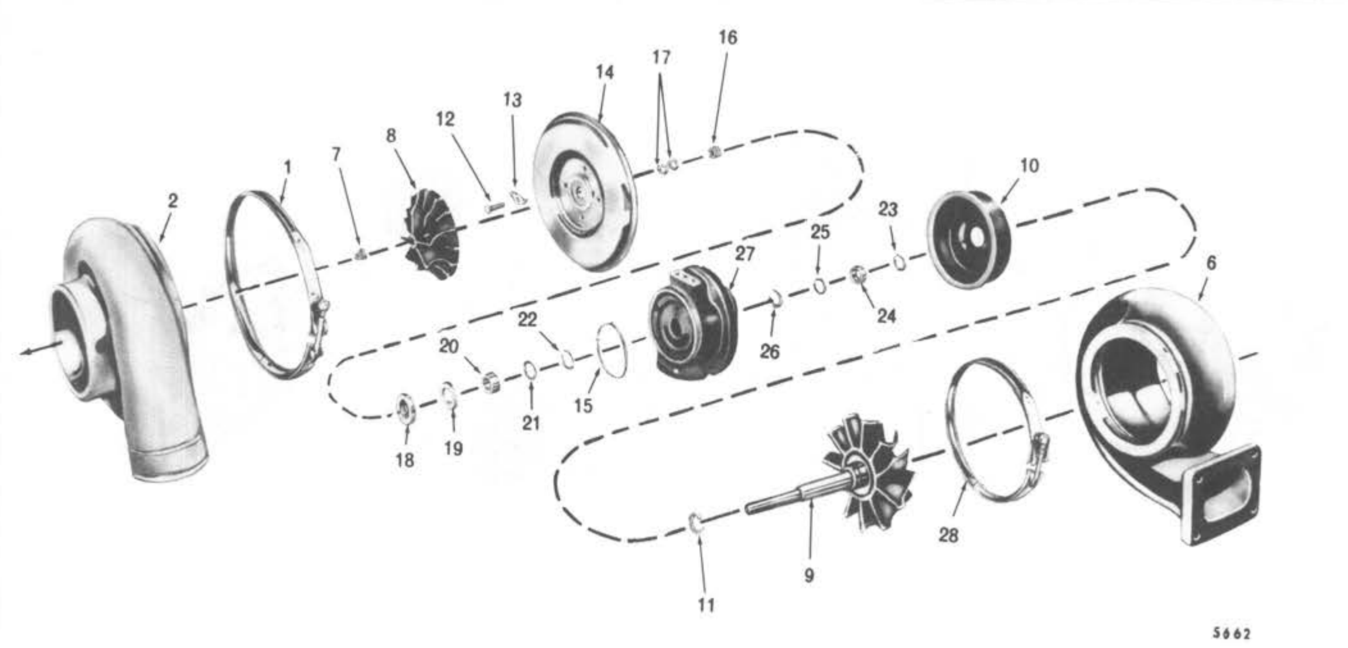
NOTICE: Tap the backplate lightly to remove it from the center housing recess.

8. Remove and discard the seal ring (15) from the groove in the center housing.

9. Remove the thrust spacer (16) — thrust bearing for T04B turbocharger — and piston ring(s) (17) from the backplate assembly. Discard the piston ring(s).

10. Remove the thrust collar (18), inboard thrust bearing (19) if used, bearing (20), bearing washer (21) if used and snap ring (22) from the center housing. Discard the thrust bearing, bearing, washer and snap ring.

11. Remove the snap ring (23), bearing (24), bearing washer (25) if used and snap ring (26) from the opposite end of the center housing. Discard the snap rings, bearing and washer.



1.	Coupling—"V" Band	10.	Shroud—Turbine Wheel	17.	Ring—Piston	23.	Ring—Snap
2.	Housing—Compressor	11.	Ring—Turbine Piston	18.	Collar—Thrust	24.	Bearing
6.	Housing—Turbine	12.	Screw	19.	Washer—Inboard Thrust	25.	Washer—Bearing
7.	Nut—Self-Locking	13.	Lockplate	20.	Bearing	26.	Ring—Snap
8.	Wheel—Compressor	14.	Backplate Assembly	21.	Washer—Bearing	27.	Housing—Center
9.	Shaft—Turbine Wheel Assembly	15.	Ring—Seal	22.	Ring—Snap	28.	Coupling—"V" Band
		16.	Spacer—Thrust				

Fig. 8 – TV71 and TV81 Turbocharger Details and Relative Location of Parts

Cleaning

Before cleaning, inspect the parts for signs of burning, rubbing or other damage which might not be evident after cleaning.

Soak all parts in a non–caustic cleaning solvent for about 25 minutes. After soaking, use a stiff bristle brush and remove all dirt particles. Dry all of the parts thoroughly.

CAUTION: Never use a caustic cleaning solution for cleaning as this will damage certain parts. Use the cleaning solution in an open or well ventilated area. Avoid breathing the fumes to avoid the possible toxic effect of the cleaning solvent. Keep away from open flames to avoid the possibility of a fire. Do not use a wire brush or a steel blade scraper to clean the parts.

Make sure that both wheel blades are thoroughly clean. Deposits left on the blades will affect the balance of the rotating assembly.

Clean all of the internal cavities and oil passages in the center housing thoroughly with dry compressed air. Clean the oil passage in the backplate assembly and the housing thrust plate with dry compressed air.

CAUTION:To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.

Remove the oil inlet and outlet lines from the engine and thoroughly clean the oil lines inside and out. An oil line that is dented or crimped enough to restrict the flow of oil must be replaced.

Inspection

Inspect all of the parts for signs of damage, corrosion or deterioration. Check for nicked, crossed or stripped threads.

Visually check the turbine wheel shroud and turbine wheel for signs of rubbing. For shaft bearing journal dimensions and wear limits, refer to Section 3.0.

Inspect the shaft for signs of scoring, scratches or bearing seizure.

Check the compressor wheel for signs of rubbing or damage from foreign material. Check to see that the wheel bore is not galled. The wheel must be free of dirt and other foreign material.

Inspect the seal parts for signs of rubbing or scoring of the running faces. Inspect the backplate assembly for wear or damaged bore (piston ring groove). Inspect the housing for contact with the rotating parts. The oil and air passages must be clean and free of obstructions.

Inspect the exhaust outlet elbow seal ring for signs of wear or breakage.

Minor surface damage may be burnished or polished. Use a Silicone Carbide abrasive cloth for aluminum parts or a crocus abrasive cloth for steel parts.

It is recommended that the seal ring, piston rings, thrust bearings, bearing washers, snap rings, lockplates and bolts be replaced at time of disassembly. The backplate must be replaced if the thrust bearing is excessively worn.

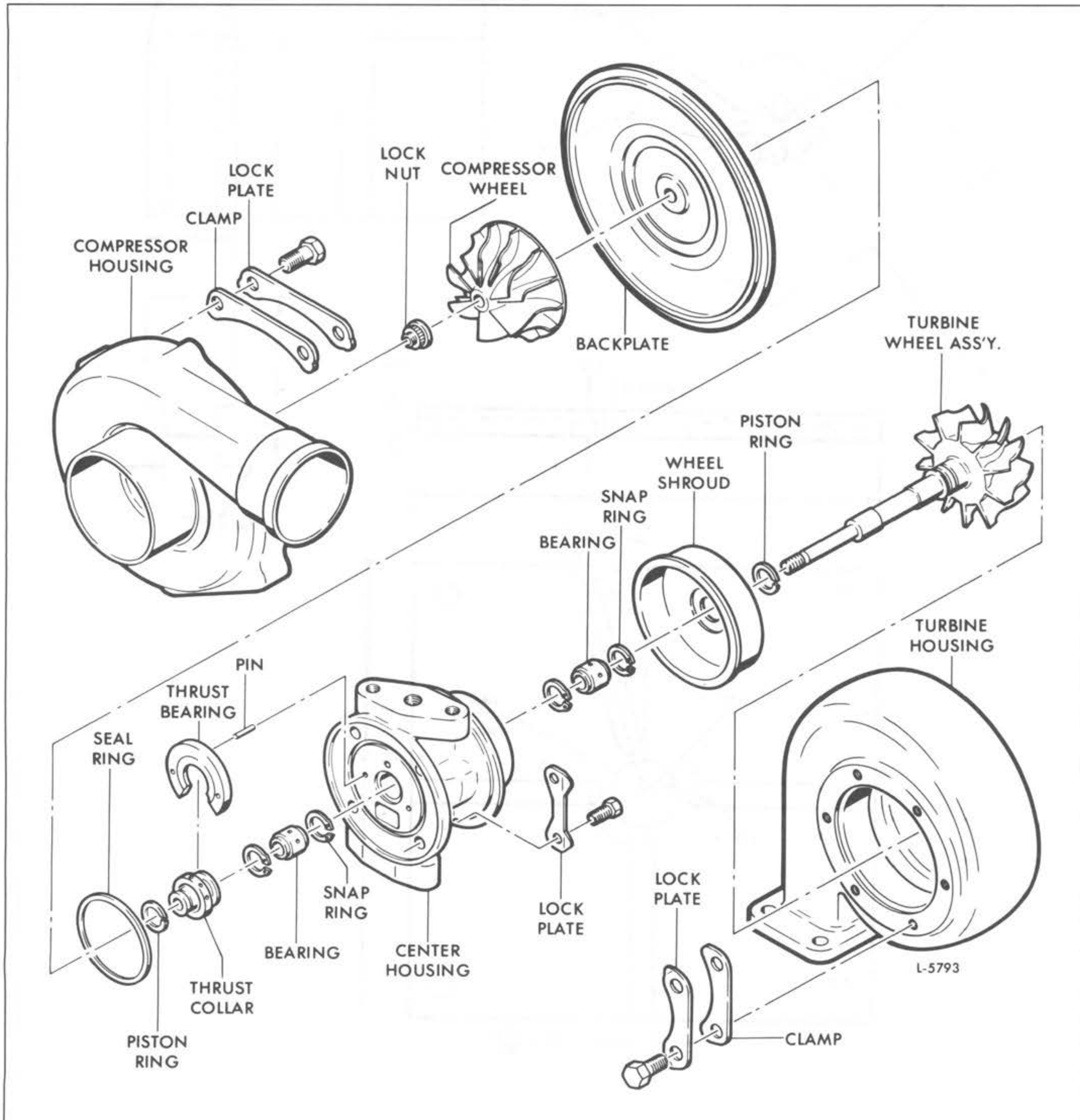


Fig. 9 – T04B Turbocharger Details and Relative Location of Parts

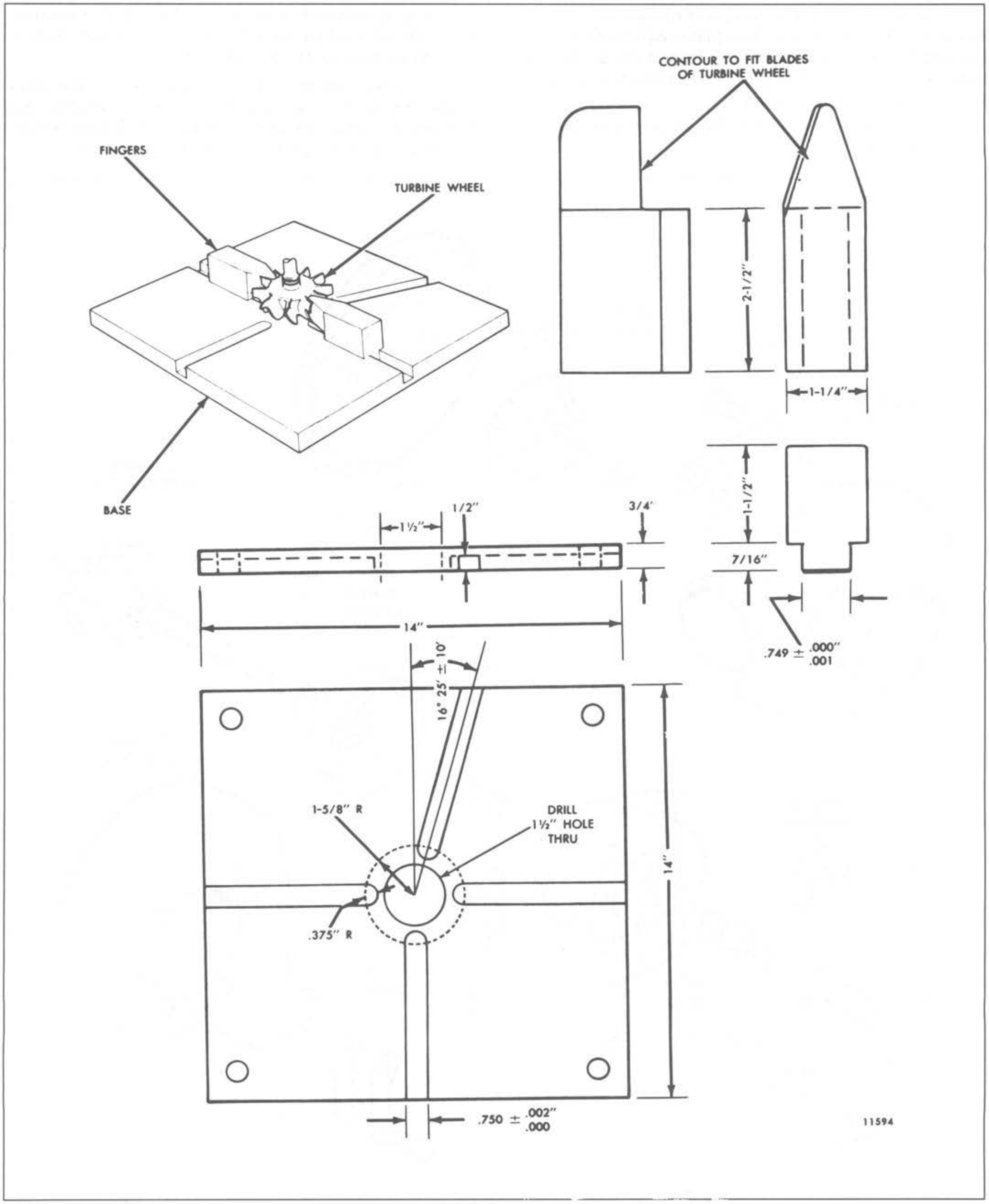


Fig. 10 – Turbocharger Holding Fixture

ASSEMBLE TURBOCHARGER

T18A40, T18A90, TV71 And TV81 Turbochargers

Check each part prior to installation to ensure cleanliness. As the parts are assembled, cover the openings to prevent entry of dirt or other foreign material.

Refer to Figs. 7 and 8 for parts orientation and proceed as follows:

1. Lubricate the new bearings (20 and 24) with clean engine oil.
2. Install a new snap ring (26), bearing washer (25), bearing (24) and snap ring (23) in the turbine end of the center housing (27).
3. Install a new snap ring (22), bearing washer (21) and bearing in the compressor end of the center housing.
4. Install a new piston ring(s) (17) on the thrust spacer (16) and gently insert the spacer into the backplate assembly (14). The current thrust spacer (16) has two grooves. When replacing the former one groove spacer with the two groove spacer, be sure and include two piston rings.

   NOTICE: Do not force the piston ring(s) into place.

5. Make sure the compressor bearing is in place, then position the new inboard thrust washer (19) flat against the center housing with the hole and cutout in the thrust washer in alignment with the pins in the center housing.
6. Install the thrust collar (18) snugly against the thrust washer. Lubricate the thrust collar and thrust washer with clean engine oil.
7. Install a new seal ring (15) in the groove at the compressor end of the center housing.
8. Align the oil feed holes in the center housing (27) and the backplate assembly (14) and attach the backplate to the center housing with four bolts (12) and new lockplates (13). Tighten the T18A bolts to 90–110 **lb–in** (10–12 N•m) torque or the TV71 and TV81 bolts to 80–100 **lb–in** or (9–11 N•m) torque and bend the lockplate tangs up against the side of the bolt heads.

   NOTICE: If a new backplate with a warning plate is inadvertently installed, *the warning plate must be removed and the three drive screw holes plugged to prevent air leakage.*

A new steel lockplate and high strength bolts are now being used in the T18A Series turbocharger. The new high strength bolts and lockplates must be used together and the bolts must be tightened to 160 –180 **lb–in** (18–20 N•m) torque. Be sure and bend the lockplate tangs up against the side of the bolt heads, after tightening the bolts. Only the current steel lockplate and high strength bolt are serviced.

9. On TV71 and TV81 turbochargers, install a new turbine piston ring (11) on the wheel shaft assembly.

   NOTICE: Before installing the piston ring, fill the piston ring groove with Dow Corning High Vacuum Silicone grease, or equivalent.

10. Position the wheel shroud (10) against the center housing (27) and insert the wheel shaft assembly (9) through the wheel shroud and into the center housing. Lubricate the wheel shaft assembly journal prior to assembly.

    NOTICE: Be careful not to scuff or scratch the bearings when installing the shaft.

11. Place the turbine wheel shaft assembly, shroud, center housing and backplate upright in a suitable holding fixture as shown in Fig. 10.

    NOTICE: If a holding fixture is not available, clamp a suitable socket or box wrench in a vise and place the extended hub on the shaft in the socket or wrench.

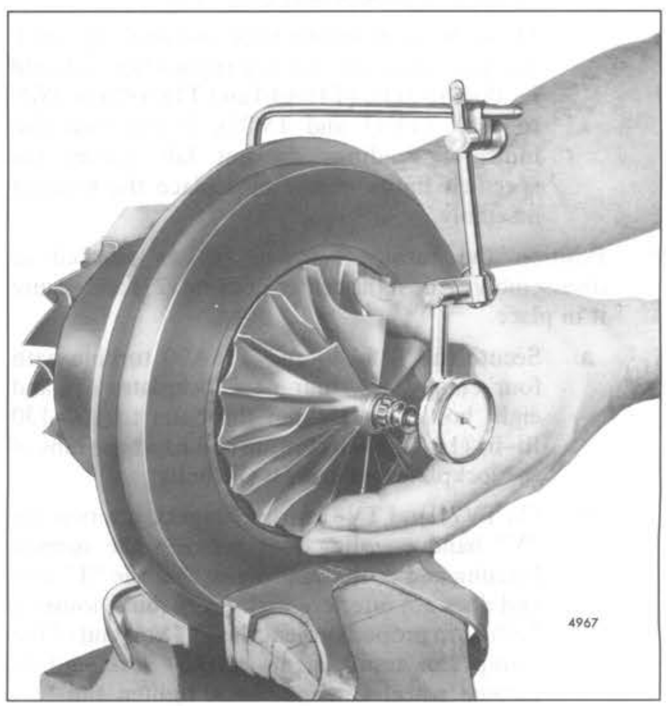


Fig. 11 – Checking Bearing Axial End Play

12. With the compressor wheel at room temperature, position it over the shaft.
13. Lightly lubricate the shaft threads and wheel face that will be under the nut with engine oil and install the retaining nut. Tighten the nut to 125–150 **lb–in** (14–17 N•m) torque to seat the compressor wheel against the thrust spacer.
14. Loosen the nut and inspect the nut face and the front face of the compressor wheel to be sure they are smooth and clean.
15. Retighten the nut to 35–55 **lb–in** (4–6 N•m) torque.
16. Continue to tighten the retaining nut until the shaft increases .007"–.008" in length (T18A40) or .009"–.010" in length (T18A90, TV71 and TV81). Tighten the retaining nut in such a manner as not to impose bending load on the shaft.

    NOTICE: If equipment is not available to measure the shaft stretch, tighten the wheel retaining nut to 35–55 **lb–in** (4–6 N•m) torque. Then continue to tighten the nut through an angle of 100–110° turn for the T18A40 or 120–130° turn for the T18A90, TV71 and TV81 (90° = 1/4 turn).

17. Check the bearing axial end play:
    a. Clamp the center housing assembly in a bench vise equipped with soft jaws as shown in Fig. 11.
    b. Fasten the dial indicator and magnetic base (J 7872–2) to the center housing so that the indicator tip rests on the end of the rotating shaft on the compressor side (Fig. 11).
    c. Move the shaft axially back and forth by hand. The total indicator reading (thrust float) should be .004" to .009" (T18A40 and T18A90) or .003" to .010" (TV71 and TV81). If the total dial indicator readings do not fall within the specified limits, repair or replace the rotating assembly.
18. Position the turbine housing (6) as marked at disassembly against the center housing (27) and secure it in place.
    a. Secure the T18A40 and T18A90 turbine with four clamps (5), four new lockplates (4) and eight bolts (3). Tighten the bolts to 100–130 **lb–in** (11–15 N•m) torque and bend the tabs of the lockplates up against the bolts.
    b. On TV71 and TV81 turbochargers, position the "V" band coupling (28) between the turbine housing and center housing so that the "T" bolt end does not interfere with the turbine housing. Failure to properly orient the "T" bolt end of the clamp can result in an exhaust leak and/or turbine wheel damage. Then tighten the "V" band coupling nut, as follows:
        1. Lubricate the toggle bolt threads with a high temperature anti–seize compound such as Jet Lube (Mil Spec A–907D), or equivalent.
        2. Tighten the nut on the "V" band toggle bolt to approximately 160 **lb–in** (18 N•m) torque.

    NOTICE: Do not pull a misaligned turbine housing into alignment with the "V" band coupling. The parts must be aligned and seated first.

        3. Loosen the "V" band coupling nut to approximately 50 **lb–in** (6 N•m) torque, then re–torque the nut to 152–168 **lb–in** (17–19 N•m) torque.
19. Position the compressor housing (2) as marked at disassembly against the backplate assembly (14) and secure it in place with the "V" band coupling (1). Lightly lubricate the threads of the toggle bolt with engine oil and tighten the nut to 110–130 **lb–in** (12–15 N•m) torque.
20. Check the shaft radial movement:
    a. Position the magnetic base J 7872–2 with the swivel adaptor J 7872–3 on the flat surface of the turbine housing inlet flange as shown in Fig. 11.
    b. Fasten the dial indicator extension rod J 7872–1 to the dial indicator J 8001–3 and attach the dial indicator to the swivel adaptor.

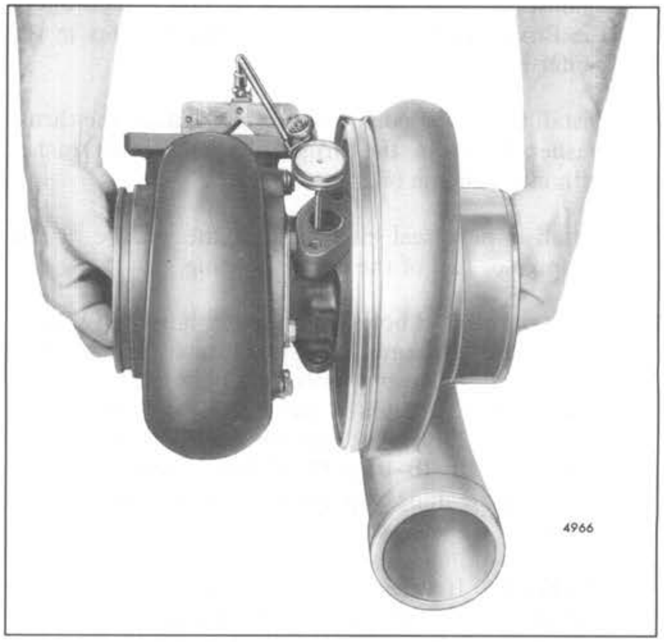


Fig. 12 – Checking Shaft Radial Movement

c. Insert the extension rod J 7872–1 into the oil drain tube mounting pad opening so that the rod is against the wheel shaft and is perpendicular to the shaft.

NOTICE: Make sure the extension rod does not make contact with the sides of the center housing, otherwise it will be impossible to obtain an accurate reading.

d. Grasp each end of the rotating assembly (Fig. 11) and, applying equal pressure at each end, move the rotating shaft first toward and then away from the dial indicator, creating a transverse movement in the shaft. Refer to Section 3.0 for dial indicator displacement. If the displacement does not fall within these limits, disassemble and repair or replace the rotating assembly.

21. If it is to be stored, lubricate the unit internally and install protective covers on all openings.

22. Stamp the letter "R" in the lower left–hand corner of the name plate to identify that the turbocharger has been reworked.

T04B Turbocharger

Check each part prior to installation to ensure cleanliness. As the parts are assembled, cover the openings to prevent entry of dirt or other foreign material.

Refer to Fig. 9 for parts orientation and proceed as follows:

1. Lubricate the new bearings with clean engine oil.

2. Install a new snap ring, bearing and snap ring in the turbine end of the center housing.

3. Install a new snap ring, bearing and snap ring in the compressor end of the center housing.

4. Fill the piston ring groove in the turbine wheel shaft assembly with high vacuum silicone grease. Then install the piston ring on the wheel assembly.

5. Position the wheel shroud on the wheel of the shaft assembly and insert the shaft assembly into the center housing as far as it will go.

NOTICE: Be careful not to scuff or scratch the bearings when installing the shaft and do not force the piston ring into the center housing bore.

6. Place the turbine wheel shaft assembly, shroud and center housing upright in a suitable holding fixture, as shown in Fig. 10.

NOTICE: If a holding fixture is not available, clamp a suitable socket or box wrench in a vise and place the extended hub on the shaft in the socket or wrench.

7. Lubricate the thrust collar and thrust bearing with clean engine oil and install the thrust collar on the shaft of the turbine wheel assembly. Then install the thrust bearing in the groove of the collar and slide the assembled parts down against the center housing so that the pins engage the holes in the thrust bearing.

8. Install a new piston ring on the thrust collar.

NOTICE: To avoid breakage, do not force the piston ring into place.

9. Install a new seal ring in the groove at the compressor end of the center housing.

10. Install the backplate assembly over the shaft and carefully guide the piston ring on the shaft into the backplate bore, ring gap first.

11. Align the oil feed holes in the center housing and the backplate assembly and attach the backplate to the center housing with bolts and new lockplates. Tighten the bolts to 75–90 **lb–in** (8–10 N•m) torque and bend the lockplate tabs up against the side of the bolt heads.

NOTICE: If a new backplate with a warning plate is inadvertently installed, *the warning plate must be removed and the three drive screw holes plugged to prevent air leakage.*

12. With the compressor wheel at room temperature, position it over the shaft.

13. Lightly lubricate the shaft threads and wheel face that will be under the nut with engine oil and install the locknut on the shaft. Tighten the nut to 18–20 **lb–in** (2 N•m) torque above the drag torque required to bottom the locknut.

NOTICE: Bottoming of the locknut will be indicated by the sharp increase above the drag torque observed while running the nut down.

14. Retighten the locknut through an angle of 90°. This additional tightening will result in stretching the shaft .0055" to .0065" in length.

NOTICE: Tighten the retaining nut in such a manner as not to impose a bending load on the shaft.

15. Check the bearing axial end play:

a. Clamp the center housing assembly in a bench vise quipped with soft jaws as shown in Fig. 11.

b. Fasten the dial indicator and magnetic base (J 7872–2) to the center housing so that the indicator tip rests on the end of the rotating shaft on the compressor side (Fig. 11).

c. Move the shaft axially back and forth by hand. The total indicator reading should be between .004" and .009". If the total dial indicator readings do not fall within the specified limits, repair or replace the rotating assembly.

16. Position the turbine housing as marked at disassembly against the center housing and secure it in place with clamps, new lockplates and bolts. Tighten the bolts to 100–130 **lb–in** (11–15 N•m) torque and bend the tabs of the lockplates up against the bolts.

17. Position the compressor housing as marked at disassembly against the center housing and secure it in place with clamps, new lockplates and bolts. Tighten the bolts to 100–130 **lb–in** (11–15 N•m) torque and bend the tabs of the lockplates up against the bolts.

18. Check the shaft radial movement:

a. Position the magnetic base J 7872–2 with the swivel adaptor J 7872–3 on the flat surface of the turbine housing inlet flange as shown in Fig. 12.

b. Fasten the dial indicator extension rod J 7872–1 to the dial indicator J 8001–3 and attach the dial indicator to the swivel adpator.

c. Insert the extension rod J 7872–1 into the oil drain tube mounting pad opening so that the rod is against the wheel shaft and is perpendicular to the shaft.

NOTICE: Make sure the extension rod does not make contact with the sides of the center housing, otherwise it will be impossible to obtain an accurate reading.

d. Grasp each end of the rotating assembly (Fig. 12) and, applying equal pressure at each end, move the rotating shaft first toward and then away from the dial indicator, creating a transverse movement in the shaft. The dial indicator displacement should be between .003" and .007". If the displacement does not fall within these limits, disassemble and repair or replace the rotating assembly.

19. If it is to be stored, lubricate the unit internally and install protective covers on all openings.

20. Stamp the letter "R" in the lower left–hand corner of the name plate to identify that the turbocharger has been reworked.

Install Turbocharger

1. Attach a chain hoist and a suitable lifting sling to the turbocharger assembly.

2. Remove the covers from the air inlet and exhaust outlet openings on the engine that were placed over the openings when the turbocharger was removed.

NOTICE: On TV71 and TV81 turbochargers, be sure gaskets are installed at the three mounting bracket to flywheel housing attaching bolts.

3. Place the turbocharger assembly into position on the mounting bracket. Use a new gasket between the exhaust manifold adaptor and the turbine housing flange.

NOTICE: When attaching the exhaust flange or adaptor to the turbine housing, be sure the inner diameter of the flange or adaptor is the same as the turbine housing inner diameter. The turbine opening in the T18A40 turbocharger is 3.850", the T18A90 turbocharger is 4.250", the TV71 turbocharger is 3.480", the TV81 turbocharger is 3.892" and in the T04B turbocharger the diameter is 2.581".

4. Secure the turbocharger to the mounting bracket with bolts, lock washers and nuts. Tighten the nuts just enough to hold the turbocharger tight against the bracket.

NOTICE: When self–locking nuts are used to secure the turbocharger to the mounting bracket, be sure there is full thread engagement (at least one full thread above the nut) of the self–locking nuts on the bolts.

5. Slide the blower air inlet hose over the compressor housing outlet opening. Then center the hose between the turbocharger and the blower air inlet housing and secure the clamps with the "T" section positioned away from the parting line on the air inlet housing (Fig. 17).

6. When installing the left bank exhaust manifold to turbocharger tube on a blower mounted turbocharger, it is very important that the tube is installed correctly. If the tube is installed incorrectly, it can crack in the flange area and adversely affect performance.

The solid left bank tube is almost symmetrical, thus it is difficult to identify which end goes where. Therefore, position the tube between the exhaust manifold and the turbocharger and check to determine that the conical seat at each end of the tube is a flush fit with the openings. If not, reverse the position of the tube and recheck to be sure each end of the tube is a flush fit with the openings.

To help in the installation of the tube, loosen the exhaust manifold mounting bolts and then tighten them alternately while tightening the tube clamps.

NOTICE: Be sure the exhaust manifold remains seated on the locating pads on the cylinder head.

7. Tighten the turbocharger to exhaust manifold adaptor bolts securely. Then remove the chain hoist and lifting sling from the turbocharger.
8. Install the oil drain line between the opening in the bottom side of the center housing and the cylinder block.
9. Attach the oil inlet line to the cylinder block.
10. After installing a rebuilt or new turbocharger, it is very important that all moving parts of the turbocharger center housing be lubricated as follows:
    a. Clean the area and disconnect the oil inlet (supply) line at the bearing (center) housing (Fig. 4).
    b. Fill the bearing housing cavity with clean engine oil. Turn the rotating assembly by hand to coat all of the internal surfaces with oil.
    c. Add additional clean engine oil to completely fill the bearing housing cavity and reinstall the oil line. Clean off any spilled oil.

NOTICE: The lube oil supply connector formerly installed in the plate is now assembled directly to the turbocharger center housing. The oil inlet of current TV turbochargers is being threaded by the manufacturer (Fig.13).

    d. Start and run the engine at idle until oil pressure and supply has reached all of the turbocharger moving parts. A good indicator that all of the moving parts are getting lubrication is when the oil pressure gage registers pressure (10 psig or 69 kPa at idle speed).

CAUTION: Do not hold the compressor wheel, for any reason, while the engine is running. This could result in personal injury.

The free floating bearings in the turbocharger center housing require positive lubrication. This is provided by the above procedure *before the turbocharger reaches its maximum operating speed* which is produced by high engine speeds. Starting any turbocharged engine and accelerating to any speed above idle before engine oil supply and pressure has reached the free floating bearings can cause severe damage to the shaft and bearings of the turbocharger.

11. Check all connections, ducts and gaskets for leaks after starting the engine.
12. Operate the engine at rated output and listen for sounds of metallic contact from the turbocharger. If any such noise is apparent, stop the engine immediately and correct the cause.

NOTICE: After the turbocharger has been operating long enough to permit the unit and the oil to warm up, the rotating assembly should coast freely to a stop after the engine is stopped. If the rotating assembly jerks to a sudden stop, the cause should be immediately determined and eliminated.

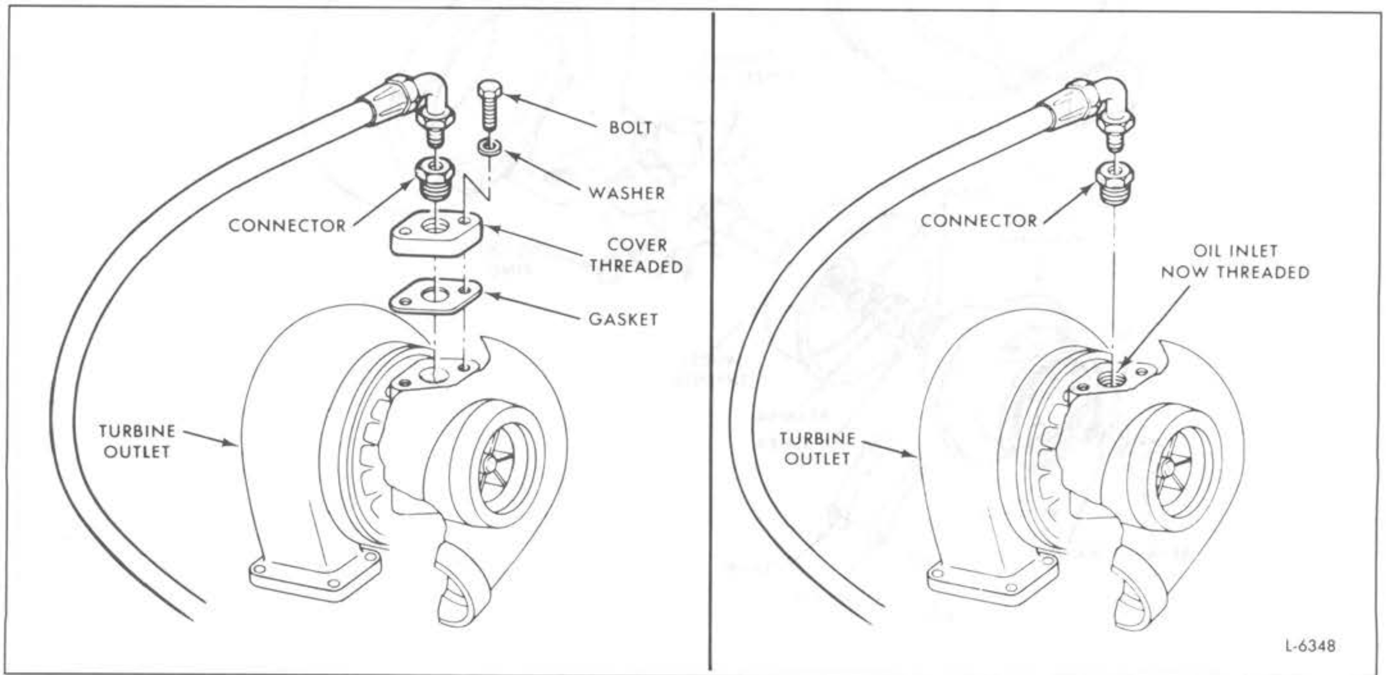


Fig. 13 – Former and Current Lube Oil Supply Connections

TH08A TURBOCHARGER

Remove Turbocharger

1. Disconnect the exhaust manifold adaptor attached to the turbine housing.
2. Disconnect the air inlet hose attached to the compressor housing.
3. Remove the oil inlet line from the top of the center housing.
4. Remove the oil outlet line from the bottom of the center housing.
5. Attach a chain hoist and a suitable lifting sling to the turbocharger assembly.
6. Remove the nuts and lock washers securing the turbocharger assembly to the mounting bracket. Then lift the turbocharger assembly away from the engine and place it on a bench.
7. Cover the end of each oil inlet and oil outlet line and the air inlet and exhaust outlet openings on the engine to prevent the entry of foreign material.

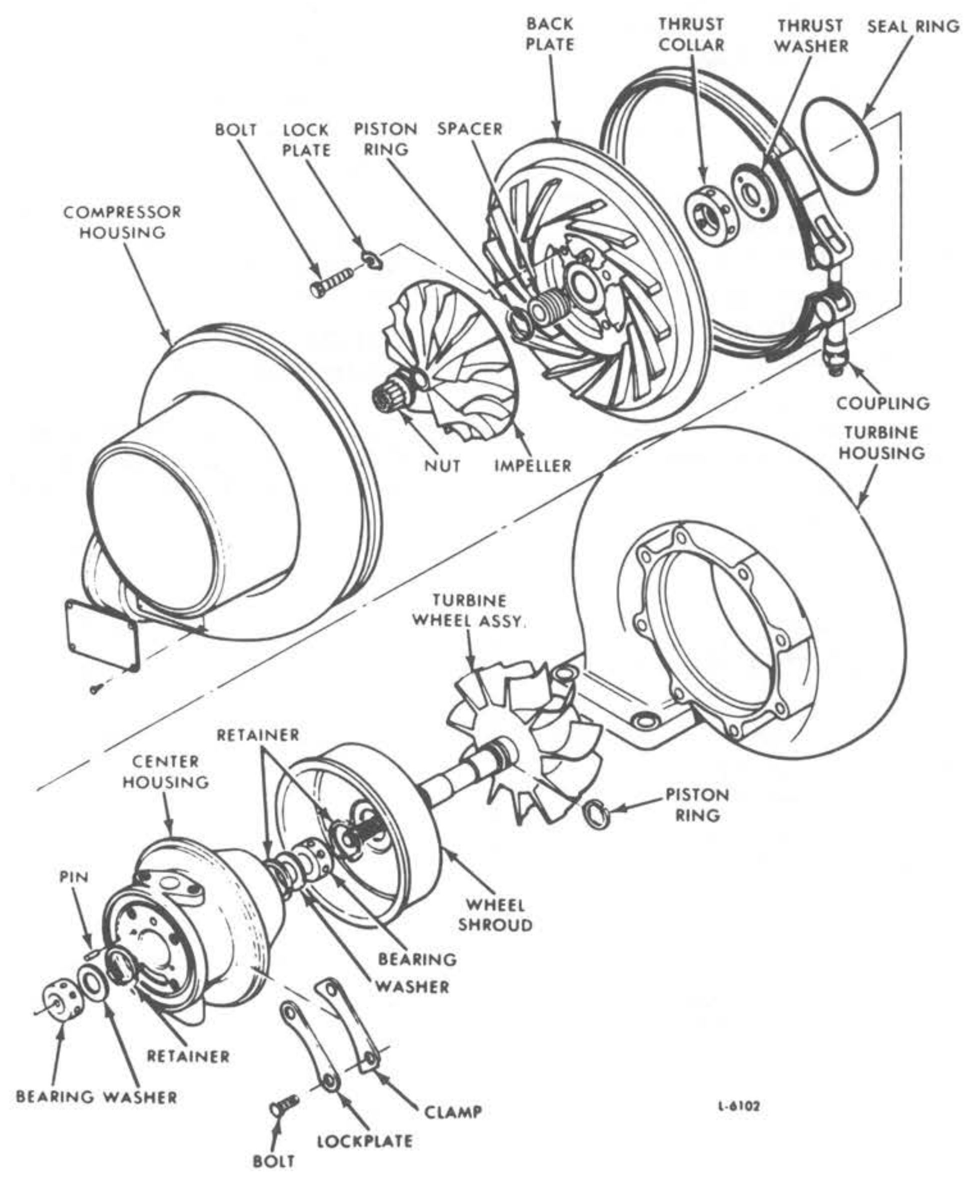


Fig. 13A – TH08A Turbocharger Details and Relative Location of Parts

Disassemble Turbocharger

Refer to Fig. 13A for the location of the various parts and disassemble the turbocharger assembly as follows:

1. Thoroughly clean the exterior of the turbocharger with a non–caustic cleaning solvent.

2. Matchmark the compressor housing, center housing and the turbine housing with a punch or chisel (Fig. 14) so they may be installed in the same relative position.

3. Loosen the "V" band coupling securing the compressor housing to the backplate assembly and remove the compressor housing and "V" band. If necessary, tap the compressor housing with a plastic hammer to loosen it.

4. Bend the ends of the turbine housing attaching bolt lockplates down. Then remove the eight bolts securing the turbine housing to the center housing. If necessary, tap the turbine housing with a plastic hammer to loosen it.

5. Remove the compressor wheel from the shaft as follows:

   NOTICE: The hexagon countersunk hole in the end of the turbine wheel must be scraped clean before installing it in the holding fixture.

   a. Clamp the turbine wheel holding fixture J 21225 in a bench vise. Then place the center housing and rotating assembly in the holding fixture, turbine wheel down (Fig. 10), with the hexagon countersunk hole in the turbine wheel over the protruding hexagon head in the holding fixture. If required, use a suitable holding fixture.

   b. To prevent the possibility of bending the shaft, remove the lock nut from the shaft with a double universal socket and a tee handle.

   c. Place a clean shop towel on the bed of the press and under the turbine wheel to protect the blades. Then place the tapered end of the removing tool J 9496 in the center of the shaft and the opposite end under the ram of the press. Press the shaft out of the compressor wheel.

   d. Remove the compressor wheel from the top of the center housing, then remove the center housing and shaft from the arbor press and place them on a bench. Pull the shaft assembly straight out of the center housing to prevent the threads on the end of the shaft from damaging the shaft bearings.

6. Remove and discard the turbine piston ring from the wheel shaft.

7. Place the center housing, compressor housing end up, on the bench, bend the end of the center housing thrust collar attaching bolt lockplates down. Then remove the four bolts and lockplates securing the thrust collar to the center housing.

8. Support the center housing on edge on the work bench. Then insert a 1/2" wood dowel approximately 8" long through the shaft bearings and against the thrust collar. Tap the thrust collar out of the center housing with a hammer.

9. Remove the thrust spacer and seal ring from the thrust collar, then remove the seal ring from the outside diameter of the thrust collar.

10. Remove the thrust ring and the thrust collar bearing from the center housing.

11. Remove the shaft bearing from the compressor wheel end of the center housing by lifting it straight up out of the housing with one finger inserted in the bearing.

12. Remove the shaft bearing from the turbine end of the center housing as follows:

    a. Place the center housing, turbine housing end up, on the bench.

    b. Remove the shaft bearing retainer from the center housing with a pair of snap ring pliers.

    c. Lift the bearing straight up out of the housing.

    d. If necessary, remove the two spacers and the two remaining retainers inside the center housing.

13. The turbine wheel shroud which is attached to the turbine end of the center housing does not need to be removed. The plate is not readily removable after it has been subjected to prolonged exhaust heat.

Cleaning

Before cleaning, inspect the parts for signs of burning, rubbing or other damage which might not be evident after cleaning.

Soak all parts in a non–caustic cleaning solvent for about 25 minutes. Use a stiff bristle brush and remove all dirt particles. Dry all of the parts thoroughly.

CAUTION: Never use a caustic cleaning solution for cleaning as this will damage certain parts. Use the cleaning solution in an open or well ventilated area. Avoid breathing the fumes. Keep away from open flames. Do not use a wire brush or a steel blade scraper to clean the parts.

Make sure that both wheel blades are thoroughly clean. Deposits left on the blades will affect the balance of the rotating assembly.

Clean all of the internal cavities and oil passages in the center housing thoroughly with dry compressed air.

CAUTION:To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.

Make sure all of the metal chips, from the tapping operation, are removed from the oil reservoir and oil passages in the center housing.

Clean the oil passage in the center housing backplate or thrust plate with dry compressed air.

Remove the oil inlet and outlet lines from the engine and thoroughly clean the oil lines inside and out. An oil line that is dented or crimped enough to restrict the flow of oil must be replaced.

Inspection

Inspect the turbocharger parts for signs of damage, corrosion or deterioration. If necessary, replace with new parts.

Examine the turbine wheel for signs of rubbing or wear. For shaft bearing journal dimensions and wear limits, refer to Section 3.0.

Examine the compressor wheel for signs of rubbing and bent blades. The wheel must be free of dirt and foreign material.

Check the compressor and turbine housings for signs of wheel contact.

Examine the thrust ring, shaft bearings and wear spacers, thrust spacer, seal ring and thrust plate bearing for signs of rubbing, scoring or wear. For shaft bearing dimensions and wear limits, refer to Section 3.0.

Assemble Turbocharger

NOTICE: If foreign particles fall into the turbocharger during the assembly procedure, remove the particles immediately, even though extensive disassembly is required.

Refer to Fig. 13A for the location of the various parts and assemble the turbocharger, as follows:

1. Lubricate the bearings with clean engine oil and install the retainers, bearings and washers from the forward end of the center housing.

   NOTICE: Install the rounded face of the retainer toward the bearing.

2. Install a new piston ring on the turbine wheel shaft.
3. Place the turbine wheel upright and guide the shaft through the shroud and bearings. Be careful not to scuff or scratch the bearings.

   NOTICE: Do not use force to compress the piston ring into place. A gentle rocking and pushing action will allow the ring to seat and the shaft to bottom. A thin tool may be used as an aid in compressing the ring, if necessary.

4. Check to see that the compressor bearing is in place, then install the thrust washer. Be sure that the hole and cut–out engage the pins in the center housing and that the washer is seated flat against the housing.
5. Install the thrust ring snugly against the thrust washer. Lubricate with clean engine oil.
6. Install a new seal ring in the groove of the center housing.
7. Align the oil feed holes of the center housing and thrust collar and install the thrust collar.
8. Install lock plates and bolts. Tighten the bolts to 80–100 **lb–in** (9–11 N•m) torque. Bend both sides of the lock plate up against the flat of the bolt head.
9. Install the piston ring on the thrust spacer. Gently insert the spacer into the thrust collar bore. Do not force the piston ring into place.

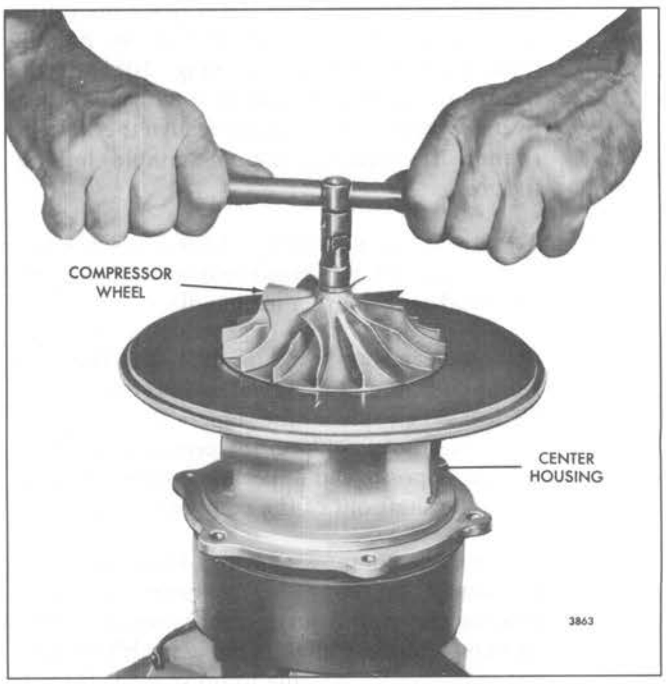


Fig. 14 – Tightening Compressor Wheel Lock Nut using Holding Fixture J 21225

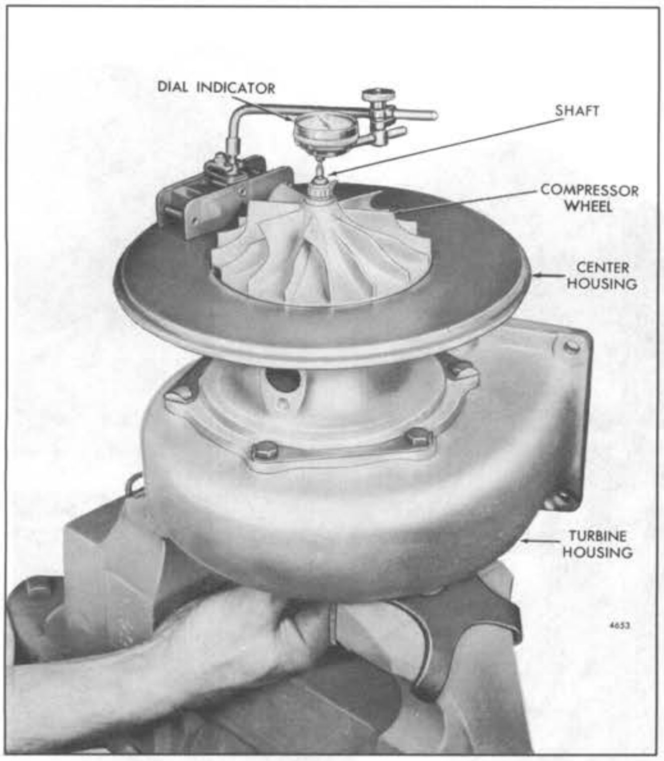


Fig. 15 – Checking Shaft End Play using Adaptor J 21224

10. Install the impeller onto the shaft and pull down with the lock nut until it is bottomed. Tighten the locknut to 18–20 **lb–in** (2 N•m) torque. Continue to tighten the locknut through an angle of 120° (Fig. 14). This will stretch the shaft the required .005"–.006".

NOTICE: Do not use a box wrench or any other type wrench to tighten the lock nut as the excessive side strain may bend the shaft. Use a sliding tee handle with wrench J 21223–01 and apply an even pressure on each end of the tee handle. This will eliminate the possibility of bending the shaft while tightening the locknut.

11. Check the shaft end play, as follows:

   a. Clamp the turbine housing and center housing and rotating assembly in a bench vise equipped with soft jaws, as shown in Fig. 15.

   b. Attach a clamp or a magnetic base indicator on the center housing and position the stem of the dial indicator on the end of the shaft.

   c. Push up on the rotating assembly by hand and note the indicator reading.

   d. Push down on the rotating assembly by hand and note the indicator reading.

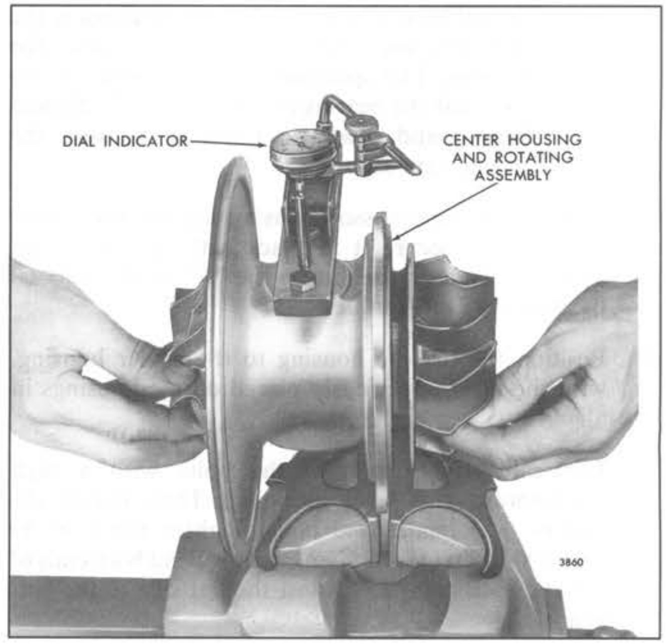


Fig. 16 – Checking Shaft Radial Movement with Tool J 21224

   e. The end play is the difference between the two readings. The specified shaft end play is .003" to .008".

12. Check the shaft radial movement (bearing clearance), as follows:

   a. Clamp the flange of the center housing in a bench vise equipped with soft jaws (Fig. 16), with the oil outlet opening in the center housing facing up.

   b. Place the dial indicator adaptor J 21224 over the oil outlet opening in the center housing with the large flat end of the plunger against the center of the shaft and secure the tool in place with two 3/8"–16 bolts of suitable length.

   c. Attach a clamp or a magnetic base type indicator to the dial indicator adaptor and position the stem of the dial indicator on the end of the plunger.

NOTICE: For a true reading, the dial indicator stem must be on the same center line as the plunger of the dial indicator adaptor.

   d. Raise the rotating assembly up by hand, as shown in Fig. 16, and note the indicator reading. Then push the rotating assembly down by hand and note the indicator reading.

NOTICE: Raise and lower both ends of the rotating assembly evenly when checking the radial movement.

e. The difference between the two readings is the total clearance between the shaft and the bearings. The specified clearance between the shaft and the bearings is .003" to .007". Repeat Steps d and e several times to be sure the readings are accurate.

13. Position the compressor housing against the center housing and secure it in place with the "V" band coupling. Tighten the nut on the "V" band to 40–60 **lb–in** (5–7 N•m) torque.

14. Position the turbine housing to the center housing, with the marks previously placed on the housings in alignment.

15. Lubricate the threads of the bolts with a high temperature anti–seize lubricant. Then install the clamps, lock plates and bolts. Tighten the bolts to 160–190 **lb–in** (18–22 N•m) torque. Bend both ends of the end lock plate up against the flat side of the bolt head.

16. With the turbocharger assembled, spin the rotating assembly by hand. The rotating assembly must turn freely without indications of dragging or binding.

17. Cover all openings in the turbocharger to prevent any foreign material from entering.

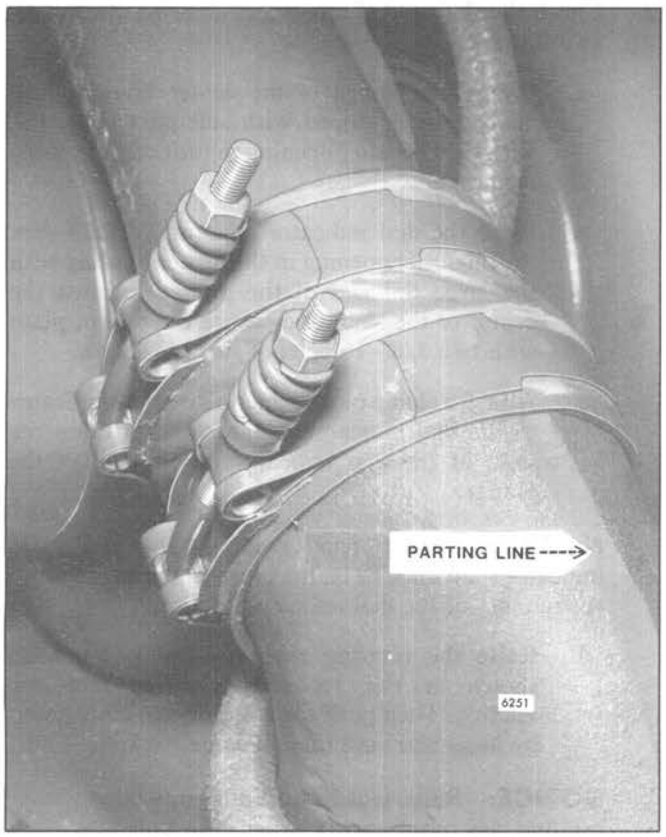


Fig. 17 – Properly Positioned Clamps

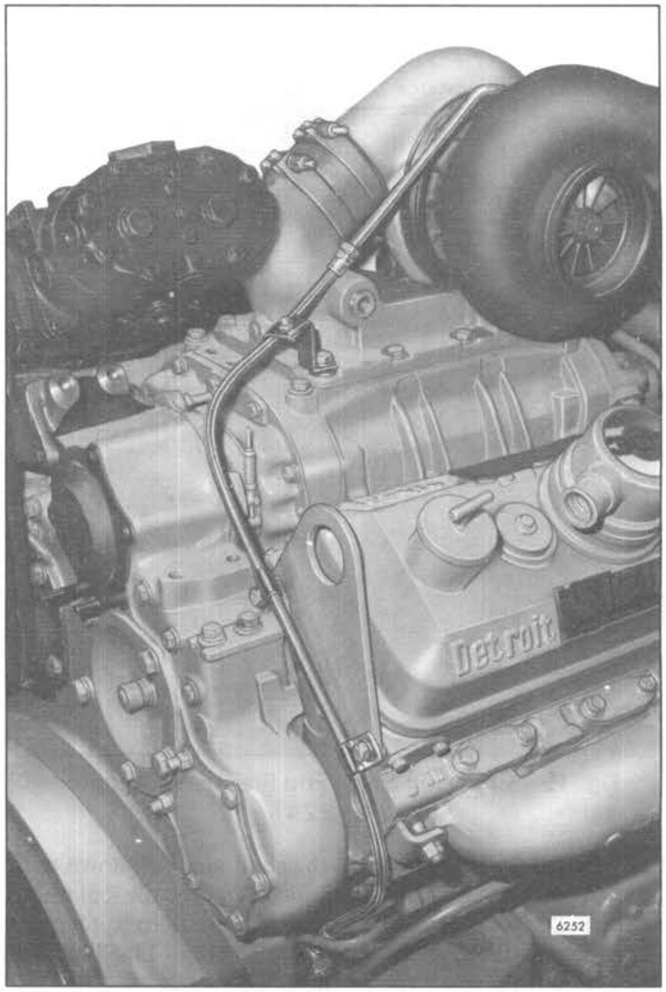


Fig. 18 – Typical 6V–92 Right–Bank Turbo Oil Supply Hose Routing

Install Turbocharger

1. Attach a chain hoist and a suitable lifting sling to the turbocharger assembly.

2. Remove the covers from the air inlet and exhaust outlet openings that were placed over the openings when the turbocharger was removed.

NOTICE: Turbocharged engines use a lockplate for positive locking of the bolts holding the turbocharger mounting support to the cylinder head. It is recommended that whenever a turbocharger is installed on an engine new lockplates and attaching parts be used to ensure positive locking of the attaching bolts. After the attaching bolts have been tightened to 30–35 lb–ft (41–47 N•m) torque, bend the lockplate against the flat of each of the bolt heads.

3. Place the turbocharger assembly into position on the mounting bracket.

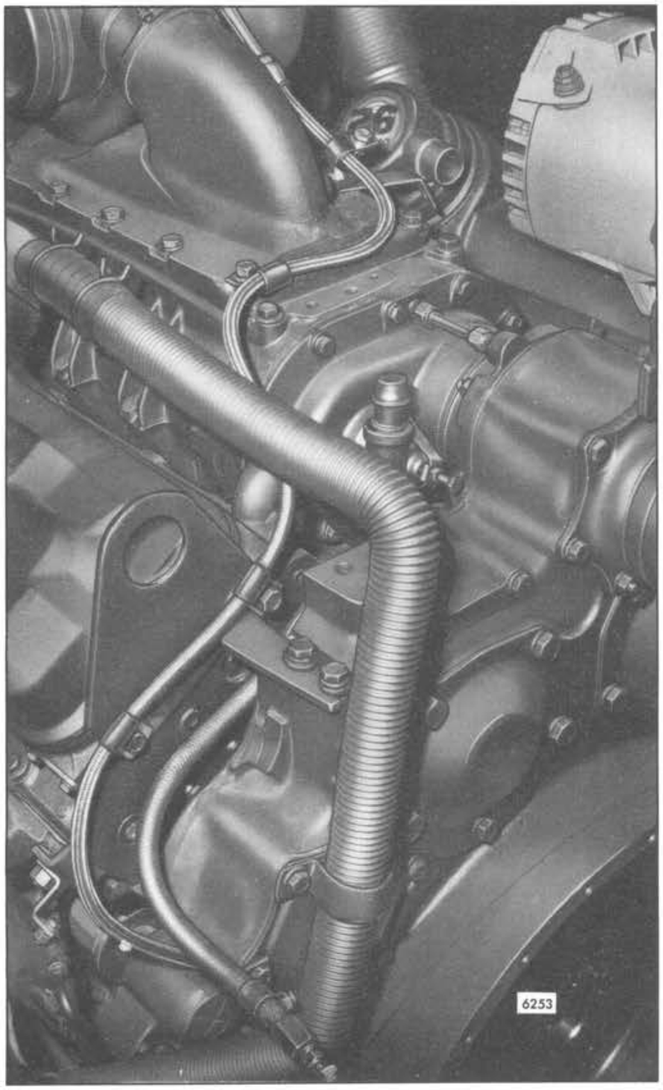


Fig. 19 – Typical 8V–92 Left-Bank Turbo Oil Supply Hose Routing

4. Place a new gasket between the exhaust manifold adaptor and the exhaust flange of the turbine housing, then secure the turbocharger to the adaptor with four bolts, lock washers and nuts. Tighten the nuts just enough to hold the turbocharger tight against the adaptor at this time.

5. Slide the blower air inlet hose over the compressor housing outlet opening. Then center the hose between the turbocharger and the blower air inlet housing and secure the clamps with the "T" section positioned away from the parting line on the air inlet housing (Fig. 17).

6. Tighten the turbocharger to exhaust manifold adaptor bolts securely. Then remove the chain hoist and lifting sling from the turbocharger.

7. Install the oil drain line between the opening in the bottom side of the center housing and the cylinder block.

8. Attach the oil inlet line to the cylinder block.

9. After installing a rebuilt or new turbocharger, it is very important that all moving parts of the turbocharger center housing be lubricated as follows:

   a. Clean the area and disconnect the oil inlet (supply) line at the bearing (center) housing (Fig. 4).

   b. Fill the bearing housing cavity with clean engine oil. Turn the rotating assembly by hand to coat all of the internal surfaces with oil.

   c. Add additional clean engine oil to completely fill the bearing housing cavity and reinstall the oil line. Clean off any spilled oil.

   d. Start and run the engine at idle until oil pressure and supply has reached all of the turbocharger moving parts. A good indicator that all moving parts are getting lubrication is when the oil pressure gage registers pressure (10 psig or 69 kPa at idle speed).

CAUTION: Do not hold the compressor wheel, for any reason, while the engine is running. This could result in personal injury.

The free floating bearings in the turbocharger center housing require positive lubrication. This is provided by the above procedure *before the turbocharger reaches its maximum operating speed* which is produced by high engine speeds. Starting any turbocharged engine and accelerating to any speed above idle before engine oil supply and pressure has reached the free floating bearings can cause severe damage to the shaft and bearings of the turbocharger.

10. Check all ducts and gaskets for leaks.

11. Operate the engine at rated output and listen for sounds of metallic contact from the turbocharger. If any such noise is apparent, stop the engine immediately and correct the cause.

NOTICE: After the turbocharger has been operating long enough to permit the unit and the oil to warm up, the rotating assembly should coast freely to a stop after the engine is stopped. If the rotating assembly jerks to a sudden stop, the cause should be immediately determined and eliminated.

TURBOCHARGER INTERCOOLER

An intercooler is placed between the air discharge side of each turbocharger and the air inlet side of the engine blower (Fig. 1). The intercooler is used to reduce the temperature of the compressed air leaving the turbocharger before it reaches the blower. This permits a more dense charge of air to be delivered to the engine.

Cooling is accomplished by a raw water pump driven off the rear end of the engine supplying water to the intercooler. The water makes six passes through the core and is discharged from the connection diagonally opposite the inlet. The air from the turbocharger enters the finned side of the intercooler at the face opposite the water inlet, and flows counterflow to the direction of water flow through the core.

The coolant circulated through the intercoolers of a turbocharged intercooled engine is protected by a cone-shaped 20 mesh water filter (screen). The filter is located at the water connection in the water pump to engine oil cooler tube. Refer to Section 15.1 for service and preventive maintenance.

Remove Intercooler

1. Drain the raw water system.
2. Disconnect the air and water inlet hose connections at the air shutdown housing, the turbocharger
3. Remove the intercooler air inlet housing and then remove the intercooler from the air outlet housing. Discard the gaskets.

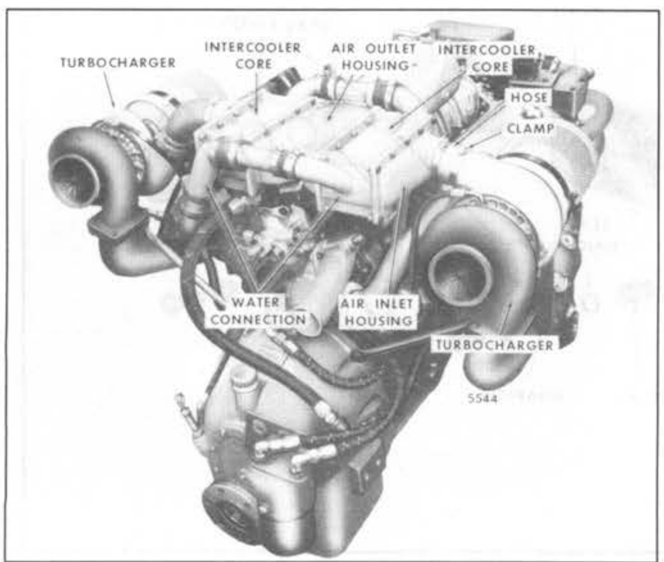


Fig. 1 – Turbocharger Intercooler Mounting

Disassemble Intercooler

1. Remove the two bolts and lock washers and withdraw the drain adaptor with the drain cock from the drain hole below the intercooler outlet connector (Fig. 2).
2. Remove three bolts and lock washers from each connector and withdraw the inlet and outlet connectors straight out from the intercooler. Remove and discard the gaskets.
3. Remove the drain, inlet and outlet tubes and seal rings from the water openings in the intercooler. Remove and discard the two seal rings on each tube.
4. Remove the four cross-head screws from the intercooler adaptor plate, then remove the plate and discard the seal ring.
5. Remove the top one-piece felt pad.
6. Lift the intercooler core straight up and out of the housing.
7. If necessary, remove the eight upright felt pads for cleaning.

Inspection

If inspection or trouble shooting (Section 3.0) reveals marine growth or debris has plugged the tubes of the intercooler, or the air side of the cooler has become plugged with foreign material and greasy soot accumulations, they must be cleaned.

Clean Intercooler

CAUTION: Protect your eyes and avoid breathing the fumes or direct contact of the acid with your skin.

Remove only the covers of the intercoolers.

NOTICE: Prior to removing the covers, matchmark each cover in its original position.

Clean the intercooler core by immersing it in a scale solvent consisting of 1/2 pound of oxalic acid to each 2-1/2 gallons of a solution composed of 1/3 muriatic acid and 2/3 water. The cleaning action is evident by the bubbling and foaming. Carefully observe the process and remove the intercooler core from the solution when the bubbling stops (this generally takes from 30 to 60 seconds). Then thoroughly flush the intercooler core with clean hot water under pressure.

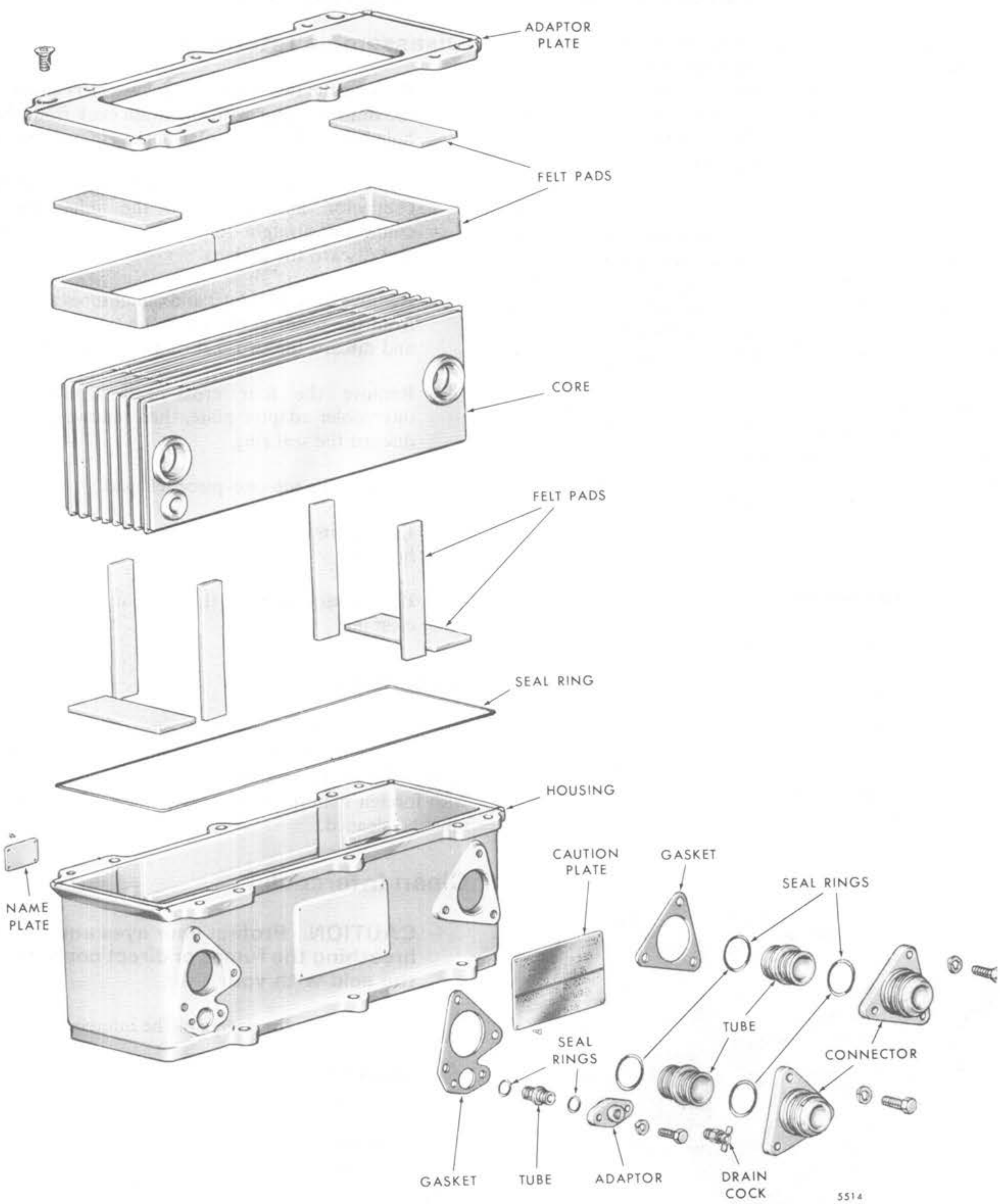


Fig. 2 – Intercooler Details and Relative Location of Parts

The coolant side of the cooler should be cleaned first. If the coolant side of the cooler does not require cleaning proceed with cleaning the air side of the cooler.

Glass bead both sides of the cooler and covers in a suitable glass beading machine.

Rod out each tube in the core with a suitable brass rod and wire brush.

Remove any blasting material with compressed air.

Reassemble the covers using new gaskets, at this time only hand tighten the cover bolts.

Place the complete assembly on a flat drill press table with slots, in order to allow the excess cover gasket material to set in and allow the covers to be square with the top and bottom of the core.

Tighten the cover bolts to the standard bolt torque, and trim excess gasket material from the top and bottom of the cooler.

Pressure Check Intercooler

1. Make a suitable adaptor to which an air hose can be attached and fasten it to the inlet pipe of the cooler core. Use a suitable piece of hose, a plug and clamp to seal the outlet pipe.
2. Attach an air hose and supply approximately 20 psi (138 kPa) air pressure. Then submerge the cooler core in a tank of water. Any leaks will be indicated by air bubbles in the water.

   CAUTION: When making this pressure test, be sure that personnel are adequately protected against any stream of pressurized water from a leak or rupture of a fitting, hose or the intercooler core.

3. After the pressure test is completed, remove the air hose, clamp, plug, hose and adaptor and dry the cooler core with compressed air. Replace the cooler core if leaks were indicated.

Assemble Intercooler

1. If removed, fix the eight upright felt pads in place in the intercooler housing using Silastic 732 RTV, or equivalent.
2. Place the intercooler core straight down into the housing.
3. Fix the one–piece felt pad around the top side of the housing. It should butt together at the center of the housing and must not overlap.
4. Lubricate a *new* seal ring and the groove in the adaptor plate with vegetable shortening and install the seal ring in the plate. Place the adaptor plate on the intercooler housing and thread the four 3/8"–16 x .75" screws into the housing. Tighten the screws to 50 **lb–in** (5.65 N•m) torque.
5. Lubricate *new* seal rings and the two grooves on each drain, inlet and outlet tube with vegetable shortening and place the seal rings on the tubes. Then place the drain, inlet and outlet tubes in the water openings in the housing.
6. Use *new* gaskets and install the water inlet and outlet connectors on the housing with three 3/8"–16 x 1" bolts and lock washers. Tighten the bolts to 240 **lb–in** (27.12 N•m) torque.

   NOTICE: The gasket with the drain hole is used at the outlet opening.

7. Install the drain adaptor and drain cock with two 5/16"–18 x .88" bolts and lock washers. Tighten the bolts to 120 **lb–in** (13.56 N•m) torque.

Install Intercooler

1. Use *new* gaskets and install the intercooler on the air outlet housing with twenty 3/8"–16 x 1" bolts with lock washers and nuts. Tighten the nuts.
2. Use new gaskets and attach the inlet housing to the intercooler with twenty 3/8"–16 x 1–1/8" bolts with lock washers and nuts. Tighten the nuts.
3. Connect the air and water inlet and outlet hoses at the air shutdown housing, turbocharger and intercooler. Tighten the hose clamps.
4. Fill the raw water system. Start the engine and check for any air or water leaks.

TURBOCHARGER AFTERCOOLER

The aftercooler mounts in the cylinder block opening between the cylinders, beneath the blower assembly (Fig. 1). The aftercooler (Fig. 2) cools the air going into the engine after it passes through both the turbocharger and the blower. The air flows downward through the aftercooler and the coolant flows from rear to front through the aftercooler and returns through the left bank thermostat housing (6 and 8V engines) and to the water manifold (12 and 16V engines).

The top deck of the cylinder block has been revised to accept the aftercooler. A water inlet adaptor plug or cup plug replaces the rear 2 1/2" core plug in the bottom of the cylinder block opening (Fig. 3 or 4) to supply water to the aftercooler. Tool J 25275 should be used to install or remove this adaptor plug. Use tool J 28711 to install the cup plug.

A limited number of 6, 8 and 16V blocks used the stainless steel cup plugs and aftercooler inlet adaptor to seal the water holes in the air box floor of the cylinder blocks (Fig. 4). The 2 1/2" cup plug and the solid aftercooler inlet adaptor will remain available to service the blocks.

Remove Aftercooler

Drain the block before removing the aftercooler as some coolant may remain in the cooler if only the radiator is drained.

1. Loosen the two 7/16"-14 x 5 1/4" attaching bolts and lift the turbocharger from the air inlet adaptor (refer to Section 3.5).

2. Remove the air inlet adaptor from the blower.

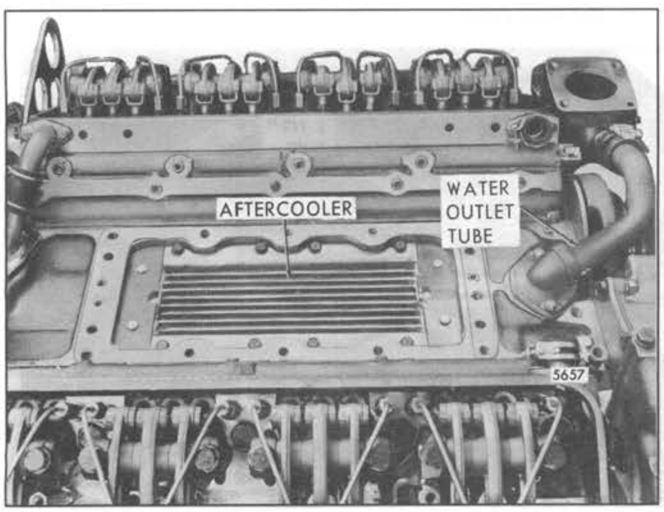


Fig. 1 – Aftercooler Mounted in Cylinder Block

3. Remove the blower and any accessories attached to the blower from the cylinder block (refer to Section 3.4).

4. Loosen the hose clamps and slide the cylinder block water outlet tube hose back against the thermostat housing (6 and 8V engines) or water manifold (12 and 16V engines).

5. Remove the water outlet tube from the front of the cylinder block. Discard the gasket.

6. Remove and discard the 5/16"-18 x 9/16" attaching bolts with nylon locking patch and lift the aftercooler from the cylinder block opening between the cylinders. *Do not remove the four bolts in the top face of the aftercooler (Fig. 1). They are part of the aftercooler assembly and need not be removed for any reason.*

NOTICE: Be careful not to damage the cooler fins when lifting the aftercooler from the cylinder block.

7. Remove and discard the seal rings from the grooves in the water inlet and outlet tube ends of the aftercooler.

Clean Aftercooler

The length of time an aftercooler will function satisfactorily before cleaning will be governed largely by the kind of coolant and coolant additive used in the engine.

Check all of the cooler fins and air and water passages for plugging at major overhaul. Clean the fins of dirt or any other foreign obstructions with a small brush. Do not apply more than 40 psi (276 kPa) air pressure.

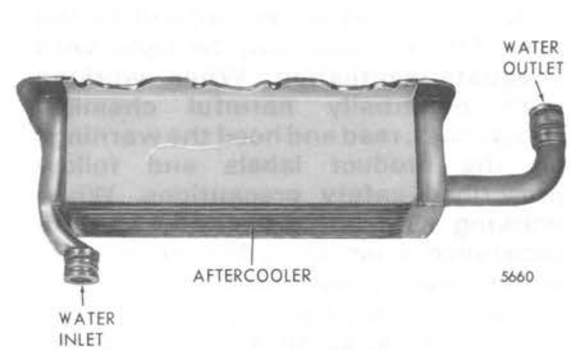


Fig. 2 – Aftercooler

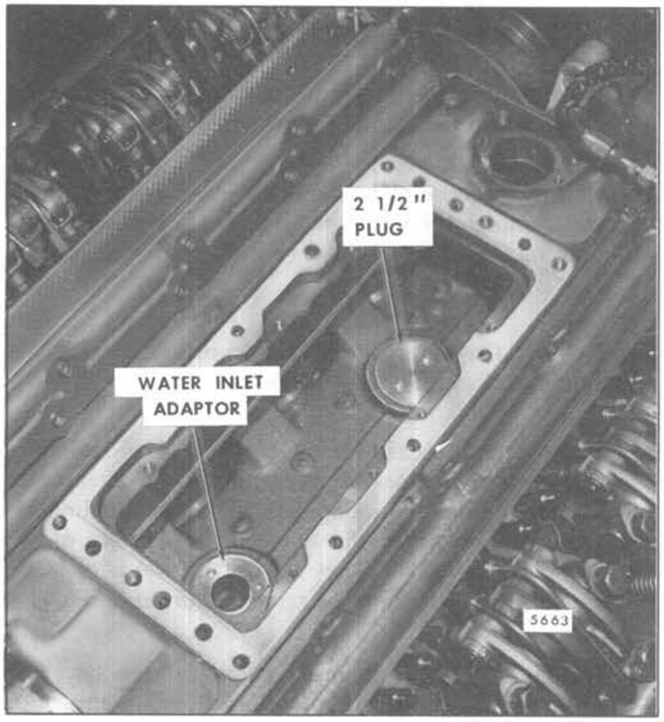


Fig. 3 – Location of Water Inlet Adaptor Plug in Cylinder Block

If an aftercooler core becomes clogged with oil, dirt or carbon during its service life on an engine, the procedure below may be used to clean it:

NOTICE: This procedure is not effective on scale (mineral salts) plugging. If scale plugging has occurred, the air system should be thoroughly inspected and the cause of the scaling determined and eliminated.

1. Stem clean the outside of the core to remove any loose deposits or debris.

CAUTION: Some chemical agents (detergents, solvents, alkalis, etc.) may irritate the skin or be harmful to the eyes. Others must only be used with adequate ventilation. When working with potentially harmful chemical substances, read and heed the warnings on the product labels and follow prescribed safety precautions. When working with any potentially harmful substance – including live steam, hot water and compressed air – wear appropriate safety equipment (face shield, gloves, apron, etc.) if required, and use extreme care to avoid personal injury.

2. Immerse the core in a tank filled with a solution of clean parts dip such as "Soak–NS", or equivalent. Allow it to soak for approximately 12 hours. Leave the water connections open so that the cleaning solution can penetrate both water and air sides of the core.

3. Remove the core from the tank and rinse it thoroughly with a steam cleaner or high–pressure hot water.

4. Blow out the air and water sides of the core using compressed air. To ensure that debris is not forced farther into the fins, direct the stream of air opposite to the direction of normal coolant and air flow.

CAUTION: To avoid personal injury, wear appropriate safety equipment (face shield, rubber gloves and apron).

5. Rinse the core with clean solvent (mineral spirits) to remove any residual oil or grease.

6. Remove the solvent from the core using a steam cleaner or high–pressure hot water rinse.

CAUTION:To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.

7. Using compressed air, blow dry the air and water sides of the core. Wear eye protection and do not exceed 40 psi (276 kPa) air pressue.

8. Visually inspect the cooler core tubes and fins to ensure that the cleaning process has completely removed all contamination. If necessary, repeat the cleaning procedure and reinspect.

Install Aftercooler

1. Install new seal rings in the two grooves on the water inlet and outlet tube ends of the aftercooler. Coat the seal rings lightly with engine oil or vegetable shortening. Do not scratch or nick the sealing edge of the seal rings.

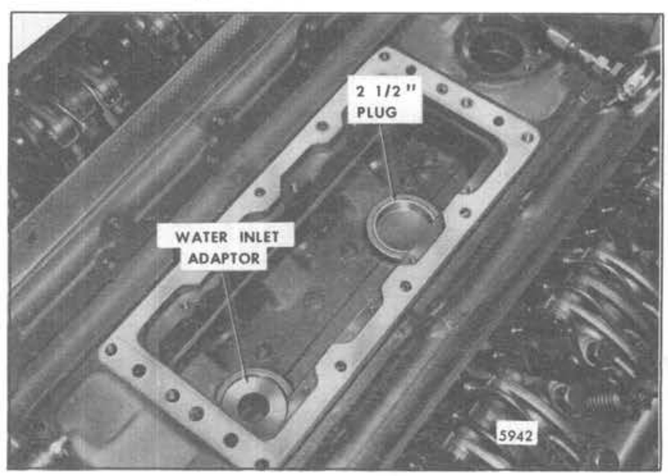


Fig. 4 – Installing Aftercooler Water Plug

2. Place the aftercooler, water outlet end first, into the cylinder block opening between the cylinders. The water inlet end of the cooler seats in the water inlet adaptor plug (Fig. 3 or 4). Install new 5/16"–18 x 9/16" attaching bolts with nylon locking patch (six bolts – 6 and 12V or eight bolts – 8 and 16V).

   Do not tighten the bolts until the water outlet tube to thermostat housing (6 or 8V engines) or water manifold (12 and 16V engine) hose and clamps are aligned and tightened.

3. Use a new gasket and attach the water outlet tube with two 5/16" bolts and lock washers to the cylinder block. Do not tighten the attaching bolts.

4. Align the water outlet tube to the thermostat housing (6 or 8V engines) or water manifold (12 and 16V engine) with the hose and clamps in position. Tighten the clamps.

   NOTICE: The aftercooler water outlet hose used on 16V–92 turbocharged–aftercooled engines has been replaced by a longer hose (2.26" to 2.75"). This change has been made to eliminate the possibility of coolant leakage caused by misalignment of the aftercooler water outlet tube and water outlet elbow during aftercooler installation. The extra hose length further ensures that properly installed hoses do not leak during engine operation.

5. Tighten the two 5/16" water outlet tube bolts, then tighten the aftercooler attaching bolts.

6. Use a new blower to cylinder block gasket and install the blower and any accessories attached to the blower (refer to Section 3.4).

7. Attach the air inlet adaptor to the blower with the 7/16"–14 x 1 1/2" attaching bolts and lock washers (eight bolts – 6 and 12V, ten bolts – 8 and 16V). Tighten the bolts to 46–50 lb–ft (62–68 N•m) torque.

8. Install the turbocharger (refer to Section 3.5). Tighten the two 7/16"–14 x 5 1/4" bolts to 46–50 lb–ft (62–68 N•m) torque.

SHOP NOTES - TROUBLESHOOTING SPECIFICATIONS - SERVICE TOOLS

SHOP NOTES

BLOWER DRIVE SEAL RING

The rubber seal ring used between the blower end plate and the blower drive support can be replaced without removing the blower, as follows:

1. Remove the clamp and cut and remove the old seal ring.

2. After thoroughly cleaning the blower drive groove area, make a square cut on a new seal ring and install the seal ring around the groove, with the cut at the top. Attach the two ends of the seal ring together with Loctite No. 06, or equivalent, as follows:

   a. The cutting blade to be used must be clean and free of contaminants. If a razor edge is to be used, remove the protective oil film by wiping with solvent.

   b. Make a square cut in the replacement seal. The cut ends must remain clean to achieve a satisfactory bond.

   c. Apply a thin film of Loctite Super Bonder Adhesive to one of the cut ends. Shake off excess adhesive. Use adhesive sparingly and avoid contact with skin.

   d. Position the seal in the blower drive groove, locating the adhesive treated end first. Place the other end of the seal in the groove and slide it into the adhesive end to make the joint. Apply light pressure to the joint and hold firmly for 30 seconds.

   e. To remove excess adhesive around the joint, apply a chlorinated solvent (Acetone, MEK or Methylene Chloride) to a cloth and wipe the joint.

CAUTION: This adhesive contains cyanoacrylate. Keep away from children. Irritating liquid and vapor. Hazardous if swallowed. Use with adequate ventilation. In case of skin contact, flush with plenty of water. For eye or mouth contact, get medical attention.

3. Install the plain clamp between the raised edges of the seal ring and tighten.

NOTICE: If a former seal ring (without groove) is used, it should be replaced with the current molded (two raised edges) type seal ring.

BLOCK MODIFICATION FOR FRONT-MOUNTED TURBOCHARGER LUBE OIL SUPPLY LINE

At the time of an out-of-frame overhaul, 6V-92 and 8V-92 cylinder blocks may be modified to accept a front-mounted turbo lube oil supply line (Fig. 1). Use the following procedure.

1. Fabricate the locating template shown in Fig. 2.
2. With the cylinder block completely stripped, mount the locating template on the block dowel pins (see Fig. 2 for establishing hole location).
3. Drill a 7/16" hole 1-1/2" deep into the oil gallery at the "B" location. Thread the hole with a 1/4" NPTF tap. If an additional oil feed location is required on the opposite bank, flip the template and repeat the modification procedure.
4. Remove the oil gallery plug (location "C" in Fig. 2) and blow out all metal chips using an air hose and suitable nozzle.

CAUTION: Do not exceed 20 psi (138 kPa) air pressure. Wear adequate eye protection to avoid personal injury.

If the oil cooler side of the block is drilled for the turbo oil supply, pay special attention to the area around the 1" cup plug that divides the vertical oil gallery between the oil cooler inlet and outlet passages (Fig. 3). Remove the cup plug and flush the oil gallery with the air hose and a cleaning solvent in combination to ensure the removal of all metal chips.

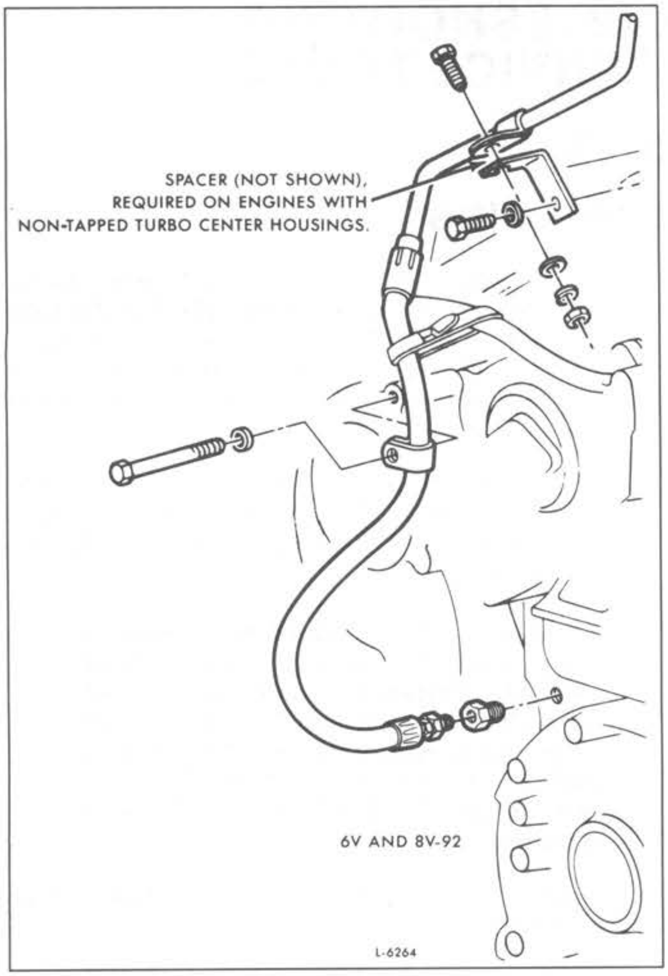


Fig. 1 – Turbo Lube Oil Supply Line Routing

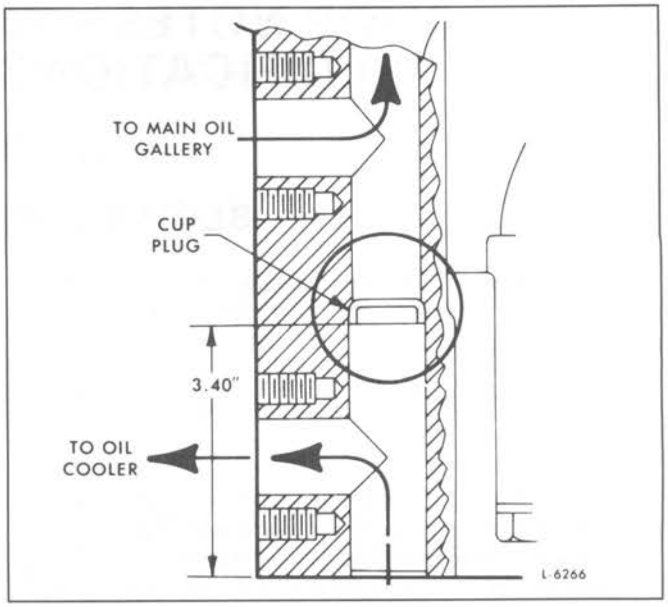


Fig. 3 – Location of Cup Plug in Oil Gallery

5. After cleaning the block thoroughly, apply Loctite J 26558–92 pipe sealant with Teflon (or equivalent) to the oil gallery plug and the cup plug and reinstall. Torque the oil gallery plug to 78–85 lb–ft (105–115 N•m). Install the cup plug to a depth of 3.40" with tool J 33420 (Fig. 3).

NOTICE: Neglecting to install the cup plug allows lube oil to completely bypass both the filter and the oil cooler. The resulting unfiltered and improperly cooled oil can seriously damage the engine.

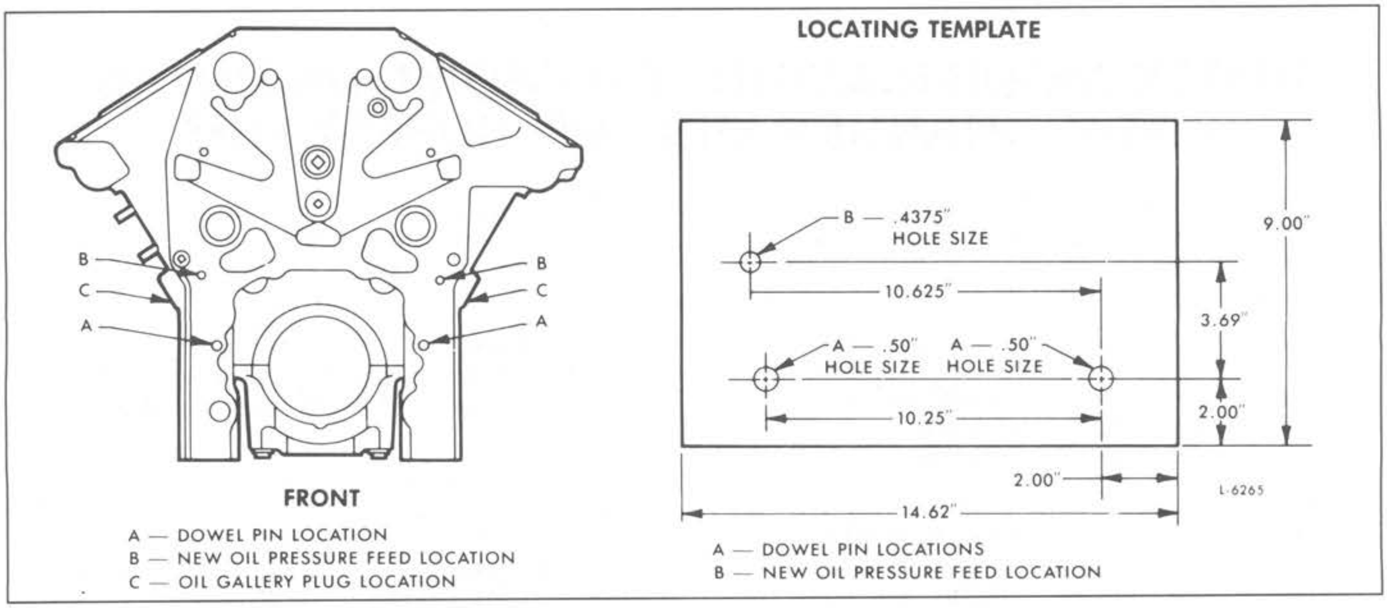


Fig. 2 – Locating Template

DRILLING PROCEDURE FOR AIR SHUTDOWN REPLACEMENT SHAFT

Whenever a replacement air shutdown valve shaft is installed on a Series 149 engine, the shaft must be match–drilled to the cam and the flapper valve in order to ensure positive air shutdown operation. Failure to properly index the shaft can result in improper flapper valve operation and engine run–on at shutdown. Use the following procedure to drill the air shutdown valve shaft:

1. Install a 1/8" drill bit in the chuck of a drill press, then locate and align the bit through the existing hole in the shutdown cam (Fig. 4). Lock the cam in the holding fixture on the drill press, and withdraw the bit.

2. Insert the replacement shaft into the cam until the end of the shaft is recessed 1/8" from the end of the cam. Start the drill and bore a hole through the shaft (Fig. 4). Withdraw the drill bit, install the pin handle through the hole and remove the shaft from the drill press.

3. Insert the shaft into the shutdown housing bore and install the spacer on the end of the shaft. Place a .015" feeler gage between the housing and spacer and mark the shaft with a center punch inserted into the existing hole in the spacer (Fig. 5).

4. Remove the shaft from the housing. Locate and align the 1/8" drill bit through the hole in the spacer and lock the spacer in the holding fixture on the drill press. Withdraw the drill bit.

5. Insert the shaft through the spacer, locate the center punched mark and drill a hole through the shaft. Remove the shaft and spacer from the drill press.

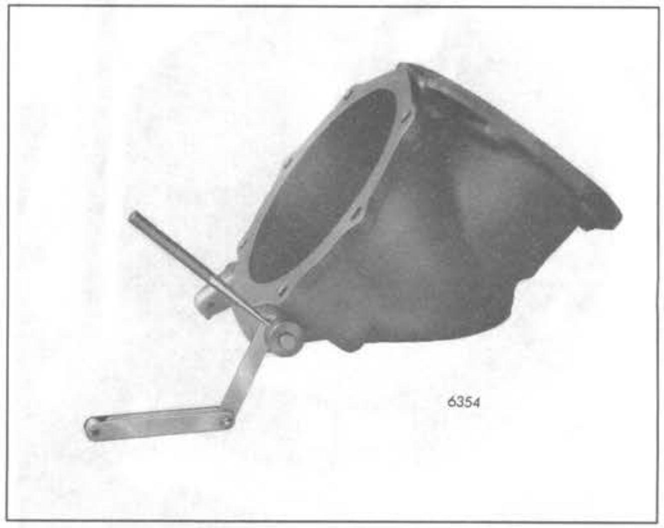


Fig. 5 – Center Punch Shaft thru Spacer Hole

6. Assemble the shaft, seal rings spring, flapper valve and spacer in the housing (see Section 3.3). If using a new valve, center punch for holes in approximately the same position as on the old valve. If reusing the old valve, center punch for holes just inside the existing holes.

7. Align the notch on the cam with the latch and hold in this position with a piece of stiff wire (Fig. 6).

8. Place the housing on the drill press. With the valve held in the wide open *run* position, align the 1/8" drill bit with the marks center punched on the valve in Step 6. Then, drill through the valve and shaft (Fig. 7). Install the retaining pins to hold the valve to the shaft.

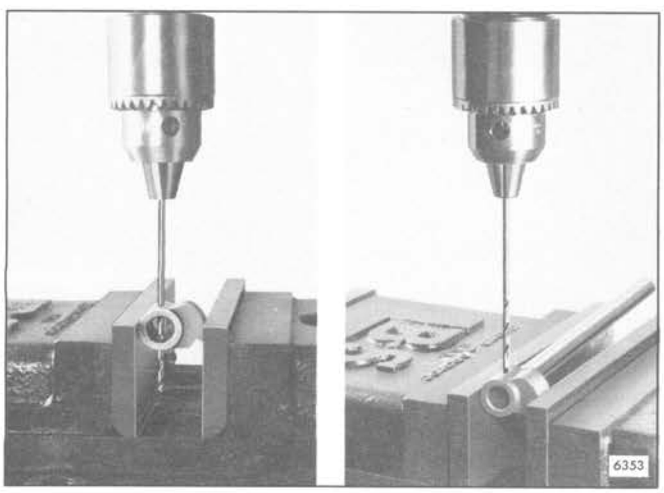


Fig. 4 – Aligning Drill Bit and Drilling Shaft

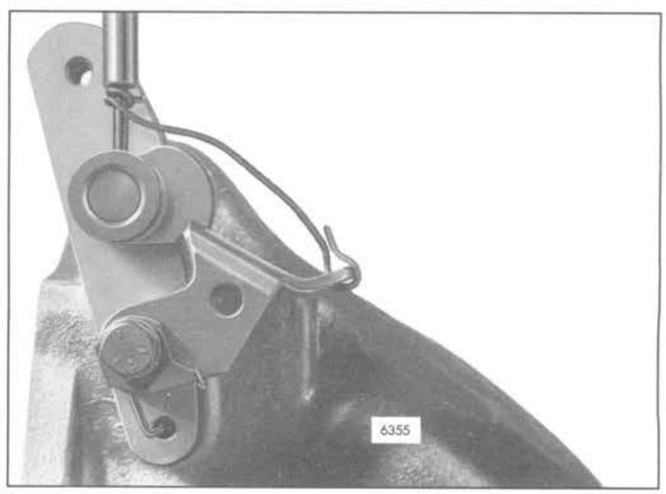


Fig. 6 – Cam and Latch Wired to Prevent Movement

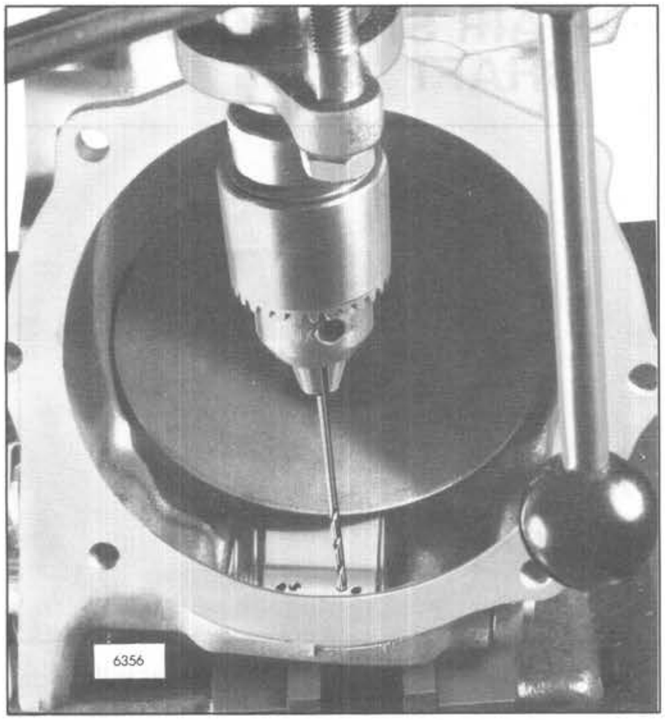


Fig. 7 – Drilling Valve-to-Shaft Holes

9. Clean the air shutdown assembly thoroughly and check for proper operation before installing it on the engine.

TROUBLESHOOTING

TURBOCHARGER

CONDITION	PROBABLE CAUSE	SUGGESTED REMEDY
NOISY OPERATION OR VIBRATION	WHEEL SHAFT BEARINGS ARE NOT BEING LUBRICATED	Locate cause of loss of oil pressure and repair. Remove, dis-assemble and inspect turbocharger for bearing damage.
	IMPROPER CLEARANCE BETWEEN TURBINE WHEEL AND HOUSING	Remove, disassemble, and inspect turbocharger.
	LEAK IN ENGINE AIR INTAKE OR EXHAUST MANIFOLD	Tighten all loose connections or replace exhaust manifold gaskets as necessary.
ENGINE WILL NOT DELIVER RATED POWER	CLOGGED AIR INTAKE SYSTEM	Check air cleaner and clean air intake ducts.
	FOREIGN MATERIAL LODGED IN COMPRESSOR OR TURBINE WHEELS	Remove, disassemble and clean turbocharger.
	EXCESSIVE DIRT BUILD-UP IN COMPRESSOR	Thoroughly clean compressor assembly. Clean air cleaner and check for leaks.
	LEAK IN ENGINE AIR INTAKE OR EXHAUST MANIFOLD	Tighten all loose connections or replace exhaust manifold gaskets as necessary.
	ROTATING ASSEMBLY BEARING SEIZURE	Remove and overhaul turbocharger.

INTERCOOLER

CONDITION	PROBABLE CAUSE	SUGGESTED REMEDY
BLACK SMOKE (AIR SIDE)	AIR INLET RESTRICTION	CLEAN SILENCER (SEE SECT. 3.2)
	INJECTORS — HIGH OUTPUT	SEE SECT. 2.0
	DIRTY FINS INTERCOOLER	CLEAN INTERCOOLER FINS
OVERHEATING (WATER SIDE)	THERMOSTATS	CHECK THERMOSTAT (SEE SECT. 5.2.1)
	RAW WATER PUMP	CHECK IMPELLER (SEE SECT. 5.6)
	HEAT EXCHANGER	CLEAN ELEMENT (SEE SECT. 5.5)
	INTERCOOLER (WATER SIDE)	CLEAN INTERCOOLER (SEE SECT. 3.5.2)
	SEA STRAINERS	CLEAN SEA STRAINER
	INDUSTRIAL FILTER	CLEAN FILTER

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 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 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	LIMITS
Blower			
Backlash (timing gears)	.0005"	.0025"	.0040"
Oil seal (below end plate surface)	.0020"	.0080"	
Oil strainer (below end plate surface)	.0000"	.0150"	
Dowel pin (projection beyond inside face of front end plate)	.3200"		
Dowel pin (projection beyond inside face of rear end plate)	.3200"		
Clearances:			
Rotor to end plate (gear end)	.0070"		
Rotor to end plate (front end – 6V–92)	.0120"		
Rotor to end plate (front end – 8V–92 and 16V–92)	.0140"		
Rotor to housing (inlet side)	.0150"		
Rotor to housing (outlet side)	.0040"		
Trailing edge of R.H. helix rotor to leading edge of L.H. helix rotor	.0040"	.0080"	.0080"
Leading edge of R.H. helix rotor to leading edge of L.H. helix rotor	.0100"		
T18A40 and T18A90 Turbochargers (Airesearch)			
End play — rotating shaft	.0040"	.0090"	
Radial movement — rotating shaft	.0030"	.0070"	
Turbine wheel shaft journal bearing:			
Inside diameter		.6272"	
Outside diameter	.9780"		
Journal diameter — turbine wheel shaft	.6247"		
Bearing bore — (center housing) inside diameter	—	.9835"	
Back plate seal bore inside diameter	—	.6885"	
Thrust collar:			
Thickness	.2990"		
Bore – inside diameter (18A40)		.3758"	
Bore – inside diameter (18A90)		.4390"	

ENGINE PARTS (Standard Size, New)	MINIMUM	MAXIMUM	LIMITS
Thrust spacer:			
Outside diameter (18A40)	.6715"		
Outside diameter (18A90)	.8600"		
Ring groove width		.0695"	
Thrust washer, inboard thickness	.0900"		
Compressor wheel bore:			
Inside diameter (18A40)		.3739"	
Inside diameter (18A90)		.4378"	
TV81 Turbocharger (Airesearch)			
End play — rotating shaft	.0030"	.0100"	
Radial movement — rotating shaft	.0030"	.0070"	
Turbine wheel shaft journal bearing:			
Inside diameter	.6268"	.6272"	
Outside diameter	.9782"	.9787"	
Journal diameter — turbine wheel shaft	.6250"	.6254"	
Bearing bore – (center housing) inside diameter	.9827"	.9832"	.9842"
Back plate seal bore inside diameter	.6875"	.6885"	.6895"
Thrust collar:			
Thickness	.2990"	.3000"	.2970"
Bore – inside diameter	.3754"	.3758"	.3778"
Thrust spacer:			
Outside diameter	.6715"	.6725"	.6705"
Ring groove width	.0685"	.0695"	.0715"
Thrust washer, inboard thickness	.0900"	.0920"	
Compressor wheel bore inside diameter	.3736"	.3739"	.3749"

STANDARD BOLT AND NUT TORQUE SPECIFICATIONS

THREAD SIZE	260M BOLTS TORQUE (lb-ft)	260M BOLTS TORQUE N•m	THREAD SIZE	280M OR BETTER TORQUE (lb-ft)	280M OR BETTER TORQUE N•m
1/4–20	5–7	7–9	1/4–20	7–9	10–12
1/4–28	6–8	8–11	1/4–28	8–10	11–14
5/16–18	10–13	14–18	5/16–18	13–17	18–23
5/16–24	11–14	15–19	5/16–24	15–19	20–26
3/8–16	23–26	31–35	3/8–16	30–35	41–47
3/8–24	26–29	35–40	3/8–24	35–39	47–53
7/16–14	35–38	47–51	7/16–14	46–50	62–68
7/16–20	43–46	58–62	7/16–20	57–61	77–83
1/2–13	53–56	72–76	1/2–13	71–75	96–102
1/2–20	62–70	84–95	1/2–20	83–93	113–126
9/16–12	68–75	92–102	9/16–12	90–100	122–136
9/16–18	80–88	109–119	9/16–18	107–117	146–159
5/8–11	103–110	140–149	5/8–11	137–147	186–200
5/8–18	126–134	171–181	5/8–18	168–178	228–242
3/4–10	180–188	244–254	3/4–10	240–250	325–339
3/4–16	218–225	295–305	3/4–16	290–300	393–407
7/8–9	308–315	417–427	7/8–9	410–420	556–569
7/8–14	356–364	483–494	7/8–14	475–485	644–657
1–8	435–443	590–600	1–8	580–590	786–800
1–14	514–521	697–705	1–14	685–695	928–942

Grade identification markings are normally stamped on the heads of the bolts. To aid identification of the various bolts used in Detroit Diesel engines, refer to the following chart.

Grade Identification Marking on Bolt Head	GM Number	SAE Grade Designation	Nominal Size Diameter (inch)	Tensile Strength Min. (psi)
None	GM 255-M	1	No. 6 thru 1 1/2	60,000
None	GM 260-M	2	No. 6 thru 3/4 over 3/4 to 1 1/2	74,000 60,000
Bolts and Screws	GM 280-M	5	No. 6 thru 1 over 1 to 1 1/2	120,000 105,000
Hex Head Sems Only	GM 275-M	5.1	No. 6 thru 3/8	120,000
Bolts and Screws	GM 290-M	7	1/4 thru 1 1/2	133,000
Bolts and Screws	GM 300-M	8	1/4 thru 1 1/2	150,000
Bolts and Screws	GM 455-M	None	No. 6 thru 1 1/2	55,000

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BOLT IDENTIFICATION CHART

EXCEPTIONS TO STANDARD BOLT AND NUT TORQUE SPECIFICATIONS

APPLICATION	THREAD SIZE	TORQUE lb–ft	TORQUE N•m
Air inlet housing adaptor–to–blower housing bolt	3/8–16	16–20	22–27
Air inlet housing–to–adaptor bolt	3/8–16	16–20	22–27
Blower side angle bolt	3/8–16	30–35	41–47
Blower end plate–to–cylinder block bot	7/16–14	40–45	54–61
Blower rotor gear retainer bolt (large bearing blower)	1/2–20	100–110	136–150
Fuel pump drive disc bolt	1/2–20	55–65	75–88

TURBOCHARGER

APPLICATION	THREAD SIZE	TORQUE lb–in	TORQUE N•m
"V" band coupling locknut (comp.)	1/4–28	110–130	12–15
"V" band coupling locknut (turb. TV71–TV81)	1/4–28	152–168	17–19
Backplate to center housing bolts	5/16–18	90–110	10–12
Turbine housing to center housing bolts	5/16–18	100–130	11–15
Turbine housing to center housing bolts (TH08A)	5/16–18	160–190	18–21
Compressor wheel locknut (18A40)	3/8–24	*125–150	14–17
Compressor wheel locknut (18A90)	7/16–20	*125–150	14–17

*Refer to Section 3.5 for additional instructions.

SERVICE TOOLS

TOOL NAME	TOOL NO.
Blower	
Blower alignment tool	J 33001
Blower clearance feeler set	J 1698–02
Blower service tool set	J 6270–G
Installer, lip type oil seal/wear sleeve (part of J6270–G)	J 35787–A
Turbocharger (Airesearch)	
Dial indicator set (magnetic base)	J 7872
Turbocharger inlet shield	J 26554–A
Turbocharger Aftercooler	
Adaptor cup plug installer	J 28711
Adaptor plug remover and installer	J 25275

SECTION 4

LUBRICATION SYSTEM

CONTENTS

LUBRICATION SYSTEM

6V AND 8V ENGINES

Figure 1 schematically illustrates the flow of oil through a typical 6V or 8V–92 engine lubrication system including the various components such as the oil pump, full–flow oil filter, oil cooler, pressure regulator and bypass valve.

The oil pump is placed in the crankshaft front cover and consists of a pair of spur gears, one large and one small, which mesh together and ride in a cavity inside the crankshaft cover. The large gear is concentric with and splined to a pump drive hub on the front end of the crankshaft. The pump idler gear is much smaller and runs on a bushing and hardened steel shaft pressed into the crankshaft cover.

The oil is drawn by suction from the oil pan through the intake screen and pipe to the oil pump where it is pressurized. The oil then passes from the pump into a short gallery in the cylinder block to the oil cooler adaptor plate. At the same time, oil from the pump is directed to a spring–loaded pressure relief valve mounted on the cylinder block. This valve discharges excess oil directly to the oil sump when the pump pressure exceeds 105 psi (724 kPa).

From the oil cooler adaptor plate, the oil passes into the full–flow filter, through the oil cooler and then back into the cylinder block where a short vertical oil gallery and a short diagonal oil gallery carry the oil to the main longitudinal oil gallery through the middle of the block. Valves are also provided to bypass the oil filter and oil cooler should either one become plugged.

Stabilized lubricating oil pressure is maintained within the engine at all speeds, regardless of the oil temperature, by means of a pressure regulator valve located at the end of a vertical oil gallery connected to the main oil gallery. This vertical gallery is located at the front of the cylinder block on the side opposite the cooler (Fig. 1). When the oil pressure at the valve exceeds 50 psi (345 kPa), the regulator valve opens, discharging oil back into the sump.

From the main oil gallery, the pressurized oil flows through drilled passages to each main bearing then passes to an adjacent pair of connecting rods by means of grooves in the unloaded halves of the main and connecting rod bearings and drilled passages in the crankshaft. The rifle drilled connecting rods carry oil from the rod bearings to the piston pin bushing.

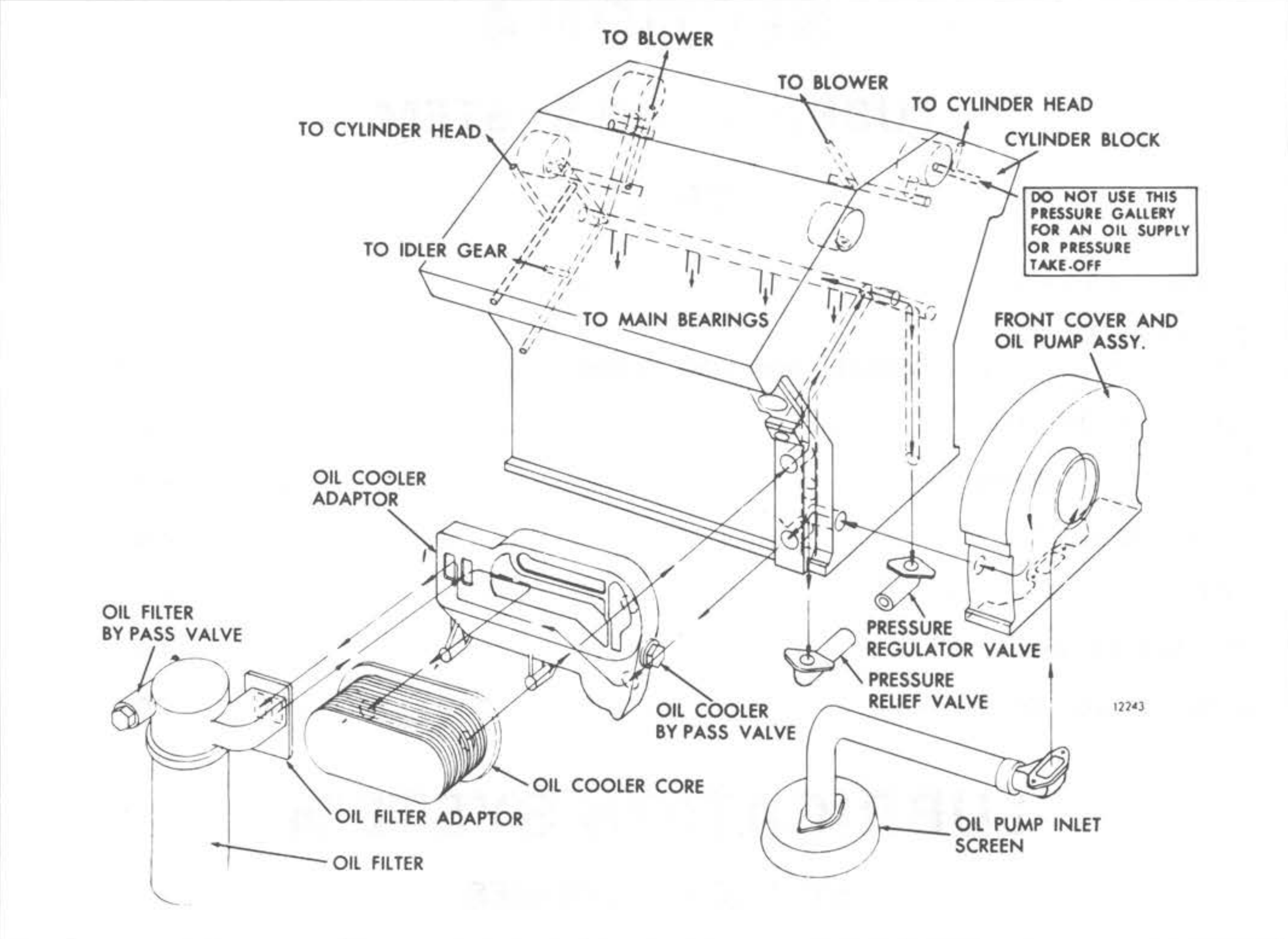


Fig. 1 – Schematic Diagram of Typical 6V and 8V Lubrication Systems

At the rear of the block, two diagonally drilled oil passages, which intersect the main oil gallery, carry oil to the two rear camshaft end bearings. Oil is then conducted through the rifle drilled camshaft to the intermediate and front end bearings. Oil from the camshaft intermediate bearings is directed against the camshaft lobes and cam rollers which run in an oil bath. This oil from the intermediate bearings provides lubrication of the cam lobes immediately after starting the engine when the oil is cold and before camshaft bearing oil flow and oil drainage from the cylinder head have had time to build up.

The diagonally drilled oil passage on the right side at the rear of the block intersects with a vertical passage to carry oil to the right bank cylinder head. A short gallery also intersects with this diagonal passage to lubricate the idler gear bearing. Another gallery intersecting the diagonal passage from the camshaft at the front of the block supplies oil to the left bank cylinder head.

NOTICE: Do not use the oil gallery on the upper front left bank of the cylinder block (Fig. 1) for an oil supply or pressure take–off. This gallery intersects the cylinder head oil supply gallery. If used, it will reduce oil pressure to the rocker arm assemblies.

Drilled passages, intersecting longitudinal galleries which parallel the camshafts, lead to the blower and supply oil for the blower drive gears and bearings.

Oil from the right–bank camshaft front end bearing lubricates the water pump drive gear and bearings and the front camshaft gear.

The gear train is lubricated by the overflow of oil from the camshaft pocket spilling into the gear train compartment and by splash from the oil pan. A certain amount of oil also spills into the gear train compartment from both camshaft rear end bearings, the blower drive gear bearing and the idler gear bearing. The blower drive gear bearing is lubricated through an external pipe from the blower rear end plate to the blower drive support.

The valve and injector operating mechanism is lubricated from a longitudinal oil passage, on the camshaft side of each cylinder head, which connects to the main oil gallery in the cylinder block. Oil from this passage enters the drilled rocker arm shafts through the lower end of the rocker shaft bolts and rocker shaft brackets. Excess oil from the rocker arms lubricates the exhaust valves and cam followers.

Lubrication System Maintenance

Use the proper viscosity grade and type of *heavy duty* oil as outlined in Section 13.3. Change the oil and replace the oil filter elements at the periods recommended by the oil supplier (based on his analysis of the drained engine oil) to ensure trouble–free lubrication and longer engine life. For fuel leak detection refer to Section 2.0.

The oil level should never be allowed to drop below the *low* mark on the dipstick. Overfilling the crankcase may contribute to abnormal oil consumption, high oil temperature, and also result in oil leaking past the crankshaft rear oil seal.

To obtain the true oil level, the engine should be stopped and sufficient time (approximately twenty minutes) allowed for the oil to drain back from the various parts of the engine. If more oil is required, add only enough to bring the level to the *full* mark on the dipstick.

Cleaning Lubrication System

Thorough flushing of the lubrication system is required at times. Should the engine lubrication system become contaminated by an ethylene glycol base antifreeze solution or other soluble material, refer to Section 5 for the recommended cleaning procedures.

Detection Of Lube Oil Leaks

Detroit Diesel uses red dye to detect lube oil system leaks during engine test. Customers receiving new engines may notice some residual dye remaining in their lube oil systems. This dye should be quickly dispersed after the first few hours of engine operation.

12 AND 16V ENGINES

Figure 2 schematically illustrates the flow of oil through a typical 16V–92 engine lubrication system.

> **NOTICE:** Do not use the oil gallery on the upper bank at the front of each cylinder block (Fig. 2) for an oil supply or pressure take–off. This oil gallery intersects the cylinder head oil supply gallery. If used, it will reduce pressure to the rocker arm assemblies.

The lubricating oil is circulated by a gear–type pressure pump mounted on the number seven and eight bearing caps (12V engine) or number nine and ten main bearing caps (16V engine) and gear–driven from the rear end of the crankshaft. On some engines, the oil pump is mounted at the front on the number one and two main bearing caps and gear–driven by an oil pump drive gear bolted to the front crankshaft gear.

An oil pressure relief valve mounted on the junction block bypasses excess oil directly into the oil sump when the pressure on the outlet side of the pump exceeds approximately 120 psi (827 kPa).

Since bypass valves are provided in the oil coolers and the oil filters, the oil will bypass the coolers or filters if they become plugged.

Stabilized lubricating oil pressure is maintained within the engine at all speeds, regardless of the oil temperature, by two pressure regulator valves located at the end of the vertical oil galleries (Fig. 2). When the oil pressure at the regulator valves exceeds 50 psi (345 kPa), the valves open, discharging excess oil back into the oil sump.

Detection Of Lube Oil Leaks

Detroit Diesel uses red dye to detect lube oil system leaks during engine test. Customers receiving new engines may notice some residual dye remaining in their lube oil systems. This dye should be quickly dispersed after the first few hours of engine operation.

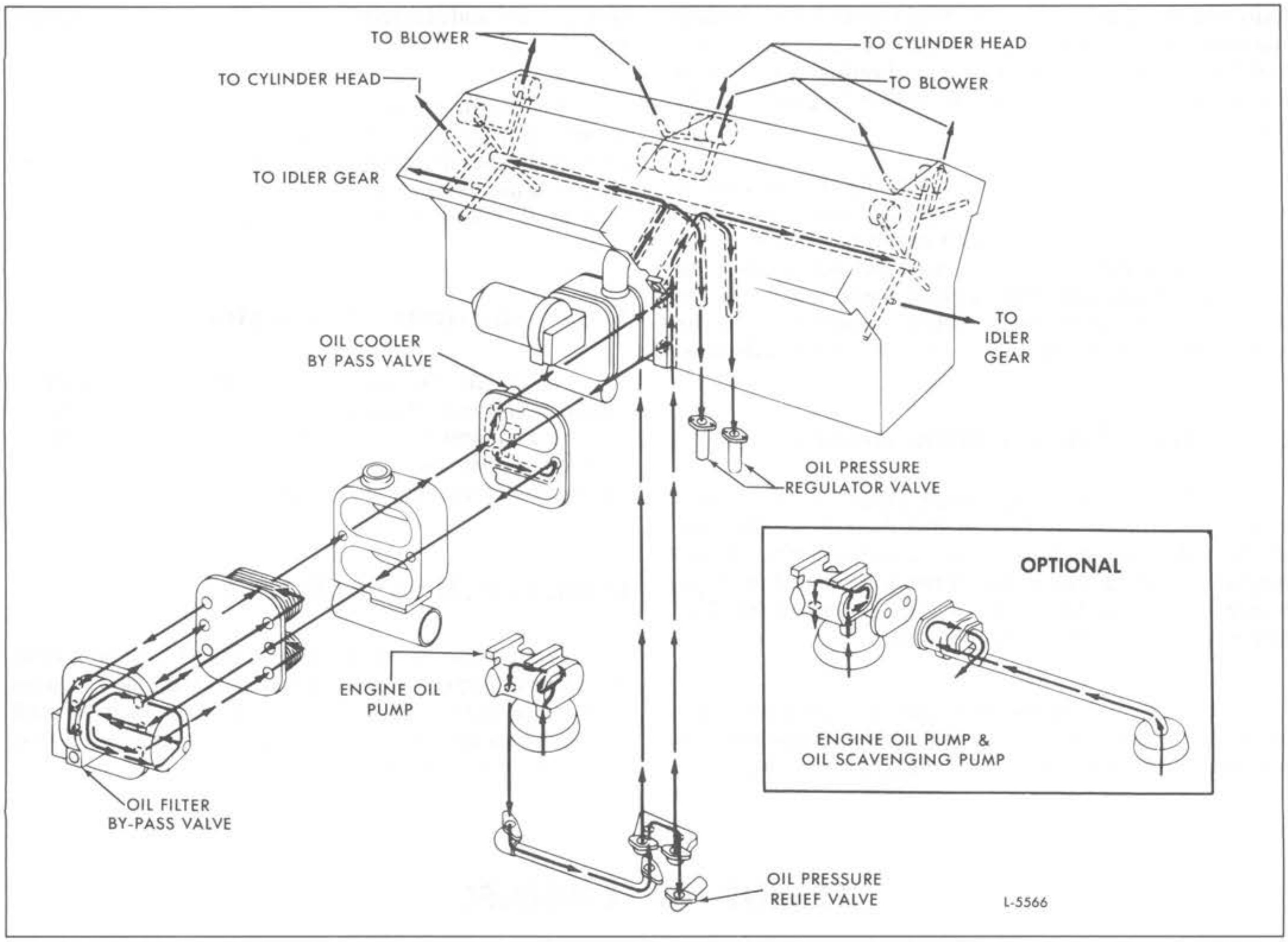


Fig. 2 – Schematic Diagram of Typical 16V Lubrication System

LUBRICATING OIL PUMP (6V-92 and 8V-92 Engines)

PUMP MOUNTED IN FRONT COVER

The gear type lubricating oil pump is mounted in the crankshaft front cover, which also functions as the oil pump body (Fig. 1). The pump consists of two spur gears which mesh and rotate in a cavity inside the crankshaft cover. The pump drive gear is concentric with and splined to a pump drive hub on the front end of the crankshaft. The pump driven gear and bushing assembly rotates on a hardened steel shaft. One end of the driven gear shaft is pressed into the crankshaft front cover and the other end is supported in the oil pump gear retaining plate.

To standardize and provide more oil pressure at lower engine speeds, the 8V-92 oil pump is now used on 6V-92 engines (effective with 6VF-51331). The 6V-92 and 8V-92 oil pumps are interchangeable and only the 8V-92 pump will be serviced. However, the component parts of the 6V-92 oil pump will continue to be serviced.

Operation

As the gears revolve, a vacuum is created on the inlet side of the pump and oil is drawn from the oil pan through the intake screen and pipe assembly into a passage, in the crankshaft front cover, which leads to the inlet port in the pump. The oil then enters the cavities between the gears and the crankshaft front cover, and is then forced out under pressure through the discharge port into a short gallery in the cylinder block which leads to the oil filter, block main oil gallery. At the same time, the oil is directed through a short vertical gallery to the pressure relief valve which opens at approximately 105 psi (724 kPa) to return excess oil to the oil pan.

Remove Oil Pump

1. Drain the oil and remove the oil pan.
2. Remove the oil pan gasket and clean all traces of the gasket from both the oil pan and the cylinder block.
3. Remove the bolts and lock washers which secure the oil inlet pipe and screen support to the crankshaft front cover and to the main bearing cap. Then, remove the oil inlet pipe and screen support as an assembly.
4. Remove the crankshaft front cover from the engine as outlined in Section 1.3.5.
5. Remove the oil pump drive hub and key from the crankshaft.

Disassemble Oil Pump

1. Remove the self-locking bolts that secure the oil pump gear retaining plate to the crankshaft front cover. Then, remove the retaining plate.
2. Remove the oil pump drive and driven gears from the crankshaft front cover.

Inspection

Clean all of the parts with fuel oil and dry them with compressed air.

CAUTION: To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.

Examine the oil pump gear cavity in the crankshaft front cover. Replace the cover if the surfaces are worn or scored excessively. If necessary, replace the crankshaft front oil seal, as outlined in Section 1.3.2.

Replace the driven gear shaft if it is worn or scored excessively. When a new shaft is pressed in place, the shoulder on the shaft must be flush to .020" below the finished face of the crankshaft front cover.

The clearance between the driven gear bushing and the shaft is .001" to .0025" when new parts are used, or a maximum of .0035" with used parts.

Inspect the teeth on the oil pump gears and the pump drive hub. Also, examine the bushing in the driven gear for wear. The bushing is not serviced separately. Therefore, if the bushing is worn, it will be necessary to replace both the drive and driven gears as they are only serviced as a set. The use of excessively worn gears will result in low oil pressure which may cause serious damage throughout the engine.

Inspect the inner face of the oil pump gear retaining plate. Replace the retaining plate if it is scored or worn.

Remove the screen and cover from the oil inlet pipe assembly. Then, clean the parts with fuel oil and dry them with compressed air. Reassemble the screen, cover and oil intake pipe.

Whenever the oil pump is removed for service, remove and inspect the oil pressure regulator and oil pressure relief valves as outlined in Section 4.1.1.

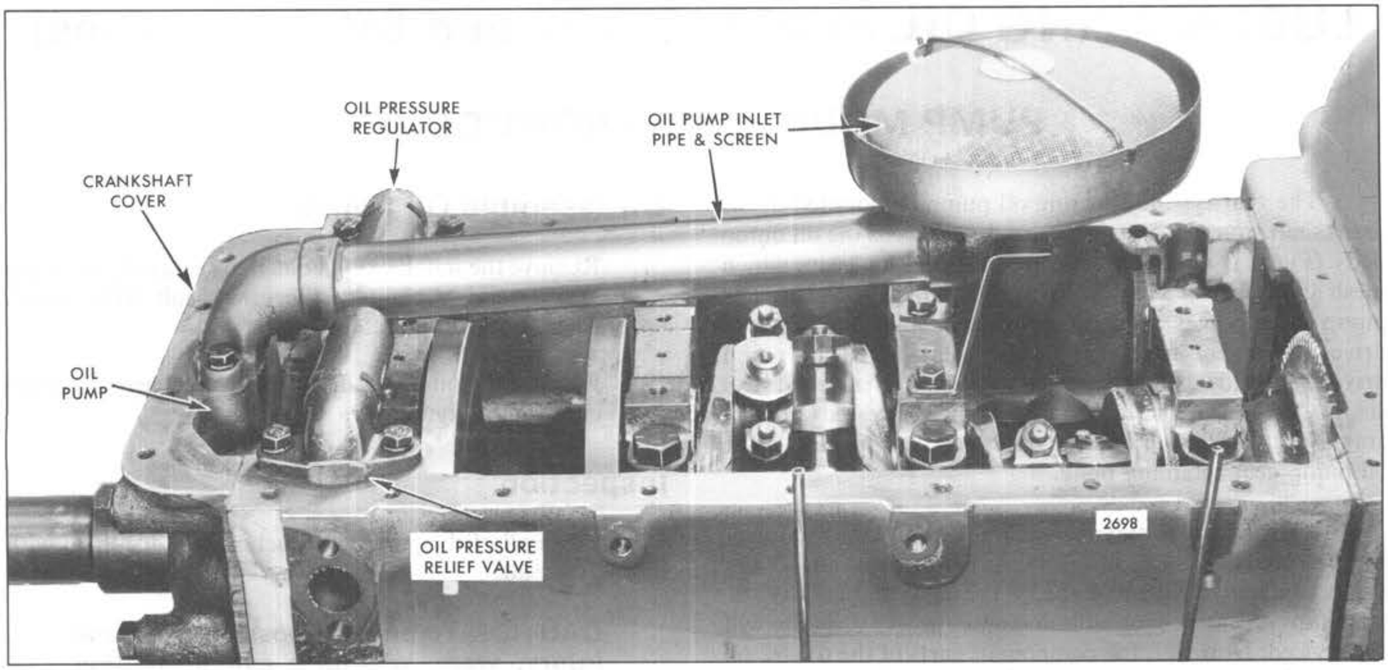


Fig. 1 – Typical Lubricating Oil Pump Mounting (6V–92 or 8V–92 Engine)

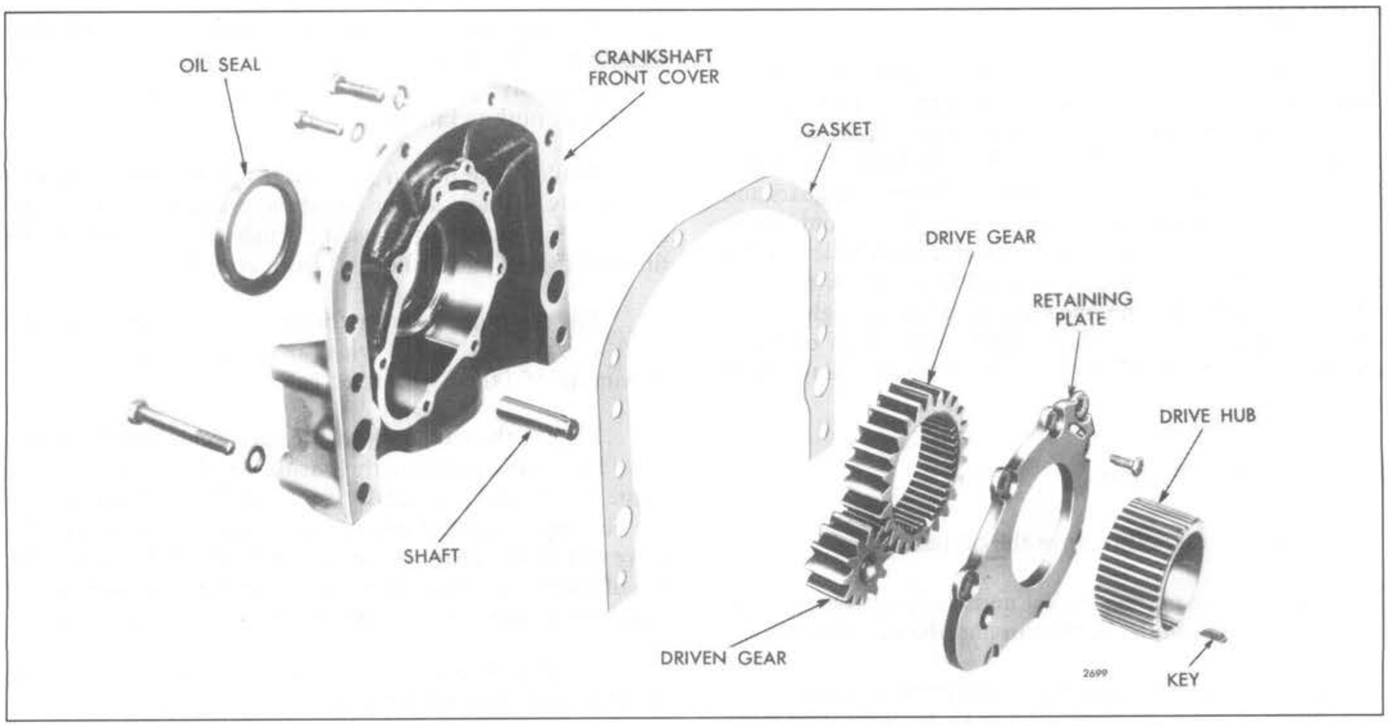


Fig. 2 – Lubricating Oil Pump Details and Relative Locations of Parts (6V–92 or 8V–92 Engine)

Assemble Oil Pump

Refer to Fig. 2 and assemble the oil pump as follows:

1. Lubricate the oil pump gears and the driven gear shaft with engine oil. Then, install the gears in the crankshaft front cover.
2. Install the gear retaining plate and secure it to the crankshaft front cover with eight 5/16"–18 x 3/4" self–locking bolts. Tighten the bolts to 13–17 lb–ft (18–23 N•m) torque.

   NOTICE: Self–locking bolts must be used due to the close clearance between the oil pump and the crankshaft.

3. Install the key in the crankshaft and slide the oil pump drive hub in place.

Install Oil Pump

1. Install the crankshaft front cover on the engine as outlined in Section 1.3.5.
2. Refer to Fig. 1 and install the oil inlet pipe and screen assembly. Use a new gasket between the oil inlet pipe and the crankshaft front cover.
3. Install the oil pan, using the new gasket. Starting with the center bolt on each side and working toward each end of the oil pan, tighten the 3/8"–16 bolts to 10–20 lb–ft (14–27 N•m) torque.
4. Fill the oil pan, to the proper level on the dipstick, with the lubricating oil recommended in the *Lubrication Specifications* in Section 13.3.

PUMP MOUNTED ON MAIN BEARING CAPS

The gear–type scavenging oil pump used on the 6V–92 and 8V–92 engines is mounted on the No. 1 and 2 main bearing caps and is driven by an oil pump drive gear mounted on the crankshaft (Fig. 3).

An opening is provided on the oil pump body for mounting an oil pump inlet pipe and screen assembly. A scavenging oil pump inlet pipe and screen is mounted on the oil pump scavenging body and is supported with brackets to a main bearing cap.

Oil is drawn by suction from the oil pan through the oil pump inlet screen and pipe into the oil pump where it is pressurized.

Remove Oil Pump

1. Remove the drain plug from the oil pan and drain the oil.

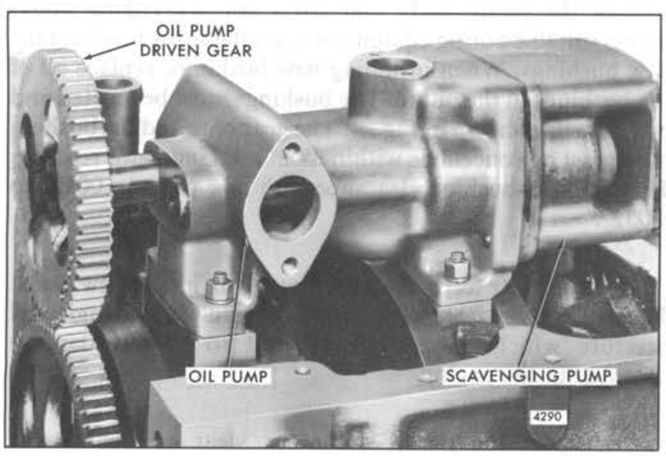


Fig. 3 – Oil Pump Mounting (6V–92 and 8V–92 Engine)

2. Remove the oil pan bolts and remove the oil pan. Clean all traces of the gasket from both the oil pan and the cylinder block.
3. Remove the two mounting bolts and lock washers and remove the oil pressure regulator valve from the cylinder block.
4. Remove the four bolts and lock washers which attach the oil pressure relief valve to the oil pump body and cylinder block.
5. Remove the two self–locking bolts and lift the screen off the inlet pipe. Remove the two bolts and remove the oil pump inlet pipe.
6. Remove the bolts and lock washers which attach the support brackets to the oil pump scavenging inlet pipe and to the main bearing cap.
7. Remove the two bolts and lock washers which attach the oil pump scavenging inlet pipe and baffle plate to the scavenging pump body. Remove the scavenging inlet pipe and baffle plate.
8. Remove the nuts and lock washers which attach the oil pump to the main bearing caps. Then, remove the oil pump assembly.

   NOTICE: Shims are used between the oil pump mounting feet and the main bearing caps. Whenever the original pump is reinstalled, the same shims or an equal number of new (identical) shims must be placed under both the front and rear mounting feet and the number then adjusted to obtain the proper clearance between the gears.

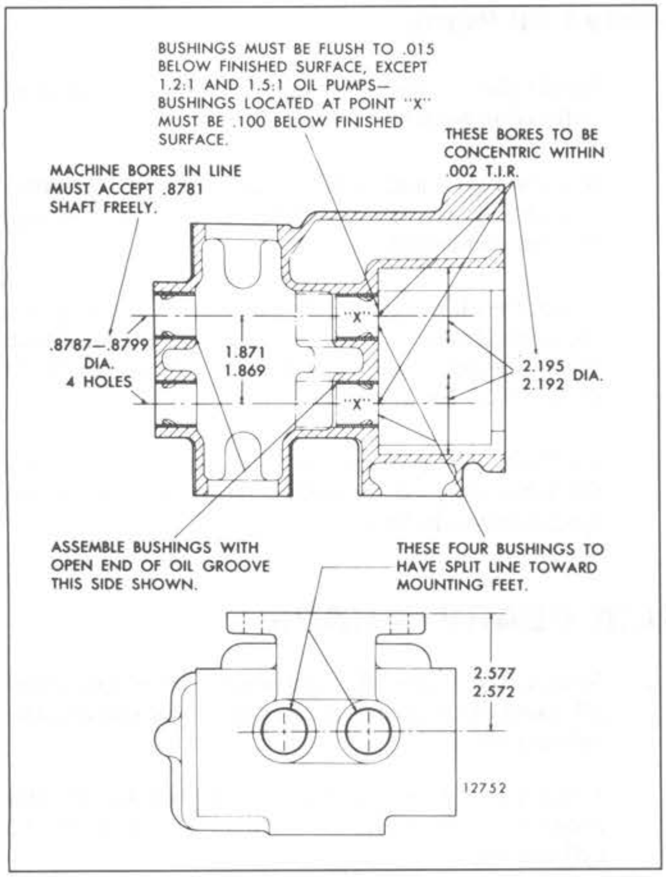


Fig. 4 – Diameter and Location of Bushing in Oil Pump (6V–92 and 8V–92 Engine)

Disassemble Oil Pump

Observe carefully the position of all parts including the oil pump inlet pipe and the scavenging oil pump inlet pipe during disassembly to facilitate reassembly of the oil pump.

1. Remove the four self–locking bolts which attach the scavenging pump body to the oil pump body. Then, remove the scavenging pump body.

2. Remove the scavenging pump drive and driven gears from the oil pump drive and driven shafts.

3. Remove the Woodruff key from the drive shaft and slide the spacer off the end of the shafts.

4. Withdraw the driven shaft and driven gear as an assembly from the oil pump body.

5. Remove the bolt and special washer securing the oil pump driven gear to the drive shaft and remove the gear.

6. Withdraw the drive shaft and gear as an assembly from the oil pump body.

7. Press the oil pump drive shaft out of the oil pump gear. Remove the Woodruff key from the shaft.

8. Press the driven shaft out of the driven gear in the same manner as in Step 7 above. Remove the Woodruff key from the shaft.

9. Remove the cover and gasket from the oil pump body.

Inspection

Wash all of the parts in clean fuel oil and dry them with compressed air.

CAUTION:To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.

The greatest amount of wear in the oil pump is imposed on the internal drive and driven gears. This wear may be kept to a minimum by keeping the lubricating oil clean and acid–free. If dirt and sludge are allowed to accumulate in the lubricating system, pronounced gear wear may occur in a comparatively short period of time. Proper servicing of oil filters will increase the life of the gears.

Examine the internal gear cavity of the pump body and scavenger pump, if used, for wear or scoring. Also, inspect the pump cover, or spacer between the pump and the scavenger pump bodies, for wear. Replace the parts, if necessary.

Inspect the bushings in the pump body and cover (or scavenging body). If the bushings are worn excessively, replace the pump body and cover (or scavenging body) unless suitable boring equipment is available for finishing the new bushings. When installing new bushings, replace all of the bushings in the pump. The bushings must be located and positioned as shown in Fig. 4. The gear bore and the bushing bore must be concentric within .002" total indicator reading. The shaft–to–bushing clearance with new parts is .0015" to .0032".

If the gear teeth are scored or worn, install new gears. The use of excessively worn gears will result in low engine oil pressure which, in turn, may lead to serious damage throughout the engine.

Inspect the pump shafts for wear and check the keyways. Replace the shafts, if necessary.

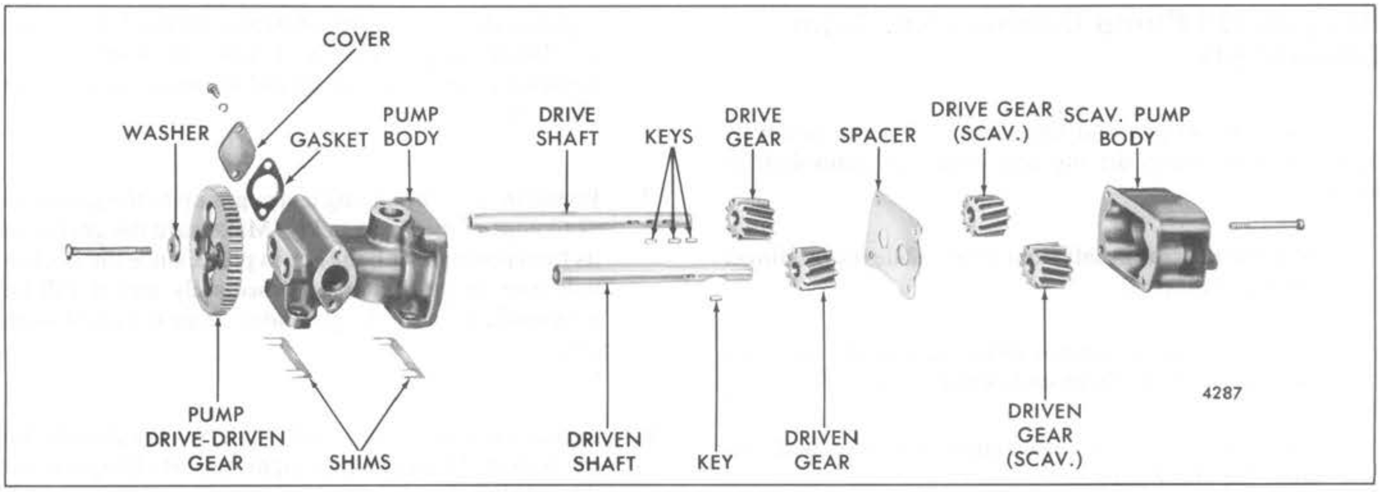


Fig. 5 – Lubricating Oil Pump Details and Relative Location of Parts (6V–92 and 8V–92 Engine)

Remove the oil inlet screen from the oil inlet pipe and clean both the screen and pipe with fuel oil and dry them with compressed air.

Inspect the external pump drive–driven gear for wear and replace it, if necessary.

Inspection of the pressure relief valve and oil pressure regulator are covered in Section 4.1.1.

Assemble Oil Pump

Refer to Fig. 5 and assemble the oil pump as follows:

1. Insert the Woodruff key in the keyway of the oil pump drive shaft and apply a light coat of engine oil on the shaft.
2. Press the drive shaft into the oil pump drive gear. Position the gear 7.570" from the end of the drive shaft (Fig. 6). Use tool J 22397.

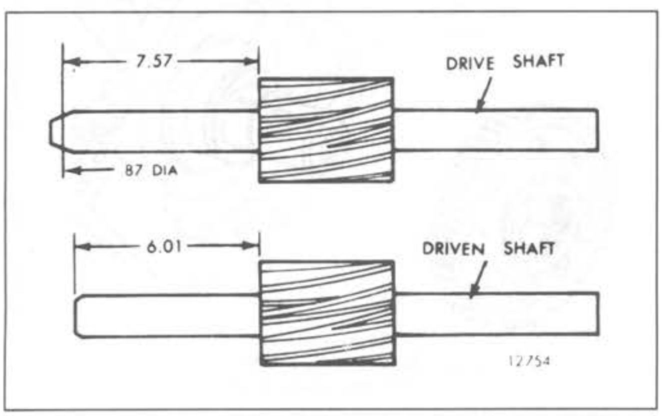


Fig. 6 – Location of Oil Pump Gear on Shaft

3. Insert the Woodruff key in the keyway of the driven shaft. Apply a light coat of engine oil on the shaft. Press the shaft in the driven gear. Position the gear 6.010" from the end of the shaft (Fgi. 6). Use tool J 22398.
4. Install the drive shaft and gear as an assembly in the oil pump body.
5. Install the oil pump driven gear on the drive shaft. Place the special washer on the bolt with the crown side toward the head of the bolt and tighten the bolt to 60–65 lb–ft (81–85 N•m) torque.
6. Install the driven shaft and gear as an assembly in the pump body.
7. Slide the spacer on the shafts. Insert the two remaining Woodruff keys in the drive shaft. Slide the scavenging pump gears on the shafts.

NOTICE: The scavenging pump drive and driven gears must be in the same relative position as the oil pump drive and driven gears.

8. Secure the scavenging pump body to the oil pump body with four self–locking bolts.
9. Place a new gasket on the oil pump body side cover and fasten it to the pump body with two bolts and lock washers.

NOTICE: The oil pump gears must turn freely after assembly. Any bind in the pump must be eliminated before it is installed on the engine.

Remove Oil Pump Driving Gear from Crankshaft

With the oil pan and lubricating oil pump removed, remove the oil pump driving gear from the crankshaft as follows:

1. Remove the crankshaft front cover. Slide the oil slinger off the crankshaft.
2. If required, use a suitable puller to pull the oil pump drive gear off the front end of the crankshaft.
3. After the gear is removed, remove the Woodruff key from the crankshaft.
4. Slide the oil pump drive gear spacer off the end of the crankshaft.

Install Oil Pump Driving Gear on Crankshaft

Whenever a 6V–92 or 8V–92 engine crankshaft-mounted oil pump drive gear requires replacement, Loctite RC/620 retaining compound (or equivalent) *must* be used to ensure proper gear retention. Use the following procedure:

1. Measure the crankshaft diameter and gear bore. Both parts must be within the specifications shown. Replace, if necessary.

   C/S dia. – 2.498/2.500 inch

   Gear Bore – 2.5005/2.5010 inch

2. Clean the crankshaft, spacer, gear and key with a chlorinated solvent such as that used with a dye penetrant kit. Make sure the parts are dry before proceeding.
3. Install the spacer and key, but do not apply primer or retaining compound to either part.
4. Apply Loctite Primer "T" to the crankshaft and the gear bore. Allow to dry a minimum of 5 minutes before beginning Step 5. Follow the manufacturer's instructions on the container.
5. Shake well before using and apply a small amount of Loctite RC/620 to the gear bore (Fig. 7). Spread the compound to make sure the entire bore is covered. Remove excess compound from the chamfer area of the gear, but do not wipe dry.
6. Apply a *thin bead* of RC/620 around the O.D. of the crankshaft approximately 1–1/4" in front of the installed spacer. Do not spread the bead or wipe dry (Fig. 7).
7. Install the gear by sliding it straight up to the spacer so as to engage the key quickly. Make sure the gear is in its final position with the key in place, since the Loctite will start to grab almost immediately and it will be impossible to move the gear later. Wipe the crankshaft clean.
8. If necessary, use Tool J 22285 to press the gear on the crankshaft. Drive the gear tight against the spacer on the crankshaft.
9. Install the oil slinger with the dished side away from the gear.
10. Install the engine front cover as outlined in Section 1.3.5.
11. Allow the Loctite to cure for four hours minimum before starting the engine.

NOTICE: Chemicals such as Loctite RC/620 have a shelf life of one year which should not be exceeded. Check with a Loctite supplier for product use beyond its recommended life.

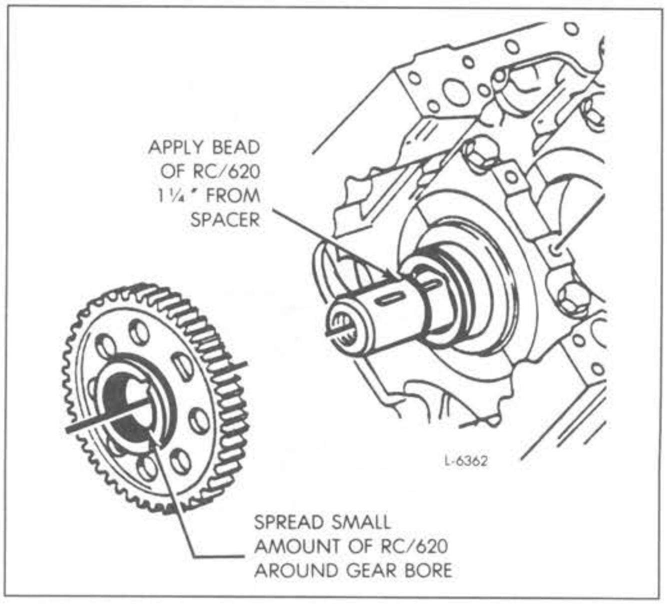


Fig. 7 – Location of Loctite RC/620

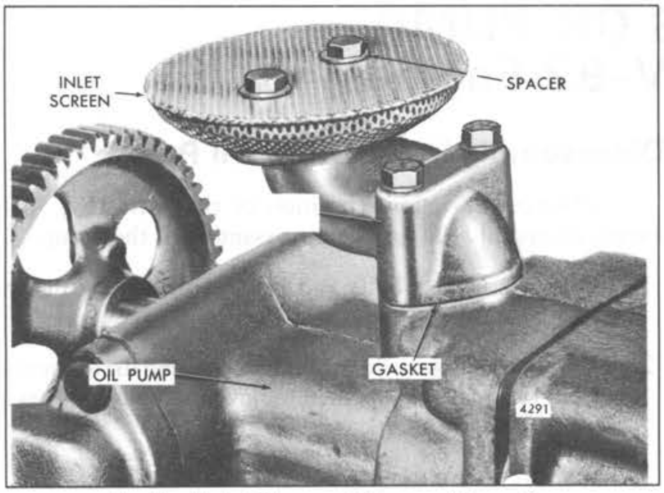


Fig. 8 – Inlet Pipe and Screen Mounting

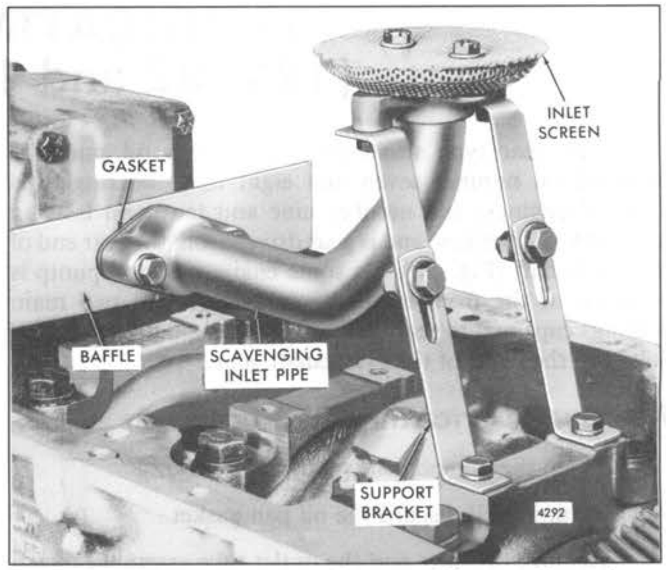


Fig. 9 – Scavenging Inlet Pipe and Screen Mounting

Install Oil Pump

1. Position the oil pump over the studs on the No. 1 and 2 main bearing caps so that the gear teeth mesh with the crankshaft oil pump drive gear teeth.

2. Fasten the oil pump to the main bearing caps with four nuts and lock washers.

   NOTICE: Place the same number of shims between the oil pump feet and the main bearing caps as were removed. Removing or installing shims controls the gear tooth adjustment. The addition or removal of one set of .005" shims will change the gear tooth clearance by .0035".

3. With the engine in the running position, check the tooth clearance between the oil pump gear and the crankshaft gear. Use a feeler gage or a suitable indicator. The clearance should be .006" to .012".

4. Use two new gaskets and position the oil pressure relief valve on the cylinder block and against the oil pump body. Secure the oil pressure relief valve with four bolts and lock washers.

5. Use a new gasket and position the oil pump inlet pipe on the oil pump body. Secure the inlet pipe with two bolts and lock washers. Place the screen on the inlet pipe and fasten it with two self–locking bolts and two spacers (Fig. 8).

6. Place a new gasket between the scavenging pump body and baffle plate and between the baffle plate and the scavenging oil pump inlet pipe. Secure the pipe and baffle with two bolts and lock washers to the scavenging pump body (Fig. 9).

7. Attach the two support brackets to the scavenging inlet pipe. Secure the brackets to the main bearing cap with bolts and lock washers.

8. Place the screen on the scavenging inlet pipe and fasten it with two self–locking bolts and two plain washers.

9. Recheck all of the bolts for tightness to ensure there will be no leaks in the oil pump and pipe connections.

10. Use a new gasket and secure the oil pump pressure regulator valve to the cylinder block with two bolts and lock washers.

11. Place a new gasket on the oil pan and install the pan on the cylinder block. Start all of the oil pan bolts before tightening them. Tighten the bolts snugly but not excessively, starting with the center bolts and working toward each end of the oil pan. Excessive tightening of the bolts will crush the oil pan gasket unnecessarily.

12. Fill the oil pan to the proper level with the oil recommended in the *Lubrication Specifications* in Section 13.3.

LUBRICATING OIL PUMP (12V–92 and 16V–92 Engines)

The gear–type scavenging lubricating oil pump is mounted on number seven and eight main bearing caps (12V–92 engines) and number nine and ten main bearing caps (16V–92 engines) and is gear driven from the rear end of the crankshaft (Fig. 10). On some engines, the oil pump is mounted at the front on the number one and two main bearings caps and is gear–driven by an oil pump drive gear bolted to the front of the crankshaft gear.

Remove Lubricating Oil Pump

1. Drain the oil and remove the oil pan(s).
2. Remove and discard the oil pan gasket.
3. Remove the inlet and the outlet tube assemblies from the oil pump and the scavenging pump (Fig. 10).
4. Remove the nuts and lock washers which attach the oil pump to the main bearing caps, then remove the oil pump.

   NOTICE: On some engines, shims are used between the oil pump mounting feet and the main bearing caps. Whenever the original pump is reinstalled, the same shims or an equal number of new (identical) shims must be placed under both the front and rear mounting feet and the number then adjusted to obtain the proper clearance between the pump drive and driven gears.

Disassemble Lubricating Oil Pump

Observe the relative position of the parts (Fig. 14) during disassembly to facilitate reassembly of the pump:

1. Remove the five bolts and lift the scavenging pump body from the pump body.
2. Withdraw the scavenging pump drive and driven gears from the pump shafts, then remove the Woodruff keys from the drive shaft.
3. Remove the spacer.
4. Withdraw the driven shaft and gear as an assembly from the pump body.
5. Attach puller J 24420–A to the pump driven gear. Place a couple of washers or a nut between the end of the pump shaft and the puller screw to protect the end of the pump shaft. Then remove the gear by turning the puller screw clockwise (Fig. 11).
6. Remove the key from the shaft.
7. Withdraw the drive shaft and gear as an assembly from the pump body.
8. Press the oil pump drive shaft out of the oil pump gear (Fig. 12).
9. Remove the key from the shaft.

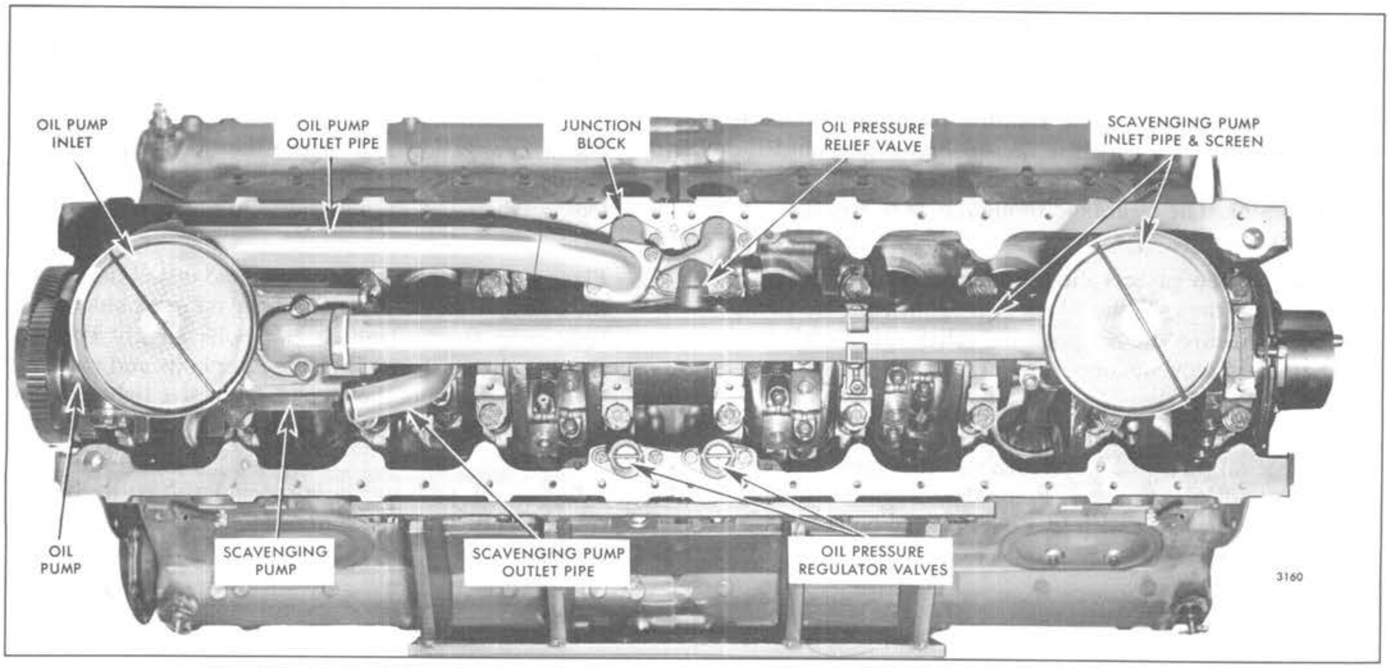


Fig. 10 – Typical Lubricating Oil Pump Rear Mounted (12V–92 and 16V–92 Engines)

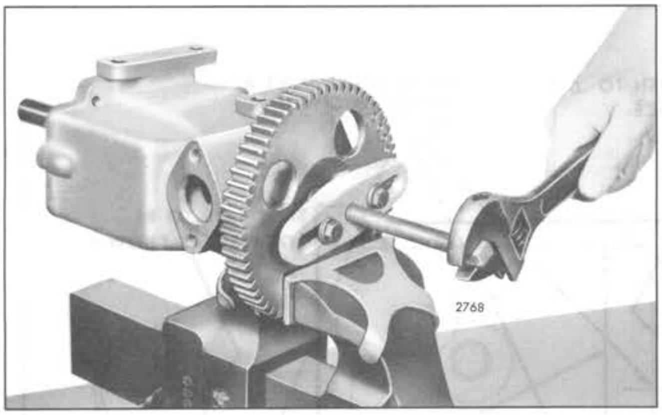


Fig. 11 – Removing Oil Pump Drive–Driven Gear

Inspection

Wash all of the parts in clean fuel oil and dry them with compressed air.

CAUTION: To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.

The greatest amount of wear in the oil pump is imposed on the internal drive and driven gears. This wear may be kept to a minimum by keeping the lubricating oil clean and acid–free. If dirt and sludge are allowed to accumulate in the lubricating system, pronounced gear wear may occur in a comparatively short period of time. Proper servicing of oil filters will increase the life of the gears.

Examine the internal gear cavity of the pump body and scavenger pump for wear or scoring. Also, inspect the spacer between the pump and the scavenger pump bodies for wear. Replace the parts, if necessary.

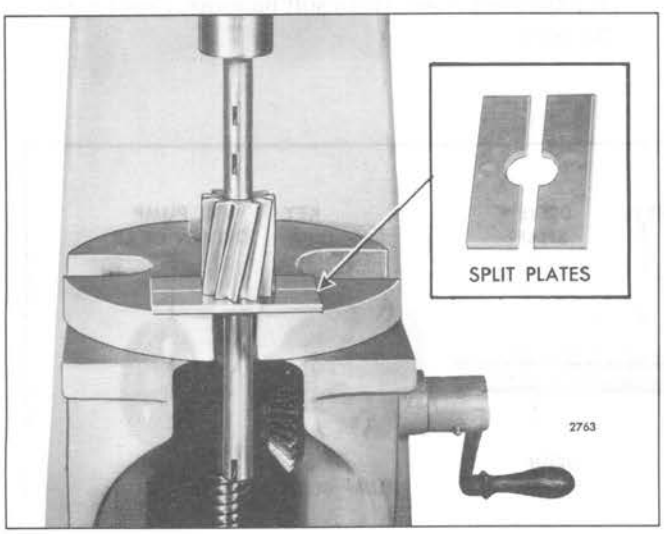


Fig. 12 – Pressing Oil Pump Gear From Shaft

Inspect the bushings in the pump body and scavenging body. If the bushings are worn excessively, replace the pump body and scavenging body unless suitable boring equipment is available for finishing the new bushings. When installing new bushings, replace all of the bushings in the pump. The bushings must be located and positioned as shown in Fig. 13. The gear bore and the bushing bore must be concentric within .002" total indicator reading. The shaft–to–bushing clearance with new parts is .0015" to .0032".

If the gear teeth are scored or worn, install new gears. The use of excessively worn gears will result in low engine oil pressure which, in turn, may lead to serious damage throughout the engine.

Inspect the pump shafts for wear and check the keyways. Replace the shafts, if necessary.

Remove the oil inlet screen from the oil inlet pipe and clean both the screen and pipe with fuel oil and dry them with compressed air.

Inspect the external pump drive–driven gear for wear and replace it, if necessary.

Inspection of the pressure relief valve and oil pressure regulator are covered in Section 4.1.1.

Assemble Lubricating Oil Pump

1. Install the oil pump gear key in the oil pump drive shaft.
2. Lubricate the drive shaft, then press the oil pump drive gear on the shaft with tool J 9380 (Fig. 15). Tool J 9380 will position the gear 5.50" from the end of the shaft as well as prevent the shaft from bending during gear installation.
3. Lubricate the driven shaft and press the oil pump driven gear on the shaft. Use tool J 9381 to position the gear 4.68" from the end of the shaft.
4. Install the drive shaft and gear assembly in the pump body in its original position.
5. Install the key in the driven gear end of the drive shaft.
6. Press the driven gear on the drive shaft until the clearance between the gear hub and the pump body is .010" (Fig. 16).
7. Install the driven shaft and gear assembly in the pump body.

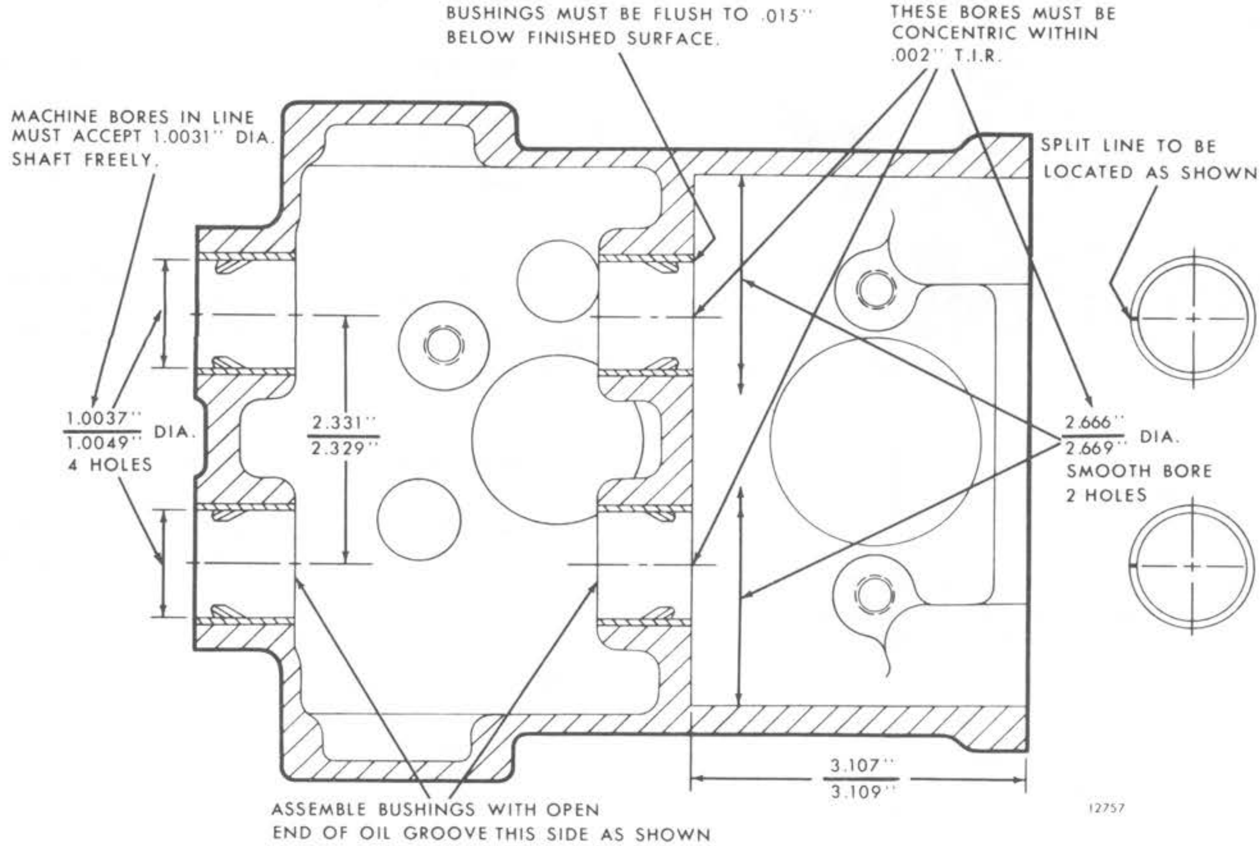


Fig. 13 – Diameter and Location of Bushing in Oil Pump (12V–92 and 16V–92 Engines)

8. Slide the spacer on the shafts. Install the keys in the drive shaft, then slide the scavenging pump gears on the shafts. The right–hand and left–hand scavenging pump gears must be in the same relative position as the oil pump gears (Fig. 14).

   Secure the scavenging pump body to the oil pump body with five bolts and lock washers.

9. Rotate the oil pump driven gear by hand to make certain the gears and the shafts rotate freely. If necessary, loosen the scavenging pump body bolts. Tap the body bolts with a soft hammer, then retighten the bolts.

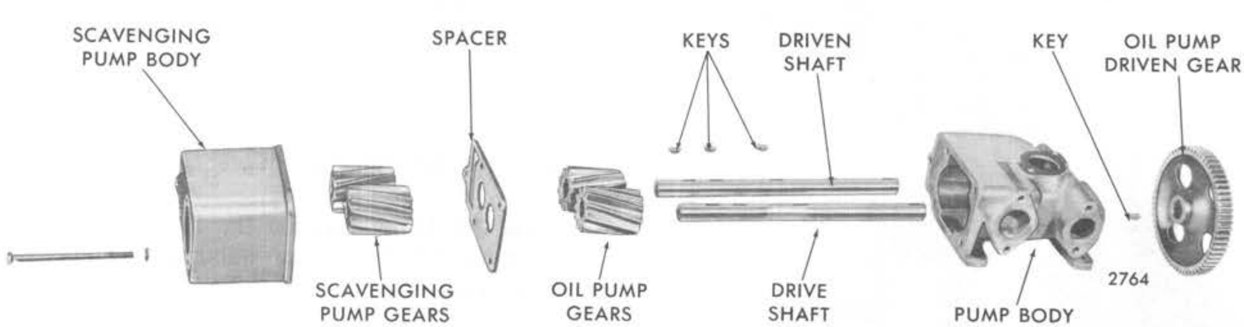


Fig. 14 – Lubricating Oil Pump Details and Relative Location of Parts (12V–92 and 16V–92 Engines)

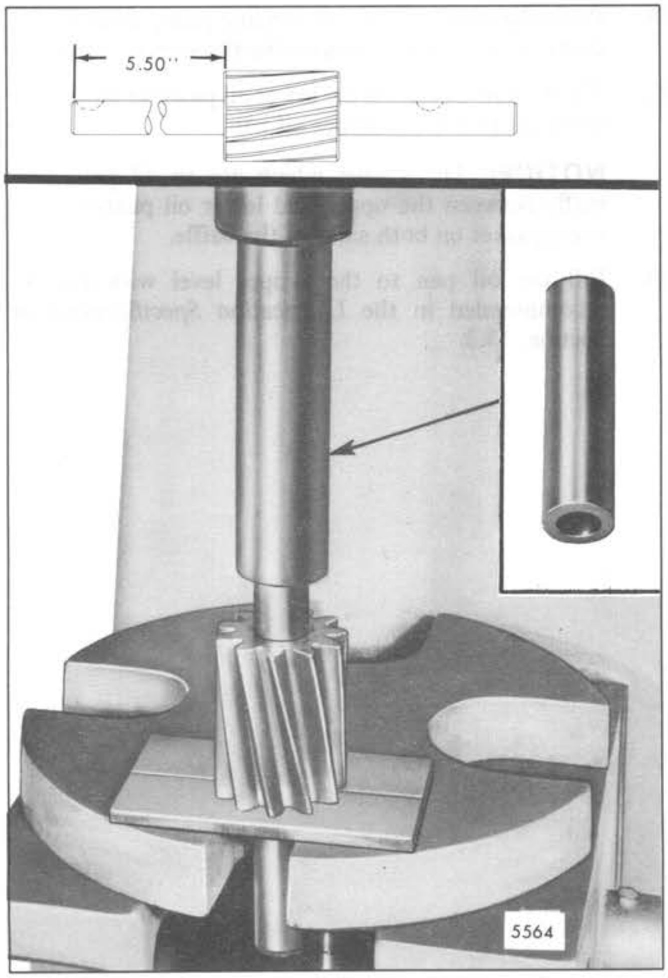


Fig. 15 – Installing Oil Pump Gear on Shaft using Tool J 9380

Remove Oil Pump Drive Gear

Since the oil pump drive gear is bolted to the rear crankshaft timing gear, oil pump drive gear removal, inspection and installation, is covered in Section 1.7.5.

Install Lubricating Oil Pump

1. Position the rear mounted oil pump on the number seven and eight main bearing caps (12V–92 engines) and number nine and ten main bearing caps (16V–92 engines) so that the oil pump drive gear teeth mesh with the oil pump driven gear teeth. Secure the oil pump to the bearing caps with four nuts and lock washers (Fig. 10).

2. Check the backlash (clearance) between the oil pump drive and driven gears with a feeler gage or a suitable dial indicator. The backlash should be .006" to .012".

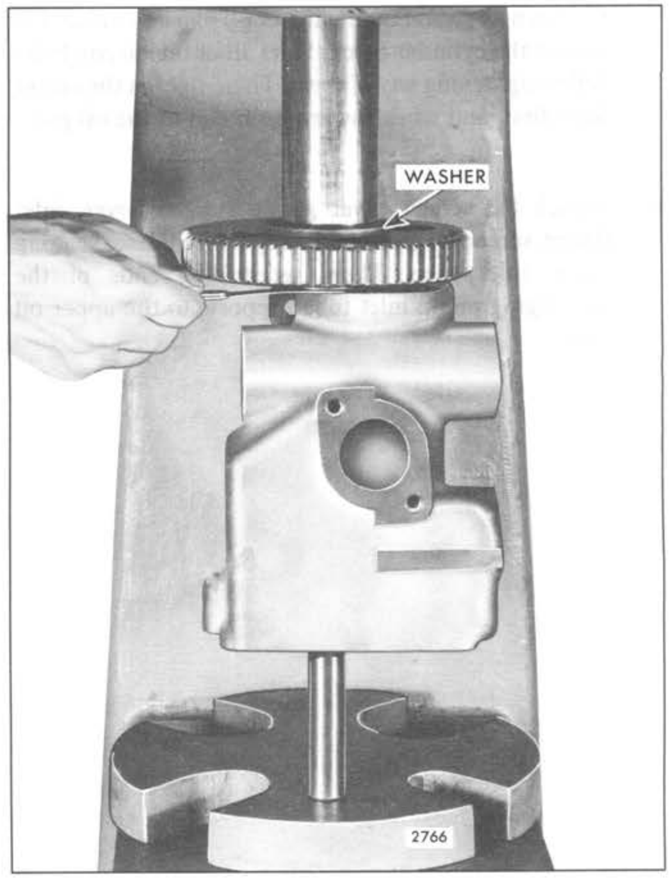


Fig. 16 – Installing Oil Pump Drive–Driven Gear on Shaft

Install shims between the oil pump mounting feet and the main bearing caps, as required, to obtain the proper backlash. Install or remove the same number of shims, under both mounting feet, to keep the pump level. The addition or removal of each .005" shim will change the gear backlash .0035".

3. Install the junction block if it was removed (Fig. 10). When installing the junction block, use new junction block–to–cylinder block gaskets to prevent oil leaks.

4. Install the oil pump inlet and outlet pipes. Use a new inlet pipe–to–oil pump gasket. Also, use a new gasket at each end of the oil pump outlet tube.

5. Install the oil pump screen cover gasket, screen cover, inlet pipe flange and screen stop on the oil pump inlet pipe. Next, place the screen in the screen cover and lock it in place with the screen retainer.

6. Install the scavenging pump inlet and outlet pipes. Use a new inlet pipe–to–scavenging pump gasket and a new outlet pipe–to–scavenging pump gasket.

7. Install the scavenging pump inlet pipe support.

8. Refer to Section 4.1.1 for the oil pressure regulator and oil pressure relief valve coverage.

9. Place a new gasket on the upper oil pan and install the pan on the cylinder block. Start all of the oil pan bolts before tightening any of them. Then, tighten the center bolts first, and work toward each end of the oil pan.

10. Attach the screen cover gasket, screen cover, inlet flange, screen stop and tube supports to the scavenging pump inlet tube. Then, secure the ends of the scavenging pump inlet tube supports to the upper oil pan.

11. Place the screen in the scavenging pump inlet screen cover, then lock it in place with the screen retainer.

12. Place a new gasket on the lower oil pan and attach the lower oil pan to the upper oil pan.

    NOTICE: On engines which use an oil pan baffle between the upper and lower oil pan(s), use a gasket on both sides of the baffle.

13. Fill the oil pan to the proper level with the oil recommended in the *Lubrication Specifications* in Section 13.3.

LUBRICATING OIL PRESSURE REGULATOR AND RELIEF VALVES

OIL PRESSURE REGULATOR VALVE (6V and 8V Engines)

Stabilized lubricating oil pressure is maintained within the engine at all speeds, regardless of the oil temperature, by an oil pressure regulator valve. The valve is installed at the end of the vertical oil gallery near the front of the cylinder block on the side opposite the oil cooler (Fig. 1).

The oil pressure regulator consists of a valve body, a hollow piston–type valve, a spring, a spring seat and a pin to retain the valve assembly within the valve body (Fig. 2).

Current regulator valve assemblies (identified by a blue paint mark on the casting seam) include a flat washer between the valve and the valve spring. The washer raises valve operating pressure by 5 psi (34.5 kPa). Because of the increased lubrication that results from the higher operating pressure, DDC recommends modifying the former valve assembly when the oil pan is removed for engine repair or service. Modify the valve by installing one (1) .406" x .812" x .065" flat washer between the valve and the spring.

The valve is held on its seat by the spring, which is compressed by the pin in back of the spring seat. The entire assembly is bolted to the lower flange of the cylinder block and sealed against leaks by a gasket between the block and the valve body. When conditions are such that the oil pressure at the valve exceeds 50 psi (345 kPa), the valve is forced from its seat and oil from the engine gallery is bypassed to the engine oil pan. Thus stabilized lubricating oil pressure is maintained at all times.

Under normal conditions, the oil pressure regulator should require very little attention. If sludge accumulates in the lubrication system, the valve may not work freely, thereby remaining open or failing to open at the normal operating pressure.

Whenever the lubricating oil pump is removed for inspection, remove the regulator valve and spring and thoroughly clean and inspect them.

Remove Oil Pressure Regulator

1. Remove the two regulator–to–cylinder block attaching bolts and lock washers.
2. Tap the regulator body lightly to loosen it from the gasket and the cylinder block. Remove the regulator and the gasket.

Disassemble Oil Pressure Regulator

1. Clamp the regulator assembly in the soft jaws of a bench vise and remove the spring seat retaining pin from the regulator body.
2. Remove the spring seat, spring and valve from regulator body.

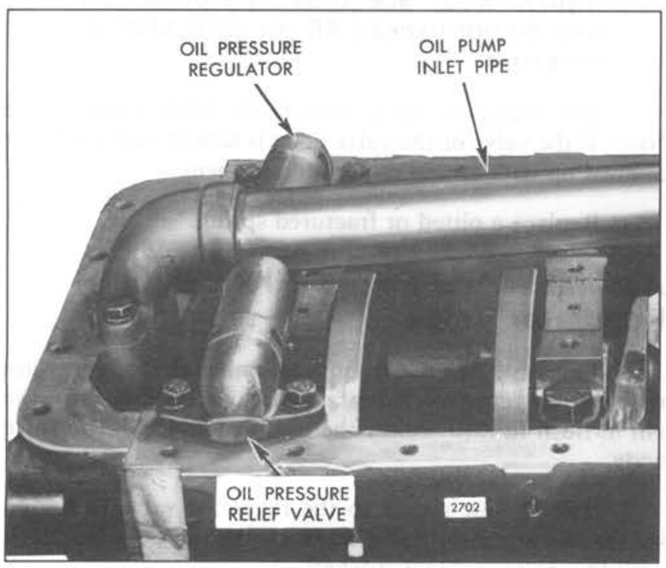


Fig. 1 – Oil Pressure Regulator Valve and Relief Valve Mounting (6V or 8V Engine Oil Pump in Front Cover)

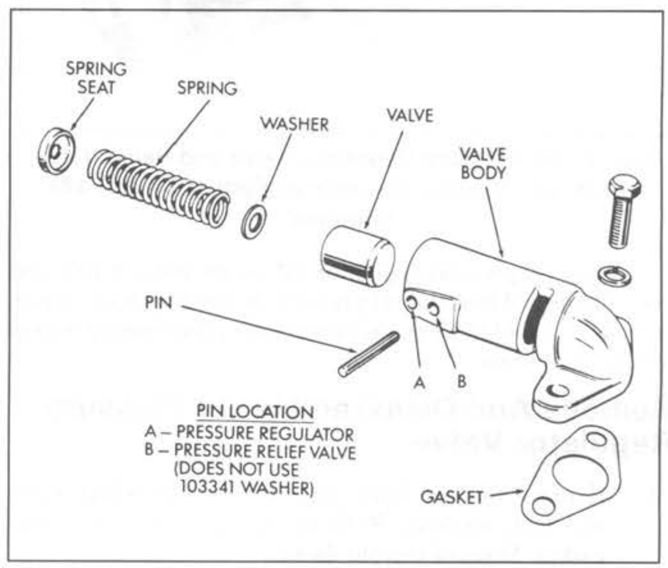


Fig. 2 – Oil Pressure Regulator Valve and Relief Valve and Relative Location of Parts

Inspection

Clean all of the regulator components in fuel oil and dry them with compressed air. Then inspect them for wear or damage.

CAUTION:To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.

The regulator valve must move freely in the valve body. If the valve or the valve body is scored and cannot be cleaned up with crocus cloth, replace them.

Replace a pitted or fractured spring.

Assemble Oil Pressure Regulator

After the parts have been cleaned and inspected, refer to Fig. 2 and assemble the regulator as follows:

1. Apply clean engine oil to the outer face of the valve and slide it into the regulator body, closed end first.
2. Insert the spring in the valve and install the spring seat. While compressing the spring, install the retaining pin behind the spring seat. Press the pin flush to .010" below the surface of the valve body.

NOTICE: The valve body used on the 6V and 8V engines (with an oil pump in the front cover) has two retaining pin holes (Fig. 2). Install the pin in the outermost hole for the regulator valve. The inner hole is used when the valve is assembled as an oil pump relief valve assembly. It is important that the retaining pin be positioned correctly so the proper valve opening pressure will be obtained.

Install Oil Pressure Regulator

1. Remove all traces of old gasket material from the regulator body and the cylinder block.
2. Affix a new gasket to a cast iron regulator body and secure the regulator assembly to the cylinder block with two bolts and lock washers. When installing a regulator assembly with an aluminum housing, use 3/8" plain washers on the bolts and be sure the washers are against the aluminum housing.

OIL PRESSURE REGULATOR VALVE (12V and 16V Engines)

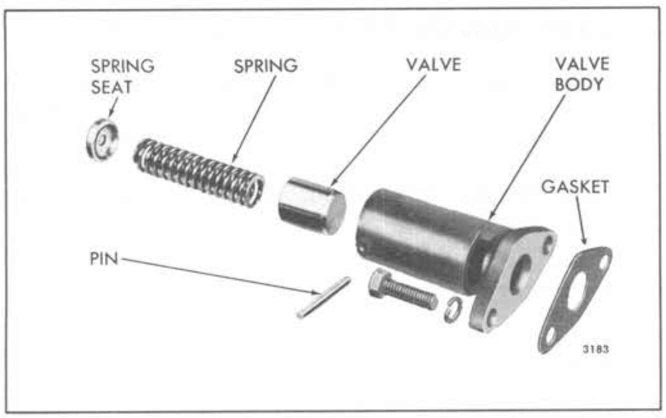


Fig. 3 – Oil Pressure Regulator Valve and Relief Valve Details and Relative Location of Parts (12V and 16V Engines)

Two oil pressure regulator valves are used on 12V and 16V engines. When the oil pressure at the regulator valves exceeds 50 psi (345 kPa), the valves open, discharging excess oil into the oil pan.

Remove And Disassemble Oil Pressure Regulator Valve

1. Remove the regulator valve–to–cylinder block bolts and lock washers. Remove the regulator valve and gasket. Discard the old gasket.
2. Drive the spring seat retaining pin out of the valve body.
3. Remove the spring seat, spring and valve from the valve body (Fig. 3).

Inspection

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

CAUTION:To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.

The regulator valve must move freely in the valve body. If the valve or the valve body is scored and cannot be cleaned up with crocus cloth, replace them.

Replace a pitted or fractured spring.

Assemble And Install Oil Pressure Regulator Valve

Lubricate the valve and assemble the oil pressure regulator by reversing the disassembly procedure. Press the pin in flush to .010" below the outside surface of the valve body.

Affix a new gasket to the regulator valve body and secure the regulator valve assembly to the cylinder block with two bolts and lock washers.

Install the second valve as outlined below.

OIL PRESSURE RELIEF VALVE (6V AND 8V ENGINES)

Oil leaving the pump under pressure passes into the pressure relief valve body. The spring–loaded valve opens when the pressure exceeds approximately 105 psi (724 kPa) and directs the excess oil to the oil pan. The pressure relief valve is located at the lower end of the vertical oil gallery near the front of the cylinder block on the oil cooler side (Fig. 1).

The pressure relief valve consists of a valve body, a hollow piston–type valve, a spring, spring seat and a pin to retain the valve assembly within the valve body.

The relief valve assembly used on the 6V and 8V engines is composed of the same parts as the regulator valve assembly (Fig. 2). However, the retaining pin is located in the inner pin hole in the valve body to provide the necessary tension on the spring.

To provide sufficient clearance between the relief valve housing and the stabilizer bolts, on engines equipped with a main bearing cap mounted lubricating oil pump, a new relief valve is now being used. To eliminate the possibility of cracking the valve housing at assembly, the casting was thickened and the corner of the valve housing at the stabilizer bolt location was removed. The former and new relief valves are not separately interchangeable and only the new relief valve will be serviced.

NOTICE: Be sure and use the correct main bearing cap bolt and washer at the stabilizer positions to obtain minimum clearance.

Service operations for the pressure relief valve are similar to those of the regulator valve.

The spring in the 6V and 8V relief valve assemblies is the same as used in the oil pressure regulator assemblies.

Replace the springs when they are pitted or fractured.

OIL PRESSURE RELIEF VALVE (12V AND 16V ENGINES)

The oil pressure relief valve, mounted on the junction block, bypasses excess oil directly into the oil sump when the oil pressure in the cylinder block main oil galleries exceeds approximately 120 psi or 827 kPa (Fig. 3, Section 4.1).

The valve, spring, spring seat and the pin used in the oil pressure relief valve are identical to the parts used in the oil pressure regulator valve (Fig. 3). Therefore, the removal, disassembly, inspection, assembly and installation procedures given for the oil pressure regulator valve also apply to the relief valve.

LUBRICATING OIL FILTERS

The V–92 engines are equipped with a full–flow type lubricating oil filter. A bypass type oil filter may be used in addition to the full–flow type filter when additional filtration is desired.

Full–Flow Oil Filter

The full–flow type lubricating oil filter is installed ahead of the oil cooler in the lubrication system. The 6V and 8V engines are equipped with a single filter (Fig. 1). The 12V and 16V engines use either two single or two dual oil filters. The filters may be mounted directly to the oil cooler adaptor or remotely mounted on the oil cooler cover and connected by flexible hoses to a filter junction which is attached to the oil cooler adaptor (Fig. 2). Certain units may be equipped with an oil cooler cover which also functions as an oil filter adaptor.

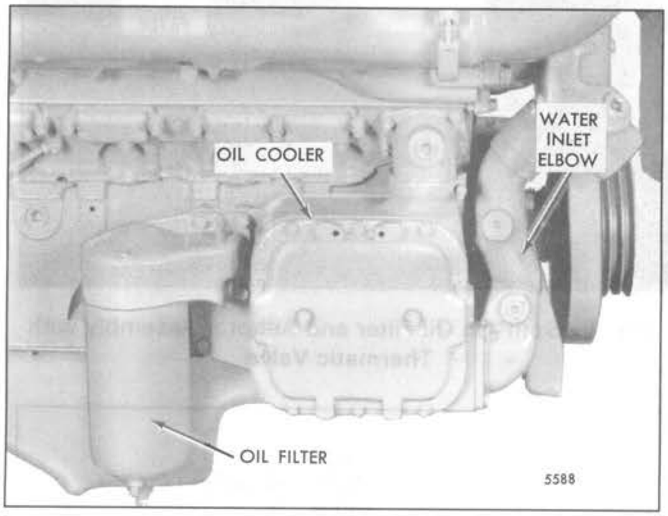


Fig. 1 – Typical Full–Flow Oil Filter Mounting (6V or 8V Engine)

The filter assembly consists of a replaceable element enclosed within a shell which is mounted on an adaptor or base. When the filter shell is in place, the element is restrained from movement by a coil spring.

All of the oil supplied to the engine by the oil pump passes through the filter before reaching the various moving parts of the engine. The oil is forced by pump pressure through a passage in the filter adaptor or base to the space surrounding the filter element. Impurities are filtered out as the oil is forced through the element to a central passage surrounding the center stud and out through another passage in the filter adaptor or base and then to the oil cooler.

A valve, which opens at approximately 18–21 psi (124–145 kPa), is located in the filter adaptor or base and will bypass the oil directly to the oil cooler should the filter become clogged.

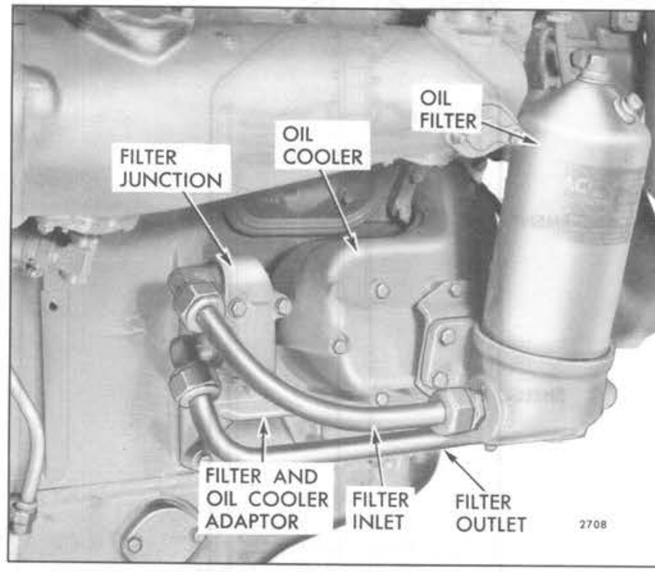


Fig. 2 – Typical Full–Flow Remote Mounted Oil Filter

Conversion adaptor kits (K–4 for the 6V–92 and the K–5 for the 8V–92) for spin–on, full–flow lube oil filters are now available as field replacement items.

NOTICE: Spin–on filters should not replace filter assemblies on transmissions.

The spin–on lubricating oil filter (throwaway type) and mounting adaptor are now being installed on certain engines. The spin–on filter requires a new mounting adaptor which in some cases is part of the oil cooler cover.

Bypass Oil Filter

When additional filtration is desired, an oil filter of the bypass type may also be installed on the engine (Fig. 3). However, the size of the orifice on the discharge side of the filter must not exceed .101" (6V and 8V engines) or .125" (12V and 16V engines) to control the oil flow rate and to provide sufficient oil pressure when the engine is running at idle speed.

When the engine is running, a portion of the lubricating oil is bled off the oil gallery and passed through the bypass filter. Eventually all of the oil passes through the filter, filtering out fine foreign particles that may be present.

The bypass filter assembly consists of a replaceable element contained in a shell mounted on a combination base and mounting bracket. When the shell is in place, the filter element is restrained from movement by a coil spring at the top. A hollow center stud serves as the outlet passage from the filter as well as securing the shell in place.

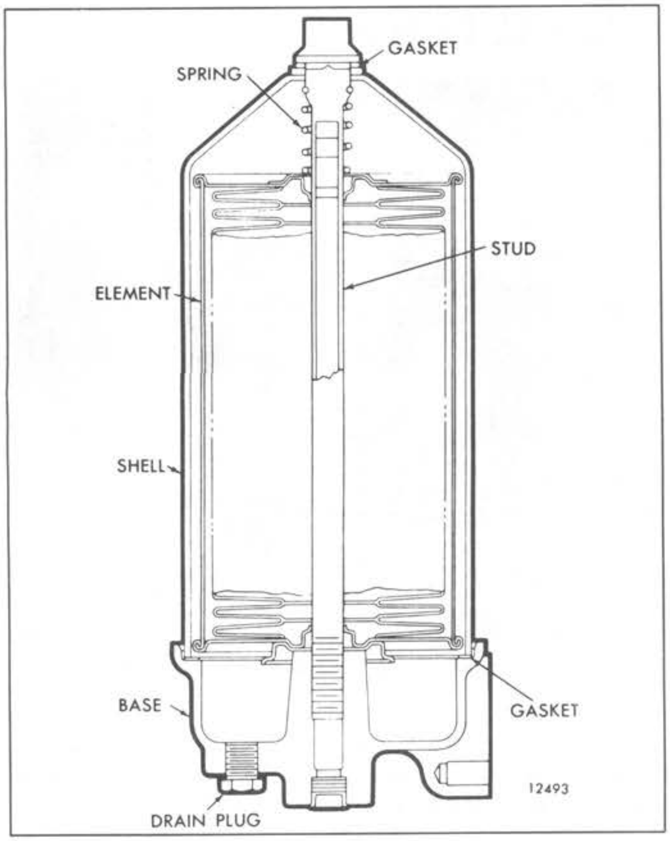


Fig. 3 – Typical Bypass Type Oil Filter

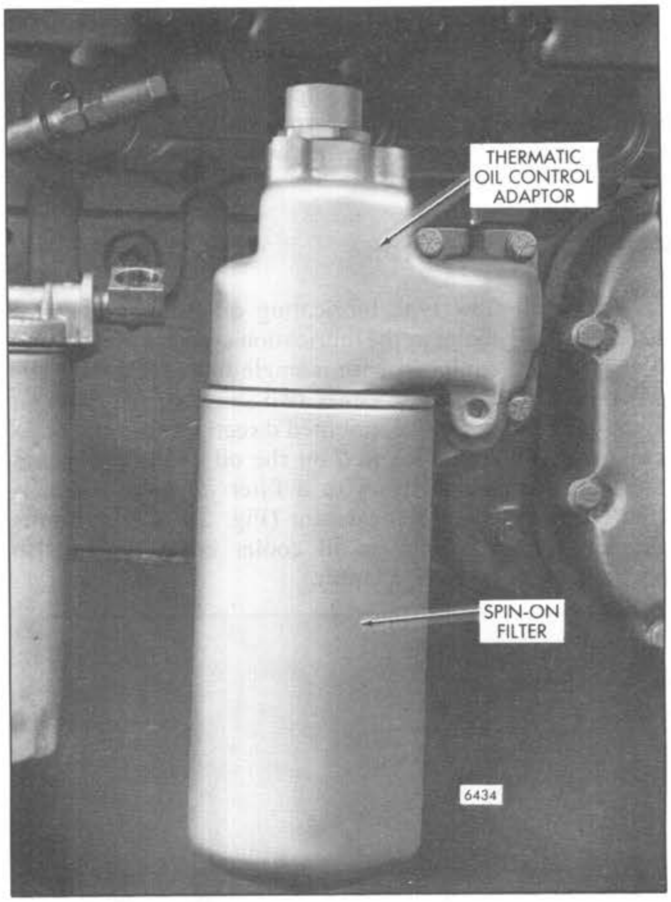


Fig. 4 – Spin–On Oil Filter and Adaptor Assembly with Thermatic Valve

Thermatic Oil Control Valve

A spin–on lube oil filter adaptor assembly with a temperature–sensitive thermatic oil control valve (Fig. 4) is available as an option on certain Series 92 industrial engines. This valve was formerly used on certified automotive models, but was discontinued effective with 1988 production build engines. A service kit is available from DDC distributors to completely replace the thermatic valve when no longer required.

The thermatic valve is installed in the top of the oil filter adaptor assembly where it operates like a thermostat to control the flow of lube oil through the engine and oil cooler. The valve operates in the following manner (Fig. 5).

At lube oil temperatures below 215°F (102°C) the valve stays in the bypass mode. Filtered engine oil bypasses the oil cooler and flows directly to the main oil gallery. With no oil passing through the oil cooler, engine oil warms up rapidly. When oil temperature is between 215°F–230°F (102°C–110°C) the thermatic valve is partially open. The valve senses oil temperature and modulates oil both through and around the oil cooler. At oil temperatures above 230°F (110°C) the valve is fully open and all the oil flows through the oil cooler.

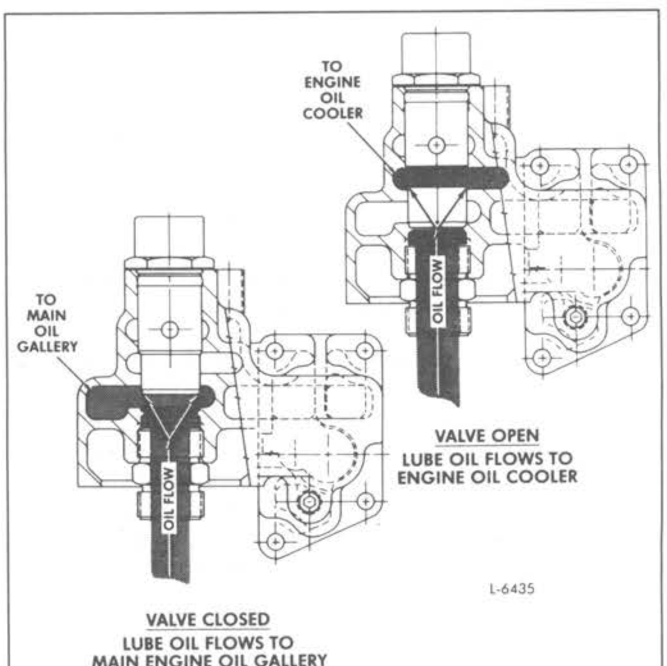


Fig. 5 – Thermatic Valve Operation

Use of the thermatic valve allows the engine lube oil to reach its normal range quickly, reducing the amount of time during which the engine operates on heavier cold engine oil. During light load engine operation, the valve keeps the oil within the proper temperature range for optimum lubrication. By maintaining the oil temperature within the 215°F–230°F (102°C–110°C) range, friction and pumping losses are minimized, resulting in more efficient engine operation. The thermatic oil control valve assembly also incorporates a relief valve which permits oil to bypass the oil cooler if the cooler should become plugged.

Oil Filter Maintenance

With the use of detergent lubricating oils, the color of the lubricant has lost value as an indicator of oil cleanliness or proper filter action. Due to the ability of the detergent compounds to hold minute carbon particles in suspension, heavy duty oils will always appear dark colored on the oil level dipstick.

Heavy sludge deposits found on the filter elements at the time of an oil change must be taken as an indication that the detergency of the oil has been exhausted. When this occurs, the oil drain interval should be shortened. The removal of abrasive dust, metal particles and carbon must be ensured by replacement of the oil filter elements at the time the engine oil is changed.

Selection of a reliable oil supplier, strict observation of his oil change period recommendations and proper filter maintenance will ensure trouble–free lubrication and longer engine life.

- An optional AC service filter is available which has a synthetic (fiberglass), rather than an organic (cellulose) filtering medium. The filter is available in spin–on or canister style and is otherwise identical to the current production filter. The new filter traps particles as small as 12 microns (at 98% efficiency per AC test procedures), compared to 45 microns for the production filter. Because of its increased filtering capability, DDC recommends using it on new, rebuilt, or newly overhauled engines being placed in service.

NOTICE: The new service filter will improve oil filtration on a properly maintained and operated engine. It will not prevent wear or malfunctions caused by poor maintenance or improper engine operation.

Replace Oil Filter Element

Replace the element in either the full–flow or bypass type oil filter assembly (Figs. 3 and 6) as follows:

1. Remove the drain plug from the filter shell or the filter adaptor or base and drain the oil.
2. Back out the center stud and withdraw the shell, element and stud as an assembly. Discard the element and the shell gasket.
3. Remove the center stud and gasket. Retain the gasket unless it is damaged and oil leaks occurred.
4. Remove the nut on the full–flow filter center stud.
5. Remove and discard the element retainer seal (Fig. 6). Install a new seal.
6. Clean the filter shell and the adaptor or base.
7. Install the center stud gasket and slide the stud (with the spring, washer, seal and retainer installed on the full–flow filter stud) through the filter shell.
8. Install a new shell gasket in the filter adaptor or base.

   NOTICE: Before installing the filter shell gasket, be sure all of the old gasket material is removed from the filter shell and the adaptor or base. Also make sure the gasket surfaces of the shell and the adaptor or base have no nicks, burrs or other damage.
9. Position the new filter element carefully over the center stud and within the shell. Then, place the shell, element and stud assembly in position on the filter adaptor or base and tighten the stud to 50–60 lb–ft (68–81 N•m) torque.

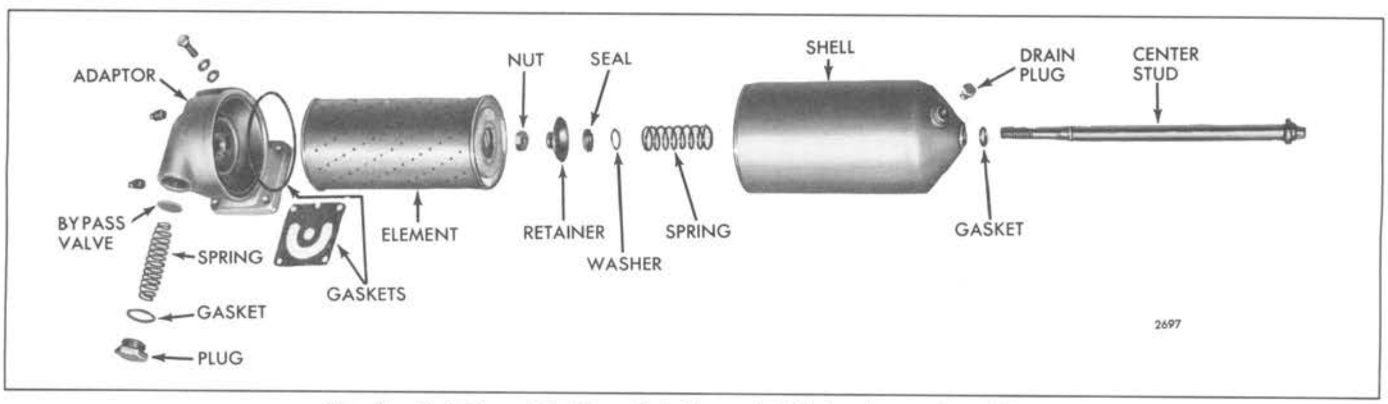


Fig. 6 – Full Flow Oil Filter Details and Relative Location of Parts

10. Install the drain plug.
11. Start and run the engine for a short period and check for oil leaks. After any oil leaks have been corrected and the engine has been stopped long enough (approximately twenty (20) minutes) for the oil from various parts of the engine to drain back to the crankcase, add sufficient oil to bring it to the proper level on the dipstick.

Replace Spin–On Filter

1. Remove the oil filter using strap wrench tool J 29917 which must be used with a 1/2" drive socket wrench and extension.
2. Discard the used oil filter.
3. Clean the filter adaptor with a clean, lint–free cloth.
4. Lightly coat the oil filter gasket (seal) with clean engine oil. When installing an oil filter on a DDEC engine, fill 2/3 full with clean engine oil before installing. This will insure full lubrication of bearing surfaces when the engine is started and prevent logging a faulty low oil pressure code (45).
5. Start the new filter on the adaptor and *tighten by hand* until the gasket touches the mounting adaptor head. Tighten an additional two–thirds turn.

NOTICE: Mechanical tightening will distort or crack the filter adaptor.

6. Start and run the engine for a short period and check for oil leaks. After any oil leaks have been corrected and the engine has been stopped long enough for oil from the various parts of the engine to drain back to the crankcase (approximately twenty (20) minutes), add sufficient oil to raise the oil level to the proper mark on the dipstick.

Remove And Install Bypass Valve

1. Remove the plug and gasket or the screw and retainer and withdraw the spring and bypass valve.
2. Wash all of the parts in clean fuel oil and dry them with compressed air.
3. Inspect the parts for wear. If necessary, install new parts.
4. Using a new gasket, reassemble and install the bypass valve. Tighten the 1 1/4"–16 bypass valve plug to 95–105 lb–ft (129–143 N•m) or the 1 1/2"–16 plug to 110–130 lb–ft (150–177 N•m) torque.

LUBRICATING OIL COOLER (Plate–Type)

In order to perform its functions satisfactorily, the lubricating oil must be kept within the proper temperature limits. If the oil is too cold, it will not flow freely. If the oil is too hot, it cannot support the bearing loads, it cannot carry away enough heat, and it may result in too great an oil flow. As a consequence, oil pressure may drop below acceptable limits and oil consumption may become excessive.

In performing its lubricating and cooling functions, the oil absorbs a considerable amount of heat and this heat must be dissipated by an oil cooler.

Each engine is provided with an oil cooler mounted on the right–hand side of the cylinder block at the lower front corner (Figs. 1 and 2) as viewed from the flywheel end of the engine. Two engine oil coolers are used on the 12 and 16V engines and are centrally located on the side of the cylinder block.

The 6 and 8V naturally aspirated engines usually are equipped with an 18 or 24 plate oil cooler (three plates per cylinder). Most current 6V turbocharged engines are equipped with an 18 plate oil cooler (three plates per cylinder). Former and certain 6V and the 8V turbocharged engines are equipped with a 24 plate oil cooler (four plates per cylinder).

To improve sealing between the oil cooler housing adaptor, gasket and plate on certain vehicle engines, additional bolt holes and 5/16"–18 bolts have been added (Fig. 3). Only the new adaptor, plate and gasket will be available for service. To use the former adaptor plate with the new gasket and adaptor, drill two additional holes as indicated in Fig. 3.

A new, one–piece cast oil cooler adaptor which elminates the need for a separate cover plate and gasket is being used on 6V and 8V–92 engines. The new adaptor also eliminates the potential for external oil leakage between the gasket surfaces of the former adaptor and oil cooler adaptor plate (Fig. 4). The new adaptor is completely interchangeable with the former adaptor and only the new will be serviced. The gasket and plate used with the former adaptor will be retained for service.

Oil from the lubricating oil pump flows through a passage in the oil cooler adaptor to the oil filter, then through the oil cooler, and finally through the outlet passage in the cooler adaptor which leads to the cylinder block oil galleries. The engine coolant is pumped through the oil cooler and completely surrounds the oil cooler core.

To ensure continuing engine lubrication should the oil cooler become plugged, a bypass valve is installed in the oil cooler adaptor (Fig. 5).

Remove Oil Cooler Assembly

1. Drain the cooling system by opening the drain cock at the bottom of the oil cooler housing or water inlet elbow.

2. Remove any accessories or equipment necessary, such as the full flow oil filter, to provide access to the oil cooler.

3. Loosen the clamps and slide the hose down on the water inlet elbow.

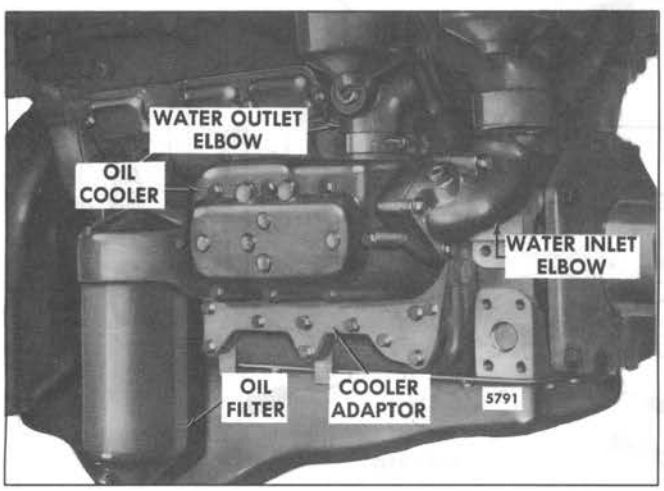


Fig. 1 – Typical Oil Cooler Mounting
(6V or 8V Engine)

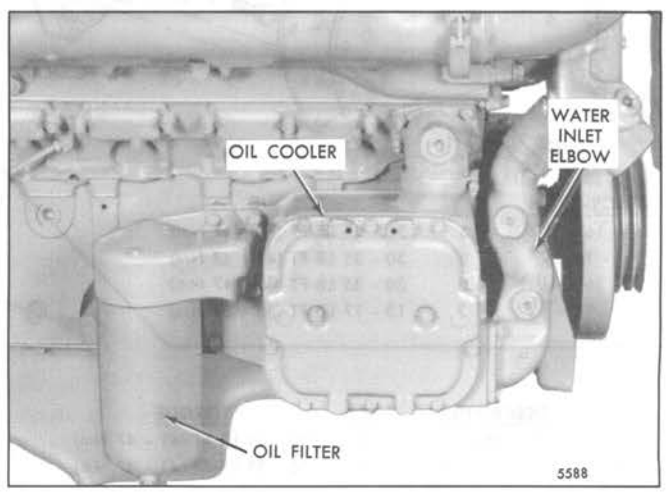


Fig. 2 – Typical Oil Cooler Mounting
(Turbocharged Engine)

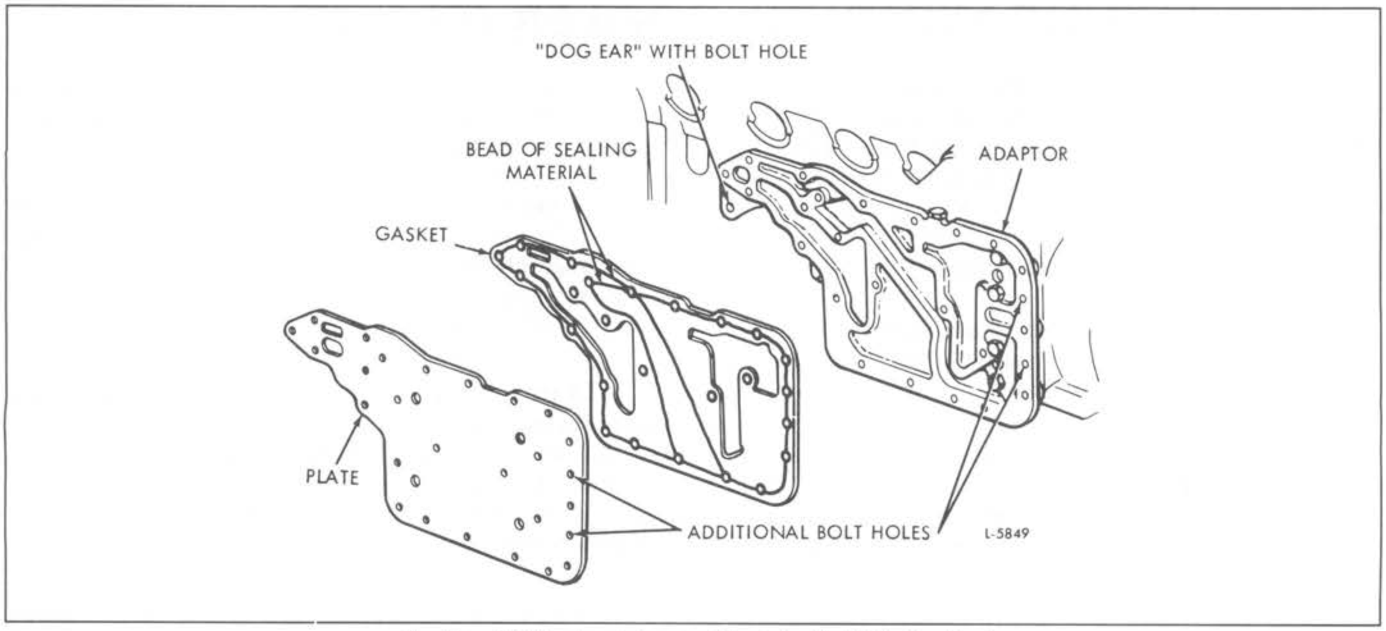
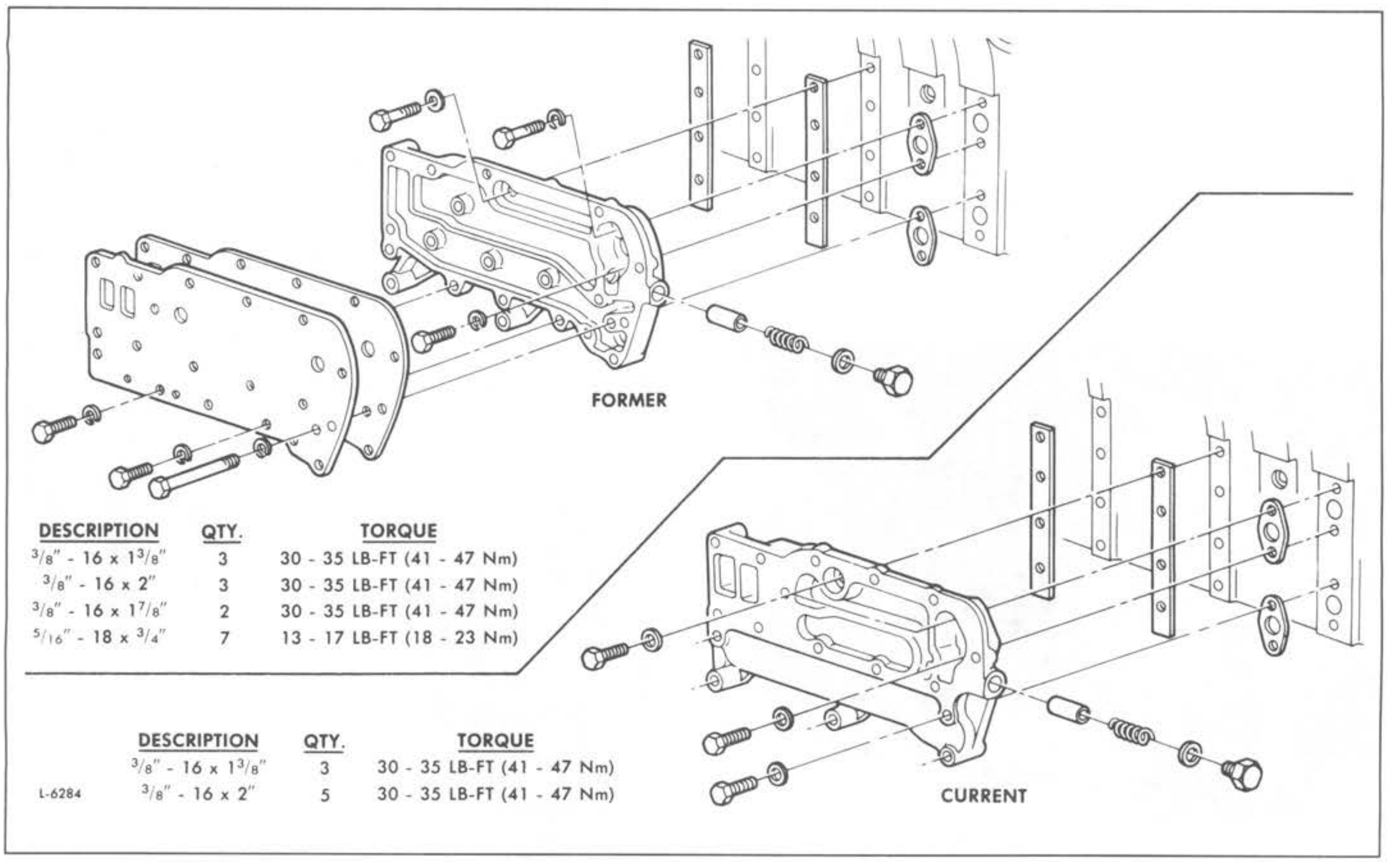


Fig. 3 – Oil Cooler Adaptor (Certain Vehicle Engine)

4. Remove the bolts and lock washers which retain the water inlet elbow to the oil cooler housing. Then remove the elbow and gasket.

5. If a water outlet elbow is used, loosen the seal clamp. Remove the bolts, nuts and lock washers and withdraw the water outlet flange and seal, or water outlet elbow, seal and gasket.



DESCRIPTION	QTY.	TORQUE
3/8" - 16 x 1 3/8"	3	30 - 35 LB-FT (41 - 47 Nm)
3/8" - 16 x 2"	3	30 - 35 LB-FT (41 - 47 Nm)
3/8" - 16 x 1 7/8"	2	30 - 35 LB-FT (41 - 47 Nm)
5/16" - 18 x 3/4"	7	13 - 17 LB-FT (18 - 23 Nm)

DESCRIPTION	QTY.	TORQUE
3/8" - 16 x 1 3/8"	3	30 - 35 LB-FT (41 - 47 Nm)
3/8" - 16 x 2"	5	30 - 35 LB-FT (41 - 47 Nm)

Fig. 4 – Former and Current Oil Cooler Configuration

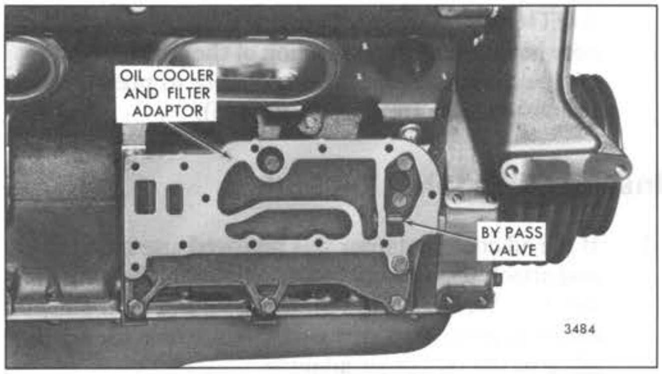


Fig. 5 – Oil Cooler Adaptor and Bypass Valve Mounting

6. Remove the bolts and lock washers and withdraw the oil cooler housing and oil cooler core as an assembly, using care to avoid dropping the oil cooler core.

   If the engine is equipped with a twin plate oil cooler (Fig. 9), remove the two outer bolts at the top of the oil cooler cover and install two studs (approximately 8–1/2" long and with a 5/16"–18 thread at one end) to support the housing, oil cooler core and cover. Then remove the remaining bolts, lock washers and two copper washers. The cover, oil cooler core, housing and gaskets may then be removed.

7. If the oil cooler adaptor is to be removed, first remove the oil filter. Then remove the bolts and lock washers which attach the adaptor to the cylinder block and withdraw the adaptor and gaskets.

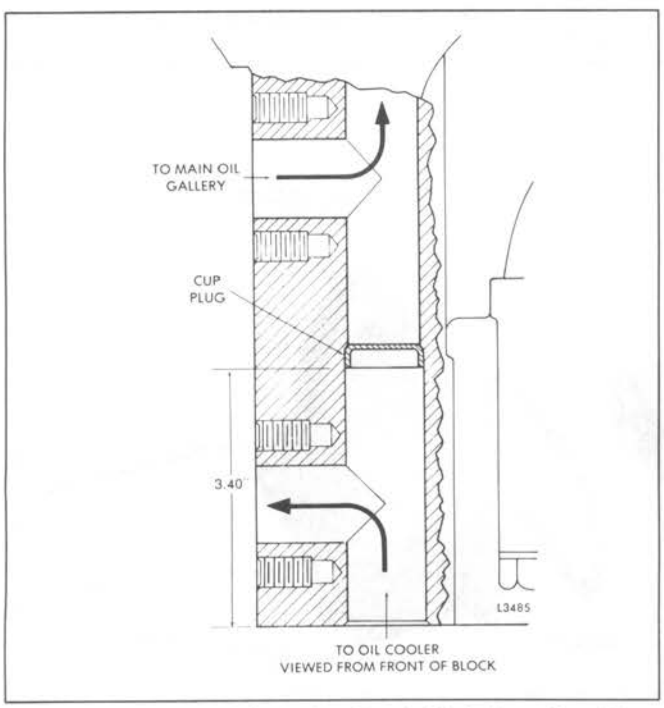


Fig. 6 – Location of Cylinder Block Oil Gallery Cup Plug

   To remove the oil cooler adaptor used with the twin plate cooler, the adaptor plate must be removed first.

8. Clean all traces of gasket material from the cylinder block and the oil cooler components.

9. Inspect the vertical oil passage in the cylinder block for the presence of the cup plug which directs the flow of oil through the oil cooler (Fig. 6). Absence of this plug will result in high oil temperature or low oil pressure (resulting from high oil temperature).

Clean Oil Cooler Core

1. Clean the oil passages in the oil cooler core by circulating a solution of 1,1,1–tricholoroethane through the passages with a force pump.

   CAUTION: Perform this operation in the open or in a well ventilated room. Avoid breathing the fumes or direct contact of the chemicals with your skin.

   Clean the oil cooler core before the sludge hardens. If the oil passages are badly clogged, circulate an alkaline cleaning solution through the oil cooler core and flush it thoroughly with clean, hot water.

   NOTICE: Do not attempt to clean an oil cooler core when an engine failure occurs in which metal particles from worn or broken parts are released into the lubricating oil. In this instance, replace the oil cooler core.

2. After cleaning the oil passages, clean the water side of the oil cooler core by immersing it in a solution made as follows: add 1/2 pound of oxalic acid to each 2–1/2 gallons of a solution composed of 1/3 muriatic acid and 2/3 water. The cleaning action is evident by the bubbling and foaming. Carefully observe the process

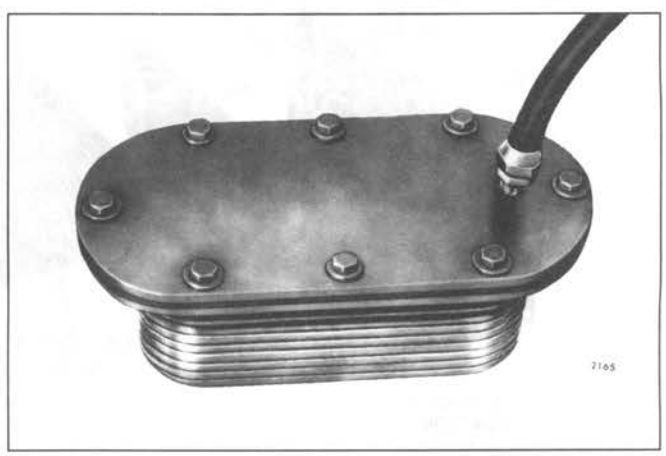


Fig. 7 – Oil Cooler Core Prepared for Pressure Check

and remove the oil cooler core from the solution when the bubbling stops (this usually takes from 30 to 60 seconds). Then thoroughly flush the oil cooler core with clean, hot water. After cleaning, dip the oil cooler core in light oil.

CAUTION: Protect your eyes and avoid breathing the fumes or direct contact of the acid with your skin.

Pressure Check Oil Cooler Core

1. Make a suitable plate and attach it to the flanged side of the oil cooler core. Use a gasket made from rubber to ensure a tight seal. Drill and tap the plate to permit an air hose fitting to be attached at the inlet side of the oil cooler core (Fig. 7).

2. Attach an air hose and apply approximately 75–150 psi (517–1 034 kPa) air pressure. Then submerge the oil cooler core and plate assembly in a tank of water heated to 180°F (82°C). Any leaks will be indicated by air bubbles in the water.

   CAUTION: When making this pressure test be sure that personnel are adequately protected against any stream of pressurized water from a leak or rupture of a fitting, hose or the oil cooler core.

3. After the pressure check is completed, remove the plate and air hose and dry the oil cooler core with compressed air. Replace the oil cooler core if leaks were indicated.

NOTICE: In cases where a leaking oil cooler core has caused contamination of the engine, the engine must be flushed immediately to prevent serious damage (refer to Section 5).

Install Oil Cooler Assembly

1. If the oil cooler adaptor was removed, use new gaskets and attach the adaptor to the cylinder block with bolts and lock washers (Figs. 4, 8 and 9). If a twin plate oil cooler is used, use a new gasket and attach the adaptor plate to the oil cooler adaptor.

   NOTICE: The current adaptor–to–block bolts with hardened washers will continue to be used. These bolts are pre–coated with a lock and seal compound and may be reused if Loctite No. 242 (J 26558–242) or equivalent, is applied to the block bolt holes before bolt installation.

2. Affix new gaskets to the inner and outer faces of the flange and insert the oil cooler core in the oil cooler housing.

   NOTICE: The inlet and outlet openings in the oil cooler core are marked "IN" and "OUT". Make sure the oil cooler core is reinstalled in its original position, otherwise the oil flow will be reversed and could result in foreign particles that may not have been removed to be loosened and circulated through the engine. If the openings are unidentified, it is suggested that they be marked before reinstalling the oil cooler core.

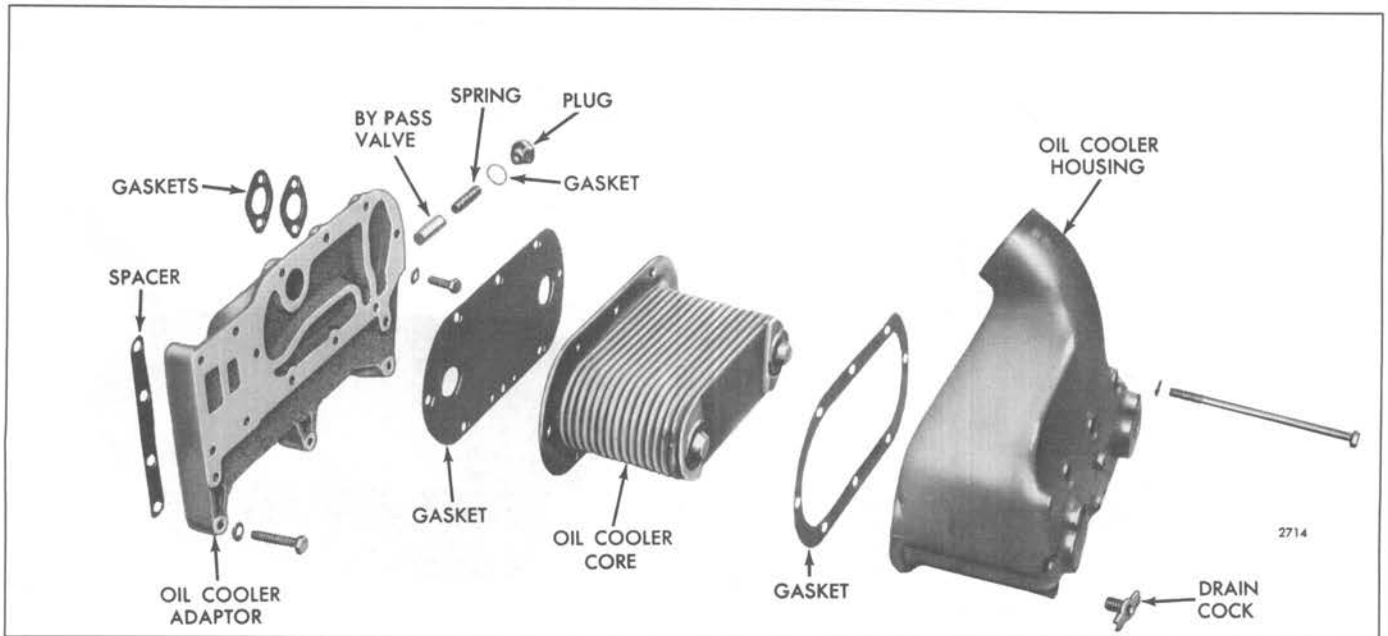


Fig. 8 – Oil Cooler Details and Relative Location of Parts

3. Place the housing and oil cooler core against the adaptor and secure them with bolts and lock washers.

If a twin plate oil cooler is used, install two guide studs. Then, using new gaskets, slide the housing, oil cooler core and cover over the dowels in the order illustrated in Fig. 9 and secure them in place with bolts, lock washers and new copper washers. Remove the studs and install the remaining two bolts and lock washers.

NOTICE: A tab is provided on current cover gaskets to ensure the gasket is installed correctly.

4. Install the water outlet flange and seal, or water outlet elbow, seal and gasket. Secure the flange or elbow to the cylinder block with bolts, nuts and lock washers. If an elbow is used, tighten the seal clamp.

5. Affix a new gasket to the oil cooler housing at the water inlet opening and secure the water inlet elbow to the housing with bolts and lock washers.

6. Slide the water inlet elbow hose in position and tighten the clamps.

7. Install any accessories which were removed to provide access to the oil cooler.

8. Close the drain cock in the oil cooler housing and fill the cooling system to the proper level.

9. Add sufficient oil to the crankcase to bring the oil level to the proper level on the dipstick.

10. Start and run the engine for a short period and check for oil and water leaks. After any leaks have been corrected and the engine has been stopped long enough (approximately twenty minutes) for the oil from various parts of the engine to drain back to the crankcase, bring the oil level up to the proper level on the dipstick.

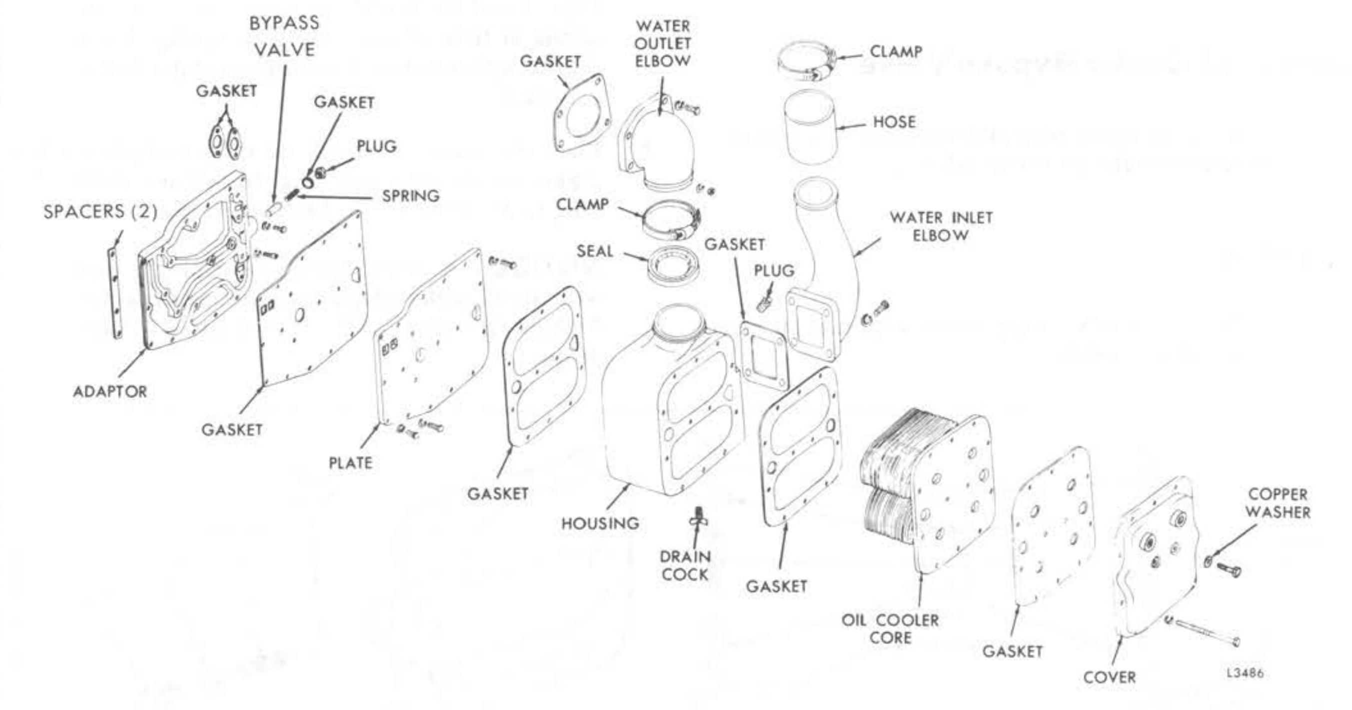


Fig. 9 – Twin Plate Oil Cooler Details and Relative Location of Parts

LUBRICATING OIL COOLER BYPASS VALVE

To ensure engine lubrication should the oil cooler become plugged, a bypass valve is installed in the inlet passage of the oil cooler adaptor (Fig. 5). The valve opens and allows the oil to bypass the oil cooler when the pressure at the inlet side exceeds the pressure at the outlet side by 40 psi (276 kPa).

The bypass valve assembly, which consists of a valve, spring, retaining plug and gasket, should be removed, cleaned and reassembled whenever the oil cooler core is cleaned or replaced. However, the bypass valve can be disassembled without removing the oil cooler on most models.

A new bypass valve spring has been released to provide increased oil circulation through the lube oil coolers. The new valve spring (2.56" long, orange paint identification) replaces the former spring (2" long, no paint identification) in the engine models that use the adaptors shown in Figs. 3 and 10.

Remove Oil Cooler Bypass Valve

Remove the retaining plug and withdraw the gasket, spring and valve from the oil cooler adaptor.

Inspection

Clean the bypass valve components with fuel oil and dry them with compressed air.

CAUTION:To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.

Inspect the valve and spring for wear and replace them if necessary. The bypass valve spring has a free length of approximately 2–1/64". Use spring tester J 29196 to check the spring load. When a force of 12 pounds or less will compress the spring to 1.793", replace the spring.

Install Oil Cooler Bypass Valve

Refer to Figs. 8, 9 and 10 – Install the bypass valve, as follows:

1. Apply clean engine oil to the outside surface of the valve and place it in the oil cooler adaptor valve cavity, closed end first.

   NOTICE: The oil cooler adaptors shown in Figs. 3 and 10 should be updated with the new spring at time of overhaul. This spring should also be replaced at each subsequent major engine overhaul.

2. Place the spring inside of the valve and place a new gasket on the retaining plug. Install and tighten the plug to 30–40 lb-ft (41–54 N•m) torque.

   NOTICE: A *slotted* bypass valve plug is used with the oil cooler adaptor plug on some engines. Tighten this plug to 25–30 lb-ft (34–41 N•m) torque.

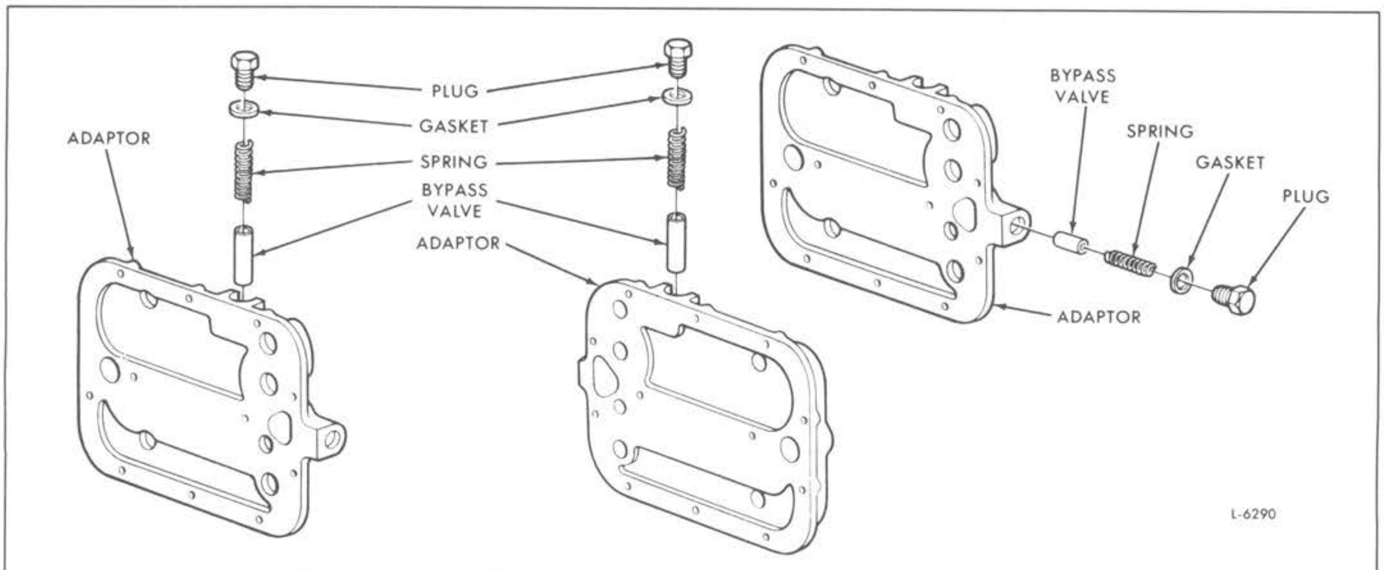


Fig. 10 – Oil Cooler Adaptors with Bypass Valve Assembly Components

LUBRICATING OIL COOLER (Tube-Type)

Certain engines are equipped with a tube-type oil cooler mounted on the side of the engine. Torqmatic converter units use a single basic oil cooler which consists of two sections; one section for the engine oil and the other section for the converter oil (Fig. 11). The Hydraulic Retarder units use a dual oil cooler of which one section cools the engine oil and three sections are used to cool the brake oil (Fig. 12).

A serviceable tube type oil cooler with removable tube bundles is now being used on certain 8V engines. The tube type oil cooler consists of a shell, two tube bundles, four seal rings and a front and rear cover (Fig. 14).

NOTICE: An improved fluoroelastomer seal ring is now being used in the single and dual tube type oil coolers. The improved seal ring is used at four locations on the oil cooler and should be used at overhaul, or whenever the oil cooler is serviced. Only the improved seal ring is serviced.

The coolant from the engine water pump flows through a passage in the oil cooler front cover, passes through the tubes of each section of the oil cooler, back to the outlet passage in the front cover, and finally to the water jackets in the cylinder block (Fig. 13).

The engine oil from the lubricating oil pump enters a passage in the oil cooler front cover, passes through the remote mounted oil filter, then around the tubes in the engine section of the oil cooler, back through the outlet passage in the front cover, and then to the oil galleries in the cylinder block (Fig. 13).

A bypass valve (Fig. 11) is provided which will permit the engine oil to flow directly through the oil cooler should the oil filter become clogged.

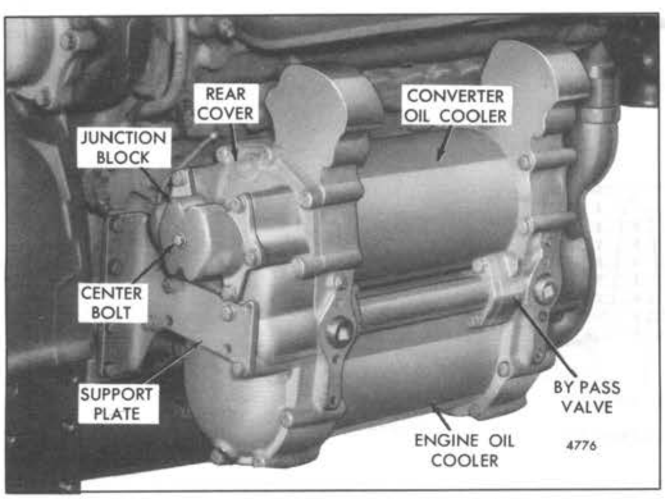


Fig. 11 – Single Tube-Type Oil Cooler Mounting

Oil from the Torqmatic converter or Hydraulic Retarder flows through a flexible hose connected to an oil passage in the oil cooler front end-casting, through the converter or retarder oil cooler sections and out through an oil passage in the oil cooler rear end-casting to a flexible hose which carries the cool oil back to the converter or Hydraulic Retarder (Fig. 13).

Remove Oil Cooler

1. Open the drain cock at the bottom of the rear oil cooler cover and drain the cooling system.

2. Disconnect the oil filter lines and the torque converter oil lines at the cooler. Also remove any accessories necessary to provide access to the oil cooler.

3. Loosen the clamps and slide the hose down on the water inlet elbow. Then remove the bolts and lock washers which attach the elbow to the oil cooler front cover and withdraw the elbow and gasket.

4. Loosen the clamp on the water outlet flange seal. Then remove the bolts, nuts and washers which attach the flange to the cylinder block. Remove the flange, gasket, seal and clamp.

5. Remove the bolts and lock washers which attach the oil cooler to the cylinder block and the oil cooler support bracket. Remove the oil cooler and the gaskets.

6. Drain the oil from the oil cooler.

7. Clean the exterior surfaces of the oil cooler with fuel oil.

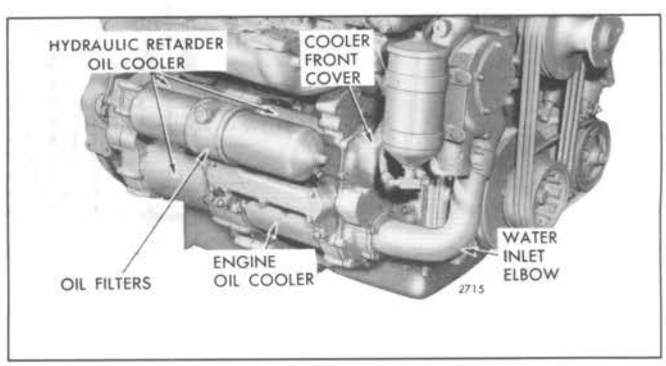


Fig. 12 – Dual Tube-Type Oil Cooler Mounting

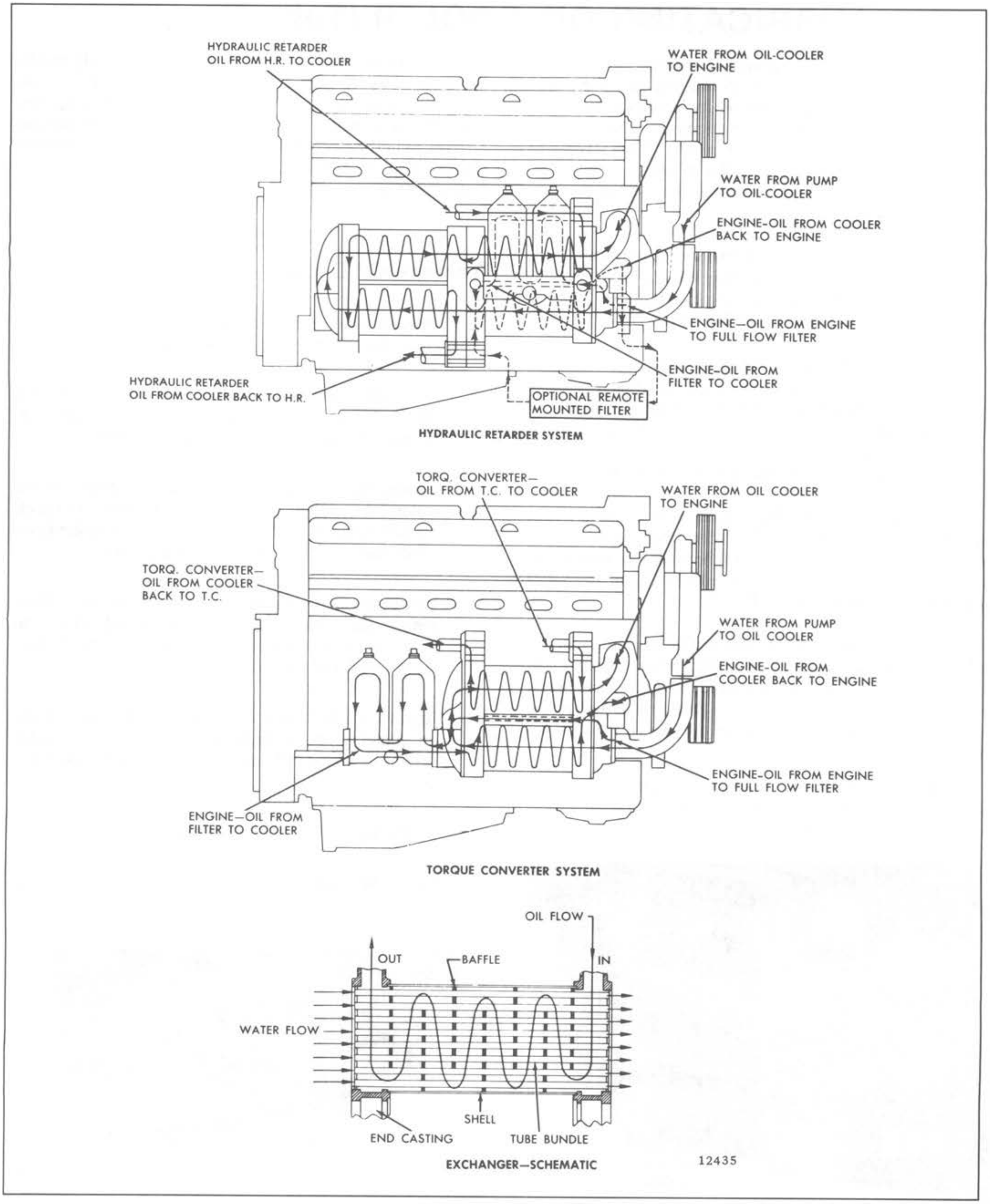


Fig. 13 – Tube–Type Oil Cooler Flow Diagrams

Remove Tube Type Bundles (Current Engines)

The tube bundles are a snug fit in the shell and easily removed. Puller holes are located in the ends of the tube bundles for help in removal. The tube bundles are serviced separately.

NOTICE: The oil cooler tube bundles must be reinstalled in their respective positions (Fig. 14). If necessary, match mark them before removing the tube bundles from the shell.

Clean Oil Cooler

1. Clean the engine oil portion of the oil cooler as follows:

   NOTICE: Do not attempt to clean an oil cooler core when an engine failure occurs in which metal particles from worn or broken parts are released into the lubricating oil. In this instance, replace the oil cooler core.

   a. Replace the oil bypass tube and the oil bypass valve assembly with a long tube connected between the front and rear end castings of the oil cooler.

   b. Seal the oil outlet (to filter) and oil inlet (from filter) openings in the front and rear oil cooler covers with steel plates and gaskets.

   c. Attach a steel plate, which is fitted with an air hose connection, to the oil outlet (to engine) in the front cover.

   d. Attach an air hose, which is connected to an air supply capable to maintaining approximately 100 psi (689 kPa) pressure during the process of expelling the solvent. Then stand the oil cooler on end so the baffles inside the cooler shell will be in a horizontal position.

   e. Fill the oil cooler with a cleaning solvent and apply air pressure to expel the solvent and sludge.

   CAUTION: This operation should be performed in the open or in a well ventilated room when toxic chemicals are used. Also, since the solvent and sludge will be expelled with considerable force, it is suggested that the oil cooler be lowered upright in a barrel to prevent injury to personnel and to keep the spray of sludge contained within a small area.

   f. Refill the oil cooler with clean solvent and attach the air hose fitting to the inlet side of the cooler.

   Apply air pressure to expel the solvent. Repeat the flushing operation in alternate directions until the solvent comes out clean twice from each direction.

   g. Remove the tube which replaced the oil bypass tube and valve assembly.

2. Clean the torque converter oil portion of the oil cooler by circulating a cleaning solvent through the oil passages.

3. Clean the water side of the oil cooler by circulating a solvent such as Oakite through the tubes. Then remove the end covers and run a brush through the tubes. After the brushing is completed, rinse the tubes with clean, hot water.

   NOTICE: Precautions must be taken so the cleaning agents do not corrode the tubes. If an acid solution is used, the residue must be neutralized.

Inspect Oil Bypass Valve

Remove the spring retainer screw and withdraw the retainer, spring and valve from the valve housing. Use spring tester J 22738–02 to check the valve spring load. Replace the spring if a load of less than 6–1/2 pounds will compress it to a length of 13/16". Examine the spring retainer. If the retainer is bent, install a new valve assembly.

Assemble Removeable Tube Type Bundles

For ease in assembling, each tube bundle is marked with an "O" and the cooler shell is marked with an "O" (Fig. 14). The "O"s must line up to ensure proper location of the baffles in the shell. The tube bundles can be installed either end first.

To avoid cutting the seal rings and leaking seal rings it is important that each tube bundle be installed in the shell as follows:

1. Place the shell in a vertical position on the floor.

2. Install the bottom seal ring in the seal ring groove and coat it with lubricating oil.

   NOTICE: The seal ring groove must be free of burrs and foreign material.

3. Prior to inserting the tube bundle, inspect both ends of the element at the lead in chamfer for nicks, dents or burrs.

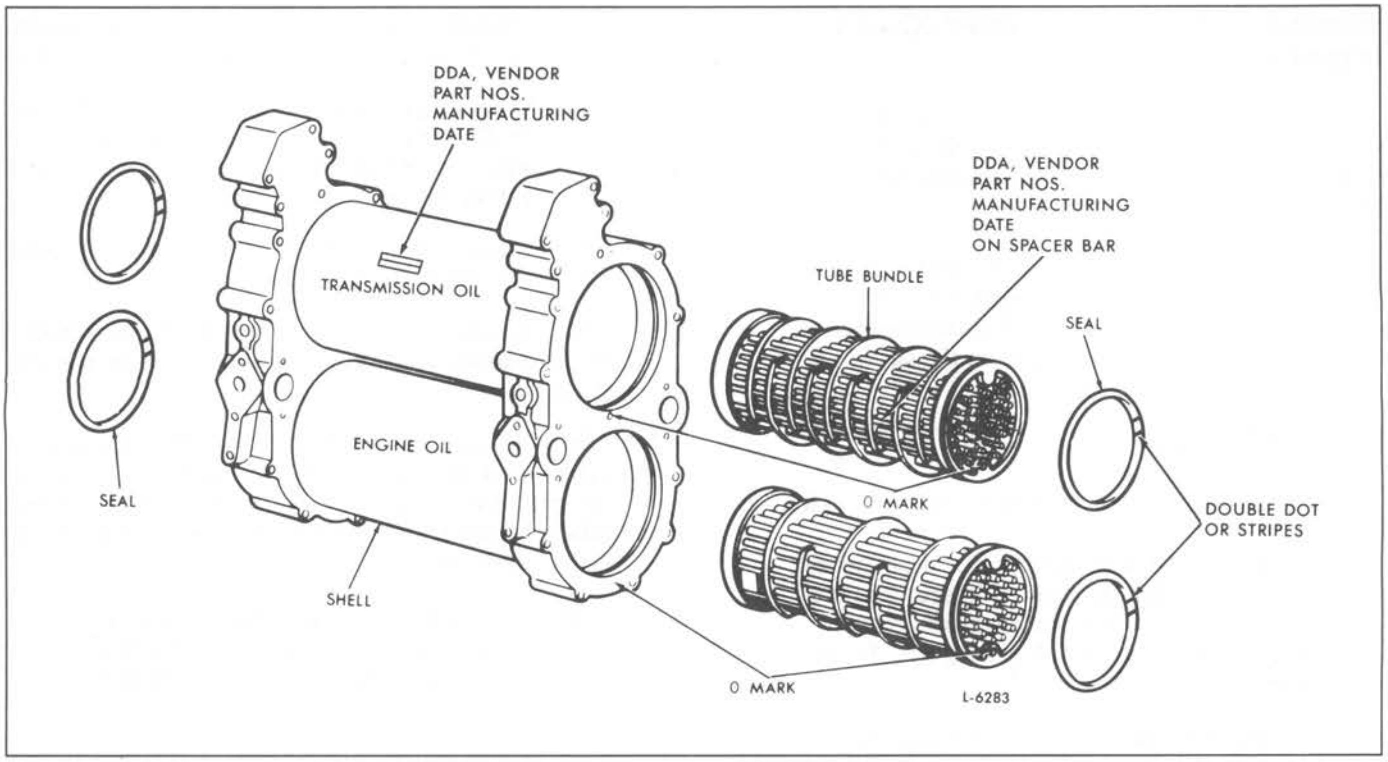


Fig. 14 – Tube–Type Oil Cooler (Removable Bundles) and Relative Location of Parts

NOTICE: Be sure the correct bundle is used in its proper location prior to installation using the bundle part number identification on the spacer bar for reference only.

4. Insert the tube bundle into the shell and carefully press the bundle just pass the upper seal ring groove.

NOTICE: Do not directly hammer on the tubes in the bundles as solder breakage or tube damage could occur.

5. Install the upper seal ring in the seal ring groove and coat with lubricating oil.
6. Invert the tube and shell assembly and press the tube bundle in the opposite direction.
7. The tube bundle should now be flush with the shell at both ends.

The above procedure applies whenever the oil cooler is assembled, even if the tube bundle has slipped out during shipment.

The new front and rear covers have a 3/8" tang on the top and bottom surface to retain the tube bundles in their proper position.

The former and current tube type oil cooler assemblies are completely interchangeable on an engine. Only the current oil cooler assemblies and their component parts will be serviced.

NOTICE: When rebuilding a tube type oil cooler, it is important to note that the current design oil cooler cannot be used with a former design oil cooler in a twin oil cooler application. If one half of a former twin oil cooler application needs replacing, it will be necessary to replace both halves of the oil cooler.

Assemble Oil Cooler

1. Place the bypass valve and spring in the valve housing. Then install the spring retainer.
2. Install a new seal ring in each oil bypass tube flange and slide one flange over each end of the tube. Attach a new gasket to each flange.
3. Install two 3/8"–16 x 5" bolts, with lock washers, through the flange and gasket at one end of the tube. Place the bypass valve assembly and a new gasket over the ends of the bolts.
4. Place the oil bypass valve and tube assembly in position and thread the bolts into the front end casting of the oil cooler. Then install two 3/8"–16 x 3-1/2" bolts and lock washers in the flange at the other end of the tube. Tighten all four bolts to 30–35 lb–ft (41–47 N•m) torque.

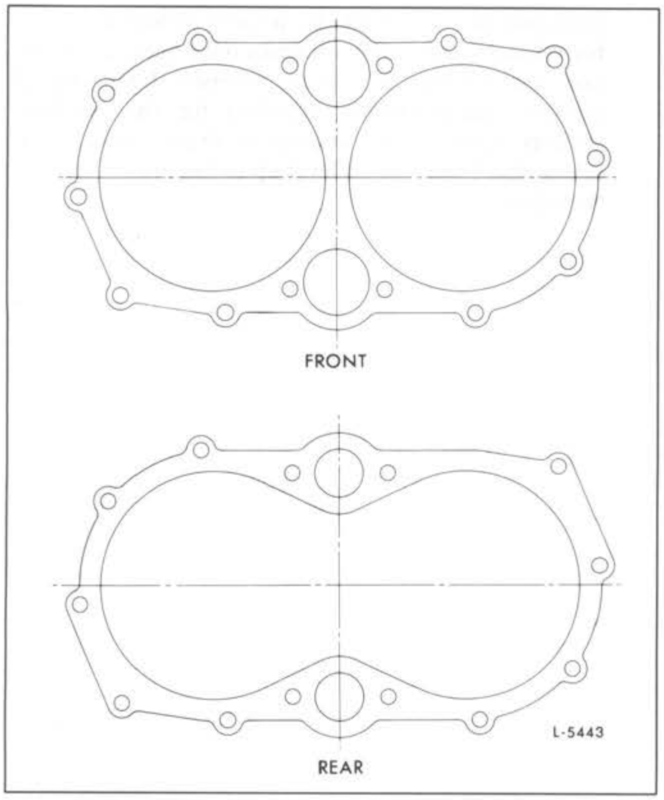


Fig. 15 – Cover Gaskets for Dual Tube Type Oil Cooler

5. Install the oil hole covers and gaskets used on the opposite side of the oil cooler, if they were previously removed.

6. Use a new front gasket (Fig. 15) and attach the front cover to the oil cooler with ten 3/8"–16 x 3" bolts and lock washers. Tighten the bolts to 30–35 lb–ft (41–47 N•m) torque.

7. Use a new rear gasket (Fig. 15) and attach the rear cover to the oil cooler with ten 3/8"–16 x 3" bolt and lock washers. Tighten the bolts to 30–35 lb–ft (41–47 N•m) torque.

8. On the single tube type oil cooler (Fig. 11), use a new gasket and attach the junction block to the oil cooler rear cover with six 3/8"–16 x 1" bolts and lock washers. Also install the 3/8"–16 x 2" center bolt and lock washer. Tighten the bolts to 30–35 lb–ft (41–47 N•m) torque.

9. On a dual tube type oil cooler (Fig. 16), assemble the two rear cooler cover support plates, the upper retainer plate and the necessary .062" shims with three 3/8"–16 x 1–5/8" bolts. Then assemble the lower retainer plate and necessary .062" shims using a new gasket between the oil cooler cover and support plate with five 3/8"–16 x 1–1/8" bolts and lock washers. Also include the center bolt and lockwasher. Tighten the bolts to 30–35 lb–ft (41–47 N•m) torque.

Install Oil Cooler

1. Attach new gaskets to the mounting pads on the oil cooler front cover and place the oil cooler in position against the cylinder block. Secure the front end of the oil cooler to the cylinder block with four 3/8"–16 x 2–1/4" bolts and lock washers. Then secure the rear end of the oil cooler to the support bracket with four 3/8"–16 x 1" bolts and lock washers. Tighten all of the oil cooler mounting bolts to 30–35 lb–ft (41–47 N•m) torque.

2. Place the water outlet flange seal and clamp in position. Then use a new gasket and install the flange. Use new copper washers with the two bolts. Tighten the bolts to 30–35 lb–ft (41–47 N•m) torque and the nuts to 35–39 lb–ft (47–53 N•m) torque.

3. Use a new gasket and attach the water inlet elbow to the oil cooler front cover with four 3/8"–16 x 1–1/8" bolts and lock washers. Tighten the bolts to 30–35 lb–ft (41–47 N•m) torque. Then slide the water inlet elbow hose in place and tighten the clamps.

4. Connect the oil filter and torque converter oil lines to the oil cooler.

5. Install any accessories that were removed to provide access to the oil cooler.

6. Install any pipe plugs that were removed.

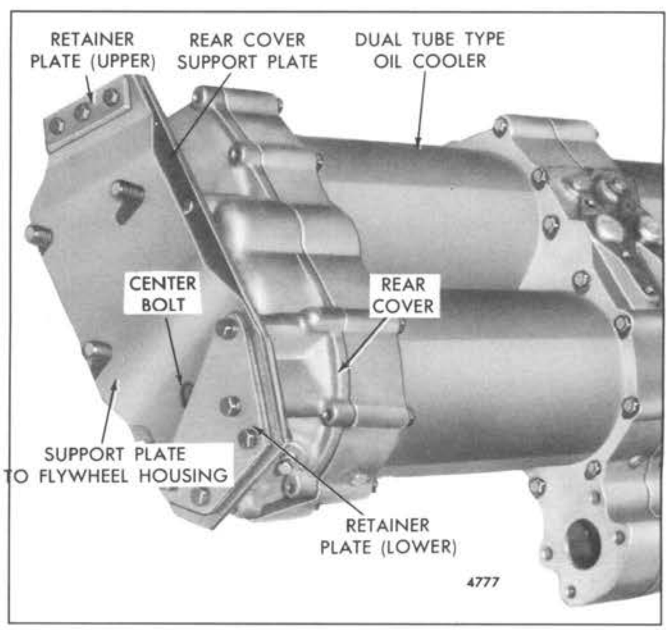


Fig. 16 – Dual Tube Type Oil Cooler

7. Close the drain cock in the oil cooler rear cover and fill the cooling system to the proper level.

8. Add sufficient oil to the crankcase to bring the oil level to the proper level on the dipstick.

9. Start and run the engine for a short period and check for oil leaks. After any oil leaks have been corrected, and the engine has been stopped long enough (approximately twenty minutes) for the oil from various parts of the engine to drain back to the crankcase, bring the oil level up to the proper level on the dipstick.

OIL LEVEL DIPSTICK

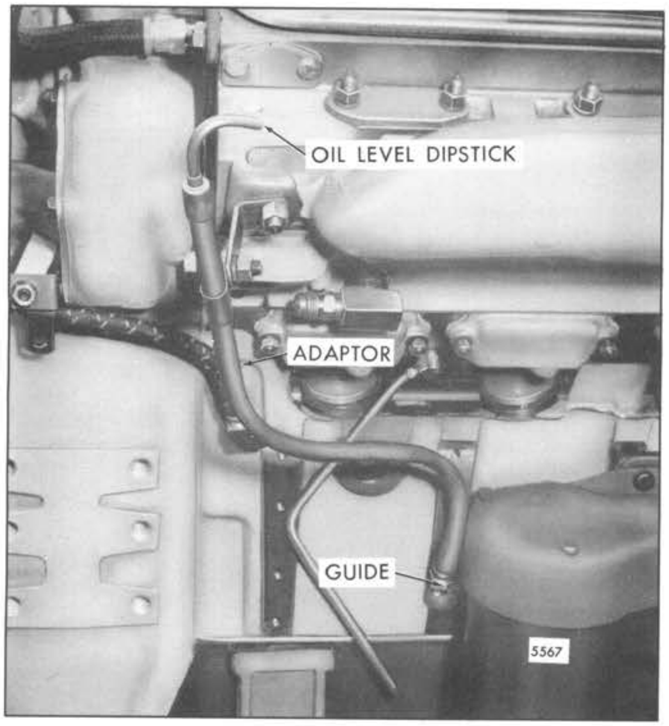


Fig. 1 – Typical Dipstick Mounting

A steel ribbon type oil level dipstick is used to check the quantity of oil in the engine oil pan. The dipstick is located in the side of the cylinder block or the oil pan (Fig. 1). The current engines include a 3/4" long rubber oil seal inside the cap of the dipstick. This prevents the escape of vapors carrying oil from the dipstick tube.

Maintain the oil level between the full and low marks on the dipstick and never allow it to drop below the low mark. No advantage is gained by having the oil level above the full mark. Overfilling will cause the oil to be churned by the crankshaft throws causing foaming or aeration of the oil. Operation below the low mark will expose the pump pick–up causing aeration and/or loss of pressure.

Check the oil level after the engine has been stopped for a minimum of twenty minutes to permit oil in the various parts of the engine to drain back into the oil pan.

Dipsticks are normally marked for use only when the equipment the engine powers is on a level surface. Improper oil levels can result if the oil level is checked with the equipment on a grade.

Fill the crankcase with oil as follows:

1. Fill the oil pan to the full mark on the dipstick.
2. Start and run the engine for approximately ten minutes.
3. Stop the engine and wait a minimum of twenty minutes. Then add the required amount of oil to reach the full mark on the dipstick.

NOTICE: Each engine oil filter will require approximately two additional quarts (1.9 litres) of oil.

Marine Engines

Dipsticks in marine engines are located and marked to provide the proper oil level at any angle within the recommended maximum installation angle applicable to the specific boat.

In a properly filled crankcase, the oil level must be below the crankshaft rear oil seal when the boat is at rest.

Coach Engines

Running level dipsticks are available on certain inclined 6V–92 coach engines. These dipsticks permit accurate reading of the oil level with the engine at idle (running level) or at rest (static level). Running level dipsticks are identified by "6V–92 FLX" or "6V–92 RTS" on the end of their handle.

OIL PAN

The V–92 engines may be equipped with a stamped steel, cast iron or aluminum oil pan. Either a one–piece oil pan (Fig. 1) or an upper and lower pan bolted together may be used. Certain 16V engines are equipped with an upper oil pan and two lower pans. Depending upon the model application, oil pans may be provided to permit an engine inclination of up to 45°.

Some oil pans are provided with an oil level dipstick adaptor and oil filler adaptor mounting holes.

A sectional oil pan gasket, consisting of two side sections and two end sections, incorporate all the necessary bolt holes.

Remove And Install Oil Pan

1. Remove the drain plug and drain the oil.

2. Remove the bolt and washer assemblies and detach the oil pan, being careful not to damage the oil pump piping and inlet screen.

   NOTICE: The stamped metal oil pans used on some marine engines have a thin protective coating to shield the metal against the action of a salt water atmosphere. Therefore, do not rest, slide or rock the engine on its oil pan. If the surface of the oil pan is scratched, electrolysis will take place and damage to the oil pan will result. Also exercise care when performing engine repairs, to avoid scratching the outer surfaces of the oil pan.

3. Clean all of the old gasket material from the cylinder block and the oil pan. Clean the oil pan with fuel oil and dry it thoroughly with compressed air.

   CAUTION:To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.

4. Inspect a cast oil pan for porosity or cracks, a stamped oil pan for dents or other damage which may necessitate repair or replacement. Check for misaligned flanges or raised surfaces surrounding the bolt holes by placing the pan on a surface plate or other large flat surface.

5. When installing the oil pan on a 6 or 8V engine, use a new gasket(s) and, starting with the center bolt on each side and working alternately toward each end of the pan, tighten the bolts to 10–20 lb–ft (14–27 N•m) torque. *Do not overtighten the bolts.* Once the bolts are tightened to the specified torque, do not retighten them as it could be detrimental to the current type oil pan gasket. If a leak should develop at the oil pan, check if the lock washer is compressed. If not, the bolt may be tightened. However, if the lock washer is compressed and leaking occurs, remove the oil pan and determine the cause of the leakage.

   NOTICE: Current oil pan bolts (stamped metal pans) are coated with a locking material. To re–activate the locking ability of the bolts, apply a drop or two of Loctite J 26558–242, or equivalent, to the threads of the bolts at re–assembly.

6. When installing the upper oil pan on a 16V engine, use a new gasket(s) and place the oil pan in position against the cylinder block and flywheel housing. Install all of the 3/8"–16 oil pan attaching bolts and lock washers finger tight only. Then install the two 3/4"–10 oil pan to flywheel housing bolts and lock washers to draw the oil pan tight against the flywheel housing. Next, tighten the 3/8"–16 oil pan bolts to draw the oil pan tight against the cylinder block. Now tighten the 3/4"–10 bolts to 240–250 lb–ft (325–339 N•m) torque and the 3/8"–16 oil pan bolts to 10–20 lb–ft (14–27 N•m) torque. When tightening the oil pan bolts, tighten the center bolts first working alternately towards each end of the oil pan. Then install the lower oil pans and tighten the attaching bolts.

7. Install and tighten the drain plug to 25–35 lb–ft (34–47 N•m) torque.

8. Fill the oil pan with new oil (refer to Sections 4.6 and 13.3) to the full mark on the dipstick. Then start and run the engine for a short period to check for oil leaks.

9. Stop the engine and, after approximately twenty minutes, check the oil level. Add oil, if necessary.

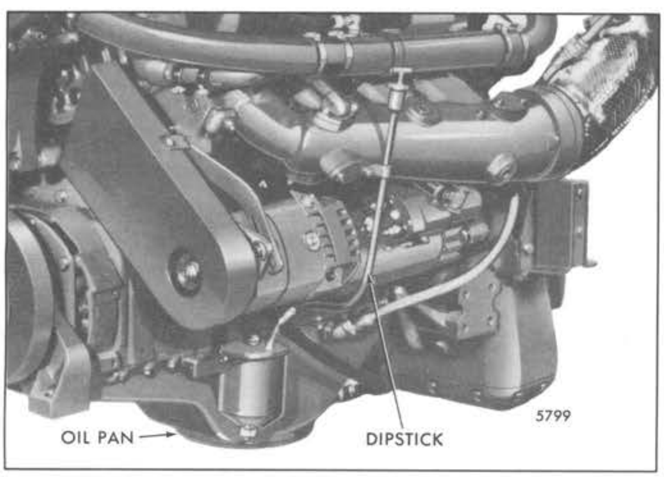


Fig. 1 – Typical One–Piece Oil Pan

VENTILATING SYSTEM

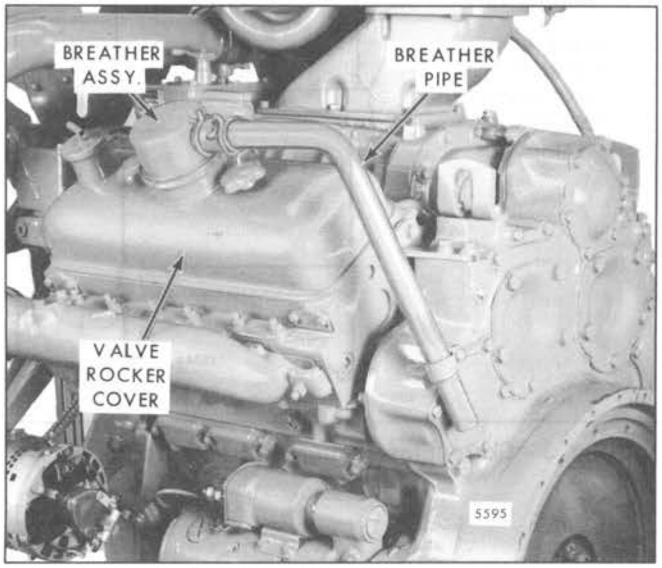


Fig. 1 – Typical Mounting of Breather Assembly on Valve Rocker Cover

Harmful vapors which may be formed within the engine are removed from the crankcase, gear train and valve compartment by a continuous pressurized ventilating system.

Breathing is through two openings in the rear main bearing bulkhead of the crankcase and one large hole in the cylinder block rear end plate. They connect to a central chamber (separated from chambers on each side which carry oil draining back from the cylinder heads) that leads to an exit at the top of the cylinder block.

The external tube(s) connects the cylinder block exit hole at the rear of the cylinder head(s).

The current left bank cylinder head to cylinder block breather system used on 6V–92 engines is now being used in 8V–92 engines effective with 8VF–017875 (Fig. 2). An elbow is bolted to the side of the cylinder head and a tube pressed in the opening at the top rear end of the cylinder block (Fig. 2). They are joined with a rubber hose and clamps. The former breather system continues for the right bank cylinder head to cylinder block breather system, and will continue to be used on both banks for certain engine applications, because of clearance considerations.

Effective with engine serial number 6VF–105223, the right–bank rocker cover breather and associated harware have been removed from 6V–92TA, TTA automotive and 6V–92TA upright coach engines. Removal of the right–bank rocker cover breather affects 6V–92TA, TTA automotive and 6V–92 upright coach engines *only*. Failure to use a rocker cover breather on the left–bank head can result in excessively high engine crankcase pressure. Excessive pressure can, in turn, cause crankshaft oil seal leakage and/or loss of oil through the dipstick tube.

The rocker cover(s) provides a large cross–sectional air flow area at maximum height for efficient breathing and oil separation. A breather assembly(s) is mounted at the openings in the rocker cover(s).

To index the breather assembly exhaust outlet on the current aluminum die cast valve rocker covers, no disassembly is required. Insert a 1–1/8" outer diameter pipe or wood dowel into the exhaust outlet, apply pressure and rotate the outlet to the desired location.

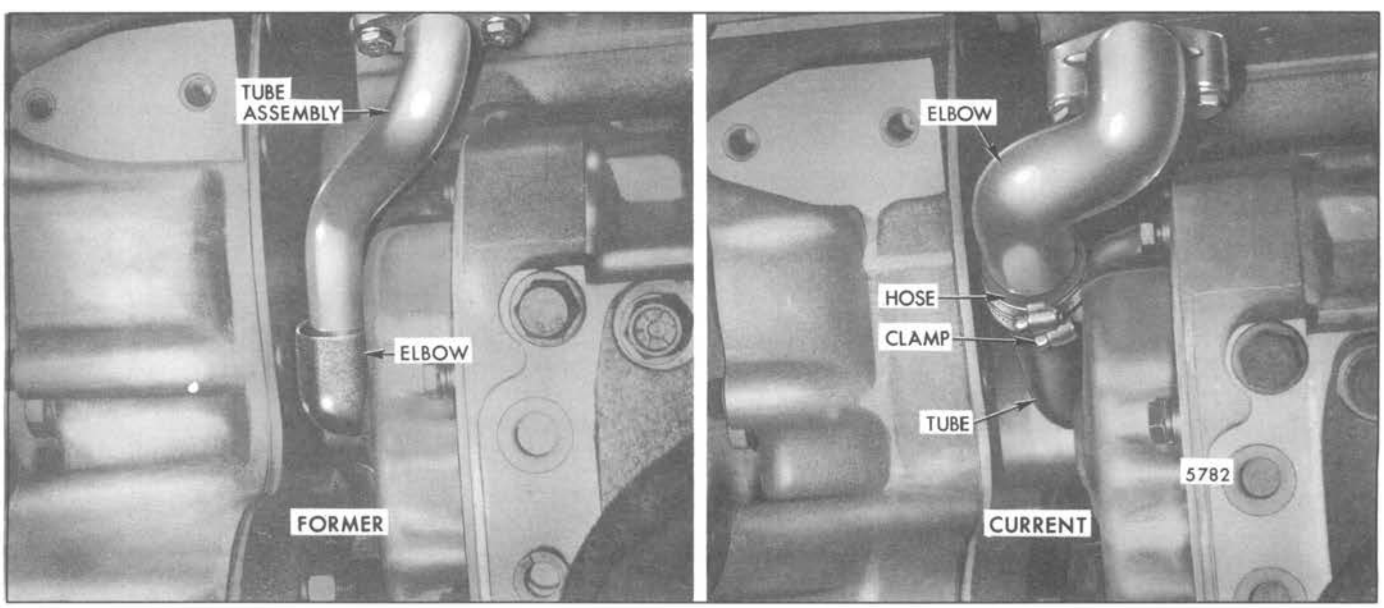


Fig. 2 – Cylinder Block to Cylinder Head Breather Systems for 6V–92 and 8V–92 Engines

Service

The element in the breather assembly mounted on the valve rocker cover should be cleaned if excessive crankcase pressure occurs (Fig. 1). Also, clean the breather pipe.

NOTICE: Dirt can collect around the breather clamp. Clean out the dirt thoroughly before disassembling the breather.

Wash the element in fuel oil and dry it with compressed air.

CAUTION:To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.

When reassembling the breather on the rocker cover, *be sure the clamp is installed with the large (open) diameter facing up* as illustrated in Fig. 3. If the clamp is improperly installed, it could eventually loosen.

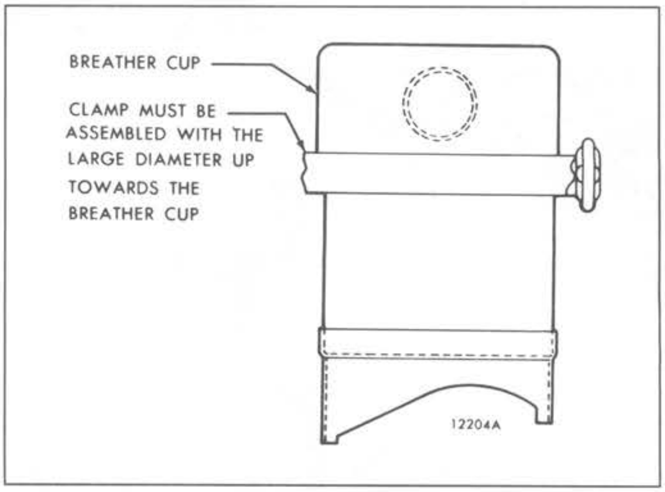


Fig. 3 – Correct Installation of Breather Clamp

SPECIFICATIONS - SERVICE TOOLS

SPECIFICATIONS

STANDARD BOLT AND NUT TORQUE SPECIFICATIONS

THREAD SIZE	260M BOLTS TORQUE (lb-ft)	N•m	THREAD SIZE	280M OR BETTER TORQUE (lb-ft)	N•m
1/4-20	5-7	7-9	1/4-20	7-9	10-12
1/4-28	6-8	8-11	1/4-28	8-10	11-14
5/16-18	10-13	14-18	5/16-18	13-17	18-23
5/16-24	11-14	15-19	5/16-24	15-19	20-26
3/8-16	23-26	31-35	3/8-16	30-35	41-47
3/8-24	26-29	35-40	3/8-24	35-39	47-53
7/16-14	35-38	47-51	7/16-14	46-50	62-68
7/16-20	43-46	58-62	7/16-20	57-61	77-83
1/2-13	53-56	72-76	1/2-13	71-75	96-102
1/2-20	62-70	84-95	1/2-20	83-93	113-126
9/16-12	68-75	92-102	9/16-12	90-100	122-136
9/16-18	80-88	109-119	9/16-18	107-117	146-159
5/8-11	103-110	140-149	5/8-11	137-147	186-200
5/8-18	126-134	171-181	5/8-18	168-178	228-242
3/4-10	180-188	244-254	3/4-10	240-250	325-339
3/4-16	218-225	295-305	3/4-16	290-300	393-407
7/8-9	308-315	417-427	7/8-9	410-420	556-569
7/8-14	356-364	483-494	7/8-14	475-485	644-657
1-8	435-443	590-600	1-8	580-590	786-800
1-14	514-521	697-705	1-14	685-695	928-942

Grade identification markings are normally stamped on the heads of the bolts. To aid identification of the various bolts used in Detroit Diesel engines, refer to the following chart.

Grade Identification Marking on Bolt Head	GM Number	SAE Grade Designation	Nominal Size Diameter (inch)	Tensile Strength Min. (psi)
None	GM 255-M	1	No. 6 thru 1 1/2	60,000
None	GM 260-M	2	No. 6 thru 3/4 over 3/4 to 1 1/2	74,000 60,000
Bolts and Screws	GM 280-M	5	No. 6 thru 1 over 1 to 1 1/2	120,000 105,000
Hex Head Sems Only	GM 275-M	5.1	No. 6 thru 3/8	120,000
Bolts and Screws	GM 290-M	7	1/4 thru 1 1/2	133,000
Bolts and Screws	GM 300-M	8	1/4 thru 1 1/2	150,000
Bolts and Screws	GM 455-M	None	No. 6 thru 1 1/2	55,000

BOLT IDENTIFICATION CHART

EXCEPTIONS TO STANDARD BOLT AND NUT TORQUE SPECIFICATIONS

APPLICATION	THREAD SIZE	TORQUE (lb–ft)	TORQUE N•m
Oil pan bolts	5/15–18	10–12	14–16
Oil pan bolts	3/8–16	10–20	14–27
Lubricating oil filter center stud	5/8–18	50–60	68–81
Oil pan drain plug (nylon washer)	18mm	25–35	34–47

SERVICE TOOLS

TOOL NAME	TOOL NO.
Bar type gear puller	J–24420
Oil pump drive and driven gear installer (16V)	J–9382
Oil pump drive gear installer (16V)	J–9380
Oil pump drive shaft gear installer (6V and 8V)	J–22397
Oil pump driven gear installer (16V)	J–9381
Oil pump driven shaft gear installer (6V and 8V)	J–22398
Oil Pump driving gear installer (6V and 8V)	J–22285
Spring tester 0–125 lbs.	J–29196
Strap wrench (spin–on filter)	J–24783

SECTION 5

COOLING SYSTEM

CONTENTS

COOLING SYSTEM

To effectively dissipate the heat generated by the engine, one of three different types of cooling systems is used on V-92 engines: radiator and fan, heat exchanger and raw water pump, or keel cooling. Each system is provided with a centrifugal type water pump that circulates the engine coolant. Each system incorporates thermostats to maintain a normal engine operating temperature (refer to Section 13.2).

Upon starting a cold engine or when the coolant is below operating temperature, the coolant flow to the radiator is blocked or restricted by the thermostats in the thermostat housings. A bypass provides coolant circulation within the engine during the warm-up period.

RADIATOR COOLING SYSTEM

Coolant is drawn from the lower portion of the radiator by the water pump and is forced through the oil cooler housing and into the cylinder block (Fig. 1).

From the cylinder block, the coolant passes up through the cylinder heads and, when the engine is at normal operating temperature, through the thermostats into the upper portion of the radiator. The coolant passes down a series of tubes where its temperature is lowered by the air stream created by the revolving fan.

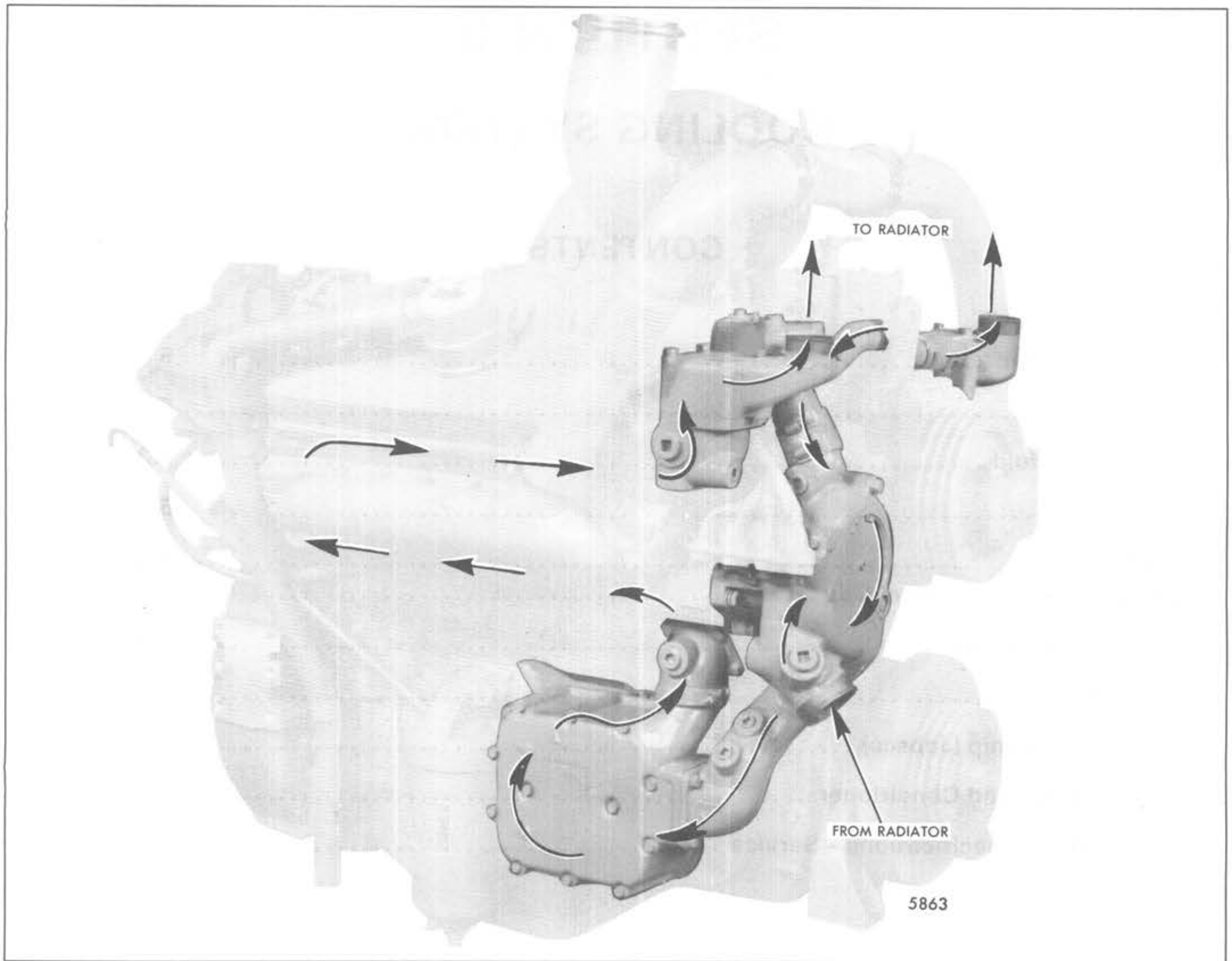


Fig. 1 – Cooling System

HEAT EXCHANGER COOLING SYSTEM

In the heat exchanger cooling system, the coolant is drawn by the engine water pump from the heat exchanger and is forced through the engine oil cooler, cylinder block, cylinder heads and exhaust manifolds to the thermostat housings. A bypass from the thermostat housings to the inlet side of the water pump permits circulation of coolant through the engine when the thermostats are closed.

When the thermostats are open, the coolant flows through the heat exchanger where it is cooled.

An engine driven raw water pump circulates raw water (sea water) through the heat exchanger to lower the temperature of the engine coolant.

KEEL COOLING SYSTEM

In the keel cooling system, the coolant is drawn by the engine water pump from the keel cooler and is forced through the engine oil cooler, cylinder block, cylinder heads and exhaust manifolds to the thermostat housings. A bypass from the thermostat housings to the inlet side of the water pump permits circulation of coolant through the engine when the thermostats are closed. When the thermostats open, the coolant flows through the keel cooling coils to be cooled.

The heat of the engine coolant is transferred through the coils of the keel cooler to the surrounding sea water.

ENGINE COOLING SYSTEM MAINTENANCE

The function of the engine coolant is to absorb the heat, developed as a result of the combustion process in the cylinders, from components of the engine such as exhaust valves, pistons and cylinder liners which are surrounded by water jackets. In addition, heat absorbed by the oil is also removed by the engine coolant in the oil–to–water oil cooler. When operating within the proper temperature range and not exceeding the recommended horsepower output of the unit, all engine parts will be within their design operating temperature range and at their proper operating clearances. Coolant must be properly selected and maintained (refer to Section 13.3 for coolant recommendations).

A pressurized cooling system, which normally operates at temperatures higher than a non–pressurized system, is used. It is essential that the cooling system is kept clean and leakproof, that the filler cap and pressure relief mechanism be correctly installed and that the coolant level be properly maintained.

CAUTION: Use extreme care when removing a coolant pressure control cap. The sudden release of pressure from a heated cooling system can result in loss of coolant and possible personal injury (scalding) from the hot liquid.

Cooling System Capacity

The capacity of the basic engine cooling system, (cylinder block, cylinder heads, water manifolds, thermostat housings and oil cooler housing) is shown in Table 1. These quantities do not include the capacity of the radiator, hoses or related equipment.

Engine	Cooling System Capacity	
	Gallons	Liters
6V-92, T, TT	6	22.7
6V-92TA, TTA	6-1/8	23.2
8V-92, T, TT	7	26.5
8V-92TA, TTA	7-1/4	27.4
12V-92, T	12	45.4
16V-92, T	14-1/2	54.9
16V-92TA	15	56.8
After Cooler Capacity		
6V-92TA	.169	.64
8V-92TA	.251	.95
16V-92TA	.502	1.90

TABLE 1

Fill Cooling System

Before starting the engine, close all of the drain cocks and fill the cooling system with coolant (Section 13.3). If the unit has a raw water pump, it should be primed, since operation without water may cause impeller failure.

Start the engine and, after the normal operating temperature has been reached, check the coolant level. The coolant level should be within two inches of the top of the filler neck.

Should a daily loss of coolant be observed, and there are no apparent leaks, there is a possibility that gases are leaking past the cylinder head water seal rings into the cooling system. The presence of air or gases in the cooling system may be detected by connecting a rubber tube between the overflow pipe and a container of water. Bubbling of the water in the container during engine operation will indicate leakage. Another method for observing air in the cooling system is by inserting a transparent tube in the engine coolant outlet line.

Drain Cooling System

To ensure that all of the coolant is drained completely from a unit, all cooling system drains should be opened. Should any entrapped water in the cylinder block or radiator freeze, it will expand and may cause damage. When freezing weather is expected, drain all units not adequately protected by antifreeze. Leave all drain cocks open until refilling the cooling system. The engine coolant is drained by opening the drain cocks and removing the cooling system filler cap. Removal of the filler cap permits air to enter the cooling passages and the coolant to drain completely from the system.

On 6V and 8V engines, cylinder block drain cocks are located on each side of the cylinder block at the rear, below the exhaust manifolds and at the front of the engine.

On 12V and 16V engines, a drain cock is located on each side of the cylinder block, below the exhaust manifold, at both the front and the rear of the engine.

In addition to the cylinder block drains, the oil cooler housing has a drain cock at the extreme bottom. Radiators are drained by opening a drain cock in the bottom tank.

Marine engine exhaust manifolds are cooled by the same coolant used in the engine. Whenever the engine cooling system is drained, open the exhaust manifold drain cocks.

Raw water pumps are drained by loosening the cover attaching screws and tapping the cover gently to loosen it. After the water has drained, tighten the screws.

Flushing

If the cooling system is contaminated, flush the cooling system as follows:

1. Drain the coolant from the engine.
2. Refill with soft clean water.

   NOTICE: If the engine is hot, fill *slowly* to prevent rapid cooling and distortion of the engine castings.

3. Start the engine and operate it for fifteen minutes to thoroughly circulate the water.
4. Drain the engine completely.
5. Refill with the solution required (refer to Section 13.3).

Cooling System Cleaners

If the engine overheats, and the fan belt tension and coolant level have been found to be satisfactory, it may be necessary to clean and flush the entire cooling system. Remove scale formation by using a reputable and safe de–scaling solvent. Immediately after using the de–scaling solvent, neutralize the system with the neutralizer. It is important that the directions printed on the container of the de–scaler be thoroughly read and followed.

After the solvent and neutralizer have been used, completely drain the engine and radiator and reverse flush, as outlined below, before filling the system.

Reverse Flushing

After the engine and radiator have been thoroughly cleaned, they should be reverse flushed. The water pump should be removed and the radiator and engine reverse flushed separately to prevent dirt and scale deposits clogging the radiator tubes or being forced through the pump. Reverse flushing is accomplished by hot water, under air pressure, being forced through the cooling system in a direction opposite to the normal flow of coolant, loosening and forcing scale deposits out.

The radiator is reverse flushed as follows:

1. Remove the radiator inlet and outlet hoses and replace the radiator cap.
2. Attach a hose at top of the radiator to lead water away from the engine.
3. Attach a hose to the bottom of the radiator and insert the flushing gun in the hose.
4. Connect the water hose of the gun to the water outlet and the air hose to the compressed air outlet.
5. Turn on the water and, when the radiator is full, turn on the air in short blasts, allowing the radiator to fill between air blasts.

   NOTICE: Apply air gradually. Do not exert more than 30 psi (207 kPa) air pressure. Too great a pressure may rupture a radiator tube.

6. Continue flushing until only clean water is expelled from the radiator.

The cylinder block and cylinder head water passages are reverse flushed as follows:

1. Remove the thermostats and the water pump.
2. Attach a hose to the water inlet of the cylinder block to drain the water away from the engine.
3. Attach a hose to the water outlet at top of the engine and insert the flushing gun in the hose.
4. Turn on the water and, when the water jackets are filled, turn on the air in short blasts, allowing the engine to fill with water between air blasts.
5. Continue flushing until the water from the engine runs clean.

If scale deposits in the radiator cannot be removed by chemical cleaners or reverse flushing as outlined above, it may be necessary to remove the upper tank and rod out the individual radiator tubes with flat steel rods. Circulate water through the radiator core from the bottom to the top during this operation.

Miscellaneous Cooling System Checks

In addition to the above cleaning procedures, the other components of the cooling system should be checked periodically to keep the engine operating at peak efficiency. The cooling system hoses, thermostats and radiator pressure cap should be checked and replaced if found to be defective.

When water connection seals and hoses are installed, be sure the connecting parts are properly aligned and the seal or hose is in its proper position before tightening the clamps.

NOTICE: In order to assure the integrity of the cooling system, it is recommended that a periodic cooling system pressure check be performed. Pressurize the cooling system (15–20 psi or 103–138 kPa) using radiator cap and cooling system tester J 24460–01. Do not exceed 20 psi (138 kPa). Any measurable drop in pressure may indicate an external/internal leak. Whenever the oil pan is removed, the cooling system should be pressure checked as a means of identifying any incipient coolant leaks.

The fan belts must be checked and adjusted, if necessary, to provide the proper tension. The fan shroud must be tight against the radiator core to prevent recirculation of air which may lower the cooling efficiency.

Contaminated Engines

When the engine cooling or lubricating system becomes contaminated, it should be flushed thoroughly to remove the contaminants before the engine is seriously damaged. One possible cause of such contamination is a cracked oil cooler core. With a cracked oil cooler core, oil will be forced into the cooling system while the engine is operating and, when it is stopped, coolant will leak into the lubricating system.

Coolant contamination of the lubricating system is especially harmful to engines when the cooling system is filled with an ethylene glycol antifreeze solution. When mixed with the oil in the crankcase, this antifreeze forms a varnish which can cause the engine to seize or result in severe bearing wear.

Make certain that the cause of the internal coolant leak has been corrected before flushing the contaminated system(s).

Contaminants may be flushed from the engine systems as follows:

COOLING SYSTEM

If the engine has had a failure resulting in the contamination of the cooling system with lubricating oil, this flushing procedure is recommended.

1. Prepare a mixture of Calgon, or equivalent, and water at the rate of two ounces (dry measure) to one gallon of water.
2. Remove the engine thermostats to permit the Calgon and water mixture to circulate through the engine and the radiator or heat exchanger.
3. Fill the cooling system with the Calgon solution.
4. Run the engine for five minutes.
5. Drain the cooling system.
6. Repeat Steps 1 through 5.
7. Fill the cooling system with clean water.
8. Let the engine run five minutes.
9. Drain the cooling system completely.
10. Install the engine thermostats.
11. Close all of the drains and refill the cooling system with fresh coolant (Refer to Section 13.3).

LUBRICATION SYSTEM

When the engine lubricating system has been contaminated by an ethylene glycol antifreeze solution, or other water soluble material, the following cleaning procedure, using Cellosolve, or equivalent, is recommended.

CAUTION: Use extreme care in the handling of these chemicals to prevent serious injury to the person or damage to finished surfaces. Wash off spilled fluid immediately with clean water.

1. Drain all of the lubricating oil.
2. Remove and discard the oil filter elements. Clean and dry the filter shells and replace the elements.
3. Mix two parts of Cellosolve, or equivalent, with one part SAE 10 engine oil. Fill the engine crankcase to the proper operating level with the mixture.
4. Start and run the engine at a fast idle (1,000 to 1,200 rpm) for thirty minutes to one hour. Check the oil pressure frequently.
5. After the specified time, stop the engine and immediately drain the crankcase and the filters. *Sufficient time must be allowed to drain all of the fluid.*
6. Replace the drain plugs and refill the crankcase with SAE 10 oil and run the engine at the same fast idle for ten or fifteen minutes and again drain the oil thoroughly.
7. Remove and discard the oil filter elements, clean the filter shells and install new elements.
8. Replace the drains and fill the crankcase to the proper level with the oil recommended for normal engine operation.
9. To test the effectiveness of the cleaning procedure, it is recommended that the engine be started and run at a fast idle (1,000 to 1,200 rpm) for approximately thirty minutes. Then, stop and immediately restart the engine. There is a possibility that the engine is not entirely free of contaminant deposits if the starting speed is slow.
10. If the procedure for cleaning the lubricating oil system was not successful, it will be necessary to disassemble the engine and to clean the affected parts thoroughly.

Make certain that the cause of the internal coolant leak has been corrected before returning the engine to service.

MAXIMUM ENGINE COOLANT TEMPERATURE

The heat–dissipating capacity of the engine cooling systems and related components must be sufficient to prevent the coolant temperature from rising above 210°F (99°C). This temperature must not be exceeded under any engine operating condition, regardless of altitude, type of coolant used or cooling system condition. Exceeding this limit can result in malfunction or serious engine damage.

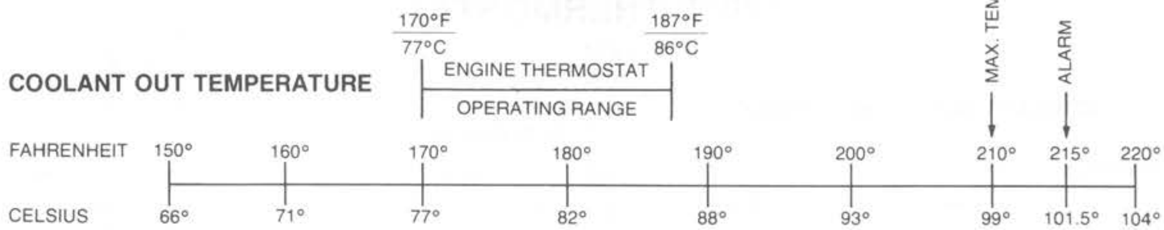
TEMPERATURE CONTROL COMPONENTS

These engines are designed to operate with 170°F (77°C) or 180°F (82°C) thermostats which, combined with a radiator or heat exchanger, regulate coolant temperature within a range of 170°F–187°F (77°–86°C) or 180°–197°F (82°–92°C). Many engines also use radiator shutters, clutch fans or conbinations of both to help control coolant temperature. These "add on" cooling system components must operate in proper sequence to prevent coolant temperature instability and/or engine overheating.

A badly adjusted operating sequence can also have a detrimental effect on the life of the "add on" components as well.

The following charts give the recommended normal temperature settings for various coolant temperature control devices. These settings should not be exceeded, since this will unnecessarily increase the engine coolant and lubricating oil temperature, possibly resulting in serious engine damage.

170°F THERMOSTAT



SHUTTERS ONLY

OPTIONAL SHUTTERS		SHUTTERS	
CLOSE	OPEN	CLOSE	OPEN
160°F / 71°C	165°F / 74°C	178° - 183°F / 81° - 84°C	185° - 190°F / 85° - 88°C

CLUTCH FAN ONLY

MODULATING FAN		ON/OFF FAN	
START ON	FULL ON	OFF	ON
180°F / 82°C	192°F / 89°C	178° - 183°F / 81° - 84°C	185° - 190°F / 85° - 88°C

CLUTCH FAN AND SHUTTER COMBINATION

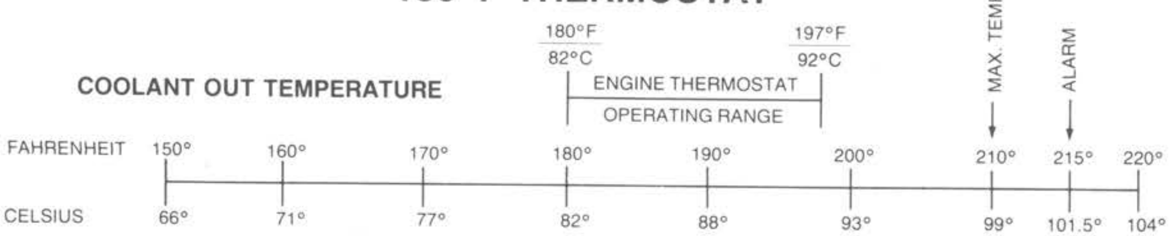
SHUTTERS		MODULATING FAN		ON/OFF FAN	
CLOSE	OPEN	START ON	FULL ON	OFF	ON
160°F / 71°C	165°F / 74°C	180°F / 82°C	192°F / 89°C	178° - 183°F / 81° - 84°C	185° - 190°F / 85° - 88°C

SHUTTER AND ON/OFF FAN CONTROL COMBINATION

SHUTTER CLOSED	FAN OFF	SHUTTER OPEN	FAN ON
178°F / 81°C	183°F / 84°C	185°F / 85°C	190°F / 88°C

CHART 1 – 170°F Thermostat

180°F THERMOSTAT



SHUTTERS ONLY

OPTIONAL SHUTTERS		SHUTTERS	
CLOSE	OPEN	CLOSE	OPEN
170°F / 77°C	175°F / 79.5°C	188° - 193°F / 87° - 89.5°C	195° - 200°F / 90.5° - 93°C

CLUTCH FAN ONLY

MODULATING FAN		ON/OFF FAN	
START ON	FULL ON	OFF	ON
190°F / 88°C	202°F / 94.5°C	188° - 193°F / 87° - 89.5°C	195° - 200°F / 90.5° - 93°C

CLUTCH FAN AND SHUTTER COMBINATION

SHUTTERS		MODULATING FAN		ON/OFF FAN	
CLOSE	OPEN	START ON	FULL ON	OFF	ON
170°F / 77°C	175°F / 79.5°C	190°F / 88°C	202°F / 94.5°C	188° - 193°F / 87° - 89.5°C	195° - 200°F / 90.5° - 93°C

SHUTTER AND ON/OFF FAN CONTROL COMBINATION

SHUTTER CLOSED	FAN OFF	SHUTTER OPEN	FAN ON
188°F / 87°C	193°F / 89.5°C	195°F / 90.5°C	200°F / 93°C

CHART 2 – 180°F Thermostat

WATER PUMP

6V-92 AND 8V-92 ENGINES

The centrifugal-type water pump circulates the engine coolant through the cylinder block, cylinder heads, radiator or heat exchanger and the oil cooler (Fig. 1).

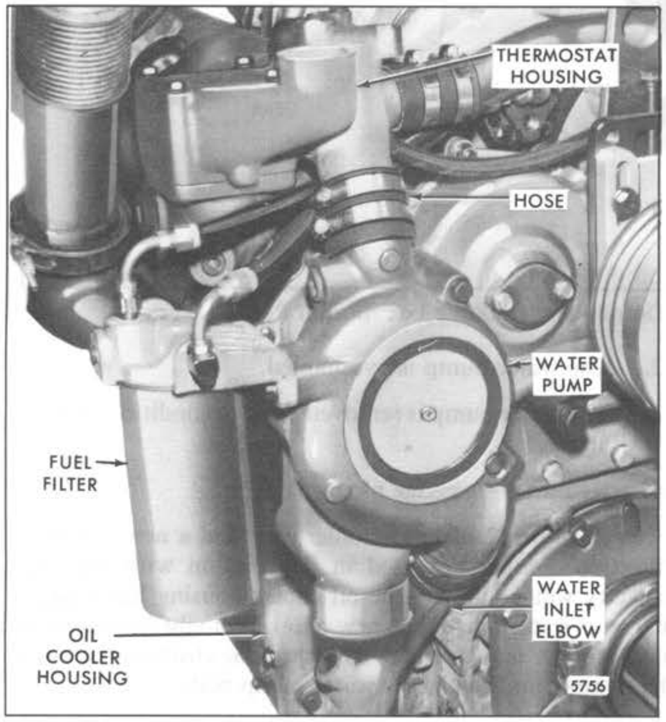


Fig. 1 – Water Pump Mounting (Former Cover with Spirolox Ring)

The pump is mounted on the engine front cover and is driven by the 66 tooth front camshaft gear (water pump drive). The water pump gear has 42 teeth and meshes with the water pump drive gear.

A bronze impeller is secured to one end of a stainless steel shaft by a locknut. The water pump gear is pressed on the opposite end of the shaft. Two ball bearings are used to carry the shaft. The larger bearing is used at the drive gear end of the shaft to accommodate the thrust load (Fig. 2 or 3).

An oil seal is located in front of the smaller bearing and a spring-loaded face type water seal is used behind the impeller.

Current engines use a higher capacity water pump which provides increased coolant circulation. The pump has a larger impeller, larger diameter inlet and outlet openings and a pump cover secured by a retaining ring.

New fresh water pumps with increased coolant flow and sealing characteristics have been released for use on engines using high-capacity pumps. The bodies of the new pumps incorporate a cast-in upper "dam" and cast-in seal cavity drain boss which act to divide incoming coolant flow and direct it more efficiently through the pump (Fig. 4). The "Y" drilled drain passage has been eliminated.

A new seal has been released for 6V 15° tilt coach engine fresh water pumps, effective with engine serial number 6VF-0103521. The new seal has a high grade carbon face, a stainless steel case and a shroud (Fig. 5). The former seal had a phenolic face, a brass case and no shroud. Because of its design, the new seal provides improved resistance to leakage even after high engine hours or mileage.

The former seal and the new seal are completely interchangeable and only the new seal will be available to service the fresh water pumps used on 6V 15° tilt coach engines.

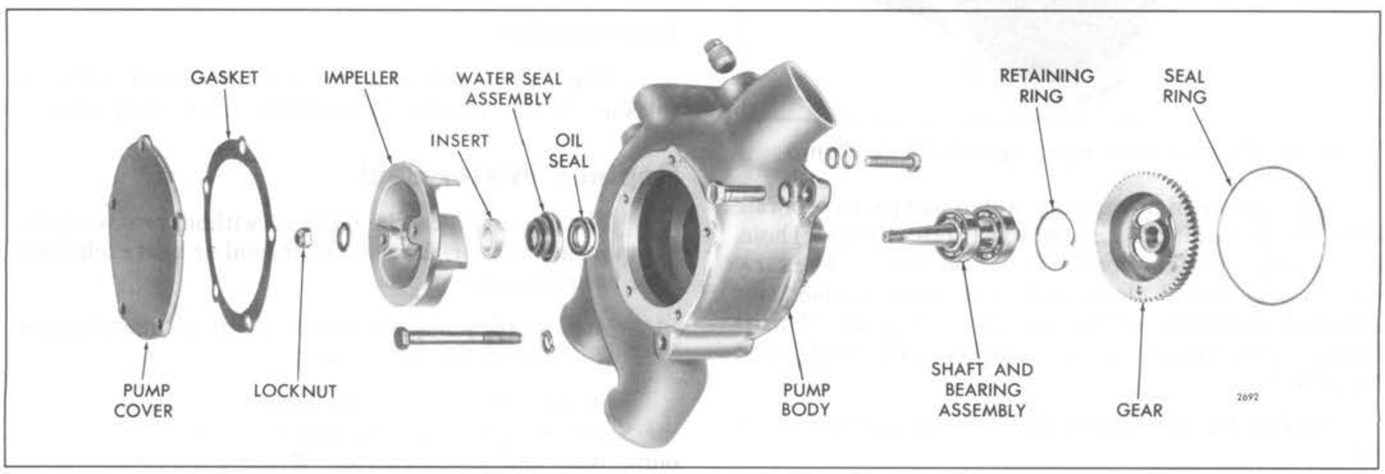


Fig. 2 – Former Water Pump Details and Relative Location of Parts

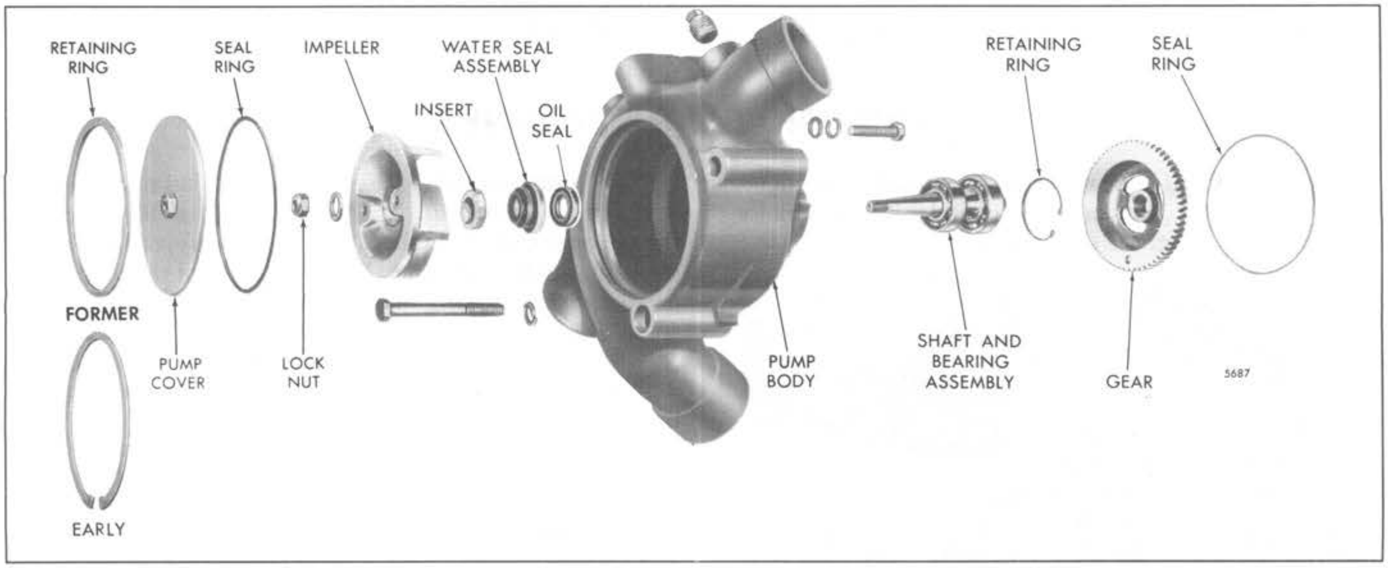


Fig. 3 – Current High–Capacity Water Pump Details and Relative Location of Parts

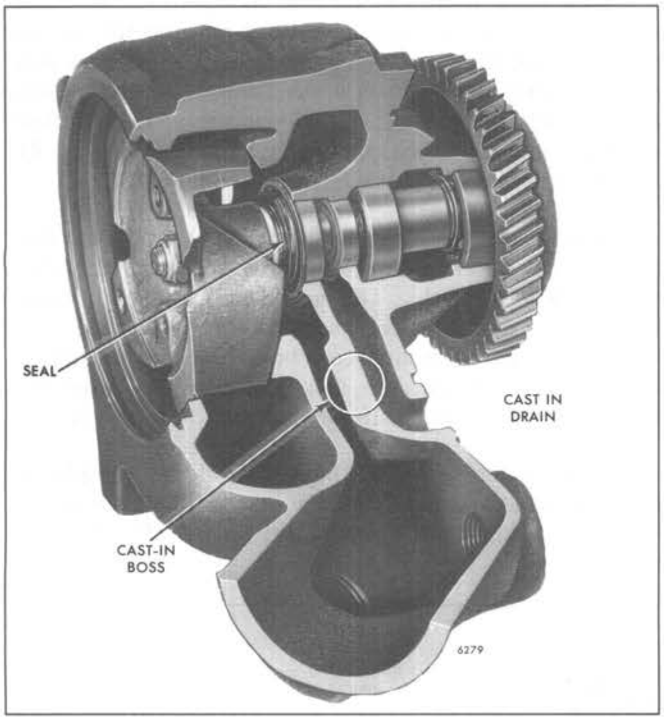


Fig. 4 – Divided Inlet High Capacity Water Pump

The former high–capacity water pumps incorporate bodies which permit the use of a large (5/16" diameter) hole, drilled straight into the bottom of the seal cavity. The early double–angle drilled drain hole has been retained for additional ventilation of the seal cavity (Fig. 6). This is effective with engine serial numbers 6VF–49834 and 8VF–46407.

Modify the early double angle drain hole (Section 5.0) when:

1. The water pump seal is replaced – 200,000 miles.
2. The water pump is overhauled.
3. The water pump is removed prior to conditions 1 and 2 above.
4. Required – passage plugged.

A 24 or 32 plate oil cooler core and a new camshaft vibration damper are used in conjunction with the high capacity water pump. The oil cooler housing has a larger diameter water inlet. The new crankshaft vibration damper has a smaller outside diameter to provide clearance between the damper and the larger water pump body.

In order to further improve the sealing of the water pump cover, a new non–metallic cover and a new scalloped retaining ring have been released (Fig. 7). The new ring is scalloped and will replace the former Spirolox ring. When used with the new ring, the new cover is completely interchangeable with the former cover and only the new cover and ring should be used to service water pumps.

Lubrication

The pump ball bearings are lubricated with oil splashed by the camshaft gear and the water pump gear.

Replace Water Seal

The water seal can be replaced without removing the pump if the radiator, fan and fan shroud or heat exchanger have been removed.

1. Remove the pump cover bolts, pump cover and gasket (Fig. 2). Discard the gasket.

On former high–capacity fresh water pumps, remove the Spirolox cover retaining ring from the groove in the pump body with a screwdriver. Remove the cover, but do not remove the seal ring.

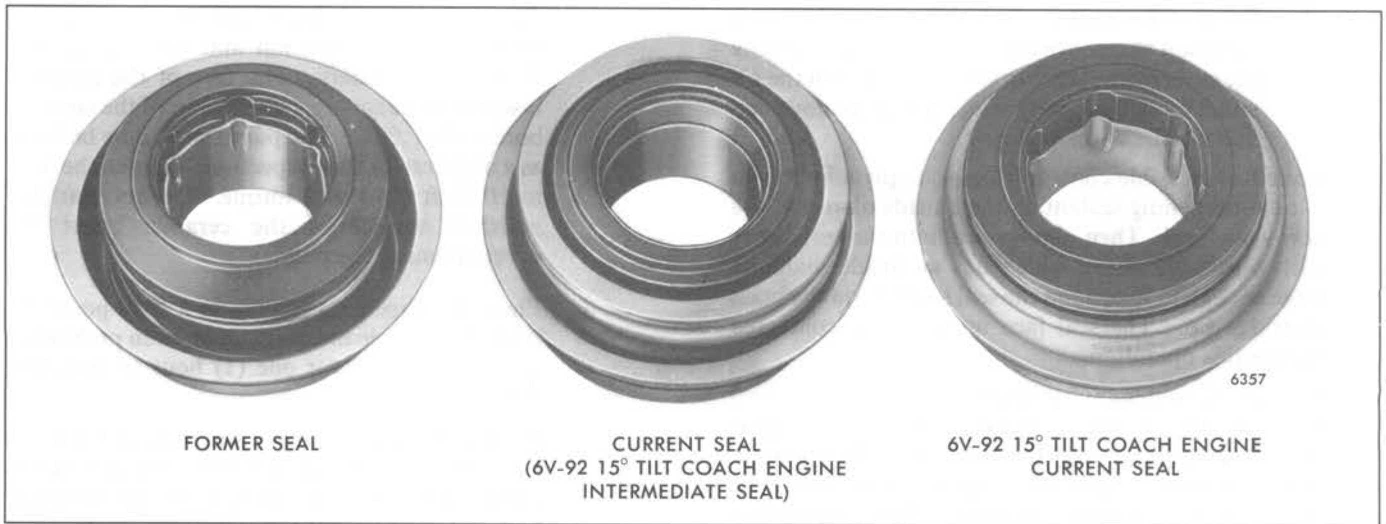


Fig. 5 – Water Pump Seals

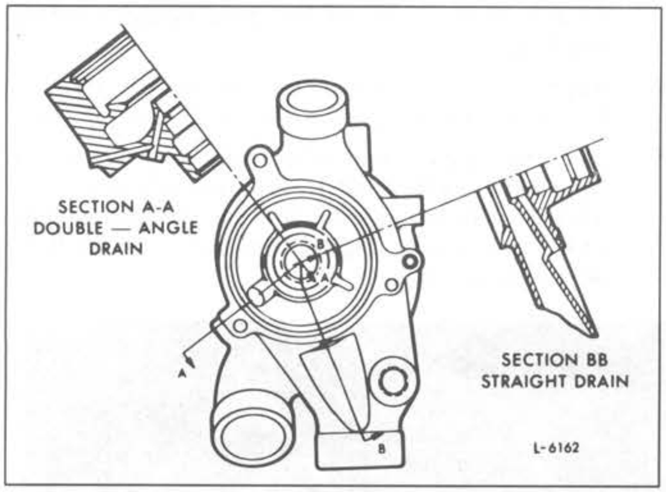


Fig. 6 – New Water Pump (6V–92 and 8V–92 Engines)

On early and current high–capacity fresh water pumps, use extreme care when removing or installing the early snap ring or the current scalloped cover retaining snap ring (Figs. 3 and 7). Remove the pump cover, but do not remove the seal ring.

CAUTION: Due to the size and tension of the ring, use snap ring pliers of a type to ensure maximum safety. Wear adequate eye protection, and press a hammer against the pump cover to help prevent personal injury should the snap ring slip off of the pliers.

The 1/4"–20 nut attached to the early and former front cover is provided to facilitate removal of the cover.

2. Remove the impeller locknut and washer and withdraw the impeller with puller J 24420–A.
3. On current seals use a channel lock type pliers to grasp the metal flange around the upper portion of the seal and twist it firmly so as to break the seal and boot assembly away from the case. Use care to avoid damaging the pump shaft during this operation.

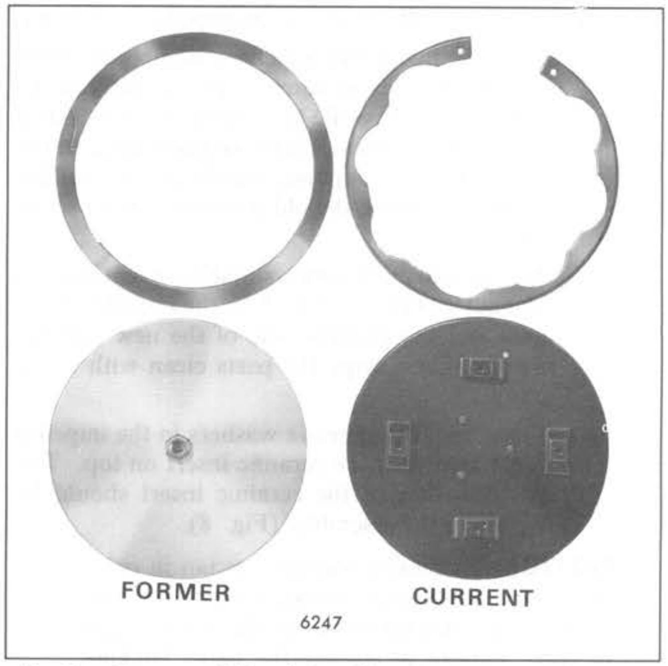


Fig. 7 – Cover and Retaining Ring (Former and Current)

4. Install the seal removal tool (J 22150–B) in the pump and secure it in place with the pump cover snap ring or bolts or retaining nuts. On the 6V and 8V high–capacity water pump, the cover seal ring should be left in place to avoid damage to the seal ring groove.
   a. Turn the puller shaft nut (J 22150–4) in a counterclockwise direction until the spears pierce the water seal case. Then, turn the puller shaft in a clockwise direction one eighth of a turn to lock the spears in place.

b. Rotate the puller shaft nut in a clockwise direction to remove the water seal. Disassembly the seal removal tool from the pump. On the 6V and 8V high–capacity water pump, remove and discard the cover seal ring.

5. To reduce possible coolant leakage, apply a light coat of non–hardening sealant on the outside diameter of a new water seal. Then, tap the seal into the seal cavity with a suitable sleeve which has an inside diameter large enough to fit around the seal and rest on the brass cartridge lip. The seal face must not be contacted during this operation.

6. Inspect the water pump impeller for wear (erosion) and reuse or replace, as required. If the impeller is reused, the ceramic impeller insert *must* be replaced. Never attempt to reuse the ceramic insert, regardless of its apparent condition. A worn ceramic insert may leak. Always replace the insert or impeller assembly (with insert) at time of water pump overhaul. Bond a new ceramic impeller insert to the impeller, as follows:

   a. Bake the insert and impeller assembly at 500°F (260°C) for 90 minutes. The insert can be removed easily while the adhesive is hot. After removing the insert, clean the insert area on the impeller with sandpaper, wire brush or a buffing wheel to remove the old adhesive, oxide, scale, etc.

   b. Wet a clean cloth with a suitable solvent such as alcohol and thoroughly clean the impeller insert area and the grooved side of the new ceramic insert. Then, wipe the parts clean with a dry cloth.

   c. Place Two (2) adhesive washers in the impeller bond area with the ceramic insert on top. The polished face of the ceramic insert should be visible to the assembler (Fig. 8).

NOTICE: Adhesive washers are tan in color but have a white paper backing which *must* be removed and discarded before the washers can be used. Failure to remove the paper backing will result in a weak or ineffective bond between the insert and impeller.

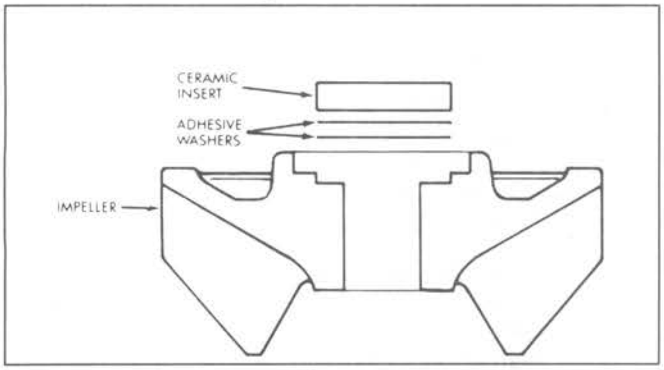


Fig. 8 – Insert, Adhesive Washer, Impeller Stackup

Clamp the ceramic insert and impeller together with a 3/8" bolt and nut and two (2) *smooth* .125" thick washers. The face of the ceramic insert must be square with the axis of the tapered bore within .004". The pump shaft may be used as a mandrel for this inspection. Tighten the bolt to 10 lb–ft (14 N•m) torque. Do not mar the polished surface of the ceramic insert by overtightening the bolt.

   d. Place the impeller assembly in a *level* position, with the ceramic insert up, in an oven preheated to 350°F (177°C) for one (1) hour to cure the adhesive.

   e. Remove the impeller from the oven and, after it has cooled to room temperature, install it in the pump. Do not loosen or remove the clamping bolt and washers until the assembly cools.

7. Make sure the mating surfaces of the water seal and the ceramic insert are free of dirt, metal particles and oil film (Fig. 2).

8. Apply a small quantity of International Compound No. 2, or equivalent, to the threads of the pump shaft.

9. Place the impeller and washer on the shaft and start a new locknut on the shaft. Hold the pump gear securely while drawing the impeller down on the tapered shaft with the locknut. Tighten the nut to 35–40 lb–ft (47–54 N•m) torque.

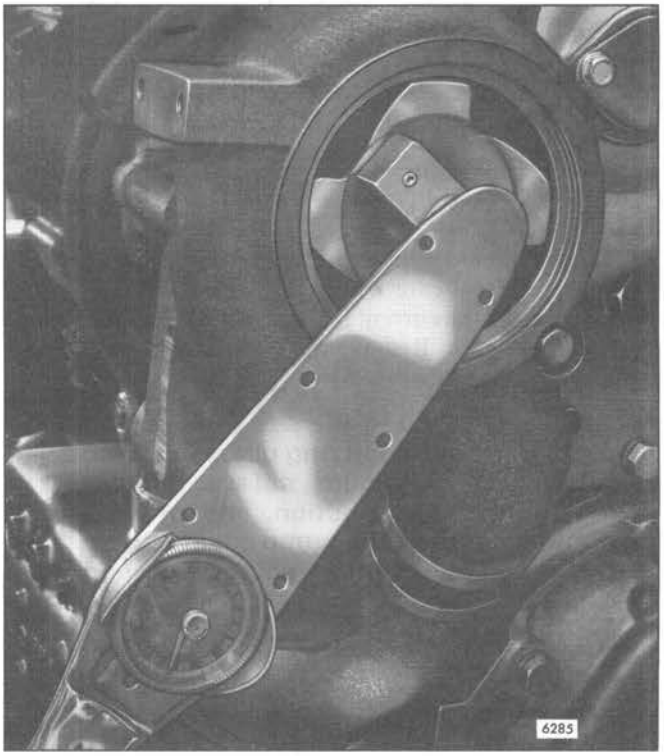


Fig. 9 – Checking Impeller and Gear Slip Torque with Tool J 33765

10. Check the water pump impeller and gear *slip torque,* as follows (Fig. 9):

a. Scribe a line across the impeller, nut and shaft.

b. Attach adaptor J 33765 to an accurately calibrated torque wrench.

c. Insert the dowel pins of the adaptor into the impeller puller holes and apply a torque of 80 lb–ft (108 N•m). Some slight movement of the crankshaft may be detected during this operation until the next cylinder in the firing order comes up on compression.

d. If slippage is felt, examine the marks scribed across the impeller and shaft. If the marks are no longer in alignment, the impeller has turned on the shaft. If the marks are still in alignment, the gear has turned on the shaft. In either case, remove the pump from the engine.

e. Replace the shaft, along with either the gear or impeller that has turned on the shaft, and bench test the completed pump assembly. (Refer to *Assembly Pump*).

11. Loosen the clamps and remove the hose from the water outlet opening of the pump.

12. Insert a feeler gage into the water outlet opening of the pump. The minimum clearance between the impeller and the pump body must be .015".

13. Use a new gasket and install the former water pump cover. The water pump cover on former pumps is secured by cadmium plated bolts with nylon inserts to prevent water leakage. Inspect them carefully to make sure the nylon inserts are in place and protrude sufficiently beyond the threads. *Under no circumstances should a standard bolt be used.* Tighten the nuts or bolts securely.

Install the water pump cover and retaining ring, as follows (Fig. 3):

a. Remove the seal ring and clean the seal ring groove of any rust or pitting.

b. Install a new seal "O" ring in the seal ring groove in the pump body.

c. Install the water pump cover making sure the seal ring is properly seated in the groove.

d. Spread the end of the retaining ring and feed it into the retaining groove in the pump body, preceeding in a clockwise direction until both layers are completely into the groove.

e. With a plastic or wooden mallet strike the pump cover at the *12:00, 9:00, 6:00 and 3:00 o'clock* positions. This will allow the retaining ring to spread into the groove. Repeat the operation several times.

f. Now strike the retaining ring outward (with the plastic or wooden mallet) starting with the visible end of the ring and proceeding in a counterclockwise direction. Strike around the circumference of the ring 2 or 3 times until the ring fully seats in the groove. The retaining ring is fully seated when 3/16" or less of the ring, measured radially, is visible.

14. Install and secure the hose on the water outlet opening with the clamps.

Remove Pump

1. Refer to Section 5 and drain the cooling system.

2. Remove the radiator, fan shroud and fan or heat exchanger, if necessary.

3. Loosen the hose clamps and remove the hoses from the pump body.

4. Remove the pump body–to–engine front cover mounting bolts and detach the pump. Use care to prevent damage to the gear teeth when disengaging the pump gear from the front camshaft gear (water pump drive gear).

Disassemble Pump

1. Turn the pump gear so the slot is over the ends of the bearing retaining ring, insert pliers J 4646 into the slot and, with the aid of a small screwdriver, remove the ring from the groove (Fig. 10).

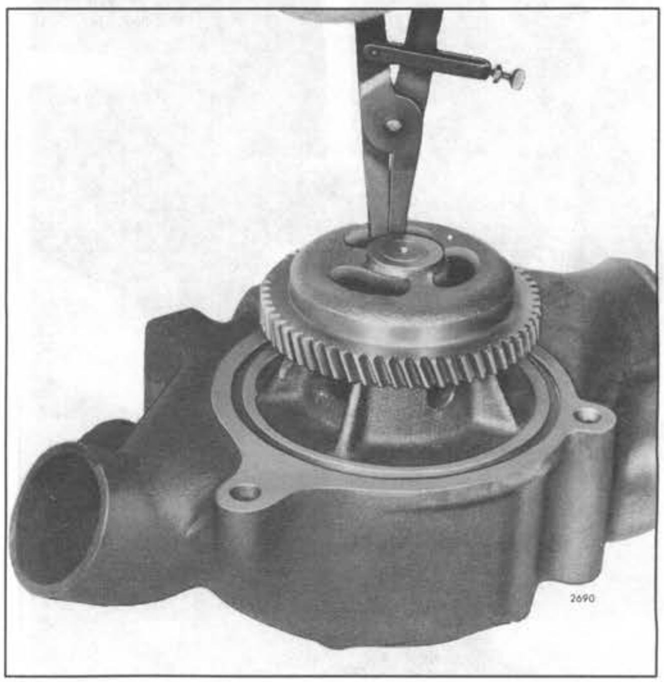


Fig. 10 – Removing Retaining Ring using Tool J 4646

2. Remove the pump cover, as outlined in *Replace Water Seal*.

3. Hold the gear securely and remove the impeller locknut and washer.

   NOTICE: While holding the gear, use care to prevent damage to the gear teeth.

4. Use puller J 24420–A to remove the impeller.

5. Press the shaft, bearings and pump gear assembly out of the pump body.

6. Place the gear on the bed of an arbor press with the shaft extending downward, then place a short piece of .625" diameter bar stock between the shaft and the ram of the press and press the shaft out of the gear (Fig. 11).

7. Support the shaft assembly on the inner race of the larger bearing with the threaded end down. Place flat stock between the ram of the press and the shaft and press the pump shaft out of the large bearing.

8. Invert the shaft, support it on the inner race of the small bearing and repeat the process described in Step 7.

9. If necessary, remove the water seal as described under *Replace Water Seal*.

10. Push the oil seal out of the pump body.

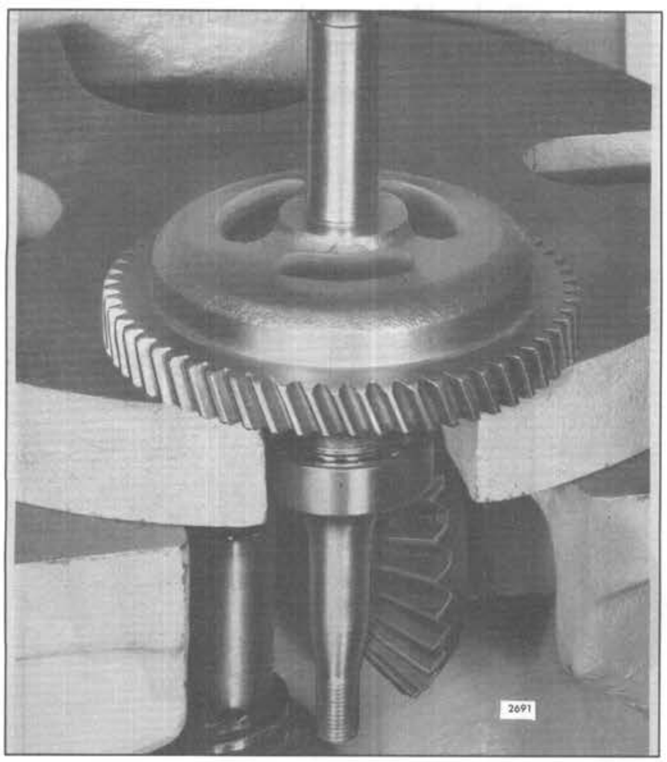


Fig. 11 – Pressing Shaft Out of Gear

New seals and a new ceramic impeller insert must be used each time the water and oil seals are removed or at water pump overhaul.

Inspection

Wash all of the pump parts in clean fuel oil and dry them with compressed air.

CAUTION:To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.

Inspect parts for cracks, wear or other damage. Replace damaged or worn parts. A new ceramic insert must be used. Refer to *Replace Water Seal*.

Make sure the drilled "Y" passage in the pump body is clear of any obstruction. Use the following procedure.

1. Mount a spring from a front crankshaft seal or an equivalent tool into a 1/4" drill motor.

2. Mark the spring with tape at 3 3/4" from the end.

   NOTICE: The measurements given in Steps 2 and 3 do not include the installed length of the 5/16" O.D. tube in the modified pumps. Add tube protrusion measurement to these dimensions (3 3/4" and 2 9/16").

3. Insert the spring into the drain hole and drill. At 2 9/16" into the passage, some resistance will be felt as the spring negotiates the corner of an intersecting passage. If the spring cannot be inserted to the 3 3/4" depth, the passage must be cleaned and modified using the "modification procedure" (see Section 5.0).

   NOTICE: The drain hole cleaning procedure just outlined should be continued after the 200,000 mile seal replacement interval is reached and/or the water pump is disassembled and modified.

The bearings should be examined for corrosion, pitting, wear and freedom of movement. Apply engine oil to the bearings, hold the inner race and slowly revolve the outer race to check for roughness. Replace the bearings, if necessary. When replacing an inner or outer bearing always replace the other bearing.

Assemble Pump

1. Lubricate the bearing bores and shaft bearing surfaces. Use bearing and gear installer J 25257 and install the bearings on the shaft (Fig. 12). Apply pressure to the inner races of the bearings only during assembly on the shaft.

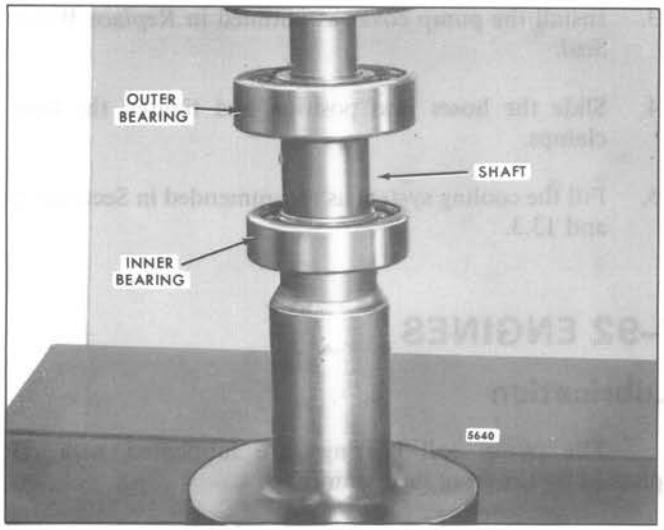


Fig. 12 – Pressing Bearing on Pump Shaft using Tool J 25257

2. Apply a film of engine oil to the sealing lip of the oil seal and the lip contact surface of the shaft. Then, insert the seal, spring loaded lip toward the gear end of the pump body. With Tool J 8501 (oil seal installer), tap the seal into place. The oil seal must be flush with the water seal counterbore in the pump body.
3. Support the pump body on the bed of an arbor press with the cover side down. Then, press the shaft and bearing assembly in place by applying pressure on the outer race of the large bearing. Take care not to damage the oil seal with the threaded end of the shaft.
4. Install the bearing retaining ring.
5. With gear installer J 25257 positioned on the impeller end of the shaft, place the gear between the shaft and the ram of the press (Fig. 13). Press the gear on the shaft so it is flush with the end of the shaft. Tool J 25257 will hold the shaft vertically to ensure the gear is pressed squarely on the shaft.

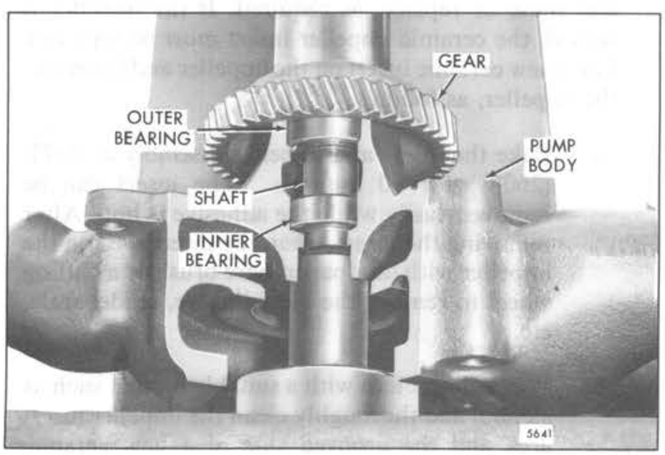


Fig. 13 – Pressing Gear on Pump Shaft using Tool J 25257

6. Place the pump body on the bed of an arbor press. To prevent possible coolant leakage, apply a light coat of non–hardening sealant on the outside diameter of a new water seal. Then, insert the seal in the cavity in the pump body and, with a sleeve large enough to fit around the seal and resting on the brass cartridge lip, press the seal into place.
7. Make sure the mating surfaces of the water seal and the ceramic insert are free of dirt, metal particles and oil film.
8. Apply a small quantity of International Compound No. 2, or equivalent, to the threads of the pump shaft.
9. Place the impeller washer and new locknut on the shaft. Hold the pump gear securely while drawing the impeller down on the tapered shaft with the locknut. Tighten the nut to 35–40 lb–ft (47–54 N•m) torque.

   NOTICE: Do not damage the gear teeth while holding the gear.

10. Check the water pump impeller and gear *slip torque*, as follows:
    a. Scribe a line across the water pump gear and shaft.
    b. Scribe a second line across the impeller, nut and shaft.
    c. Attach adaptor J 33765 onto an accurately calibrated torque wrench.
    d. With the water pump drive gear securely held in the brass jaws of a vise, insert the adaptor dowel pins into the impeller puller holes and apply a torque of 80 lb–ft (108 N•m).
    e. If slippage is felt, remove the pump from the vise and examine the scribed marks. Determine whether the gear or the impeller has turned on the shaft. In either case the shaft must be replaced, along with the component that has turned.
    f. After replacing the necessary parts, retest the completed pump assembly.
11. Insert a feeler gage into the water outlet opening of the pump. The clearance between the impeller and the water pump body must be .015" minimum.
12. Install the hose on the water outlet opening and secure it with clamps.

Install Pump On Engine

1. Affix the seal ring to the pump body. Mount the pump on the engine so the pump gear meshes with the camshaft gear. Install and tighten the mounting bolts.

2. Check the gear backlash by installing bolts, or equivalent, in the impeller puller holes. Measure the backlash with an indicator at that point. The gear backlash setting should be .001" to .006" when measured in this manner. When the specified backlash reading cannot be obtained, loosen the pump attaching bolts and pivot the pump at the dowel as required to obtain the proper lash adjustment. Retighten the mounting bolts.

3. Install the pump cover as outlined in *Replace Water Seal*.

4. Slide the hoses into position and tighten the hose clamps.

5. Fill the cooling system as recommended in Sections 5 and 13.3.

12V–92 AND 16V–92 ENGINES

The centrifugal–type water pump is mounted on the front engine cover and is driven by the right front camshaft gear (water pump drive) – (Fig. 14). The pump circulates engine coolant through the cylinder block, cylinder heads, radiator or heat exchanger and the oil cooler.

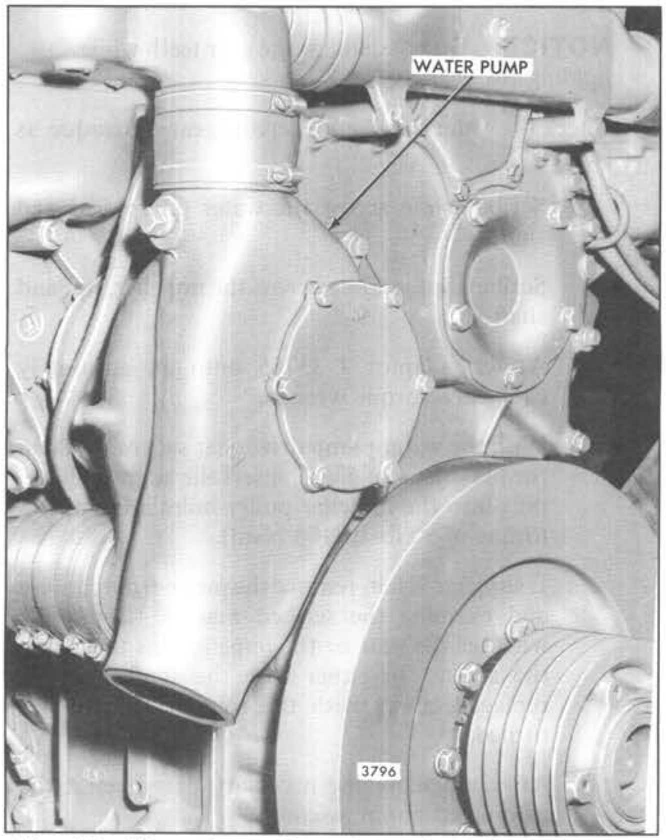


Fig. 14 – Water Pump Mounting (12V–92 and 16V–92 Engine)

The pump consists of a bronze impeller secured to a stainless steel shaft with a locknut. A gear is pressed on the opposite end of the shaft and the shaft turns on two ball bearings which are supported in a bearing and water and oil seal container. The container is secured to the pump housing with nuts and washers on studs installed in the pump body. An oil seal is used ahead of the front bearing and a spring–loaded face type water seal is used in back of the impeller.

Lubrication

The pump ball bearings are lubricated with oil splashed by the front gear train.

Replace Water Seal Assembly

The water seal assembly may be replaced without removing the pump if the fan, fan shroud and radiator or heat exchanger have been removed.

1. Remove the pump cover, gasket and deflector ring (Fig. 15).

2. Loosen and remove the impeller locknut and washer. Use puller J 24420–A to withdraw the impeller.

3. Grasp the water seal assembly with suitable pliers and pull the seal out of the retainer.

4. To reduce possible coolant leakage, apply a light coat of non–hardening sealant on the outside diameter of a new water seal. Then, tap the seal in the seal cavity with a suitable sleeve, with an inside diameter large enough to fit around the seal and rest on the brass cartridge lip.

5. Inspect the water pump impeller for wear (erosion) and reuse or replace, as required. If the impeller is reused, the ceramic impeller insert *must* be replaced. Use a new ceramic insert on the impeller and bond it to the impeller, as follows:

   a. Bake the insert and impeller assembly at 500°F (260°C) for 90 minutes. The insert can be removed easily while the adhesive is hot. After removing the insert, clean the insert area on the impeller with sandpaper, wire brush or a buffing wheel to remove the old adhesive, oxide, scale, etc.

   b. Wet a clean cloth with a suitable solvent such as alcohol and thoroughly clean the impeller insert area and the grooved side of a new ceramic insert. Then, wipe the parts with a clean dry cloth.

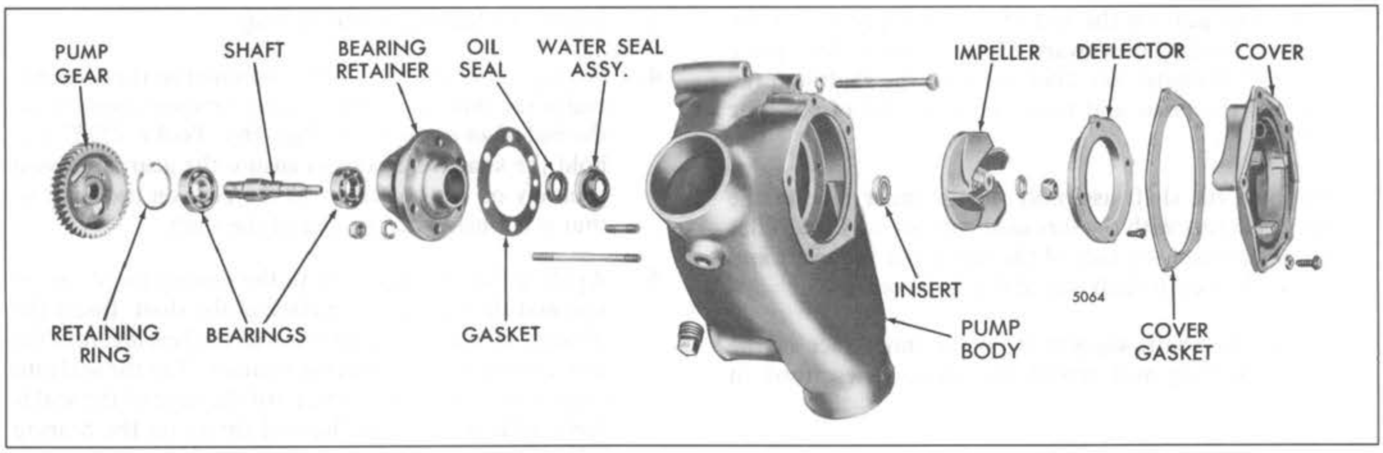


Fig. 15 – Water Pump Details and Relative Location of Parts

c. Place the adhesive washer in the impeller bond area with the ceramic insert on top. The polished face of the ceramic insert should be visible to the assembler (Fig. 8).

Clamp the ceramic insert and impeller together with a 3/8" bolt and nut and two *smooth* .125" thick washers. Tighten the bolt to 10 lb–ft (14 N•m) torque.

NOTICE: Do not mar the polished surface of the ceramic insert.

d. Place the impeller assembly in a *level* position, with the ceramic insert up, in an oven preheated to 350°F (177°C) for one hour. The face of the ceramic insert must be square with the axis of the tapered bore within .004". The pump shaft may be used as a mandrel for this inspection.

e. Remove the impeller from the oven and, after it has cooled to room temperature, install it in the pump. Do not loosen and remove the clamping bolt and washers until the assembly cools.

6. Make sure the mating surfaces of the water seal assembly and the ceramic insert are free of dirt, metal particles and oil film (Fig. 15).

7. Apply a small quantity of International Compound No. 2, or equivalent, to the threads of the pump shaft.

8. Place the impeller and washer on the shaft and start a new locknut on the shaft. Hold the pump gear securely while drawing the impeller down on the tapered shaft with the locknut. Tighten the nut to 35–40 lb–ft (47–54 N•m) torque.

9. Secure the impeller deflector ring to the pump body. Be sure the four 1/4"–20 x 5/8" screws are staked securely at three places.

10. Affix a new gasket and install the pump cover. Tighten the nuts securely.

Remove Pump

1. Drain the engine cooling system (Section 5).

2. If necessary, remove the radiator, fan shroud and fan or heat exchanger.

3. Remove the pump cover.

4. Loosen the hose clamps and remove the hoses.

5. Remove the nuts and lock washers from the rear bearing support cover–to–end plate studs, then remove the bolts and copper washers.

6. Grasp the pump firmly and remove the two pump body to engine front cover bolts and lock washers. Use caution to prevent damage to the gear teeth and detach the water pump.

Disassemble Pump

1. Remove the impeller deflector ring.

2. Turn the pump gear so the slot is over the ends of the bearing retaining ring, insert pliers J 4646 into the slot and, with the aid of a small screwdriver, remove the ring from the groove (Fig. 10).

3. Hold the gear securely and remove the impeller locknut and washer.

NOTICE: While holding the gear, use care to prevent damage to the gear teeth.

4. Use puller J 24420–A to remove the impeller.

5. Remove the bearing retainer from the pump body.

6. While supporting the bearing and seal retainer, tap the threaded end of the shaft lightly with a soft hammer to separate the shaft and bearing assembly from the retainer.

7. Place the gear on the bed of an arbor press with the shaft extending downward. Then, place a short piece of .625" diameter bar stock between the shaft and the ram of the press and press the shaft out of the gear (Fig. 11).

8. Support the shaft assembly on the inner race of the large bearing with the threaded end down. Place a flat plate between the ram of the press and the shaft and press the pump shaft out of the large bearing.

9. Invert the shaft, support it on the inner race of the small bearing and repeat the process described in Step 7.

10. The water seal may be pryed out of the bearing retainer with a screwdriver, if necessary.

11. Push the oil seal out of the retainer.

New seals and a new ceramic impeller insert must be used each time the water and oil seals are removed or at water pump overhaul.

Inspection

Wash all of the pump parts in clean fuel oil and dry the parts with compressed air.

CAUTION: To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.

Inspect them for cracks, damage or wear. Replace damaged or worn parts. A new ceramic insert must be used. Refer to *Replace Water Seal Assembly*.

The bearings should be examined for corrosion, pitting, wear and freedom of movement. Apply engine oil to the bearings. Hold the inner race and slowly revolve the outer race to check for roughness. Replace the bearings, if necessary.

Assemble Water Pump

1. Lubricate the bearing bores and shaft bearing surfaces. Use bearing and gear installer J 25257 and press the bearings against the shoulders on the shaft (Fig. 12). Apply pressure to the inner races of the bearing only during assembly on the shaft.

2. Support the bearing retainer on the bed of an arbor press, water seal end down. Then, press the shaft and bearing assembly into the retainer. Apply pressure to the outer race of the large bearing when installing the shaft and bearing assembly in the retainer.

3. Install the bearing retaining ring.

4. With gear installer J 25257 positioned on the threaded end of the shaft, place the bearing retainer assembly on the bed of an arbor press (Fig. 16). Tool J 25257 will hold the shaft vertically to ensure the gear is pressed squarely on the shaft. Press the gear on the shaft so that it is flush with the end of the shaft.

5. Apply a film of engine oil to the sealing lip of the oil seal and the lip contact surface of the shaft. Insert the oil seal, spring loaded lip towards the bearing, into the water seal end of the bearing retainer. Tap the seal into place with a suitable sleeve until the edge of the seal is flush with the edge of the seal cavity on the bearing side.

6. To reduce possible coolant leakage, apply a light coat of non–hardening sealant to the outside diameter of a new water seal. Then, press the seal in place with a suitable sleeve, with an inside diameter large enough to fit around the seal and resting on the brass cartridge lip (Fig. 17).

7. Make sure the mating surfaces of the water seal and the ceramic insert are free of dirt, metal particles and oil film.

8. Affix a new gasket and install the bearing retainer with six lock washers and nuts. Tighten the nut.

9. Apply a small quantity of International Compound No. 2, or equivalent, to the threads of the pump shaft.

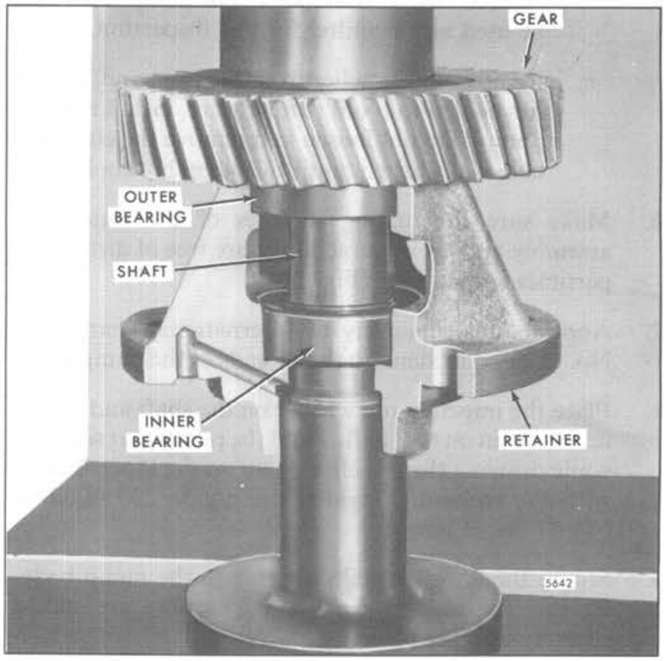


Fig. 16 – Pressing Gear on 12V–92 and 16V–92 Water Pump Shaft using Tool J 25257

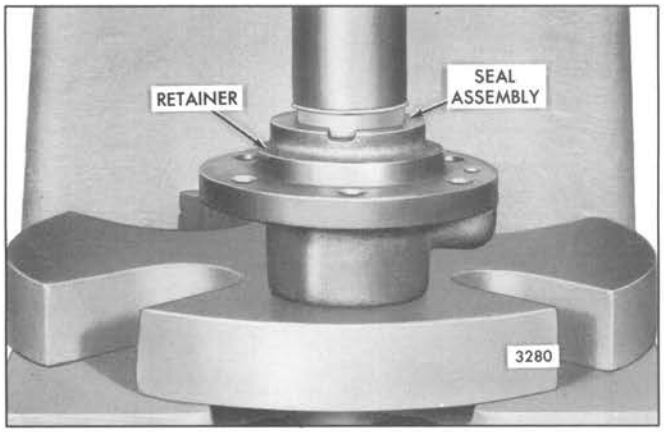


Fig. 17 – Installing Water Seal Assembly

10. Install the impeller and washer on the shaft and start a new locknut on the shaft. Hold the gear securely while drawing the impeller down on the tapered shaft with the locknut. Tighten the nut to 35–40 lb-ft (47–54 N•m) torque.

    NOTICE: Do not damage the gear teeth while holding the gear.

11. Secure the impeller deflector ring to the pump body. Be sure the four 1/4"-20 x 5/8" screws are staked securely at three places.

Install Water Pump On Engine

1. Place a new gasket on the pump body.
2. Position the pump and slide the long studs into the holes in the front cover. Make sure the pump gear and camshaft gear teeth are engaged correctly.
3. Install the pump body–to–engine front cover bolts and lock washers.
4. Secure the nuts and lock washers on the water pump body studs that extend through the front cover. Then, install the two (2) bolts and lock washers from the back side of the end plate.
5. Replace the hoses and secure them with clamps.
6. Check the gear backlash (clearance) between the water pump gear and the camshaft gear by installing bolts, or equivalent, in the impeller puller holes and measuring the lash with an indicator at that point. The gear lash setting should be .001" to .006" when measured in this manner.
7. Install the water pump cover and a new gasket on the water pump. Position the cover, as indicated by the word "TOP" which is cast on the cover.
8. Replace all of the engine parts which were removed to facilitate pump removal.
9. Refill the cooling system, as recommended in Sections 5 and 13.3.

WATER MANIFOLD

The 6 and 8V engines do not require external water manifolds. All 12 and 16V engines are equipped with external water manifolds (one per cylinder head).

Coolant, leaving the cylinder head through an opening directly over each exhaust port, enters the water manifold which is attached to the cylinder head with two studs, lock washers and nuts at each of the water openings. A separate gasket is used at each attaching flange between the manifold and cylinder head.

A four–leg manifold has replaced the former six–leg manifold. Only the new manifold will be serviced. The reduction of two legs has no detrimental effect upon engine cooling. However, when replacing the old manifold by the new, two plates, gaskets and four 3/8"–16 x .88" bolts to seal the unused openings in the cylinder head must be added. Tighten these bolts to 20–25 lb–ft (27–34 N•m) torque.

Remove Water Manifold

1. Drain the cooling system, to the level necessary, by opening the cylinder block drain cocks.

   CAUTION: To avoid being burned by the hot liquid, allow the engine to cool before draining the coolant.

2. Loosen the seal clamp at the front end of the water manifold. Then slide the seal over the neck of the thermostat housing or the water manifold.

3. Remove the water manifold attaching nuts and lock washers and lift the manifold off of the cylinder head.

4. Remove and discard the water manifold gaskets.

Install Water Manifold

1. Install new water manifold gaskets.

2. Attach the water manifold to the cylinder head with the lock washers and nuts. Tighten the nuts to 20–25 lb–ft (27–34 N•m) torque.

3. Slide the seal onto the outlet end of the water manifold and secure the seal with the clamp.

4. Fill the cooling system to the proper level.

THERMOSTAT

The temperature of the engine coolant is automatically controlled by a thermostat located in a housing attached to the water outlet end of each cylinder head. Blocking type thermostats (Fig. 1 or 3) are used when a standard cooling system is employed; semi-blocking type thermostats (Fig. 2) are used with the rapid warm-up cooling system. Two thermostats are employed in 6 and 8V engines; four thermostats are used in the 12 and 16V engines.

Operation

At coolant temperatures below 160°-180°F (71°-82°C) depending upon the thermostat used - the valves remain closed and block the flow of coolant to the radiator. During this period, all of the coolant in the standard system is circulated through the engine and is directed back to the suction side of the water pump via the bypass tube. In the rapid warm-up system enough coolant to vent the system is bypassed to the radiator top tank by means of a separate external deaeration line and then back to the water pump without going through the radiator cores. As the coolant temperature rises above 160°-180°F (71°-82°C), the thermostat valves start to open, restricting the bypass system, and permit a portion of the coolant to circulate through the radiator. When the coolant temperature reaches approximately 185°-197°F (85°-92°C) the thermostat valves are fully open, the bypass system is completely blocked off and all of the coolant is directed through the radiator.

NOTICE: Engines using shutters and equipped with 180°-197°F (82°-92°C) thermostats may have an effect on the operation of the shutters.

A defective thermostat which remains closed, or only partially open, will restrict the flow of coolant and cause the engine to overheat. A thermostat which is stuck in a full open position may not permit the engine to reach its normal operating temperature. The incomplete combustion of fuel due to cold engine operation will result in excessive carbon deposits on the pistons, rings and valves.

Properly operating thermostats are essential for efficient operation of the engine. If the engine operating temperature deviates from the normal range of 160°-197°F (71°-92°C), the thermostats should be removed and checked.

NOTICE: There are areas where approved fuel (less than 0.5% sulfur) is not commercially available or economically feasible to obtain. It is important to keep the engine cooling system temperature of these engines on the high side of normal to prevent the condensation of sulfur trioxide gas, which comb ines with combustion water to form sulfuric acid. Therefore, install a 180° or 190° F (82° or 88° C) temperature thermostat and modify the cooling system to provide rapid warm-up in order to maintain coolant temperature at a minimum of 175° F (80°C).

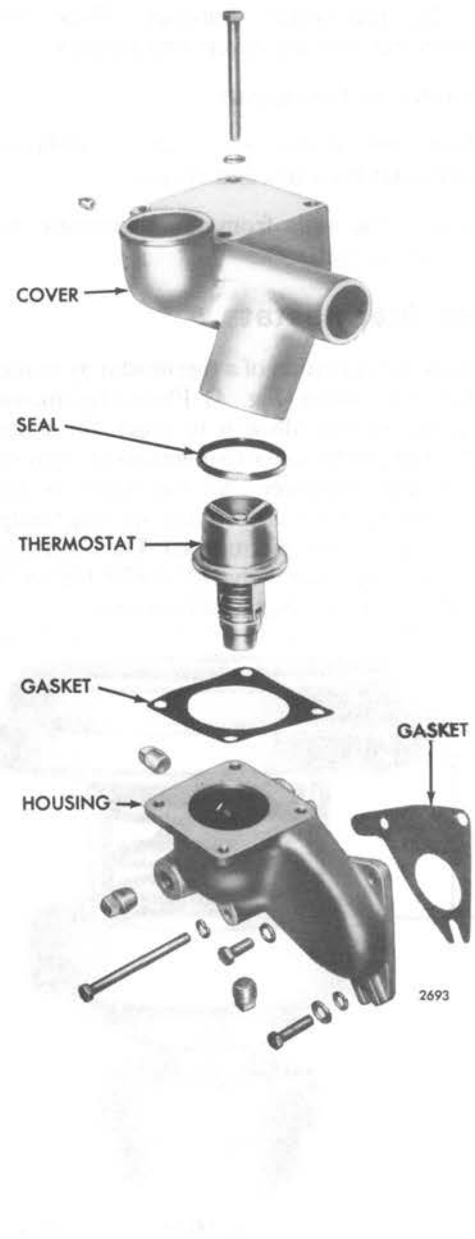


Fig. 1 - Typical Thermostat Housing and Relative Location of Parts

Remove Thermostat

Refer to Fig. 1 and remove the thermostats as follows:

1. Drain the cooling system to the necessary level by opening the drain cocks, or removing the drain plugs on the cylinder block.
2. Loosen the hose connections and remove the bypass (cross–over) tube. Then loosen the hose connections between the water pump and the right bank thermostat housing cover.
3. Remove the bolts and lock washers securing the covers to the thermostat housings. Then remove the thermostat housing covers and gaskets.
4. Remove the thermostats.
5. Clean the thermostat seating surfaces in the thermostat housings and covers.
6. Remove the seals from the thermostat covers and discard the seals.

Inspect Thermostat

Check the operation of a thermostat by immersing it in a container of hot water (Fig. 4). Place a thermometer in the container, but do not allow it to touch the bottom of the container. Agitate the water to maintain an even emperature throughout the container. As the water is heated, the thermostat should begin to open (the opening ttemperature is usually stamped on the thermostat). The thermostat should be fully open at approximately 185°–197°F (85°–92°C). Allow at least 10 minutes for thermostat to react.

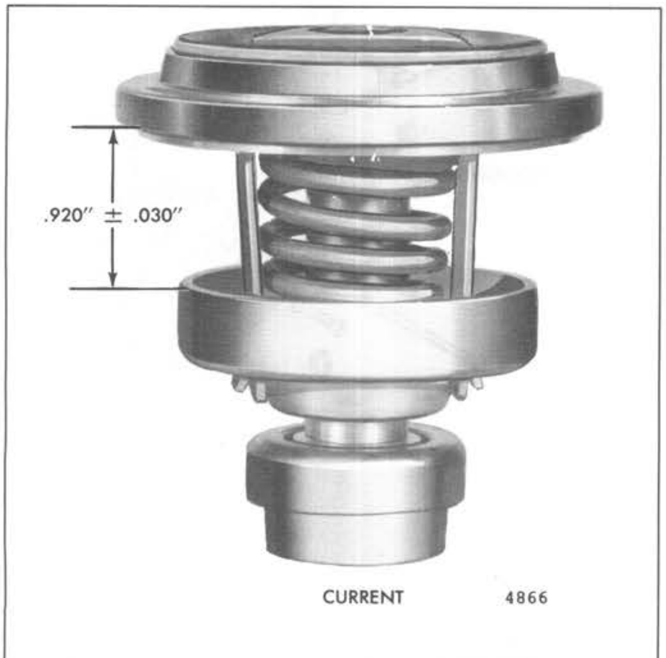


Fig. 2 – Semi–Blocking (Shielded) Type Thermostat

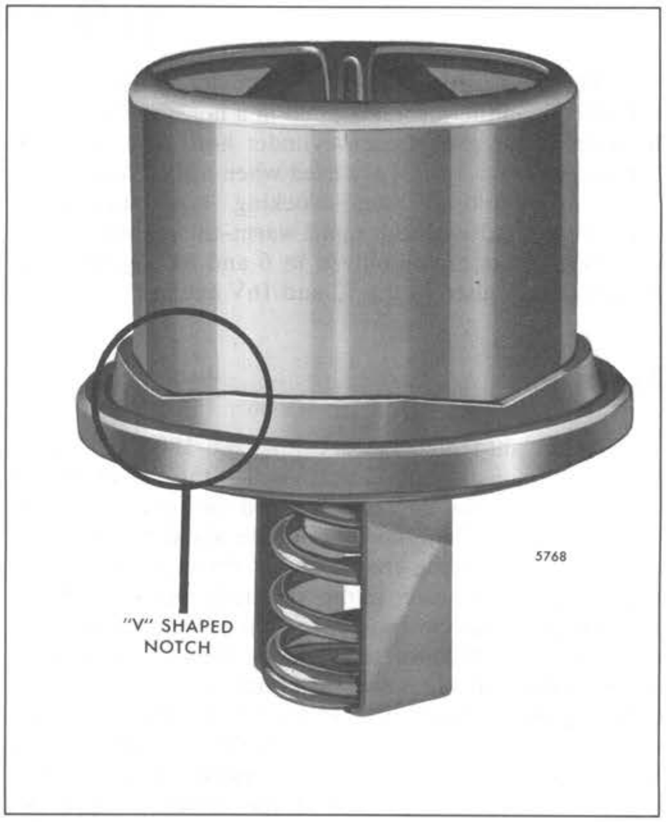


Fig. 3 – Weir Type Thermostat

Install Thermostat

1. Install new seals in the thermostat housing cover with installer J 8550 and driver handle J 7079–2. Position the seal so that the lip of the seal faces up (away from the thermostat) when the cover is installed on the thermostat housing. The seal installing tool assures that the seal is positioned the correct distance from the bottom face of the cover and parallel with the cover face.
2. Place a new gasket on the thermostat housing.
3. Set the thermostats in the thermostat housing.
4. Attach the covers to the thermostat housings with bolts and lock washers. Tighten the 3/8"–16 bolts to 30–35 lb–ft (41–47 N•m) torque.
5. Slide the hose in place between the water pump and the right bank thermostat housing cover. Tighten the clamps.
6. Install the bypass (cross–over) tube and tighten the hose clamps.
7. Close the drain cocks in the cylinder block. Then fill the cooling system.
8. Start the engine and check for leaks.

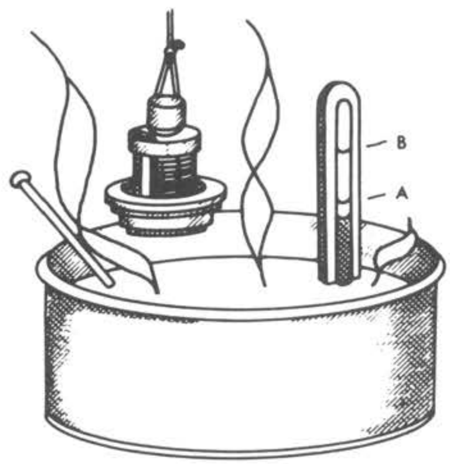


Fig. 4 – Method of Checking Thermostat Operation

RADIATOR

On some engines, the temperature of the coolant circulating through the engine is lowered by the action of the radiator and the fan. The radiator is mounted in front of the engine so that the fan will draw air through it, thereby lowering and maintaining the coolant temperature to the degree necessary for efficient engine operation.

To prolong the life of the radiator, refer to Section 13.3 for the recommended type of coolant.

To increase the cooling efficiency of the radiator, a metal shroud is placed around the fan. The fan shroud must be fitted airtight against the radiator to prevent re–circulation of the hot air drawn through the radiator. Hot air which is permitted to pass around the sides or bottom of the radiator and is again drawn through the radiator will cause overheating of the engine.

Another cause of overheating is slippage of the fan drive belts which is caused by incorrect belt tension, worn belts or worn fan belt pulley grooves, or the use of fan belts of unequal length when two or more belts are used. The belt tension and condition of the belts should be checked periodically as outlined in Section 15.1.

A radiator that has a dirty, obstructed core or is leaking, a leak in the cooling system, or an inoperative thermostat will also cause the engine to overheat. The radiator must be cleaned, the leaks eliminated, and defective thermostats replaced immediately to prevent serious damage from overheating.

The external cleanliness of the radiator should be checked if the engine overheats and no other causes are apparent.

Cleaning Radiator

The radiator should be cleaned whenever the foreign deposits are sufficient to hinder the flow of air or the transfer of heat to the air. In a hot, dusty area, periodic cleaning of the radiator will prevent a decrease in efficiency and add life to the engine.

The fan shroud and grill should be removed, if possible, to facilitate cleaning of the radiator core.

An air hose with a suitable nozzle is often sufficient to remove loose dust from the radiator core.

CAUTION:To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.

Occasionally, however, oil may be present requiring the use of a solvent, such as mineral spirits, to loosen the dirt. The use of gasoline, kerosene, or fuel oil is NOT recommended as a solvent. A spray gun is an effective means of applying the solvent to the radiator core. Use air to remove the remaining dirt. To avoid damage to the radiator fins, do not use high air or water pressure. Repeat this process as many times as necessary, then rinse the radiator with clean water and dry it with air.

CAUTION:Provide adequate ventilation of the working area to avoid possible toxic effects of the cleaning spray.

Another method of cleaning the radiator is the use of steam or a steam cleaning device, if available. If the foreign deposits are hardened, it may be necessary to apply solvents.

The scale deposit inside the radiator is a result of using hard, high mineral content water in the cooling system. The effect of heat on the minerals in the water causes the formation of scale, or hard coating, on metal surfaces within the radiator, thereby reducing the transfer of heat. Some hard water, instead of forming scale, will produce a silt–like deposit which restricts the flow of water. This must be flushed out at least twice a year — more often if necessary.

To remove the hardened scale, a direct chemical action is necessary. A flushing compound such as sal–ammoniac, at the specified rate of 1/4 pound per each gallon of radiator capacity, should be added to the coolant water in the form of a dissolved solution while the engine is running. Operate the engine for at least fifteen minutes, then drain and flush the system with clean water.

Other flushing compounds are commercially available and should be procured from a reliable source. Most compounds attack metals and should not remain in the engine for more than a few minutes. A neutralizer should be used in the cooling system immediately after a de–scaling solvent is used.

For extremely hard, stubborn coatings, such as lime scale, it may be necessary to use a stronger solution. The corrosive action of a stronger solution will affect the thin metals of the radiator, thereby reducing its operating life. A complete flushing and rinsing is mandatory and must be accomplished skillfully.

After the solvent and neutralizer have been used and the cooling system is flushed, completely drain the entire system again and fill it with coolant (refer to Section 13.3). After filling the cooling system, inspect the radiator and engine for coolant leaks.

NOTICE: When draining or filling, the cooling system must be vented.

After the radiator core has been thoroughly cleaned and dried, reinstall the fan shroud and grill, if removed.

Remove Radiator

1. Remove the radiator filler cap and open the drain cock to drain the cooling system. Also open the drain cock on the oil cooler and the engine block.
2. Remove the bolts, lock washers and nuts which attach the fan guards to the fan shroud.
3. Loosen the hose clamps at the radiator inlet hose and remove the hose.
4. Loosen the hose clamps at the radiator outlet hose and remove the hose.
5. Use a chain hoist and a suitable lifting device (through the filler neck or otherwise) and draw the hoisting chain taut to steady the radiator.
6. Remove the bolts, lock washers, plain washers, nuts and bevel washers (if used) which attach the radiator shell to the engine base.

   CAUTION: Since the shroud is very close to the tips of the fan blades, to prevent damage to these parts great care must be exercised whenever the radiator is removed.

7. Lift the radiator enough to clear the engine base and move it directly away from the engine.
8. Remove the fan shroud and the radiator core by removing the bolts securing them in place.

Inspection

Clean all radiator parts thoroughly, removing dirt, scale and other deposits.

Examine the radiator for cracks or other damage. The core fins should be straight and evenly spaced to permit a full flow of cooling air. The core tubes should be clean inside and outside and have no leaks.

If repainting the radiator core becomes necessary, it is recommended that a thin coat of dull black radiator paint or another high quality flat black paint be used. Ordinary oil paints have an undesirable glossy finish and do not transmit heat as well.

Check all radiator hoses and clamps. Replace cracked and deteriorated hoses and damaged clamps.

Install Radiator

Assemble the radiator, grill and shroud. Then mount the assembly on the engine base by reversing the procedure given for removal.

Check for clearance between the tips of the fan blades and radiator shroud after the radiator is in place. There must be sufficient clearance or damage to the fan and shroud will result when the engine is started. Use shims between the radiator and base, if necessary, to obtain the proper clearance.

CROSS–FLOW DESIGN RADIATOR

Certain vehicle engines incorporate a cooling system radiator of a cross–flow design rather than the conventional down–flow design.

As the name implies, a cross–flow radiator has a core of horizontally positioned tubes and coolant flow moves across rather than down the radiator.

Two reasons for using the cross–flow design radiator are:

1. The reduced height of the radiator permits a lower hood line design, thus providing better road visibility.
2. The area ahead of the engine crankshaft and below the radiator is open for mounting a power takeoff unit, if desired.

The intent here is to describe briefly how the cross–flow radiator functions and to identify some of the components unique in the cross–flow system.

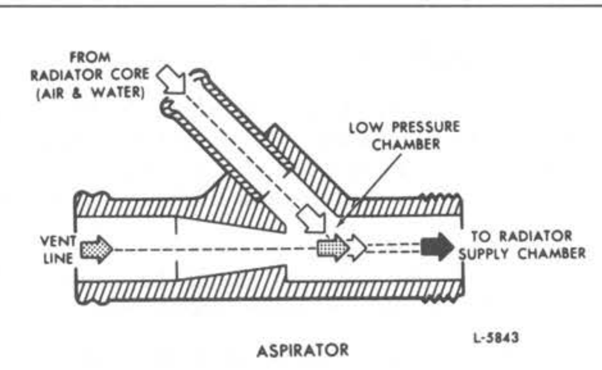


Fig. 1 – Aspirator for Cross–Flow Design Radiator

One such component is a Y–shaped device called an aspirator (Fig. 1) which is mounted externally on the filler cap side of the radiator and serves to rid the cooling system of air. The aspirator directs coolant under pressure through a venturi where entrapped air inside the radiator is picked up and moved to the supply chamber of the radiator where it is vented. The coolant line providing the drive flow originates

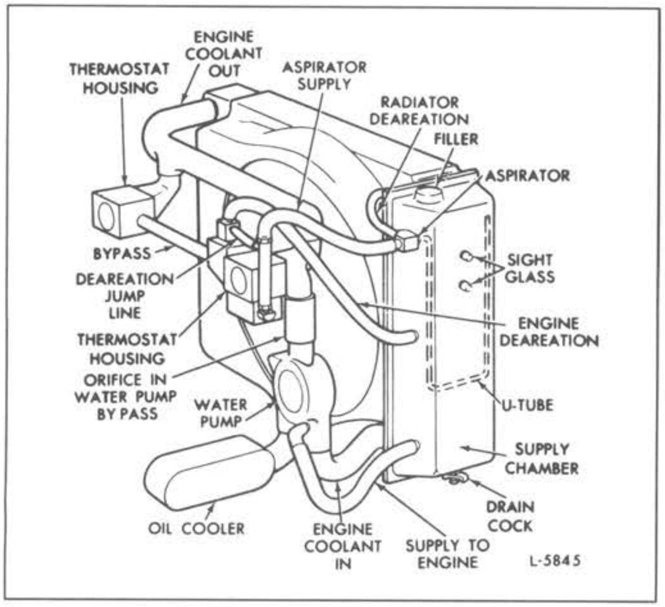


Fig. 2 – Cross–Flow Design Radiator

at the engine thermostat housing. This hookup provides a flow of coolant to the aspirator regardless of whether the thermostat is open or closed. As the coolant flow passes through the aspirator, its action pulls coolant and any air that is present from the top of the radiator core outlet chamber into an internal "U"tube which vents near the filler cap inside the radiator supply chamber to complete the deaeration process. This "U" tube insures that the entire cooling circuit, other than the supply chamber, remains completely full when the engine is stopped. Also, it keeps the coolant from seeking a common level throughout the system and, thereby, eliminates an aerated system at the next engine start–up.

The cross–flow system (Fig.2) requires a bypass restriction to provide sufficient pressure in the system for adequate engine deaeration and aspirator performance.

Properly installed hose connections are required for adequate cross–flow radiator efficiency (Fig. 2).

The cross–flow cooling system should always be drained at the radiator drain cock. This will insure that both the radiator and internal "U" tube is empty. If the"U" tube is not emptied, refilling the system will prove difficult.

Due to the design of the cross–flow radiator, air may be trapped inside of the radiator during the fill process resulting in a false coolant level reading. Therefore, after filling the cooling system, the engine should be run approximately ten minutes at 1200–1400 rpm so that any entrapped air can be vented. Generally, additional coolant (approximately 3 to 4 quarts or 2.8 to 3.8 liters) will be required to bring the coolant to the proper level.

For efficient operation of the cross–flow radiator system, it is important that no leak exists between the radiator core and the supply tank. If an internal leak has developed between the radiator core and the supply tank, it can cause the cooling system to become aerated at low speed and following engine shut down. The radiator should be tested periodically for possible internal leaks. To determine if a leak is present, proceed as follows:

1. Remove the radiator cap and run the engine for approximately ten minutes at high idle to completely deaerate the cooling system. While the engine is running, add additional coolant to the supply chamber to bring the coolant level to the bottom of the filler neck.
2. Stop the engine and drain 4 quarts (3.8 liters) of coolant from the radiator.
3. Start and run the engine at high idle for approximately ten minutes and observe the coolant level.
4. Stop the engine and again observe the coolant level. If the coolant rises substantially in the supply tank, an internal leak is present and immediate corrective action should be taken to repair the leak. If the coolant level remains constant or falls, the system is satisfactory.
5. After the test is completed, refill the cooling system to the proper coolant level.

If the leak situation is not corrected, the engine will be operating with an aerated coolant for abnormal periods of time which could lead to an engine failure.

COOLANT PRESSURE CONTROL CAP

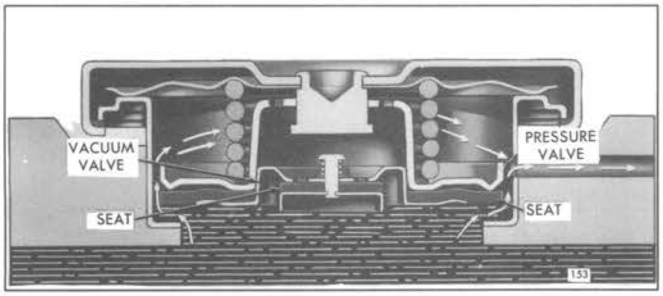


Fig. 1 – Pressure Control Cap (Pressure Valve Open)

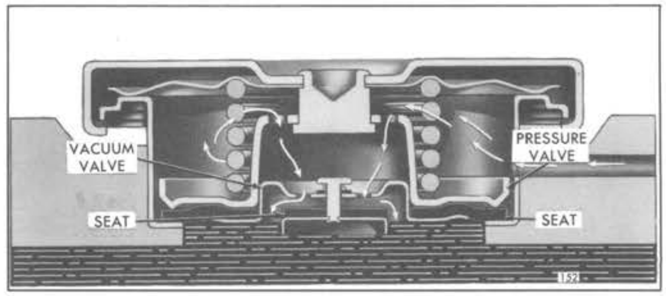


Fig. 2 – Pressure Control Cap (Vacuum Valve Open)

The radiator (or expansion tank) has a pressure control cap with a normally closed valve. The cap, with a number 7 stamped on its top, is designed to permit a pressure of approximately seven pounds (48 kPa) in the system before the valve opens while the cap with a number 9 stamped on its top needs nine pounds (62 kPa) before the valve opens. This pressure raises the boiling point of the cooling liquid and permits somewhat higher engine operating temperatures without loss of any coolant from boiling. To prevent the collapse of hoses and other parts which are not internally supported, a second valve in the cap opens under vacuum when the system cools.

CAUTION: Use extreme care when removing the coolant pressure control cap. Remove the cap *slowly* after the engine has cooled. The sudden release of pressure from a heated cooling system can result in loss of coolant and possible personal injury (scalding) from the hot liquid.

To ensure against possible damage to the cooling system from either excessive pressure or vacuum, check both valves periodically for proper opening and closing pressures. If the pressure valve does not open between 6.25 psi (43.1 kPa) and 7.5 psi (51.7 kPa) or the vacuum valve does not open at .625 psi (4.3 kPa) (differential pressure) replace the pressure control cap.

It is recommended that all series 92 on–highway vehicle engines use a minimum 9 psi (62 kPa) pressure control cap. If the pressure valve does not open between 8 psi (55 kPa) and 10 psi (69 kPa) or the vacuum valve does not open at .625 psi (4.3 kPa) (differential pressure), replace the pressure control cap.

ENGINE COOLING FAN

The engine cooling fan (Fig. 1) is belt driven from the crankshaft pulley.

The three groove pulley hub (Fig. 2), used on 6V, 8V and certain 16V engines, turns on a double–row ball bearing at the front and a single–row (shielded) ball bearing at the rear of the hub. A new three groove pulley hub, for all engines including the 12V engines, turns on a front ball bearing and a rear roller bearing and also includes a hub cap (with relief valve), a dust cup and a grease fitting (Fig. 3). On 6V and 8V compact front end engines, the pulley hub turns on tapered roller bearings (Fig. 4). The Poly–V groove pulley hub used on some 16V engines turns on two single–row tapered roller bearings (Fig. 5).

Spacers provide a means for setting the proper clearance between the fan blades and the front groove of the crankshaft pulley.

Lubrication

The bearings and the cavity between the bearings are packed with grease at the time the fan hub is assembled. Refer to Section 15.1 for the maintenance schedule.

Fan Belt Adjustment

Adjust the fan belts periodically as outlined in Section 15.1.

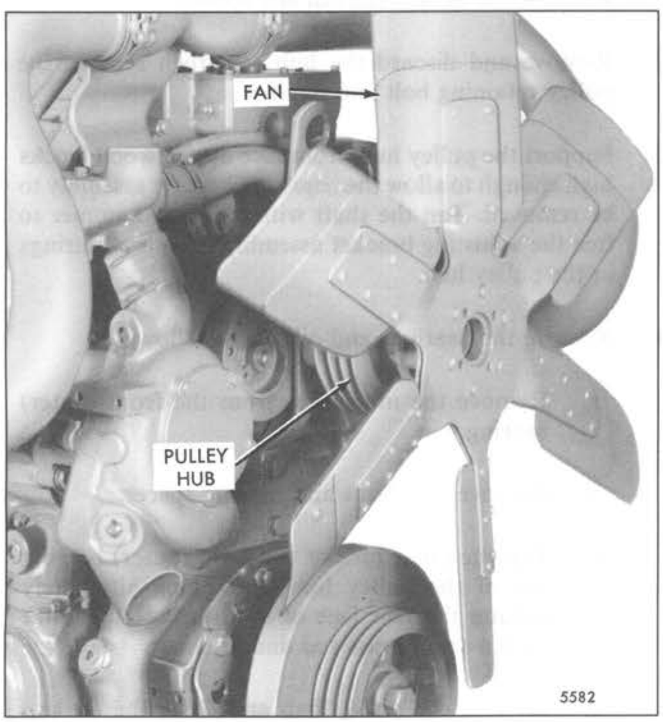


Fig. 1 – Typical Fan Mounting

Remove Fan, Hub And Adjusting Bracket

The fan blades must rotate in a vertical plane parallel with and a sufficient distance from the radiator core. Bent fan blades reduce the efficiency of the cooling system, may throw the fan out of balance, and are apt to damage the radiator core. Before removing the fan, check the blades for alignment. Do not rotate the fan by pulling on the fan blades.

1. Remove the attaching bolts, lock washers and nuts, then remove the fan and spacer (if used).

   NOTICE: If insufficient clearance exists between the fan and the radiator, remove the fan, hub and adjusting bracket as an assembly.

2. Loosen the fan hub adjusting bracket bolts and remove the drive belts. Then withdraw the bolts and washers and remove the hub and bracket assembly from the engine.

Disassemble Fan, Three Groove Pulley Hub And Bracket (Fig. 2 And 3)

1. Remove the fan to hub mounting bolts, nuts and lock washers and detach the fan and spacer.

2. Remove and discard the hub cap. Then take out the cotter pin and remove the nut. If the bearings are to be removed, take out the retaining ring.

3. Support the hub, front face up, on wood blocks high enough to allow the bracket to be removed. Tap the fan shaft with a plastic hammer to free the fan shaft and bracket assembly from the bearings in the hub.

4. Remove the ball bearings from the pulley hub as follows:

   a. Support the pulley hub, rear face up, on two wood blocks spaced far enough apart to permit removal of the bearing from the hub.

   b. Tap the front bearing out of the hub by tapping alternately around the rear face of the bearing outer race with a small brass rod and hammer.

   c. Reverse the pulley hub on the wood blocks and remove the rear bearing from the hub in the same manner.

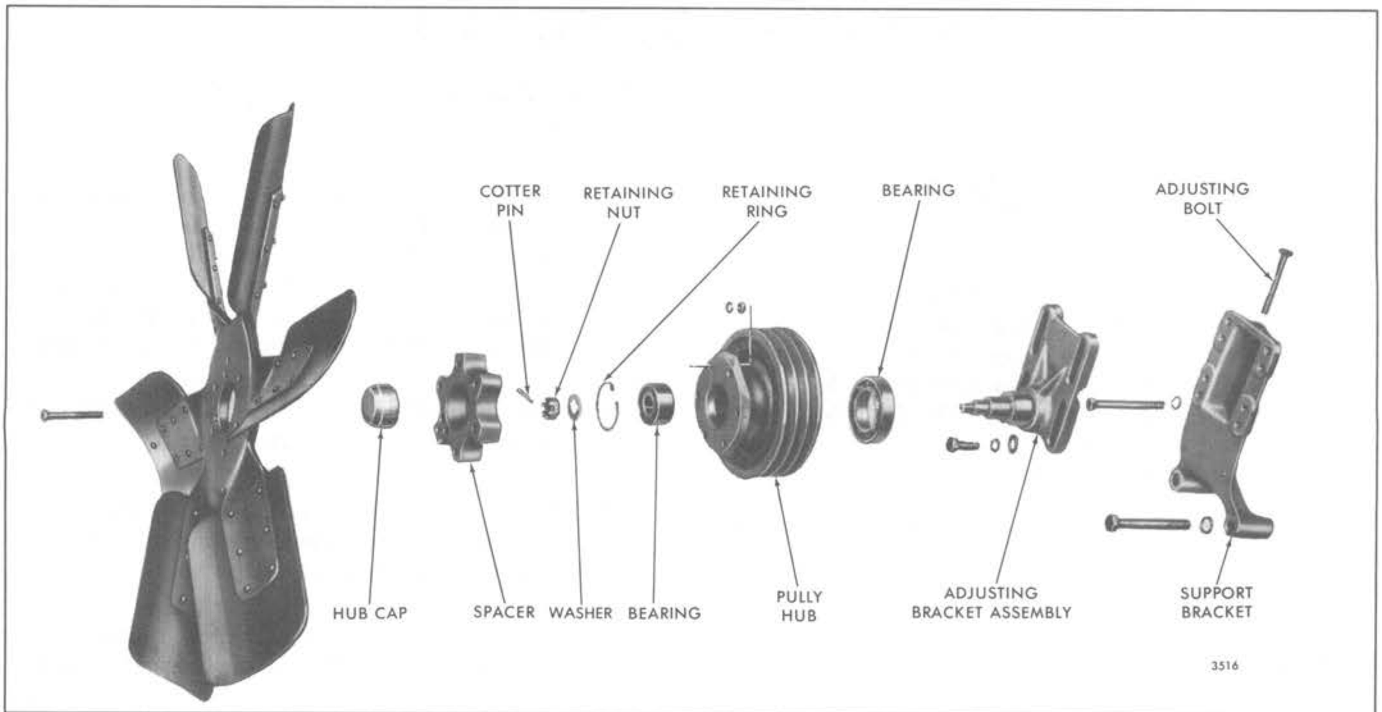


Fig. 2 – Typical Fan, Three Groove Pulley Hub and Adjusting Bracket Details and Relative Location of Parts (Former)

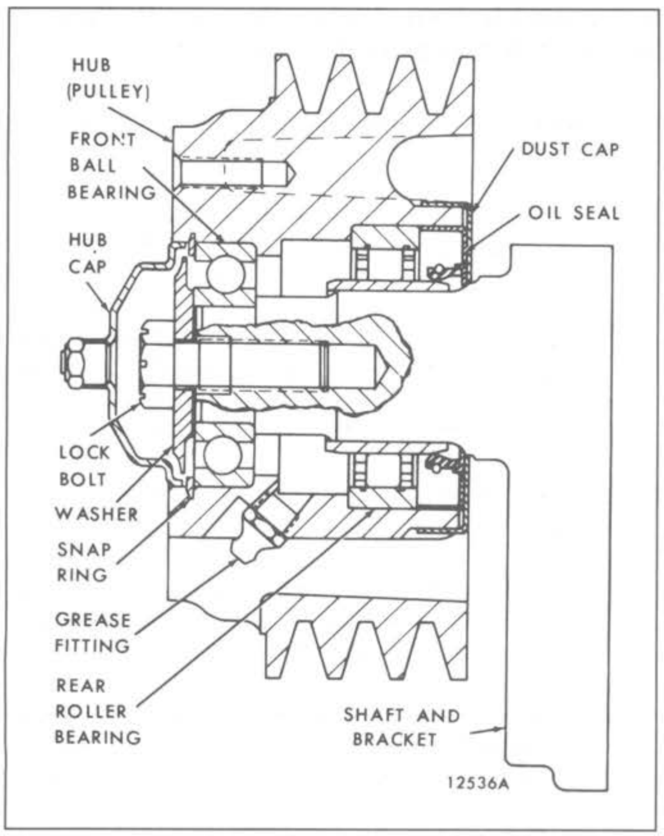


Fig. 3 – Three Groove Pulley Hub (Current)

Disassemble Fan, Hub And Bracket (Compact Front End – Fig. 4)

1. Remove the fan to hub mounting bolts, nuts and lock washers and detach the fan and spacer.

2. Remove and discard the hub cap, then remove the pulley retaining bolt and retainer.

3. Support the pulley hub, front face up, on wood blocks high enough to allow the adjusting bracket assembly to be removed. Tap the shaft with a plastic hammer to free the adjusting bracket assembly from the bearings in the pulley hub.

4. Remove the bearings and oil seal as follows:

   a. Remove the inner race from the front (outer) bearing.

   b. Remove the shims and bearing spacer.

   c. Tap the outer race of the front (outer) bearing out of the pulley hub by tapping alternately around the rear face of the bearing outer race with a small brass rod and hammer.

   d. Reverse the pulley hub and drive the oil seal from the hub. Discard the oil seal.

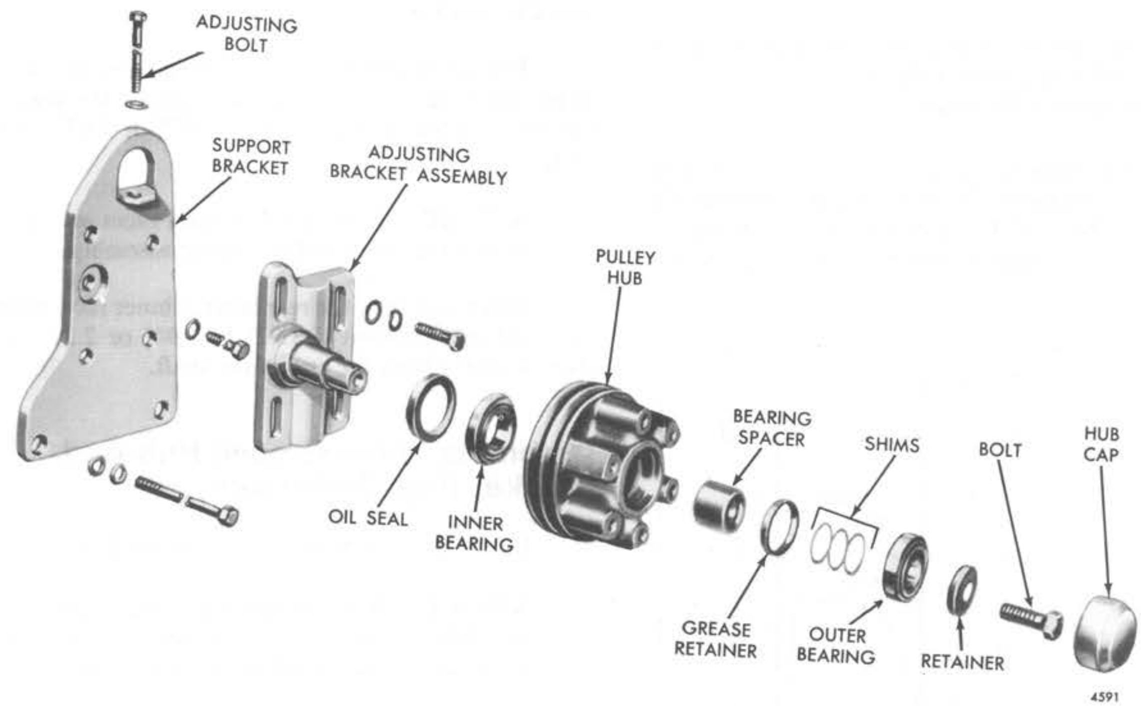


Fig. 4 – Fan Pulley, Hub and Adjusting Bracket Details for Compact Front End Engines

e. Remove the rear (inner) bearing in the same manner as outlined in Steps a and c.

f. Remove the grease retainer from the pulley hub.

Disassemble Fan, Poly–V Groove Pulley Hub And Bracket (16V Engine)

1. Remove the fan to pulley hub mounting bolts, nuts and lock washers and detach the fan and spacer.
2. Remove and discard the hub cap. Then pry out that part of the locknut staked into the shaft and remove the nut.
3. Support the pulley hub, front face up, on wood blocks high enough to allow the adjusting bracket to be removed. Tap the shaft with a plastic hammer to free the bracket assembly from the bearings in the pulley hub.
4. Support the pulley hub, front face up, on two wood blocks spaced far enough apart to permit removal of the seal and bearing from the hub.
5. Remove and discard the felt oil seal in the rear of the hub.
6. Remove the inner roller bearing out of the hub by tapping alternately around the rear face of the bearing outer race with a small brass rod and hammer.
7. Remove the spacer and shims.
8. Reverse the pulley hub on the wood blocks and remove the front roller bearing from the hub in the same manner.

Inspection

Clean the fan and related parts with clean fuel oil and dry them with compressed air.

CAUTION:To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.

Shielded bearings must not be washed; dirt may be washed in and the cleaning fluid could not be entirely removed from the bearing.

Examine the bearings for any indications of corrosion or pitting. Hold the inner race or cone so it does not turn and revolve the outer race or cup slowly by hand. If rough spots are found, replace the bearings.

Check the fan blades for cracks. Replace the fan if the blades are badly bent, since straightening may weaken the blades, particularly in the hub area.

Remove any rust or rough spots in the grooves of the fan pulley and crankshaft pulley. If the grooves are damaged or severely worn, replace the pulleys.

Examine and measure the fan hub shaft front and rear journals (industrial engines). The front journal diameter of a new shaft is .7866"–.7871" and the rear journal is 1.7705"–1.7713". If the journals are worn excessively, replace the fan shaft.

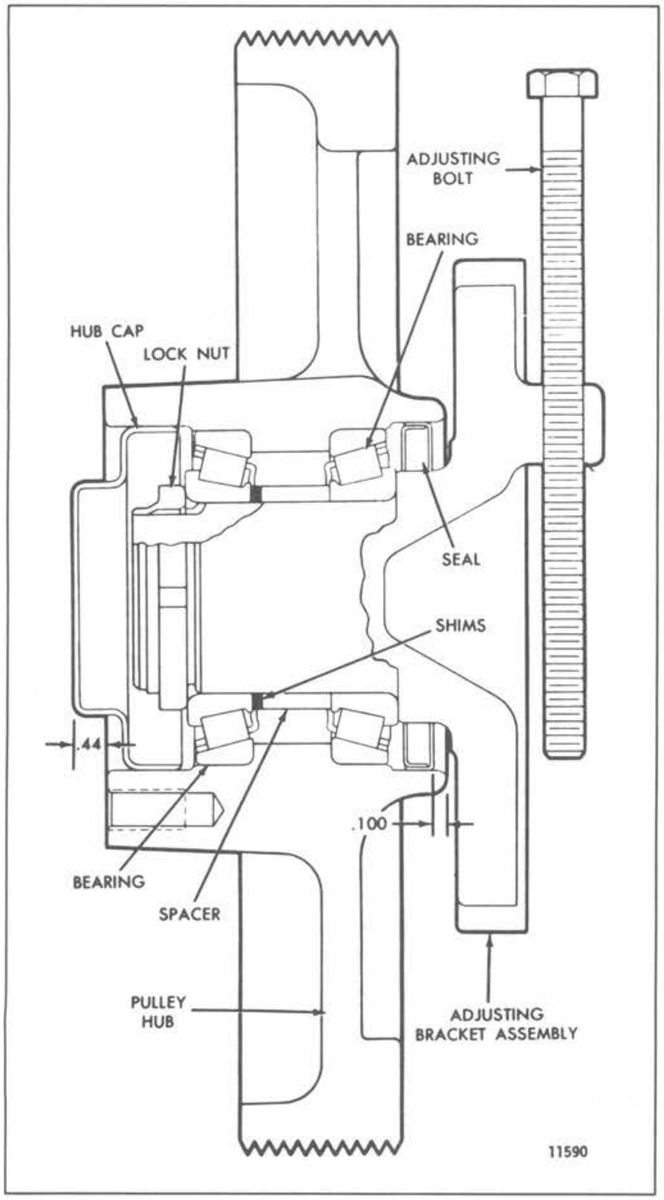


Fig. 5 – Typical 16V Engine Poly–V Groove Pulley Hub and Adjusting Bracket

Look for cracks in the adjusting and support bracket castings. When replacement of either the fan shaft or adjusting bracket is necessary, a new fan shaft and bracket assembly must be used.

The current fan shaft rear bearing inner race should be inspected for any measurable wear. Replace the inner race if the outer diameter is less that 1.7297" or 2.6333" (Heavy Duty).

NOTICE: The inner and outer races are only serviced as a rear roller bearing assembly.

When installing the rear bearing inner race, press it on the shaft and position it 1.92" to 1.94" or 2.31" to 2.33" (Heavy Duty) from the end of the shaft.

Assemble Three Groove Hub And Bracket (Fig. 2)–Former

1. Install the rear bearing in the pulley hub.

   NOTICE: When rebuilding a three groove pulley fan hub assembly for any reason, add the new hardened washer under the retaining nut.

2. To prevent the possibility of the inner bearing race spinning on the shaft, apply a small quantity of Loctite No. RC 601, or equivalent, to the full circumference of the rear bearing surface of the shaft. The bearing and shaft surfaces must be clean and dry.

   NOTICE: Make sure no Loctite gets into the bearing.

3. Pack the cavity in the pulley hub 75% (minimum) full of grease. Use Texaco Premium RB or an equivalent Lithium base multi–purpose grease.

4. Place the adjusting bracket on wood blocks setting on the bed of an arbor press. Then press the pulley hub on the fan shaft.

5. Install the front ball bearing in the pulley hub.

6. Install the retaining ring and nut. Tighten the nut to 60–90 lb–ft (81–122 N•m) torque and secure it with a cotter pin.

   NOTICE: If the holes in the nut and shaft do not line up for the cotter pin, do not back off on the nut but rather advance to the next position. Low nut torque will permit the front bearing to turn on the shaft.

7. Pack the front cavity 75% (minimum) full of grease (refer to Step 3) and install a new hub cap.

Assemble Three Groove Hub And Bracket (Fig. 3)–Current

1. Apply Texaco Premium RB grease or an equivalent Lithium base multipurpose grease to the front ball bearing and the rollers of the rear bearing, before installing them in the pulley hub.

   NOTICE: Do not overgrease.

2. Install the front ball bearing against the shoulder counterbore in the pulley hub. Then install the snap ring in the pulley hub.
3. Install the rear roller bearing outer ring and roller assembly against the shoulder in the counterbore of the pulley hub.
4. Install a new oil seal with rubber side flush with the outer edge of the hub.
5. Install the dust cap (if used) over the oil seal in the hub.
6. Place the shaft and bracket on wood blocks setting on the bed of an arbor press. Then press the rear bearing inner ring or race onto the fan shaft.
7. Pack the cavity in the hub 75% (minimum) full with Texaco Premium RB grease.
8. Install the partially assembled fan hub over the rear bearing inner ring on the shaft and against the shoulder on the pulley hub shaft.
9. Secure the hub with the washer and 1/2"–20 lock bolt. Tighten the bolt to 83–93 lb–ft (113–126 N•m) torque while rotating the pulley hub.
10. Fill a new fan hub cap 75% (minimum) full of grease and install it in the end of the pulley hub.

Assemble Hub And Bracket (Compact Front End – Fig. 4)

1. Apply Texaco Premium RB or an equivalent Lithium base multi–purpose grease to the rollers of both bearings before installing them in the pulley hub.
2. Install the rear (inner) bearing assembly (inner and outer race), with the protruding face of the inner race facing outward from the hub, by tapping alternately around the face of the bearing outer race with a small brass rod and hammer.
3. Install a new oil seal with the rubber side flush with the outer edge of the hub.
4. Place the adjusting bracket assembly on wood blocks setting on the bed of an arbor press. Then press the pulley hub on the fan shaft and install the bearing spacer.
5. Pack the cavity between the bearings 20–30% full of grease (refer to Step 1) and install the grease retainer.

   NOTICE: The grease retainer is not required when a grease fitting is installed in the pulley hub (refer to Section 5.0).

6. Place the shims against the bearing spacer. Then install the front (outer) bearing assembly (inner and outer race), with the protruding face of the inner race facing outward from the hub, as mentioned in Step 2.
7. Secure the hub with the retainer and bolt. Tighten the 1/2"–20 bolt to 83–93 lb–ft (113–126 N•m) torque while rotating the pulley.
8. Rotate the assembly and check the end play with the spindle (shaft) in a horizontal position. The end play must be within .001" to .006". If necessary, remove the bolt, washer and front (outer) bearing and adjust the number and thickness of shims to obtain the required end play. Shims are available in .015", .020" and .025" thickness. Then reassemble the fan hub and check the end play.
9. Fill a new fan hub cap 75% (minimum) full of grease and install it in the end of the fan hub (pulley).

Assemble Poly–V Groove Pulley Hub And Bracket (16V Engine)

1. Before assembling the roller bearings into the pulley hub, pressure lubricate the bearings and pack the cavity in the hub 25% full of grease. Use Texaco Premium RB or an equivalent Lithium base multi–purpose grease.
2. Install the rear roller bearing in the pulley hub.
3. Press a new oil seal in .100" from the end of the pulley hub (Fig. 5).
4. Place the adjusting bracket on wood blocks setting on the bed of an arbor press. Then press the pulley hub on the fan shaft.
5. Install the spacer and necessary shims on the fan shaft.
6. Install the front roller bearing in the pulley hub.
7. Apply International Compound No. 2 to the threads of the locknut and tighten it with socket J 22556–2 and fingers J 6534–8 to 250–260 lb–ft (339–352 N•m) torque while rotating the pulley hub.

   NOTICE: Reverse the fingers J 6534–8 in socket J 22556–2 (chamfered holes in fingers facing the socket) when fingers are used to tighten the 16V Poly–V groove pulley hub locknut.

8. Check the end play. It must be .001" to .006". If necessary, remove the locknut and front bearing and add or remove shims as required.

9. After the specified end play is obtained, remove the locknut and front bearing and fill the pulley hub cavity 20–30% full of grease (refer to Step 1). Then reinstall the front bearing and locknut.

10. Tighten the locknut to 250–260 lb–ft (339–352 N•m) torque and stake the locknut to the fan shaft.

11. Fill a new hub cap 75% (minimum) full of grease and install it in the pulley hub (Fig. 5).

Install Fan, Hub And Bracket

1. Secure the fan and spacer to the pulley hub with the six bolts, nuts and lock washers. Tighten the nuts to 15–19 lb–ft (20–26 N•m) torque.

2. Place the fan belts on the pulley.

NOTICE: Before a Poly–V belt is installed (16V engines), it is very important that the crankshaft pulley and fan pulley are in alignment (refer to Section 15.1).

3. Position the fan, hub and adjusting bracket against the support bracket and install the bolts finger tight in the support.

NOTICE: The new bolts differ from the former in that their effective lengths in inches are indicated in 1/4" high raised numbers on the bolt heads. This makes them easier to identify than the former bolts which had to be measured. Some of the new bolts are also longer than the bolts they replace.

4. Adjust the bracket to provide the proper tension on the fan belts (refer to Section 15.1). Tighten the bracket and bracket adjusting bolts.

THERMO-MODULATED FAN

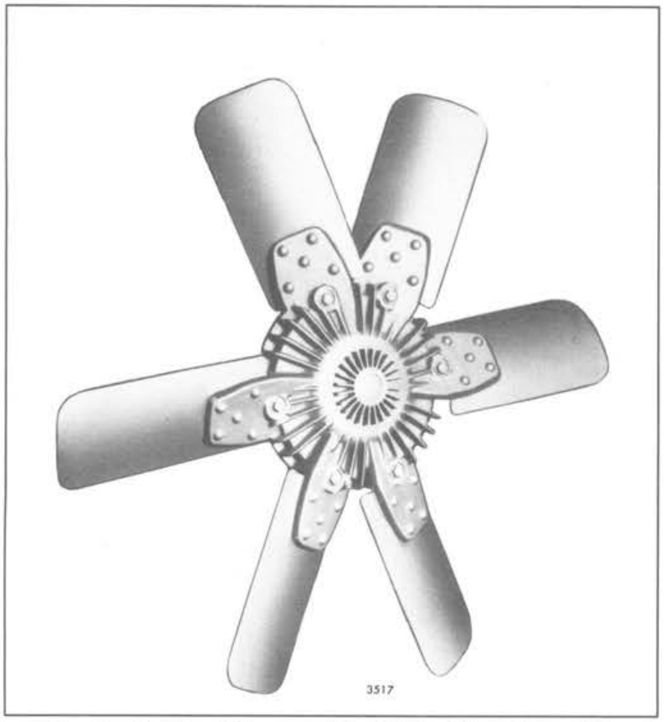


Fig. 6 – Typical Thermo-Modulated Fan Assembly

A thermo-modulated suction fan assembly has been provided on some engines (Fig. 6).

This fan assembly is designed to regulate the fan speed and maintain an efficient engine coolant temperature regardless of the variations in the engine load or outside air temperature.

The entire fan drive assembly is a compact integral unit (Fig. 7) which requires no external piping or controls and operates on a simple principle. This principle consists of transmitting torque from the input shaft to the fan by the shearing of a silicon fluid film between the input and output plates in a sealed multiplate, fluid filled clutch housing.

The thermostatic control element, which is an integral part of the fan drive, reacts to changes in engine temperature and varies the fluid film thickness between the plates and thereby changes the fan speed. Proper selection of the control element setting is determined by the vehicle manufacturer to maintain optimum cooling and no further adjustment should be necessary.

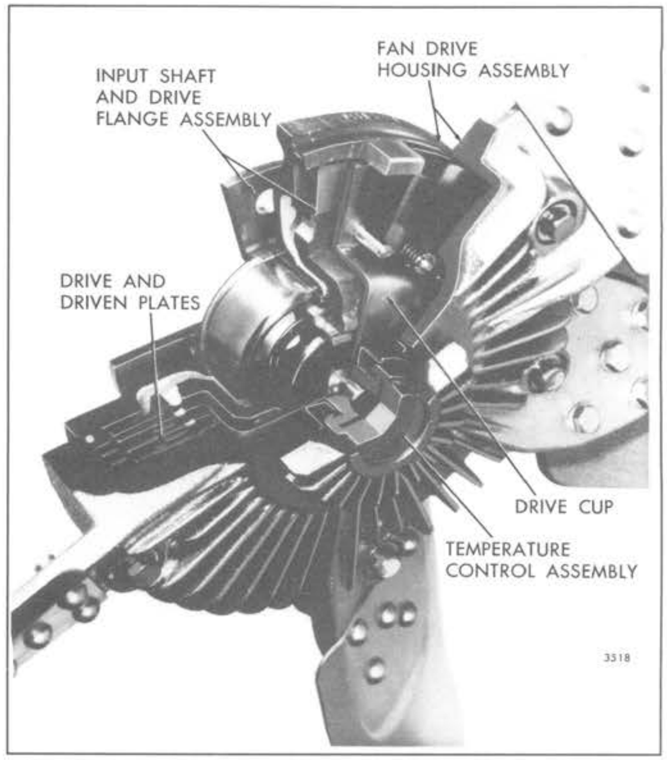


Fig. 7 – Typical Thermo-Modulated Fan Drive Assembly

The thermo-modulated fan is mounted and driven by the engine in the same manner as the conventional fan.

Lubrication

The fan drive assembly is prelubricated by the manufacturer. However, the drive fluid level and the roller bearing should be checked periodically (refer to Section 15.1).

Adjust Fan Belt

The adjustment of the fan belt tension is the same as on the conventional type fans.

Remove And Install Fan And Drive Assembly

The fan blades and fan drive may be taken off by removing the four shaft to pulley mounting bolts, and installed by reversing this procedure.

HEAT EXCHANGER

The heat exchanger core consists of a series of cells with a header at one end and a circular water outlet at the opposite end. The core is mounted inside of the expansion tank with the header or inlet end bolted to the tank and the opposite or outlet end is sealed inside a retainer. A gasket between the expansion tank and the flange of the core, another gasket between the flange of the core and the cover at the inlet side, and seals surrounding the circular outlet at the opposite end prevent the coolant from mixing with the raw cooling water on its horizontal course between the cells of the element.

In this system of engine cooling, the hot coolant leaving the thermostat housing passes through the expansion tank, then through the cells of the cooling core. After leaving the heat exchanger, the engine coolant is picked up by the fresh water pump and circulated through the cylinder block and cylinder heads. The raw water is forced horizontally between the cells of the core and serves to lower the temperature of the coolant as it passes through the cells.

To protect the heat exchanger core from electrolytic action of the raw water, a zinc electrode is located in both the heat exchanger inlet elbow and the raw water pump inlet elbow and extends into the raw water passage (Fig. 1).

The expansion tank provides a means of filling the engine cooling system, as well as space for expansion of the coolant as its temperature rises. An overflow pipe, near the top of the tank, provides a vent to the atmosphere.

NOTICE: When installing a new filler neck in the expansion tank, be sure to drill a 3/16" hole in the side of the new filler neck for the overflow pipe.

The length of time a heat exchanger will function satisfactorily before cleaning will be governed largely by the kind of coolant used in the engine, and the kind of raw water used.

Soft water, plus a good commercial rust inhibitor or antifreeze should be used as the engine coolant (refer to Section 13.3) to prevent lime deposits in the heat exchanger core as well as in the engine.

Enough coolant should be maintained in the engine to fill the cylinder block and head and to partially fill the water tank. Allow air space above the coolant in the tank for the increase in volume as the temperature of the coolant rises.

Whenever the heat exchanger fails to cool the engine properly, and the raw water pump is circulating a normal amount of cooling water around the heat exchanger core, the core should be examined for foreign deposits.

Clean Heat Exchanger Core

When foreign deposits accumulate in the heat exchanger to the extent that cooling efficiency is impaired, remove the heat exchanger core and clean it as follows:

Immerse the heat exchanger core in a scale solvent consisting of one–third (1/3) muriatic acid and two–thirds (2/3) water to which one–half (1/2) pound of oxalic acid has been added to each two and one–half (2–1/2) gallons of solution. Remove the core when foaming and bubbling stops. This usually takes from thirty to sixty seconds. Flush the core thoroughly with clean hot water under pressure.

To prevent drying and hardening of accumulated foreign substances, the heat exchanger core must be cleaned as soon as possible after removing it from service.

Inspect Zinc Electrodes

Remove the zinc electrodes from the inlet side of the raw water pump and the heat exchanger. Clean the electrodes with a wire brush or, if worn excessively, replace with new electrodes. To determine the condition of a used electrode, strike it sharply against a hard surface; a weakened electrode will break.

Remove Heat Exchanger Core (6 And 8V Engines)

Remove heat exchanger core for cleaning and inspection as follows:

1. Drain the engine coolant and the raw water system.

   CAUTION:To avoid being burned by the hot liquid, allow the engine to cool before draining the coolant.

2. Remove the four bolts and lock washers that hold the raw water inlet tube to the heat exchanger. Then withdraw the inlet tube and gasket.
3. Remove the ten bolts and lock washers that hold the heat exchanger inlet cover to the expansion tank.
4. Remove the four bolts and lock washers that hold the outlet tube to the cover. Then remove the outlet tube and gasket.
5. Remove the ten bolts and lock washers that hold the outlet cover and seal retainer to the expansion tank.
6. Withdraw the outlet cover and seal retainer, together with the seals and seal gland, from the expansion tank. Remove the gasket.
7. Withdraw the heat exchanger core and gasket from the expansion tank.

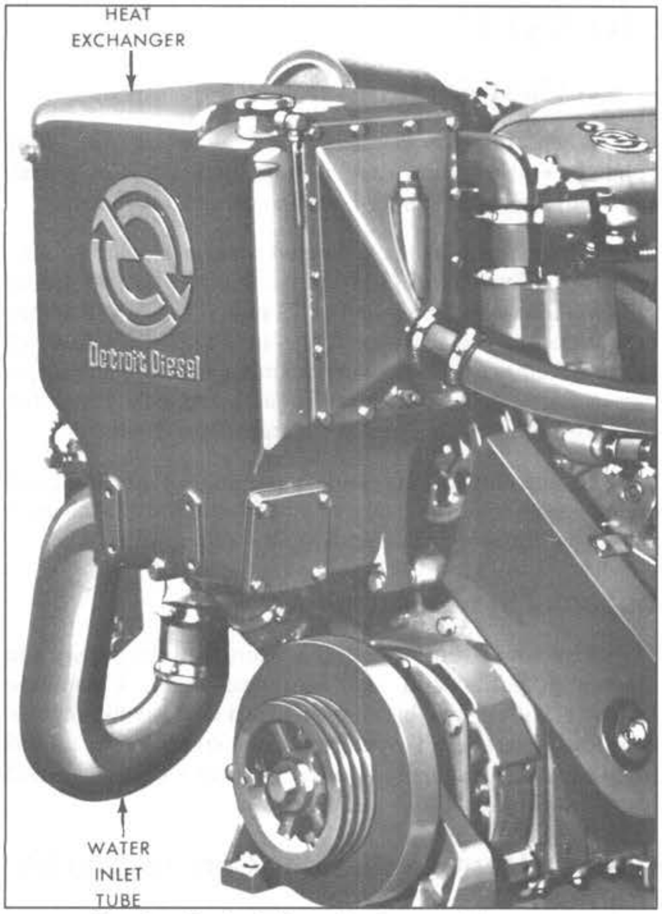


Fig. 1 – Typical Heat Exchanger Mounting

Remove Heat Exchanger Core (8VTI And 16V Engines)

1. Drain the fresh and raw water systems by opening the drain cocks in the cylinder block and the heat exchanger cover respectively.

   CAUTION:To avoid being burned by the hot liquid, allow the engine to cool before draining the coolant.

2. Remove the bolts that hold the inlet cover and the heat exchanger core to the tank. Remove the cover and the gasket.
3. Remove the bolts that hold the outlet cover to the seal retainer. Remove the cover and gasket.
4. Remove the bolts that hold the seal retainer to the tank. Remove the seal retainer, together with the seals and the seal gland, away from the tank.
5. Withdraw the heat exchanger core and gasket from the tank.

Install Heat Exchanger Core

After the heat exchanger core has been cleaned and inspected, install it by reversing the sequence of operations given for removal, using new gaskets and seals.

NOTICE: To minimize electrolytic action of the raw water, brass pipe plugs are used in the raw water system components wherever pipe plugs are required.

Refill the fresh and raw water systems and check for leaks.

RAW WATER PUMP (Jabsco)

Raw water for lowering the temperature of the engine coolant is circulated through the heat exchanger by a positive displacement pump (Fig. 1). The pump is attached to an adaptor which in turn is bolted to the flywheel housing and is driven through a coupling attached to the left–hand camshaft gear.

The pump drive shaft is supported by a pre–lubricated, shielded double–row ball bearing. An oil seal prevents oil leakage from the bearing compartment and a rotary type seal prevents water leakage along the shaft.

An impeller, splined to the end of the drive shaft, is self–lubricated by the water pumped and should not be run dry for longer than normally required for the pump to prime itself.

A wear plate in the impeller compartment prevents wear of the pump housing and can be reversed if wear on the plate becomes excessive. A slot machined in the outer periphery of the wear plate registers with a dowel in the pump housing, thus preventing it from rotating with the shaft.

The pump can be operated in a clockwise or counterclockwise direction. Raw water is drawn into the pump through an inlet opening and discharged through the outlet opening, both openings being located at the top of the pump housing.

Replace Pump Seal

Seal parts may be removed and replaced with new parts by removing the impeller, but without removing the pump from the engine.

NOTICE: Use care not to scratch or burr the lapped surface of the seal seat or that portion of the shaft which the seal contacts.

1. Remove cover screws and lift cover and gasket from the housing (Fig. 2).
2. Using two pliers, grasp a blade at each side of impeller and pull impeller from shaft. The spline plug will come out with the impeller.
3. Insert two wires, each with a hook at one end, between the housing and the seal with the hooks over the edge of the carbon seal. Pull the seal assembly from the shaft.
4. The seal seat and gasket may be removed in the same manner.
5. If removed, place a gasket and seal seat over the shaft and press them into position in the seal cavity.
6. Assemble the carbon seal, seal ring and washer in the correct relative position, and slide them over the shaft and against the seal seat. Care must be used to assure that the seal ring is contained snugly within the ferrule, thereby gripping the shaft.
7. Install the Marcel washer next to the flat washer.
8. Compress the impeller blades to clear the offset cam and press the impeller onto the splined shaft. Install the spline plug.
9. Turn the impeller several turns in that direction in which it will normally operate, to position the blade properly.
10. Install the cover on the housing, using a new gasket.

Remove Raw Water Pump From Engine

If complete disassembly or replacement of the pump becomes necessary, refer to Fig. 1 and proceed as follows:

1. Drain the raw water system.
2. Loosen the hose clamps at the outlet elbow and intermediate tube and slide the hose along the tube.
3. Loosen the hose clamps at the inlet elbow and the inlet tube and slide the hose along the tube.

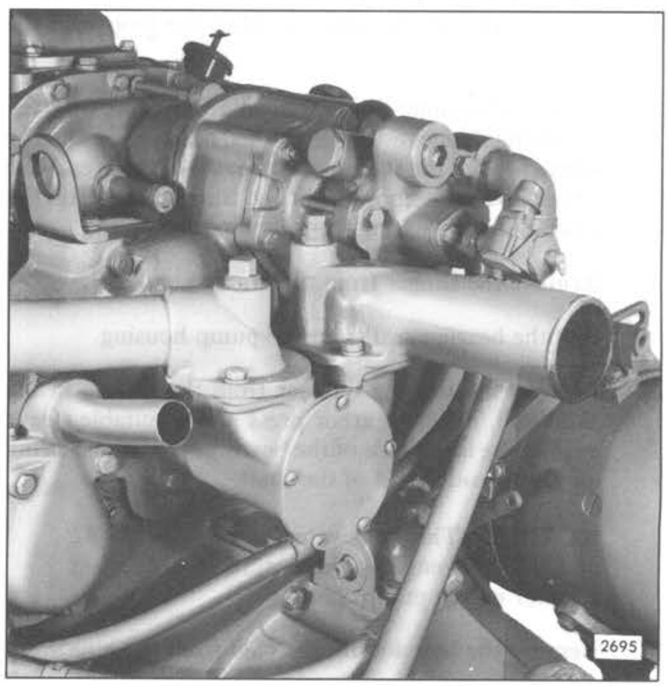


Fig. 1 – Raw Water Pump Mounting

4. Remove the bolts and lock washers holding the inlet and outlet elbows to the pump and lift the elbows from the pump. Remove the gaskets.

5. Remove the adaptor to flywheel housing bolts and lock washers.

6. Loosen the pump from the flywheel housing by tapping on the edge of the adaptor with a soft hammer.

7. Withdraw the pump straight out from the flywheel housing, disengaging the drive gear from the coupling.

NOTICE: Cover the pump opening in the flywheel housing with a clean cloth to prevent the entrance of foreign matter.

Disassemble Pump

Refer to Fig. 2 and disassemble the pump as follows:

1. Remove the seal assembly as previously outlined.

2. Mark the housing and the adaptor for reference when reassembling, then remove the bolts and lock washers and separate the adaptor from the housing.

3. Clamp the drive gear in a soft–jawed vise and remove the retaining nut and lock washer from the shaft.

4. Take the gear from the vise and, using a suitable puller, pull the gear from the shaft. Remove the Woodruff key from the shaft.

5. Remove the bearing retainer from the groove in the housing.

6. Support the pump housing in an arbor press with the mounting flange resting on the bed of the press and the splined end of the shaft under the ram of the press. Use a brass rod between the shaft and the ram and press the shaft and ball bearing from the housing.

7. Remove the slinger from the housing.

8. Pull the bearing seal from the pump housing.

9. Remove the bearing retainer from the groove in the shaft and, using an arbor press and a suitable sleeve against the inner race of the bearing, press the bearing off the threaded end of the shaft.

NOTICE: The raw water pumps on 8V–92 and 16V–92 engines do not have a bearing retainer on the pump shaft.

10. Remove the bolt and lift the cam from the housing.

11. Lift the wear plate off the dowel.

Inspect Pump Parts

After disassembly, clean all parts thoroughly, except the bearing. The *shielded bearing must not be washed*; dirt may be washed in and the cleaning fluid could not be entirely removed from the bearing. Wipe the bearing clean on the outside and then inspect it. Hold the inner race and revolve the outer race slowly to detect possible wear or rough spots. Replace the bearing if it is worn or does not roll freely.

Examine the parts of the seal assembly, the ball bearing seals and discard any parts that have been cut, cracked or otherwise damaged.

Inspect the oil seal contact surfaces of the shaft for scratches or grooves. Smooth scratched surface with crocus cloth wet with fuel oil.

Inspect the impeller to make sure the bond between the neoprene and the metal is good. If the impeller blades have a permanent set, install a new impeller.

Remove burrs from the wear plate. If wear on the plate is excessive, it may be reversed when the pump is assembled.

Assemble Pump

Using new parts where required, assemble the pump as follows:

1. Install the wear plate in the pump housing with the locating hole in the plate over the dowel in the housing.

2. Place the cam in the housing so the end of the cam is flush with the end of the housing and install the bolt.

3. Support the splined end of the shaft on a wood block on the bed of an arbor press. Start the bearing straight on the shaft and, using a sleeve between the ram of the press and the inner race of the bearing, press the bearing tight against the shoulder on the shaft.

4. Install the bearing retainer in the groove on the shaft.

5. Install the bearing seal(s) in the housing with the lip facing towards the bearing.

6. Place the slinger in position and then press the shaft and bearing into the counterbore in the housing.

7. Install the bearing retainer in the groove in the housing.

8. Install a Woodruff key in the shaft and start the gear straight on the shaft over the key.

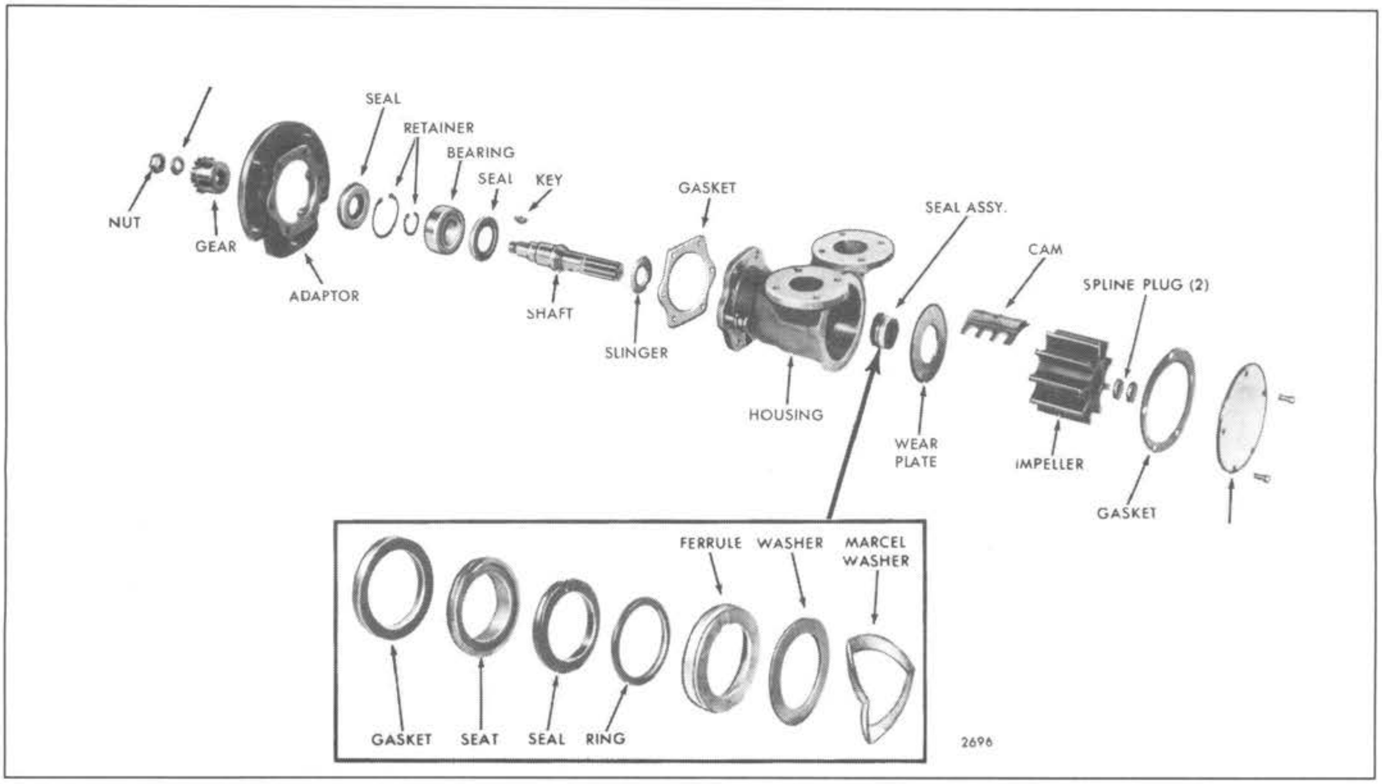


Fig. 2 – Raw Water Pump Details and Relative Location of Parts

9. Place the housing in an arbor press, with the splined end of the shaft supported on a wood block, and press the gear tight against the shoulder on the shaft.

10. Clamp the gear in a soft–jawed vise and install the lock washer and retainer nut. Tighten the nut to 25–30 lb–ft (34–41 N•m) torque. Do not exceed the specified torque, otherwise shaft fracture and consequent early pump failure may result.

11. Position the adaptor on the housing by aligning the marks made when disassembling and install the six lock washers and bolts.

Install Raw Water Pump On Engine

The pump may be installed by reversing the procedure used for removal.

Note that the end cover is marked to show the outlet port for RH rotation and the outlet port for LH rotation.

Follow these markings when installing the raw water pump to avoid any difficulty regarding direction of flow. Also, when installing the inlet elbow or the outlet elbow, be sure to use two flat washers on the bolt being installed in the blind hole in pump housing.

COOLANT FILTER AND CONDITIONER

The engine cooling system filter and conditioner is a compact by-pass type unit with a replaceable canister type element (Fig. 1), a spin-on type element (Fig. 2) or a clamp-on type element (Fig. 3).

A correctly installed and properly maintained coolant filter and conditioner provides a cleaner engine cooling system, greater heat dissipation, increased engine efficiency through improved heat conductivity and contributes to longer life of engine parts.

The filter provides mechanical filtration by means of a closely packed element through which the coolant passes. Any impurities such as sand and rust particles suspended in the cooling system will be removed by the straining action of the element. The removal of these impurities will contribute to longer water pump life and proper operation of the thermostat.

The filter also serves to condition the coolant by softening the water to minimize scale deposits, maintain an acid-free condition and act as a rust preventive.

Corrosion inhibitors are placed in the element and dissolve into the coolant, forming a protective rustproof film on all of the metal surfaces of the cooling system (refer to Section 13.3). The other components of the element perform the function of cleaning and preparing the cooling passages while the corrosion inhibitors protect them.

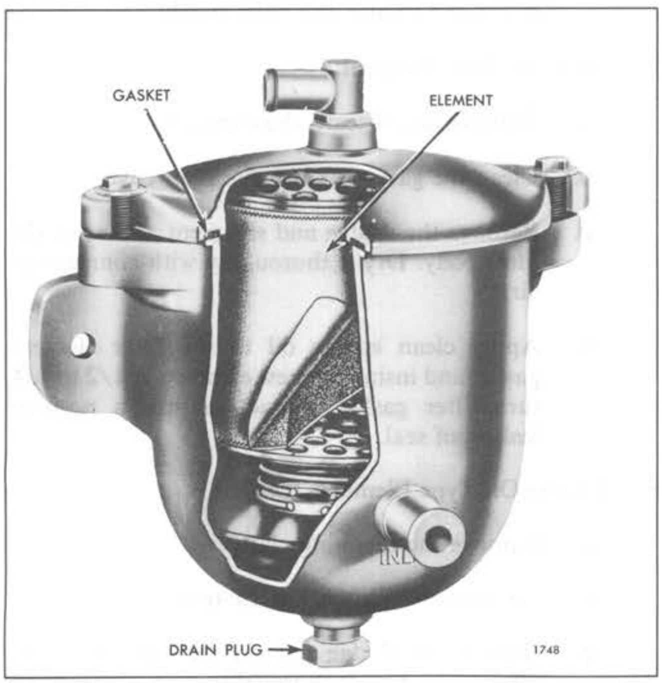


Fig. 1 – Coolant Filter and Conditioner (Canister Type)

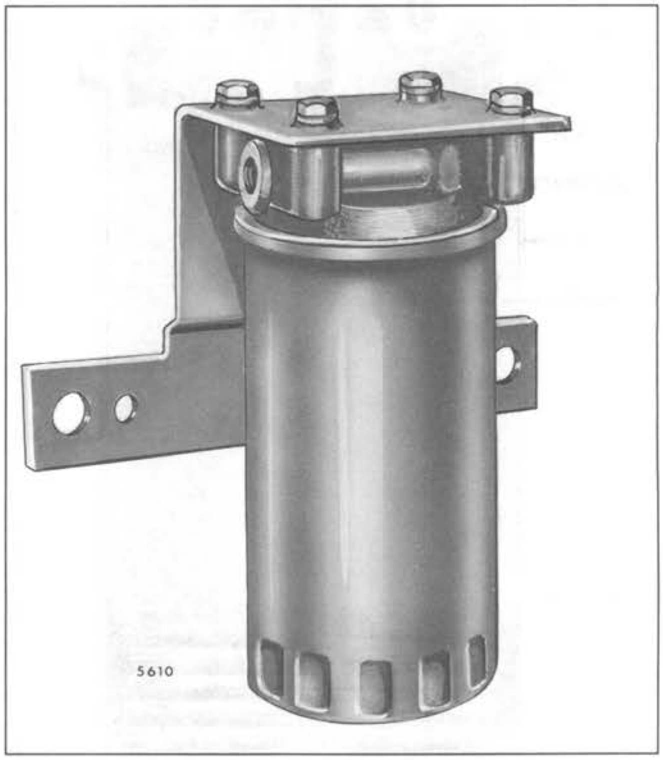


Fig. 2 – Coolant Filter and Conditioner (Spin-On Type)

Filter Installation

If a coolant filter and conditioner is to be installed on an engine which has been in service, drain and flush the cooling system prior to installation of the filter.

Filter Maintenance

Replace the chemically activated element, following the manufacturer's recommended change periods (refer to Section 15.1). The lower corrosion resistor plate (if used) must be buffed each time (discard the plate if excessive metal loss or pitting is evident) to ensure effective protection of the cooling system.

If the filter is installed on an engine which has previously been in service, it may be necessary to change the filter element two or three times at intervals of approximately 200 hours or 6,000 miles, or less, to clean up accumulations of scale and rust in the cooling system. It is advisable to drain and flush the system during these initial change intervals.

Make-up water up to 40% of the total capacity of the cooling system may safely be added before a filter element change is required.

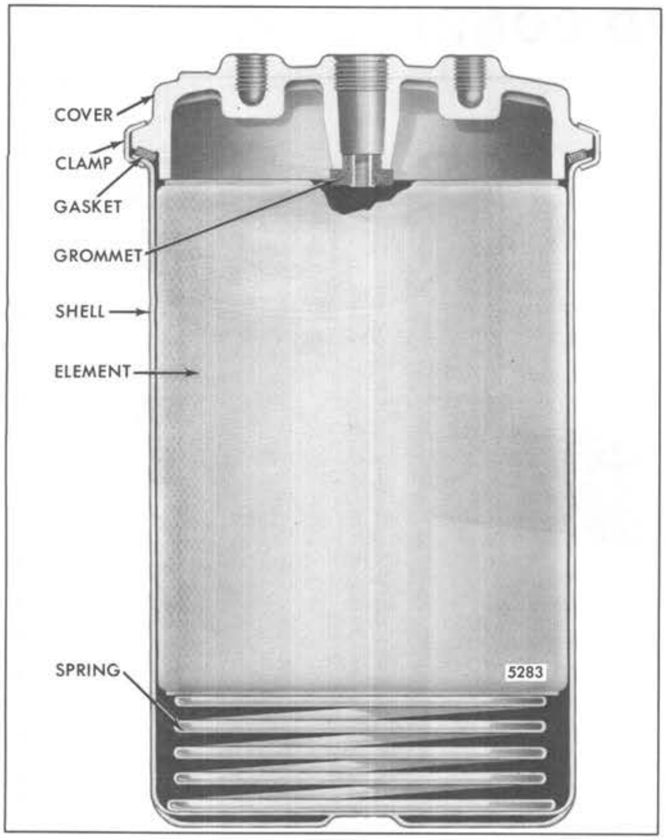


Fig. 3 – Coolant Filter and Conditioner (Clamp–On Type)

NOTICE: Sea water must never be used for make–up water in a marine engine, except under emergency conditions. If it is necessary to use sea water, the cooling system must be completely drained and flushed with fresh water upon reaching port. The filter element must be changed. Filters with resistor plates must be inspected for pitting. *Presence of salt in the coolant results in rapid pitting of the resistor plates.*

If it is necessary for any reason to drain the cooling system before an element change, the treated water should be saved and re–used. If the treated water is discarded, a new filter element must be installed since the protective agents in the used filter will have been partially consumed in treating the discarded water.

Service

The coolant filter may be grounded at the option of the user.

The current coolant filter includes a non–chromate type element. This element can be used in place of either of the former filter elements (permanent type antifreeze or plain water type) and thus provides year around cooling system protection. The current and the former filter elements are completely interchangeable in the former filter can (refer to Section 13.3).

Replace the element and service the filter and conditioner as follows:

1. Close the filter inlet and outlet shut–off valves. If shut–off valves are not provided, vise grip pliers can be used to clamp each hose closed during the filter change. Use caution to avoid damaging the hoses with the vise grip pliers.
2. Canister Type Element:
   a. Remove the drain plug in the bottom of the filter body and let drain.
   b. Remove the filter cover–to–filter body bolts.
   c. Remove and discard the element.
   d. Remove and discard the corrosion resistor plates.
   e. Remove the sludge and sediment and wash the filter body. Dry it thoroughly with compressed air.
   f. Replace the drain plug in the bottom of the filter.
   g. Insert the new element.
   h. Use a new filter cover gasket and install the filter cover and tighten the bolts evenly.
3. Spin–On Type Element:
   a. Remove and discard the element.
   b. Clean the gasket seal on the filter cover.
   c. Remove the sludge and sediment and wash the filter body. Dry it thoroughly with compressed air.
   d. Apply clean engine oil to the filter element gasket and install the new element. A 1/2 to 3/4 turn after gasket contact assures a positive leakproof seal.
4. Clamp–On Type Element:
   a. Remove the retaining clamp.
   b. Remove and discard the element.
   c. Remove the sludge and sediment and wash the filter body. Dry it thoroughly with compressed air.

d. Insert the new element.

e. Secure the filter body in place with the clamp.

5. Open the inlet and outlet lines by opening the shut–off valves or removing the vise grip plier clamps.

6. Operate the engine and check for leaks. The top of the filter and the outlet line should feel warm to the touch with the rise in coolant temperature. If not, disconnect the filter outlet line at the end opposite the filter connection to bleed the air from the system and reconnect the line. Use caution to minimize coolant loss.

SHOP NOTES - SPECIFICATIONS - SERVICE TOOLS

SHOP NOTES

FAN HUB GREASE FITTING

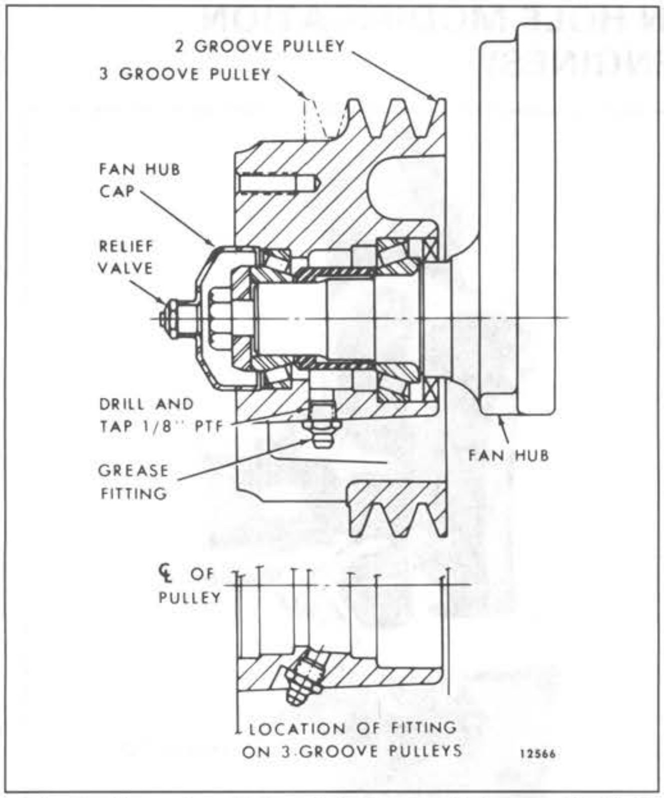


Fig. 1 – Location of Fan Hub Grease Fitting and Relief Valve

A grease fitting may be added to former fan hub assemblies used on vehicle engines to permit periodic lubrication of the bearings.

Rework the fan hub, as follows:

1. Refer to Section 5.4 and disassemble the fan hub assembly and clean the parts throughly.
2. Drill and tap the fan hub, at the location shown in Fig. 1, to accept a 1/8"PTF x 11/16" threaded lubricator fitting. Clean the hub to remove any metal chips.
3. Refer to Section 5.4 and reassemble the fan hub. Discard the former grease retainer as it is not required when a grease fitting is used.
4. Install a *new* fan hub cap which is threaded for a relief valve (Fig. 1).
5. Install a grease fitting in the fan hub and a relief valve in the fan hub cap.

Refer to Section 15.1 for the maintenance schedule.

DRAINING JABSCO RAW WATER PUMP

Although all engine units are provided with draincocks for the purpose of draining the cooling system, a small amount of coolant may remain in the impeller housing of a "Jabsco" pump.

Under normal circumstances, there would be no need in completely draining the impeller housing of a raw water pump, therefore, no drain plug has been incorporated at this location. However, certain models employ a raw water pump in conjunction with a fresh water cooling system.

In the event the engine is to be stored in below freezing temperatures, it is suggested that, in addition to draining the cooling system of the engine unit, the impeller housing of the "Jabsco" pump (if so equipped) be completely drained. This may easily be accomplished by loosening the five (5) fillister head screws which attach the end cover to the pump housing, at the impeller end of the pump; then, pulling the end cover away from the pump body, while being careful to avoid damage to the gasket. The screws need only be loosened sufficiently to allow complete draining of the impeller housing then, the screws retightened.

RAW WATER PUMP IMPELLERS

The Jabsco raw water pump is equipped with synthetic rubber impellers. Since the synthetic rubber begins to lose its elasticity at low temperatures, impellers made of natural rubber may be installed when it is necessary to pump raw water that has a temperature below 40°F (4°C). However, the standard impellers must be used when the pump operates in warmer water.

New service impellers of natural rubber are identified by a stripe of green paint.

FRESH WATER PUMP DRAIN HOLE MODIFICATION (6V AND 8V ENGINES)

After disassembling and thoroughly cleaning the water pump housing, modify the drain hole as follows:

1. After all rust and deposits have been removed from inside the pump body, paint the cavity with Rust–Oleum (Rust–Oleum No. 769® Damp Proof Red Primer or equivalent).

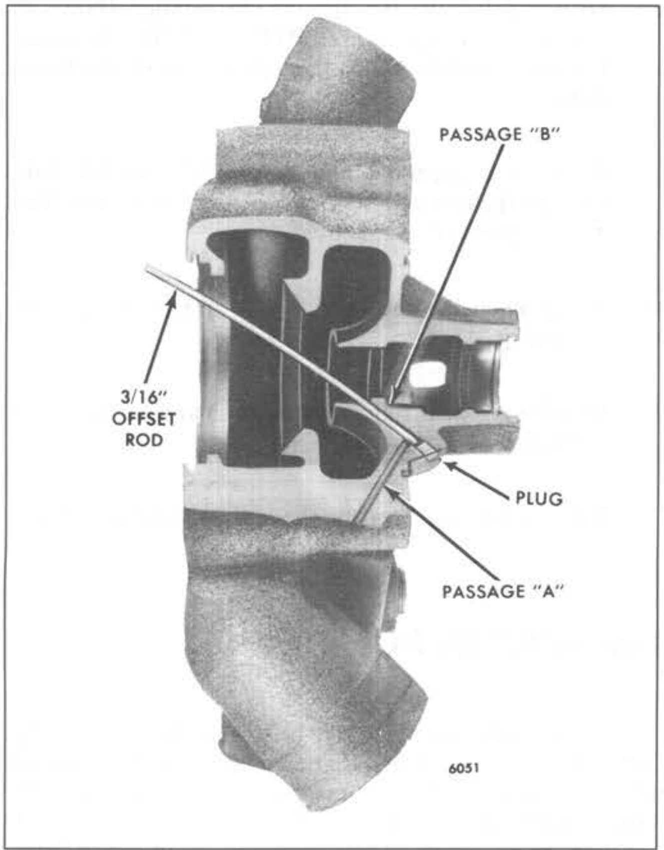


Fig. 2 – Water Pump Housing before Modification

NOTICE: The inside of the pump body may require cleaning with a wire brush to ensure paint adhesion. Be careful not to damage the oil and water seal areas. Reference instructions on the paint containers. Excess paint should be removed from the oil seal area.

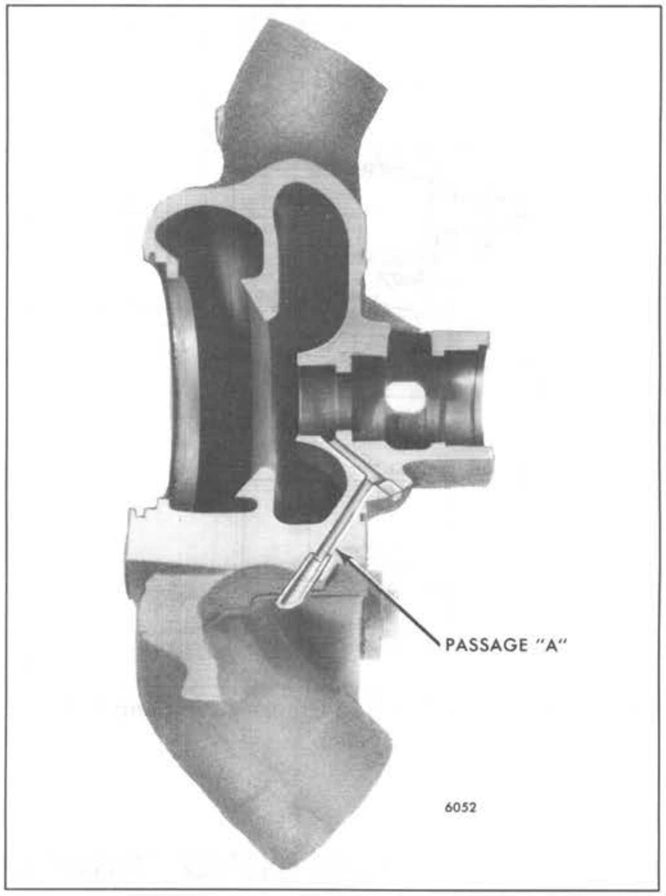


Fig. 3 – Water Pump Housing after Modification

2. With a 3/16" (.1875") offset rod, drive the plug out of passage B (Fig. 2).
3. Clean and clear passage B of debris, using a 7/32" (.2188") drill.
4. Enlarge passage A using a 7/32" (.2188") drill approximately 2 1/2", or until the drill bit meets resistance from the wall of passage B.
5. Drill the bottom of passage A approximately 1/2" using a 19/64" (.2969") drill. Be sure the drill follows the existing drain hole.

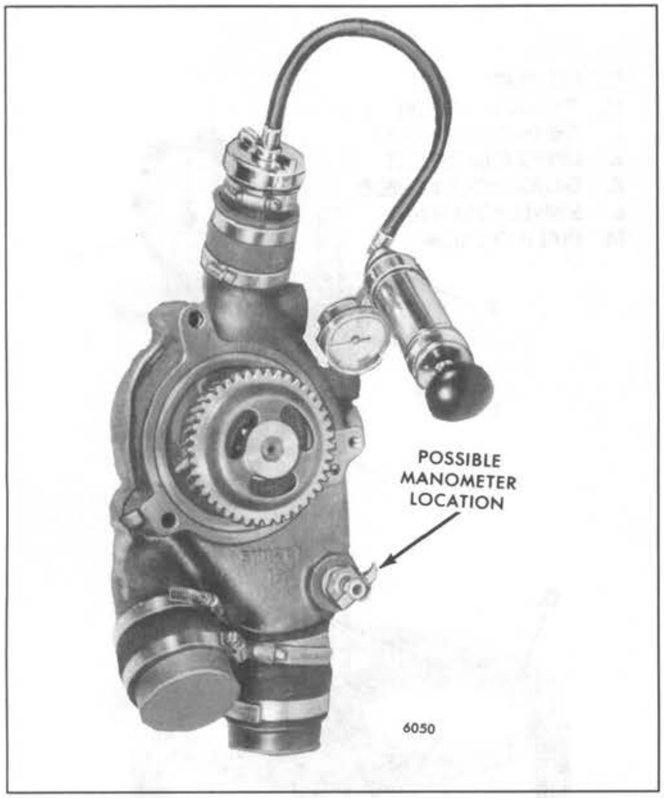


Fig. 4 – Testing Modified Water Pump Housing

6. Clean the pump body of all metal chips.

7. Press a 5/16" O.D. x 1 1/4" long steel tube into passage A until it bottoms out (Fig. 3). Cut the tube at a 45° angle with the flat or short side of the tube positioned to the engine side, away from the air flow.

8. Apply a small quantity of Loctite Sealant 601 or equivalent and install a new plug into passage B.

NOTICE: After the pump body has been completely reworked, inspect the area indicated by Arrow 1 (Fig. 3) for breakthrough. If the drill broke through, the body **should not** be used.

9. Assemble the water pump as outlined in Section 5.1.

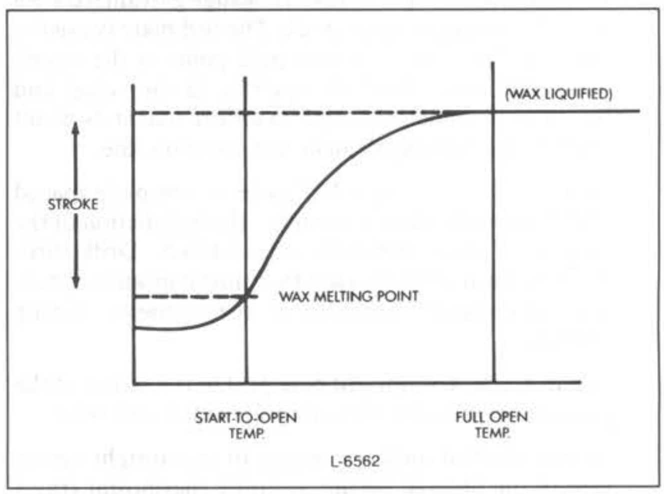
10. After the water pump is assembled, it is suggested that an air leak test be performed with a pressure testing kit such as that shown in Fig. 4. Attach the manometer at the water pump drain cock hole, then use the hand pump to raise the mercury manometer to 20 in. or 9.9 psi (68 kPa). If the manometer does not decrease in excess of .2 in. or .1 psi (.68 kPa) in 60 seconds, the pump has met the air leak test criteria. If the pump does not meet this criteria, turn the pump shaft to be sure the seal is not being held off the ceramic and perform the air leak test a second time.

THERMOSTAT FUNCTION TESTING

Thermostat print specifications normally call for three specific operating conditions: namely, start–to–open temperature, full–open temperature, and full–open dimension. The most important of these is the *start–to–open* temperature. This is the temperature at which the motor mechanism (wax compound) experiences a change from a solid to a liquid, expanding and opening the thermostat to allow coolant flow. At full–open temperature, the liquid wax is fully expanded and the full–open dimension is reached, ensuring proper coolant flow to the radiator. The start–to–open temperature is normally stamped or printed on the thermostat.

A definite relationship exists between the start–to–open temperature and operating stroke (full–open travel) of the thermostat. This relationship may be seen in the illustration below. The normal tolerance for the start–to–open temperature is +2°F or -3°F (+1.11°C or -1.67°C).

To ensure that sufficiant coolant flows through the radiator to control engine temperature, the start–to–open temperature and the full–open dimension of the thermostat should be checked. Thermostats may be tested on the simple fixture shown (Fig. 7). This fixture can be made from readily available materials.



Materials

1 Stainless steel or non–ferrous metal vessel approximately 8" diameter by 6" deep

1 2000 watt immersion–type heating element

1 Thermostatic control having a 60°F to 230°F (15.6° to 110°C) temperature range and a capillary tube sensing device

1 12" length of 1/4" copper tubing

1 3/8" drain valve

1 7 1/2" diameter piece of 12–gague galvanized sheet steel or 1/8" aluminum (for bed plate)

1 Bulkhead fitting

1 Air control valve

1 Laboratory thermometer with a 60°F to 230°F (15.6°C to 110°C) range

1 Dial indicator having a one inch travel with a 3/8" gauge holding rod and swivel post lock screw

The thermostat test fixture consists of the test vessel with control (Fig. 6) and the test plate assembly (Fig. 5).

Making the Test Fixture

1. Drill a 1/8" hole in the side of the vessel and braze a bulkhead fitting to the vessel to accept an air control valve. Shop air will be used to agitate the water and relieve temperature stratification within the vessel.
2. Manufacture an aeration line from a 12" length of 1/4" copper tubing by drilling four equally spaced 1/8" holes in the tube and crimping or blocking one end. Attach the open end of the tube to the air valve and bend the tube to the inside contour of the vessel.
3. Install a 3/8" drain valve in the lower portion of the vessel.
4. Fabricate the bed plate from 12–gauge galvanized steel or 1/8" aluminum sheet stock. The bed plate is used to suspend the thermostat at a mid–point in the vessel. This component must fit squarely in the vessel and have legs of sufficient length to ensure that stats won't contact the heating element and aeration line.

   Bore 1 9/16", 2", and 2 3/4" holes in the plate spaced 120° from each other to facilitate the installation of the variety of stats normally encountered. Drill three 7/16" holes at 60° from each thermostat mounting bore for conveniently locating a thermometer during testing.

   Install a 3/8" x 8" upright base post in the center of the plate to provide the mounting for a dial indicator.
5. Attach the dial indicator gauge to the upright center post of the plate to permit accurate thermostat travel measurement. The bed plate and dial indicator shown have components added to raise the indicator vertically above the gauge holding rod; however, the extra items are not required.

Thermostat Testing Procedure

NOTICE: This procedure will take time to do properly. Refer to Fig. 7.

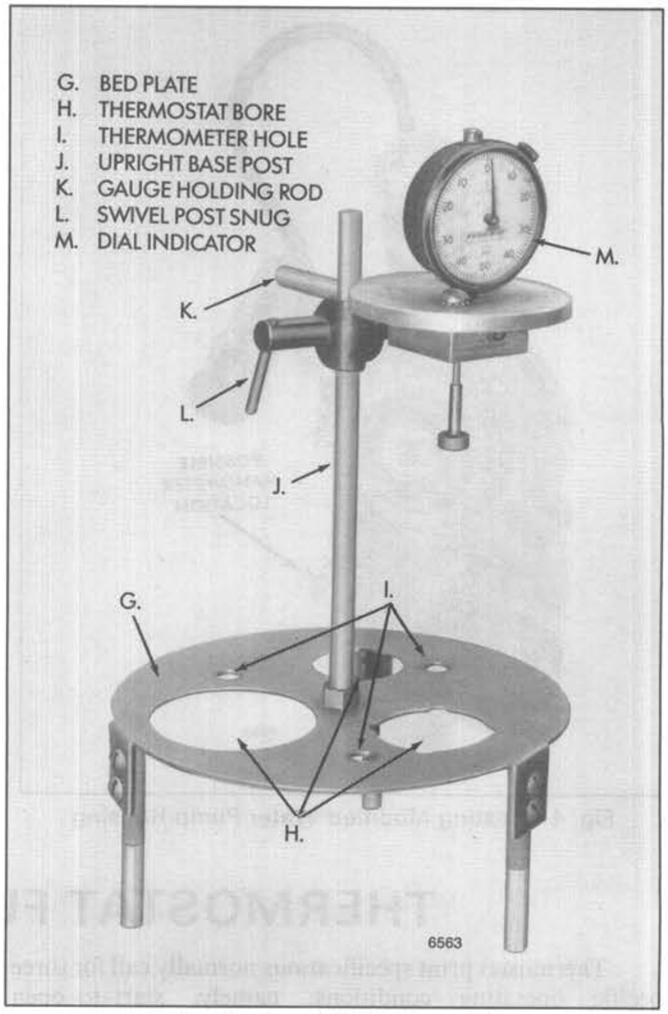


Fig. 5 – Test Plate Assembly

Place the vessel on a level surface and lower the bed plate into position, being careful to avoid contact with the heating element.

Fully submerge the thermostat in warm water and place a laboratory thermometer in one of the 7/16" holes on the bed plate. Position the dial indicator over the thermostat, centering the contact point on the motor mechanism. Zero the dial. To ensure accurate test results, allow the thermostat to warm up to water temperature before testing. Then, turn on the heating element (if necessary) and bring water temperature to a few degrees below the start–to–open temperature of the thermostat being tested. Hold at this temperature for 2–3 minutes.

With the heating element on, adjust the air valve to sufficiently agitate the water for equal heat distribution. Bring bath temperature up to the maximum specified start–to–open temperature of the thermostat. Observe the dial indicator and note the temperature at which the needle just begins to move. This is referred to as the *start–to–open temperature.* The total indicator travel, from star–to–open to full–open is referred to as the *full open travel.*

Fig. 6 – Test Vessel and Control

For full–open temperature and travel, raise bath temperature a few degrees above the specified full–open temperature and hold at that temperature for 2 to 3 minutes.

To efficiently test a number of thermostats, simply add cold water to the vessel. This will reduce the water temperature to a level below the next thermostat opening temperature, thus saving time. Turn the heating element off after completing the tests.

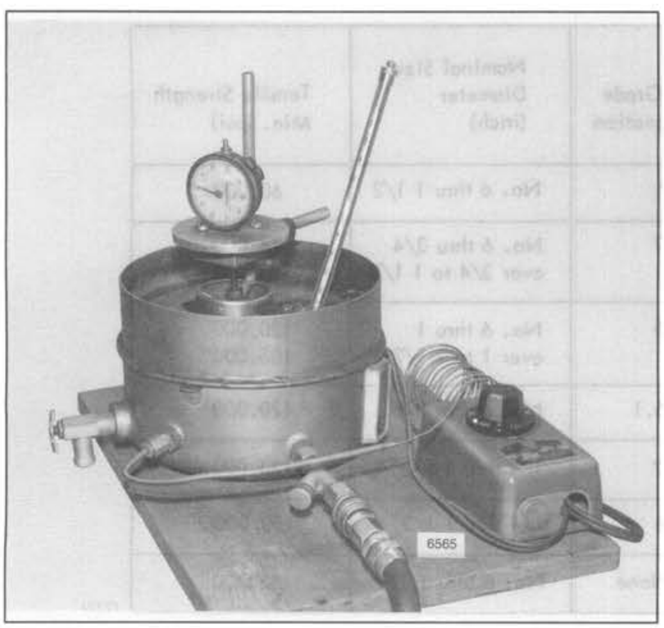


Fig. 7 – Testing a Thermostat in the Test Fixture

Conducting Cooling Tests

When conducting cooling tests on an engine, it is essential that maximum radiator/heat exchanger coolant flow be achieved. Coolant flow and, subsequently, the accuracy of cooling system test results depend to a large extent on the condition of the thermostat installation. If maximum flow does not occur, check for these causes:

1. Thermostat(s) not blocked open to correct dimension.
2. Thermostat housing seal(s) missing.
3. Thermostat housing seal(s) worn.
4. Thermostat housing cover bypass cavity sealing surface(s) not centered and/or worn.

Find Coolant Leaks with Fluorescent Dye, Black Light

Finding the source of an engine coolant leak is often a time–consuming affair. To speed the process, a fluorescent dye such as *15174 Uranine* (or equivalent) may be added to the coolant. Under an ultraviolet "black light," the Uranine dye–treated coolant turns a highly visible, bright yellow–green color, making the leak path easy to trace.

15174 Uranine is manufactured by Chemcentral Corporation and is available through their distributor network. For further information contact:

CHEMCENTRAL CORPORATION
7050 West 71st Street
Chicago, Illinois 60638

SPECIFICATIONS

STANDARD BOLT AND NUT TORQUE SPECIFICATIONS

THREAD SIZE	260M BOLTS TORQUE (lb-ft)	260M BOLTS TORQUE N•m	THREAD SIZE	280M OR BETTER TORQUE (lb-ft)	280M OR BETTER TORQUE N•m
1/4–20	5–7	7–9	1/4–20	7–9	10–12
1/4–28	6–8	8–11	1/4–28	8–10	11–14
5/16–18	10–13	14–18	5/16–18	13–17	18–23
5/16–24	11–14	15–19	5/16–24	15–19	20–26
3/8–16	23–26	31–35	3/8–16	30–35	41–47
3/8–24	26–29	35–40	3/8–24	35–39	47–53
7/16–14	35–38	47–51	7/16–14	46–50	62–68
7/16–20	43–46	58–62	7/16–20	57–61	77–83
1/2–13	53–56	72–76	1/2–13	71–75	96–102
1/2–20	62–70	84–95	1/2–20	83–93	113–126
9/16–12	68–75	92–102	9/16–12	90–100	122–136
9/16–18	80–88	109–119	9/16–18	107–117	146–159
5/8–11	103–110	140–149	5/8–11	137–147	186–200
5/8–18	126–134	171–181	5/8–18	168–178	228–242
3/4–10	180–188	244–254	3/4–10	240–250	325–339
3/4–16	218–225	295–305	3/4–16	290–300	393–407
7/8–9	308–315	417–427	7/8–9	410–420	556–569
7/8–14	356–364	483–494	7/8–14	475–485	644–657
1–8	435–443	590–600	1–8	580–590	786–800
1–14	514–521	697–705	1–14	685–695	928–942

Grade identification markings are normally stamped on the heads of the bolts. To aid identification of the various bolts used in Detroit Diesel engines, refer to the following chart.

Grade Identification Marking on Bolt Head	GM Number	SAE Grade Designation	Nominal Size Diameter (inch)	Tensile Strength Min. (psi)
None	GM 255-M	1	No. 6 thru 1 1/2	60,000
None	GM 260-M	2	No. 6 thru 3/4 over 3/4 to 1 1/2	74,000 60,000
Bolts and Screws	GM 280-M	5	No. 6 thru 1 over 1 to 1 1/2	120,000 105,000
Hex Head Sems Only	GM 275-M	5.1	No. 6 thru 3/8	120,000
Bolts and Screws	GM 290-M	7	1/4 thru 1 1/2	133,000
Bolts and Screws	GM 300-M	8	1/4 thru 1 1/2	150,000
Bolts and Screws	GM 455-M	None	No. 6 thru 1 1/2	55,000

12252

BOLT IDENTIFICATION CHART

EXCEPTIONS TO STANDARD BOLT AND NUT TORQUE SPECIFICATIONS

APPLICATION	THREAD	lb-ft	N•m
Water outlet cover plate bolt	3/8–16	20–25	27–34
Water manifold nut	3/8–24	20–25	27–34
Water pump impeller retaining nut	7/16–20	35–40	47–54

STUD TORQUE SPECIFICATIONS

APPLICATION	lb-ft	N•m
Water pump body stud (16V)	10–20	14–27
Water pump over stud (16V)	12–15	16–20

SERVICE TOOLS

TOOL NAME	TOOL NO.
Cooling system and radiator cap pressure tester	J 24460–01
Fingers, fan hub nut socket (16V)	J 6534–8
Handle	J 7079–2
Oil seal installer	J 8501
Pliers	J 4646
Puller	J 24420–A
Socket, fan hub nut (16V)	J 22556–2
Thermostat seal installer	J 8550
Water pump bearing and gear installer	J 25257
Water pump impeller/gear slip torque tool	J 33765
Water pump seal remover set	J 22150–B
Water pump impeller slip checking fixture	J 34034

SECTION 6

EXHAUST SYSTEM

CONTENTS

EXHAUST SYSTEM

Fan and radiator cooled engines are equipped with an air-cooled exhaust manifold. A water-cooled exhaust manifold is provided for engines incorporating a heat exchanger or keel cooling system.

The outlet flange may be located at the end or at the mid-section of the exhaust manifold, depending upon the installation requirements. A flexible exhaust connection or a muffler may be attached to the outlet flange.

The exhaust manifold is attached to studs located between the exhaust ports and the outer side of the two end ports in the cylinder head. Special washers and nuts secure the manifold to the cylinder head.

EXHAUST MANIFOLD (Air–Cooled)

The cast air–cooled manifold (Fig. 1) has a uniform circular cross–section and tapers upward from each end toward the center where a flange is provided for the attachment of the exhaust piping or muffler.

A new exhaust manifold hold–down crab is now being used. The new hold–down crab is made of a hardened steel and is heavier than the former hold–down crab. This will minimize wear and gouging of the manifold, crab and cylinder head mating surfaces, which results in a loss in the torque on the hold–down crab nut. The former and the new hold–down crab are interchangeable on an engine however only the new crab will be serviced.

Also a new special washer is now used at the center portions of the exhaust manifolds. This new washer will more accurately control the seating area for the 7/16" nut or bolt. Only the new speical washer will be serviced.

Remove Exhaust Manifold

Usually, the exhaust manifold will be removed with the cylinder head. However, when the exhaust manifold gaskets only need to be replaced, the manifold may be removed in the following manner without removing the cylinder head:

1. Loosen the flange seal connecting the exhaust manifold at the outlet tube.
2. Disconnect the exhaust pipe or muffler from the exhaust manifold flange.
3. Loosen and remove the nuts and bevel washers which secure the exhaust manifold to the cylinder head. It is suggested that, as a safeguard, one nut and washer be loosened and left on one of the center studs until all other nuts and washers have been removed.
4. Support the manifold and remove the nut and washer from the center stud.

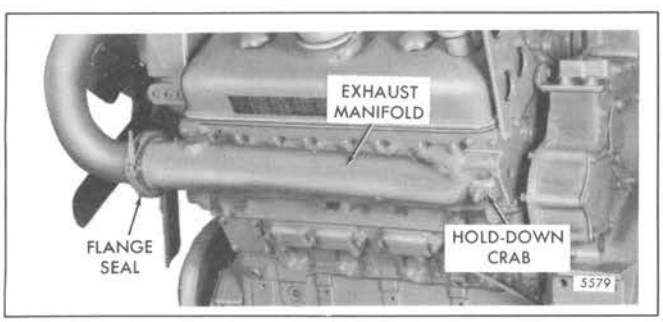


Fig. 1 – Typical Cast Air–Cooled Exhaust Manifold Mounting

5. Lift the manifold away from cylinder head.
6. Remove the manifold gaskets.

Inspection

Remove the loose scale and carbon that may have accumulated on the internal walls of the exhaust manifold. It is especially important to clean the manifold used on a turbocharged unit to eliminate the possibilty of loose scale entering and damaging the turbocharger.

Examine the exhaust manifold studs for damage. If necessary, replace the studs. New studs are driven in to 25–40 lb–ft (34–54 N•m) torque.

Install Exhaust Manifold

With all traces of the old gaskets removed from the cylinder head and bolting flanges of the exhaust manifold, install it as follows:

1. Make sure the internal walls of the manifold are clean to eliminate possible damage to the turbocharger, if used.
2. Place new gaskets over the studs and up against the cylinder head. Metal–clad gaskets may look reusable, but once they've been used and taken a "set" they cannot be reused.

   NOTICE: When installing the metal clad exhaust manifold gasket(s) be sure the crimped side of the gasket (Fig. 2) faces the cylinder head.

3. Position the exhaust manifold over the studs and up against the gasket.

   NOTICE: Be sure the locating pads on the exhaust manifold rests on the cylinder block locating pads.

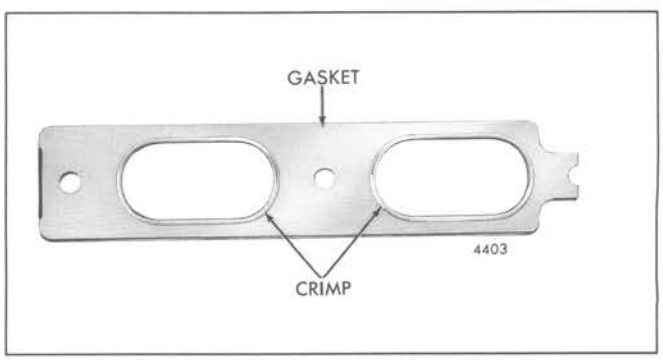


Fig. 2 – Metal Clad Exhaust Manifold Gasket

4. Install the bevel washers and nuts on the studs and draw the exhaust manifold up against the gasket. Set the bevel washers in position so that outer diameter will rest on the manifold and the crown at the center is next to the nut. Tighten the exhaust manifold stud nuts from the center of the exhaust manifold outward, alternating toward either end. Torque the nuts to 30–35 lb–ft (41–47 N•m).

5. Connect the exhaust pipe or muffler to the exhaust manifold flange.

6. Tighten the flange seal connecting the exhaust manifold to the outlet tube.

NOTICE: Do not allow exhaust piping to impose excessive loads on the turbocharger.

7. Inspect the exhaust outlet piping for dents, holes and potential sources of water infiltration such as loose clamps or deteriorated seals. Repair or replace, if necessary.

EXHAUST MANIFOLD (Water-Cooled)

The one-piece water-cooled manifold (Fig. 1) is cast with an integral water jacket surrounding the exhaust chamber. The diameter of the exhaust chamber increases uniformly from one end to the other where it terminates in a flange to which an elbow and flexible exhaust connection is attached. A portion of the engine coolant is bypassed from the rear of the cylinder block into the rear end of the jacket surrounding the exhaust manifold and is discharged from the forward end through a tube into the thermostat housing. A drain cock is installed in the bottom of the manifold for draining the water jacket. A plug is provided in the bottom of the exhaust manifold elbow for draining moisture condensed from the exhaust gases.

First model 8122–7400 marine engines were built with four-bolt design exhaust manifolds, covers, connectors, gaskets and turbo exhaust inlet elbows. This design was replaced by six-bolt design components after a short production run. The six bolt design is now standard on all 12V-92 TA marine engines.

Only the six-bolt design parts and the four-bolt design connector, cover and gasket will be serviced. When a former manifold or turbo exhaust inlet elbow requires replacement, all four-bolt design parts must be replaced by six-bolt design parts.

Remove Exhaust Manifold

Usually, the exhaust manifold will be removed with the cylinder head. However, when the exhaust manifold gasket only needs to be replaced, the manifold may be removed in the following manner without removing the cylinder head:

1. Drain the cooling system.
2. Disconnect the water inlet and the water outlet tubes from the exhaust manifold.
3. Disconnect the exhaust pipe from the flange so that it will not interfere with removal of the exhaust manifold.
4. Loosen and remove the nuts and bevel washers which secure the exhaust manifold to the cylinder head. It is suggested that, as a safeguard, one nut and washer be loosened and left on one of the center studs until all other nuts and washers have been removed.
5. Support the manifold and remove the nut and washer from the center stud.
6. Lift the manifold off the studs and away from the cylinder head.
7. Remove the manifold gasket.

Inspection

Remove the loose scale and carbon that may have accumulated on the internal walls of the exhaust manifold. It is especially important to clean the manifold used on a turbocharged unit to eliminate the possibility of loose scale entering and damaging the turbocharger.

Examine the exhaust manifold studs for damage. If necessary, replace the studs. New studs are driven in to 25–40 lb-ft (34–54 N•m) torque.

Install Exhaust Manifold

With all traces of the old gasket removed from the cylinder head and bolting flange of the exhaust manifold, it may be installed as follows:

1. Make sure the internal walls of the exhaust manifold are clean to eliminate possible damage to the turbocharger, if used.
2. Place a new gasket over the studs and up against the cylinder head.
3. Position the exhaust manifold over the studs and up against the gasket.

NOTICE: Be sure the locating pads on the exhaust manifold rests on the cylinder block locating pads.

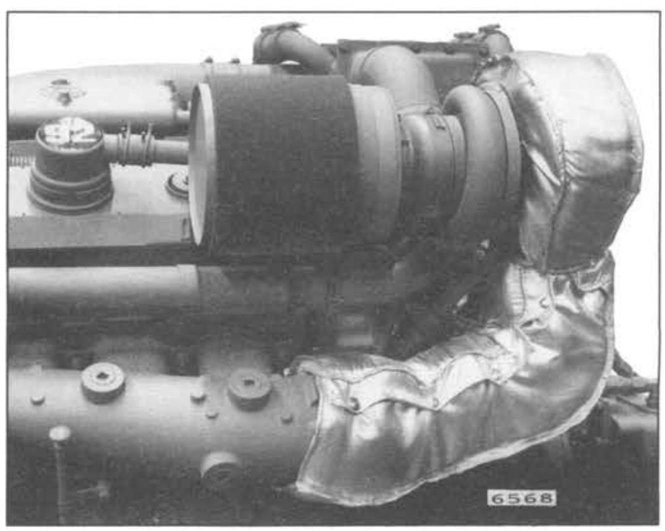


Fig. 1 – Typical Water-Cooled Exhaust Manifold Installation (8V-92 Engine Shown)

4. Install the bevel washers and nuts on the studs and draw the exhaust manifold up against the gasket. Bevel washers should be set in position so that the outer diameter will rest on the manifold and the crown at the center is next to the nut. The exhaust manifold stud nuts should be tightened from the center of the exhaust manifold outward, alternating towards either end. Torque the nuts to 30–35 lb–ft (41–47 N•m).

5. If the exhaust flange was removed from the manifold, install the flange using a new gasket.

6. Connect the exhaust pipe to the flange.

7. Connect the water inlet and outlet tubes to the manifold.

NOTICE: Do not allow exhaust piping to impose excessive loads on the turbocharger.

8. Inspect the exhaust outlet piping for dents, holes and potential sources of water infiltration such as loose clamps or deteriorated seals. Repair or replace, if necessary.

9. Fill the cooling system and check for leaks.

SECTION 7

ELECTRICAL EQUIPMENT, INSTRUMENTS AND PROTECTIVE SYSTEMS

CONTENTS

ELECTRICAL SYSTEM

A typical engine electrical system generally consists of a starting motor, a battery–charging alternator, a storage battery and the necessary wiring.

Additional equipment such as an engine protective system may also be included.

Detailed information on maintenance and repair of the specific types of electrical equipment can be found in the service manuals and bulletins issued by the equipment manufacturer..

In most instances, repairs and overhaul work on electrical equipment should be referred to an authorized repair station of the manufacturer of the equipment. Replacement parts for electrical equipment should be ordered through the equipment manufacturer's outlets, since these parts are not normally stocked by Detroit Diesel Corporation. For electrical equipment manufactured by Delco–Remy Division, repair service and parts are available through AC–Delco branches and repair stations.

BATTERY–CHARGING ALTERNATOR

The battery–charging circuit consists of an alternator, battery and the wiring. The battery–charging alternator (Figs. 1 or 2) is introduced into the electrical system to provide a source of electrical current for maintaining the storage battery in a charged condition and to supply sufficient current to carry any other electrical load requirements up to the rated capacity of the alternator.

HINGE–MOUNTED ALTERNATOR (BELT–DRIVEN)

The hinge–mounted alternating current self–rectifying alternator (Fig. 1), mounted at the rear of the engine, is belt–driven. The alternator drive pulley is keyed to a shaft which is coupled to the blower drive gear.

An adequate alternator drive ratio is necessary for an engine equipped with extra electrical accessories and one that has to operate for extended periods at idle speeds. Diodes, built into the slip ring end frame, rectify the three phase A.C. voltage to provide D.C. voltage at the battery terminal of the alternator, thereby eliminating the need for an external rectifier. The alternator is also available in various sizes and types, depending upon the specific application.

The access hole permitting the external adjustment of the voltage regulator has been eliminated on current alternators. To adjust the voltage setting on the current alternators, refer to the manufacturer's Service Bulletin for complete adjustment procedure.

Alternator Maintenance

1. Maintain proper drive belt tension as noted in Section 15.1. Replace worn or frayed belts. Belts should be replaced as a set when there is more than one belt on the alternator drive.

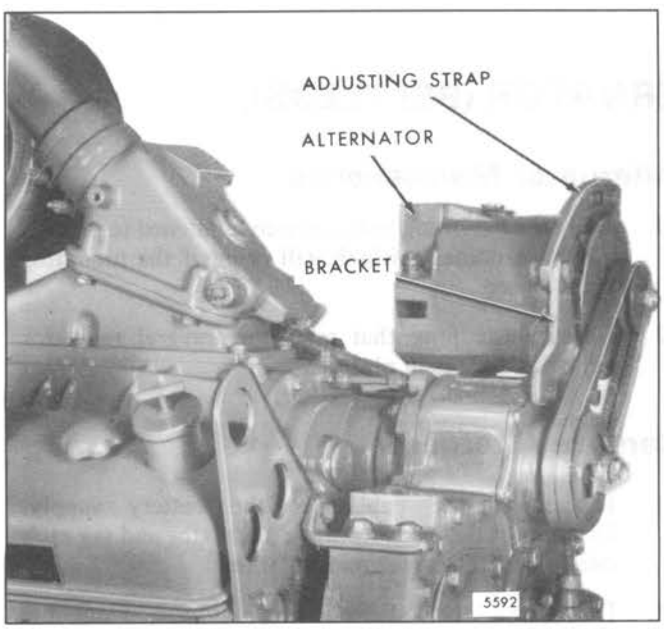


Fig. 1 – Typical Hinge–Mounted Alternator (Belt–Driven)

NOTICE: When installing or adjusting an alternator drive belt, be sure the bolt at the alternator pivot point is properly tightened, as well as the bolt in the adjusting slot.

2. Alternator bearings are permanently lubricated. There are no external oiler fittings.

Remove Alternator

1. Disconnect the cables at the battery supply. If the alternator has a separately mounted regulator and field relay, disconnect all other leads from the alternator and tag each one to ensure correct reinstallation.

2. Loosen the mounting bolts and the adjusting strap bolt. Then remove the drive belts.

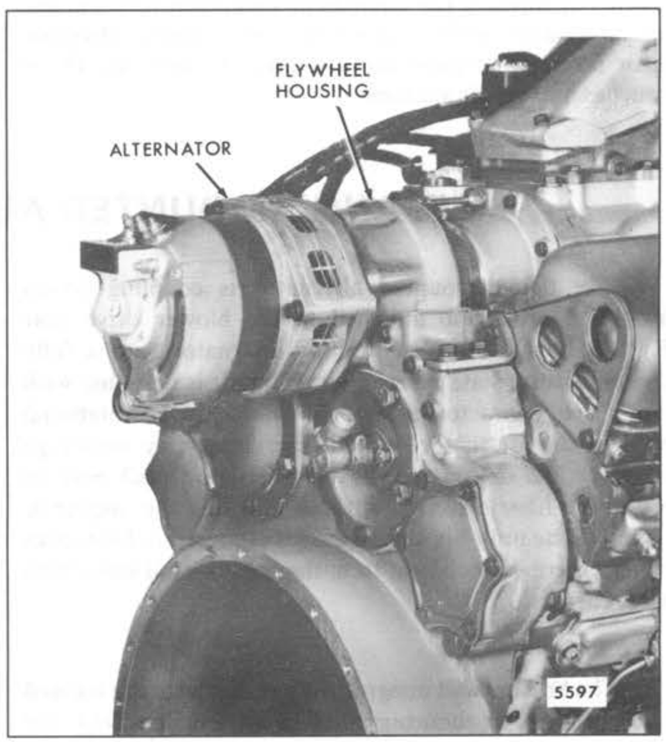


Fig. 2 – Typical Flange–Mounted Alternator (Beltless)

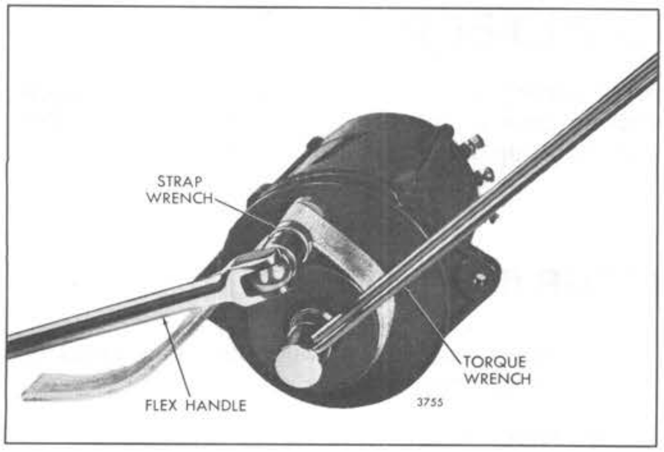


Fig. 3 – Tightening Alternator Pulley Retaining Nut

3. While supporting the alternator, remove the adjusting strap bolt, hardened washer and lock washer. Then remove the mounting bolts, hardened washer, lock washer and nuts. Remove the alternator carefully and protect it from costly physical damage.

4. Remove the pulley assembly if the alternator is to be replaced.

Alternator Service

Repairs and overhaul work on alternators should be referred to an authorized repair station of the manufacturer of this equipment. Replacement parts for alternators should be ordered through the equipment manufacturer's outlets. For alternators manufactured by Delco–Remy Division, repair service and parts are available through AC Delco branches and repair stations.

Install Alternator

1. Install the drive pulley, if it was removed. Tighten the pulley retaining nut to 50–60 lb–ft (68–81 N•m) torque.

   NOTICE: If the pulley was not removed, check the retaining nut for proper torque.

2. Position the alternator on the mounting brackets and start the bolts, with lock washers and hardened washers in place, through the bolt holes in the alternator end frames. If nuts are used, insert the bolts through the bolt holes in the mounting bracket and alternator end frame and make sure that the lock washers, hardened washers and nuts are in their proper locations.

3. Align the threaded hole in the adjusting lug of the drive end frame with the slot in the adjusting strap. Start the bolt, with the lock washer and hardened washer, through the slot of the adjusting strap and into the threaded hole in the alternator end frame.

4. Place the drive belts in the grooves of the pulleys.

5. Adjust the alternator belt tension as outlined in Section 15.1. Tighten all of the bolts after belt tightening is completed.

6. Attach the wires and cables. Be sure that each one is correctly installed in accordance with its previous location on the alternator. Keep all connections clean and tight.

FLANGE–MOUNTED ALTERNATOR (BELTLESS)

The flange–mounted alternator is coupling–driven through a drive hub attached to the blower drive gear (Fig. 2). It is a self load limiting alternator with a fully adjustable solid state integral regulator. It is designed with slow speed characteristics which allow lower rotational speed of the alternator without sacrificing any amperage output at idle or top speed. The alternator shaft may be rotated in either direction without affecting the output or cooling of the unit. Six silicon diodes mounted in heat sinks convert alternating current from the delta wound stator into direct current.

The brushes and integral voltage regulator are located in a waterproof housing that may be removed for replacement or inspection.

Alternator Maintenance

1. Keep the mounting bolts securely tightened to prevent vibration damage, which will occur if the mounting bolts loosen.

2. Be sure the plug that seals the integral regulator adjusting hole is in place.

Remove Alternator

1. Disconnect the cables at the battery supply. Disconnect the leads from the alternator and tag each one to ensure correct reinstallation.

2. Disconnect the oil feed line, if used, from the alternator.

3. Loosen the three alternator mounting bolts.

4. While supporting the alternator, remove the mounting bolts, hardened washers and lock washers and lift the alternator and fan guard as a unit from the mounting adaptor. Protect the alternator and fan guard assembly from physical damage following removal from the engine.

   NOTICE: The fan guard, which includes an oil seal, should not be separated from the alternator until the alternator half of the coupling is removed. Any attempt to separate the fan guard from the alternator could damage the oil seal.

5. Loosen the retaining nut and remove the coupling hub keyed to the alternator shaft.

6. If the alternator is to be replaced, separate the fan guard from the alternator.

7. Remove the alternator flange mounting adaptor from the flywheel housing, if necessary.

Alternator Service

To service the alternator, contact the alternator manufacturer.

Inspection

Inspect the drive coupling and hub for wear at the seal surface and the drive tangs. If worn excessively, replace them with new parts.

Oil leaks indicate a worn or damaged oil seal. Replace the oil seal in the fan guard, if necessary.

Inspect the alternator housing and flange adaptor at the mounting bolt holes for cracks and the pilot diameters for damage, cracks or distortion. Replace if necessary.

Install Alternator

1. If removed, attach the alternator mounting adaptor, using a new gasket, to the flywheel housing. The adaptor is secured to the engine by two short bolts into the flywheel housing and four long bolts through the flywheel housing, end plate and blower drive support.

   Make sure the alternator is properly fitted to the adaptor before it is bolted in place. Improper installation of the alternator can disturb adaptor alignment and cause gear train damage. See Section 1.7.7 for alignment procedure.

   NOTICE: Special hardened, plain washers seat in the six counterbored bolt holes in the adaptor. Also, the current gasket has a positioning identification tab.

2. If the fan guard and hub were removed, locate the fan guard on the alternator by engaging the mating pilot diameters. Lubricate the seal diameter on the coupling hub and the seal lip. Install the coupling hub on the shaft. Be careful not to damage the lip of the oil seal. Install the retaining nut on the shaft and tighten it to 70–80 lb–ft (95–108 N•m) torque. If the fan guard and hub were not removed, check the retaining nut for proper torque.

   NOTICE: Do not support the alternator on the fan guard.

3. Place the slotted drive coupling on the drive hub.

   NOTICE: Align the slotted drive coupling with the blower drive coupling when attaching the alternator assembly.

4. Align the bolt holes in the fan guard with the mounting holes in the alternator housing. Support the alternator assembly against the mounting flange adaptor, using a new gasket, and install the three 3/8"–16 x 3 1/2" bolts, lock washers and hardened washers through the alternator housing and fan guard mounting holes into the mounting adaptor. Tighten the bolts to 30–35 lb–ft (41–47 N•m) torque.

5. Attach the wires and cables. Be sure each one is correctly installed in accordance with its previous location on the alternator. Keep all connections clean and tight.

6. Connect the oil feed line, if used, to the alternator.

Oil Return Line

Distributor–provided Delco–Remy oil–cooled alternators formerly required a retrofit kit and customer–supplied oil supply and return lines. Because *the oil return line is no longer required* the oil return drain in the rectifier end frame of current 32SI alternators has been eliminated. The oil supply line is not affected by this change.

When an alternator having an oil return line is being serviced with a new rectifier end frame which does not have the oil return hole, or when an alternator assembly without the oil return hole is installed, perform the following steps:

1. Remove and discard the oil return line.

2. Remove the oil drain tube from the engine star cover.

3. Seal the hole in the engine star cover with the plug provided with the rectifier end frame or the complete alternator. This plug is also available from authorized Detroit Diesel or AC–Delco Parts Distributors.

ALTERNATOR PRECAUTIONS

Precautions must be taken when working on or around alternators. The diodes and transistors in the alternator circuit are very sensitive and can be easily destroyed.

Avoid grounding or shorting the output wires or the field wires between the alternator and the regulator. Never run an alternator on an open circuit.

Grounding an alternator's output wire or terminals, which are always "hot" regardless of whether or not the engine is running, or accidental reversing of the battery polarity will destroy the diodes. Grounding the field circuit will also result in the destruction of the diodes. Some voltage regulators provide protection against some of these circumstances. However, it is recommended that extreme caution be used.

Accidentally reversing the battery connections must be avoided.

Never disconnect the battery while an alternator is in operation. Disconnecting the battery may result in damage to the diodes due to the momentary high voltage and current generated by the rapid collapse of the magnetic field surrounding the field windings.

In marine applications which have two sets of batteries, switching from one set of batteries to the other while the engine is running will momentarily disconnect the batteries and result in damage to the alternator diodes.

If a booster battery is to be used, the batteries must be connected correctly (negative to negative and positive to positive).

Never use a fast charger with the battery connected or as a booster for battery output. Never attempt to polarize the alternator.

The alternator diodes are also sensitive to heat and care must be exercised to prevent damage to them from soldering irons, etc.

If faulty operation of an alternator occurs on an engine equipped with an insulated starting motor, check to be sure that a ground strap is present and is correctly installed.

STORAGE BATTERY

The lead–acid storage battery is an electro–chemical device for converting chemical energy into electrical energy.

Function Of Battery

The battery has three major functions:

1. It provides a source of current for starting the engine.
2. It acts as a stabilizer to the voltage in the electrical system.
3. It can, for a limited time, furnish current when the electrical demands exceed the output of the alternator.

In the selection of a replacement battery, it is always good practice to select one of an "electrical size" (refer to Chart) at least equal to the battery originally engineered for the particular equipment by the manufacturer.

		Minimum Battery Rating SAE Cold Cranking AMPS @ 0°F (−17.8°C)	
Engine Model	System Voltage	Above 32°F (0°C)	Below 32°F (0°C)
6V-92, 8V-92* 12V-92*	24V, 32V	950	1250
16V-92	#24V, 32V	950	1250

*Must use Delco Remy 50MT cranking motor or equivalent.
#Two cranking motors. Battery recommendation is for each motor.

BATTERY RECOMMENDATIONS

Install Battery

While the battery is built to satisfactorily withstand the conditions under which it will normally operate, excessive mechanical abuse leads to early failure.

Install the battery as follows:

1. Be sure the battery carrier is clean and that the battery rests level when installed.
2. Tighten the hold–down clamps evenly until snug. However, do not draw them down too tight or the battery case will become distorted or will crack.
3. Attach the cable clamps after making sure the cables and terminal clamps are clean and in good condition. To make the cable connections as corrosion resistant as possible, place a felt washer at the base of each terminal beneath the cable clamps. Coat the entire connection with a heavy general–purpose grease. Be sure the ground cable is clean and tight at the engine block or frame.
4. Check the polarity to be sure the battery is not reversed with respect to the generating system.
5. Connect the *grounded* terminal of the battery last to avoid short circuits which will damage the battery.

Servicing The Battery

A battery is a perishable item which requires periodic servicing. Only when the battery is properly cared for as described below can long and trouble–free service be expected.

1. Maintenance–free type batteries.
   a. On batteries equipped with charge indicator "eyes", periodically check for adequate charge.
   b. Although maintenance–free, periodically remove, check and clean battery posts, terminals and connections. Check connections for fraying or loss of insulation coverings and repair or replace.
2. If the batteries that are not the maintenance–free type, check the level of the electrolyte regularly. Add water, if necessary, but do not overfill. Overfilling can cause poor performance or early failure.
   a. Keep the top of the battery clean. When necessary, wash with a baking soda solution and rinse with fresh water. Do not allow the soda solution to enter the cells.
   b. Inspect the cables, clamps and hold–down bracket regularly. Clean and reapply a coat of grease when needed. Replace corroded or damaged parts.
   c. Use the standard battery test as the regular service test to check the condition of the battery.

Check the electrical system if the battery becomes discharged repeatedly. Many electrical troubles caused by battery failures can be prevented by systematic battery service.

Battery Safety Precautions

When batteries are being charged, an explosive gas mixture forms beneath the cover of each cell. Part of this gas escapes through the holes in the vent plugs and may form an explosive atmosphere around the battery itself if ventilation is poor.

CAUTION: Explosive gas may remain in or around the battery for several hours after it has been charged. Sparks or flames can ignite this gas causing an internal explosion which could shatter the battery. Flying pieces of the battery structure and splash of electrolyte can cause personal injury.

STARTING MOTOR

The starting motor (Fig. 1) is mounted on the flywheel housing. When the starting circuit is closed, a small drive pinion on the armature shaft engages with the teeth on the engine flywheel ring gear to crank the engine. When the engine starts, it is necessary to disengage the drive pinion to prevent the armature from overspeeding and damaging the starting motor.

See Section 7.0 for the mounting of a starter auxiliary magnetic switch.

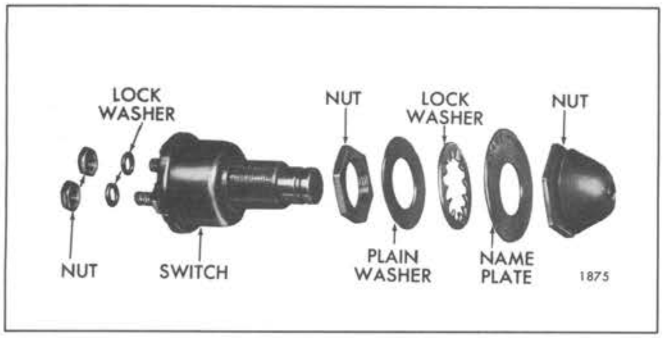


Fig. 1 – Typical Starting Motor

When repositioning of the solenoid is required on a service replacement starting motor, proceed as follows:

1. Remove the six socket head screws (1 short and 5 long) and six neoprene plugs, if a twelve hole starter mounting flange is used.
2. Turn the nose housing to the required position.

   NOTICE: The solenoid must never be located below the centerline of the starter or dust, oil, moisture and foreign material can collect and cause solenoid failures.
3. Install the six socket head screws, with the short screw in the shallow hole nearest the solenoid and six neoprene plugs, if a twelve hole starter mounting flange is used.
4. Tighten the screws to 13–17 lb–ft (18–23 N•m) torque.

Remove Starting Motor

Failure of the starting motor to crank the engine at normal cranking speed may be due to a defective battery, worn battery cables, poor connections in the cranking circuit, defective engine starting switch, low temperature, condition of the engine or a defective starting motor.

If the engine, battery and cranking circuit are in good condition, remove the starting motor as follows:

1. Remove the ground strap or cable from the battery or the cable from the starting motor solenoid. Tape the end of the cable to prevent discharging the battery from a direct short.
2. Disconnect the starting motor cables and solenoid wiring.

   NOTICE: Tag each lead to ensure correct connections when the starting motor is reinstalled.
3. Support the motor and remove the three bolts and lock washers which secure it to the flywheel housing. Then, pull the motor forward to remove it from the flywheel housing.

Check the starting motor in accordance with the Delco–Remy "Cranking Circuit" maintenance handbook.

Install Starting Motor

To install the starting motor, reverse the procedure outlined for removal. Tighten the 5/8"–11 starter attaching bolts to 137–147 lb–ft (186–200 N•m) torque when a cast iron flywheel housing is used or to 95–105 lb–ft (129–143 N•m) torque when an aluminum flywheel housing is used.

Keep all of the electrical connections clean and tight. When installing wiring terminal leads to the starting motor and the solenoid switch, tighten the No. 10–32 connections to 16–30 **lb–in** (2–3 N•m) torque and the 1/2"–13 connections to 20–25 lb–ft (27–34 N•m) torque.

INSTRUMENTS AND TACHOMETER DRIVE

INSTRUMENTS

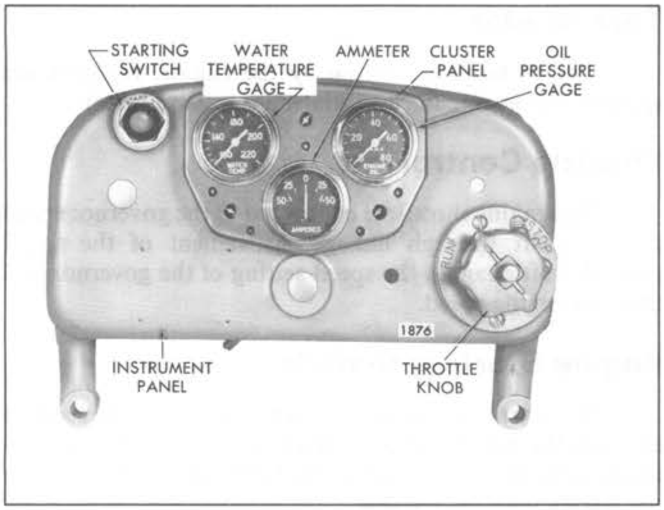


Fig. 1 – Typical Instrument Panel

The instruments generally required in the operation of a diesel engine consist of an oil pressure gage, water temperature gage, an ammeter and a mechanical tachometer. Also, closely related and usually installed in the general vicinity of these instruments are certain controls consisting of an engine starting switch, engine stop knob and an emergency stop knob (Fig. 1).

All Torqmatic converters are equipped with an oil pressure gage and, in some instances, with an oil temperature gage. These instruments are mounted on a separate panel.

Instruments, throttle control and engine starting and stopping controls are mounted in various locations depending upon the particular use of the engine.

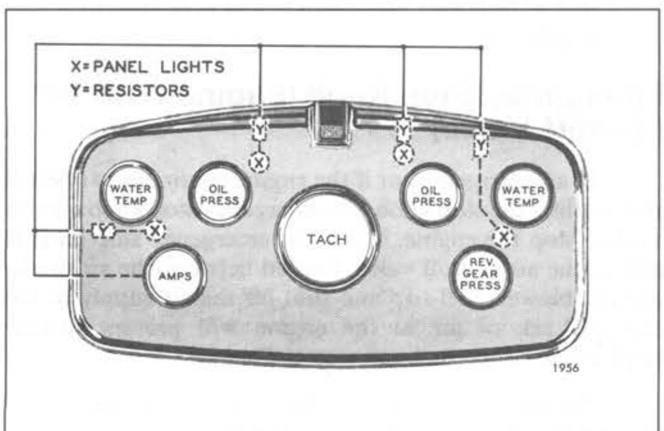


Fig. 2 – Installation of Resistors in Illuminated Instrument Panel

Marine propulsion engines are provided with an instrument panel which usually includes an engine oil pressure gage, reverse gear oil pressure gage, water temperature gage, ammeter and a tachometer. The instrument panels are generally mounted some distance from the engine. Illuminated instrument panels are provided for marine applications which require night operations.

All illuminated instrument panels are wired for a 12 volt lighting circuit. Therefore, when marine propulsion units incorporate either a 24 or 32 volt electrical system, a 12 volt tap–off from the battery may be made, or resistors (Table 1) may be installed in the circuit to protect the instrument panel bulbs. As indicated in Fig. 2, one resistor is used in the lead for each instrument panel bulb.

Resistor Specifications		
Volts	Ohms	Watts
24	50	10
32	100	10

TABLE 1

Whenever performing service or preventive maintenance procedures on marine propulsion engine units which include a 24 or 32 volt electrical system, check the lighting circuit of the instrument panels to determine if either a 12 volt tap–off from the battery or resistors have been installed in the lighting circuit to protect the instrument panel bulbs.

Anti–Vibration Instrument Mountings

Anti–vibration mountings are used in many places to absorb engine vibration in the mounting of instruments, drop relays, tachometers, etc. When it may become necessary to service a part secured by rubber mounts, care should be exercised, during removal and installation of the part, so twist is not imposed into the rubber mount diaphram. At the time the part is removed from the engine for service, the mounts should be inspected for damage and replaced, if necessary.

The attaching screw, through the center of the mount, must be held from turning during final tightening of the nut. Support the screw and tighten the nut only. If this screw turns, it will pre–load the rubber diaphragm in torsion and considerably shorten the life of the mount.

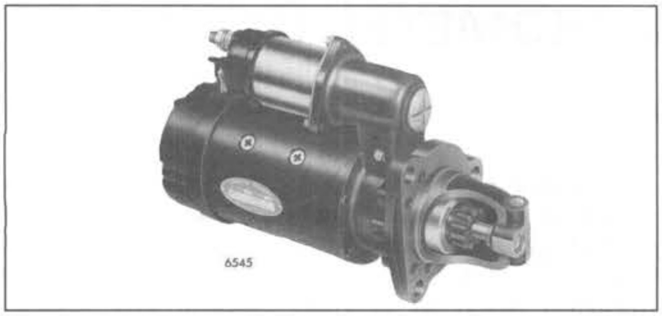


Fig. 3 – Typical Engine Starting Switch

Oil Pressure Gage

The oil pressure gage registers the pressure of the lubricating oil in the engine. As soon as the engine is started, the oil pressure gage should start to register. If the oil pressure gage does not register at least the minimum pressure listed in the *Operating Conditions* in Section 13.2, the engine should be stopped and the cause of the low oil pressure determined and corrected before the engine is started again.

Current oil pressure gages have male threads and require female fittings. When replacing a former gage with female threads, a new mounting clamp and connector must be used.

Water Temperature Gage

The engine coolant temperature is registered on the water temperature gage.

Incorrect coolant temperature readings will be registered if the gage assembly is incorrectly installed or the capillary tube is damaged.

To prevent damage to the gage assembly from vibration, the capillary tube must be securely fastened to the engine the full length with suitable clips at intervals of ten inches or less. Sharp bends in the tube must be avoided, particularly at the gage or bulb connection areas. Where the tube must be bent around any object, the bend must not be less than one inch radius.

Any extra length can be taken up by coiling, the diameter of which should not be less than two inches. The coils must be located so that they may be securely fastened to prevent vibration.

Ammeter

The ammeter is wired into the electrical circuit to show the current flow to and from the battery. After starting the engine, the ammeter should register a high charge rate at rated engine speed. This is the rate of charge received by the battery to replenish the current used to start the engine. As the engine continues to operate, the ammeter should show a decline in the charge rate to the battery. The ammeter will not show zero charge rate since the regulator voltage is set higher than the battery voltage. The small current registered prevents rapid brush wear in the battery–charging alternator. If lights or other electrical equipment are connected into the circuit, then the ammeter will show discharge when these items are operating and the engine speed is reduced.

Tachometer

The tachometer, driven by the engine, registers the speed of the engine in revolutions per minute (rpm).

Throttle Control

The engine throttle is connected to the governor speed control shaft through linkage. Movement of the speed control shaft changes the speed setting of the governor and thus the engine speed.

Engine Starting Switch

To start the engine, a switch (Fig. 3) is used to energize the starting motor. Starting switches may vary in design and their contacts must be rated sufficiently to carry the starter solenoid current.

NOTICE: Tighten the starting switch mounting nut to 36–48 **lb–in** (4–5.5 N•m) torque.

Engine Stop Knob

A stop knob is used to shut the engine down. When stopping an engine, the engine speed should be reduced to idle and the engine allowed to operate at idle for a few minutes to permit the coolant to reduce the temperature of the engine's moving parts. Then pull the stop knob and hold it until the engine stops. Pulling on the stop knob manually places the injector racks in the no–fuel position. Return the stop knob to its original position after the engine stops.

NOTICE: When an emergency shut down is necessary on a current engine with the spring loaded fuel injector control tubes, the stop knob should be pulled immediately and held until the engine stops.

Emergency Stop Knob (Engine with Air Shutoff Valve)

In an emergency, or if the engine continues to operate after pulling the stop knob, the emergency stop knob may be used to stop the engine. When the emergency stop knob is pulled, the air shutoff valve, located between the air intake and the blower, will trip and shut off the air supply to the engine. Lack of air to the engine will prevent further combustion of the fuel and stop the engine.

The emergency stop knob must be pushed back in after the engine is stopped and the air shutoff valve must be reset manually. The cause of the malfunction should be determined before the engine is started again.

TACHOMETER DRIVE

A tachometer drive shaft may be installed at any one of several locations on the engine.

At the front end of the engine, the tachometer drive shaft is pressed into the end of the right bank camshaft and extends through an adaptor attached to the balance weight cover (Fig. 4).

At the rear of the engine, the tachometer drive shaft may be installed in the end of either camshaft, the blower drive shaft, or the L.H. helix blower rotor shaft (Fig. 5). A tachometer drive shaft adaptor is attached to the flywheel housing cover or the blower rear end plate cover.

When required, a tachometer drive cable adaptor is used to change speed or to change direction of rotation, depending upon the location of the tachometer drive. A special key is used to connect the drive shaft to the tachometer drive cable adaptor.

The cable connection at the current tachometer head is a 5/8" threaded connection in place of the former 7/8" connection. To eliminate possible misalignment, the current tachometer angle drive has a short flexible cable and incorporates an integral oil seal. The output shaft key size has been increased from 5/32" to SAE 3/16". New flexible drive cables are also required with the current tachometers and angle drives.

Remove Tachometer Drive (Camshaft or Blower Drive Shaft Driven)

If replacement is necessary, remove the tachometer drive shaft as follows:

1. Disconnect the tachometer drive cable from the tachometer drive cable adaptor.
2. If used, remove the tachometer drive cable adaptor and key (key and seal assembly if the tachometer drive shaft is driven by the blower drive shaft).
3. Remove the tachometer drive shaft adaptor and gasket from the balance weight cover if the tachometer drive is located at the front of the engine. For a rear mounted tachometer drive, remove the flywheel housing cover and adaptor assembly and gasket. Examine the oil seal(s), if used, for wear or damage. Replace the oil seal (camshaft drive) or oil seal unit (blower drive shaft drive), if necessary.
4. If the tachometer drive shaft is driven by the blower drive shaft, remove the blower drive shaft.
5. Remove a tachometer drive shaft that is pressed into the camshaft as follows:
   a. If the tachometer drive shaft is pressed into the end of the camshaft, it cannot be turned since the end is either square or knurled. If threads (5/16"-24 or 3/8"-24) are provided on the outer end of the tachometer drive shaft to accommodate a removing tool, thread remover J 5901-3 on the shaft. Then attach slide hammer J 23907-1 to the remover. A few sharp blows of the weight against the slide hammer rod will remove the tachometer drive shaft.
   b. If threads are not provided on the outer end of the tachometer drive shaft, or if the end of the shaft is broken off, drill and tap the shaft. Then thread a stud into the shaft and remove the shaft with the remover and slide hammer.

NOTICE: Use adequate protective measures to prevent metal particles from falling into the gear train and oil pan.

Install Tachometer Drive (Camshaft or Blower Drive Shaft Driven)

When installing a tachometer drive cover assembly or a drive adaptor, it is important they be aligned properly with the tachometer drive shaft (Section 7.0).

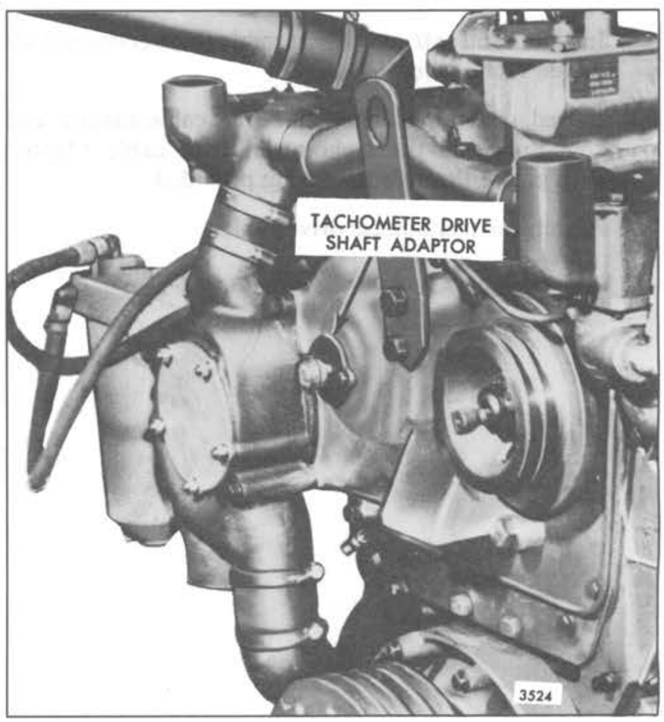


Fig. 4 – Front Mounted Tachometer Drive

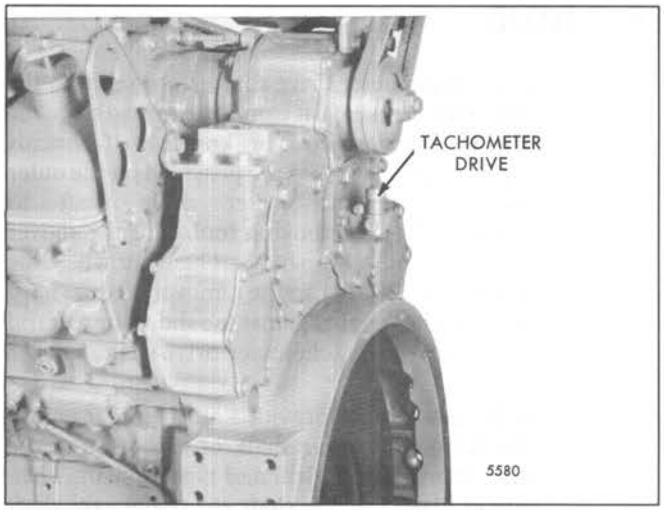


Fig. 5 – Rear Mounted Tachometer Drive

1. Start the tachometer drive shaft in the end of the camshaft or blower drive shaft. Then, using a suitable sleeve, tap or press against the shoulder on the tachometer drive shaft until the shoulder contacts the camshaft or blower drive shaft.
2. Install the blower drive shaft.
3. Use a new gasket and install the tachometer drive cover and adaptor on the balance weight cover or flywheel housing.
4. Check alignment of the tachometer drive shaft as outlined in Section 7.0.
5. Install the oil seal and key assembly (blower drive shaft driven tachometer drive).
6. If used, install the tachometer drive cable adaptor and key. Lubricate the tachometer drive cable adaptor with grease through the fitting provided.
7. Attach the tachometer drive cable.

Remove Tachometer Drive (Driven by Blower Rotor Shaft)

If replacement is necessary, remove the tachometer drive shaft as follows:

1. Disconnect the tachometer drive cable from the tachometer drive cable adaptor.
2. Remove the tachometer drive cable adaptor and key.
3. Remove the blower from the engine as outlined in Section 3.4.
4. Remove the blower rear end plate cover.
5. Remove the tachometer drive shaft, which also functions as the L.H. blower rotor gear retaining bolt, with a 3/4" wrench.

Install Tachometer Drive (Driven by Blower Rotor Shaft)

1. Lubricate the threads with engine oil and install the combination blower rotor retaining bolt and tachometer drive shaft. Tighten it to 55–65 lb–ft (75–88 N•m) torque.
2. Install the blower rear end plate cover.
3. Align the blower rear end plate cover with the tachometer drive shaft. Check the alignment of the drive shaft as outlined in Section 7.0.
4. Install the blower on the engine as outlined in Section 3.4.
5. Install the tachometer drive cable adaptor and key.
6. Attach the tachometer drive cable.

ENGINE PROTECTIVE SYSTEMS

MANUAL SHUTDOWN SYSTEM

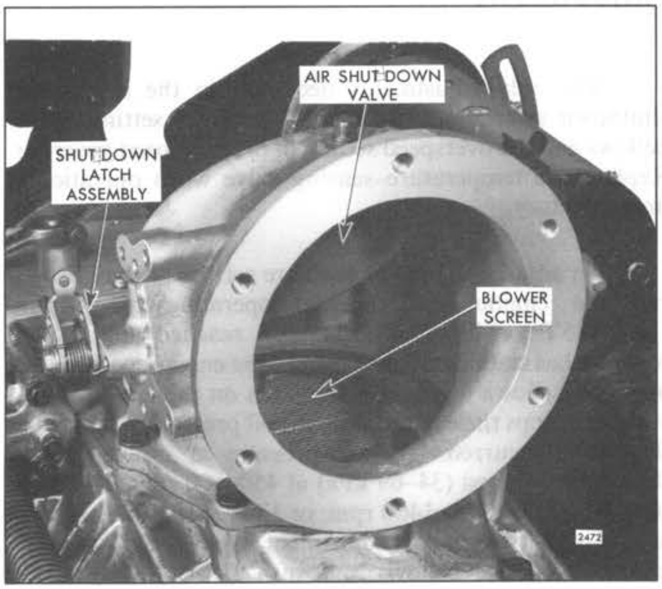


Fig. 1 – Typical Manually Operated Emergency Engine Shutdown Valve Mounting

A manually–operated emergency engine shutdown device, mounted in the air shutdown housing, enables the engine operator to stop the engine in the event an abnormal condition should arise. If the engine continues to run after the engine throttle is placed in the no–fuel position, or if combustible liquids or gases are accidentally introduced into the combustion chamber causing overspeeding of the engine, the shutdown device will prevent damage to the engine by cutting off the air supply and thus stopping the engine. The device consists of a shutdown valve mounted in the air shutdown housing and a suitable operating mechanism (Fig. 1).

The air shutdown valve is retained in the open position by a latch. A Bowden wire or cable assembly is used to trip the latch. Pulling the emergency shutdown knob all the way out will stop the engine. After the engine stops, the operator must push the emergency shutdown knob all the way in and manually reset the air shutdown valve before the engine is started again.

Service

For removal and installation or disassembly and assembly of the manual shutdown device, refer to Section 3.3.

AUTOMATIC MECHANICAL SHUTDOWN SYSTEM

The automatic mechanical shutdown system (Fig. 2) is designed to stop the engine if there is a loss of oil pressure, loss of engine coolant, overheating of the engine coolant or overspeeding of the engine. Engine oil pressure is utilized to activate the components of the system.

A coolant temperature–sensing valve and an adaptor and copper plug assembly are mounted on the exhaust manifold outlet. The power element of the temperature–sensing valve is placed against one end of the copper plug, and the other end of the plug extends into the exhaust manifold. Engine coolant is directed through the adaptor and passes over the power element of the valve. Engine oil, under pressure, is directed through a restricted fitting to the temperature–sensing valve and to an oil pressure actuated bellows located on the air inlet housing.

The pressure of the oil entering the bellows overcomes the tension of the bellows spring and permits the latch to retain the air shutdown valve in the open position. If the oil pressure drops below a pre–determined value, the spring in the bellows will release the latch and permit the air shutdown valve to close and thus stop the engine.

The overspeed governor (Fig. 3), used on certain applications, consists of a valve actuated by a set of spring–loaded weights. Engine oil is supplied to the valve through a connection in the oil line between the bellows and the temperature–sensing valve. An outlet in the governor valve is connected to the engine oil sump. Whenever the engine speed exceeds the overspeed governor setting, the valve (actuated by the governor weights) is moved from its seat and permits the oil to flow to the engine sump. This decreases the oil pressure to the bellows, thus actuating the shutdown mechanism and stopping the engine.

Operation

To start an engine equipped with a mechanical shutdown system, first manually open the air shutdown valve and then press the engine starting switch. As soon as the engine starts, the starting switch may be released, but the

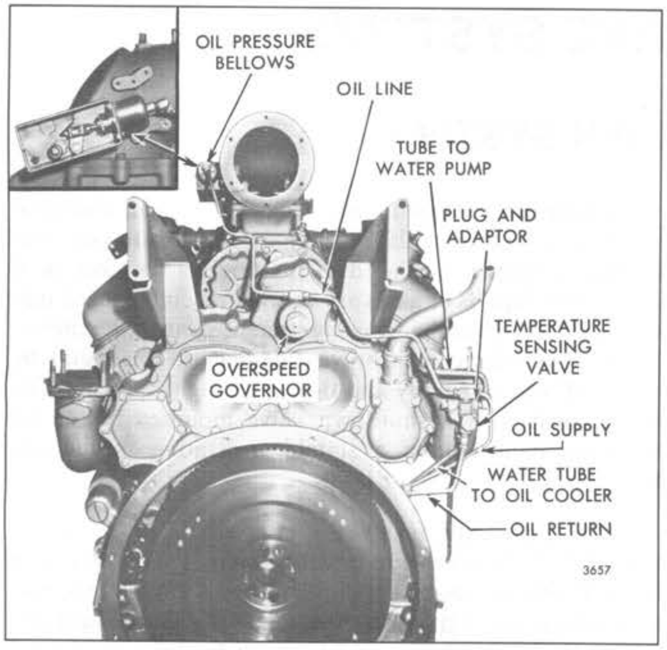


Fig. 2 – Typical Automatic Mechanical Shutdown System Mounting

air shutdown valve must be held in the open position until the engine oil pressure increases sufficiently to permit the bellows to retain the latch in the open position.

During operation, if the engine oil pressure drops below the setting of the pressure sensitive bellows, the spring within the bellows will release the latch and permit the air shutdown valve to close, thus stopping the engine.

If the engine coolant overheats, the temperature–sensing valve will open and permit the oil in the protective system to flow to the engine crankcase.

The resulting decrease in oil pressure will actuate the shutdown mechanism and stop the engine. Also, if the engine loses its coolant, the copper plug will be heated by the hot exhaust gases passing over it and cause the temperature–sensing valve to open and actuate the shutdown mechanism.

Whenever the engine speed exceeds the overspeed governor setting, the oil in the line flows to the sump, resulting in a decrease in oil pressure. The oil pressure bellows then releases the latch and permits the air shutdown valve to close.

When an engine is stopped by the action of the shutdown system, the engine cannot be started again until the particular device which actuated the shutdown mechanism has returned to its normal position. The abnormal condition which caused the engine to stop must be corrected before attempting to start it again.

Adjustment

The only adjustments necessary in the mechanical shutdown system are the low oil pressure setting of the bellows and the overspeed setting of the overspeed governor. Replace the temperature–sensing valve when operation is unsatisfactory.

To adjust the low oil pressure setting of the bellows, run the engine until normal operating temperature (160°–185°F or 71°–85°C) has been reached and the oil pressure has stabilized. Then reduce the engine speed slowly until the bellows disengages the latch on the air shutdown valve and stops the engine. Note the oil pressure at which the shutdown occurred. The oil pressure at disengagement should be 5–10 psi (34–69 kPa) at 450–600 rpm; 10–15 psi (69–103 kPa) at 601–1400 rpm; or 15–20 psi (103–138 kPa) at 1401 and above rpm. If adjustment is necessary, loosen the lock nut on the bellows and turn the adjusting screw clockwise to increase the oil pressure setting or counterclockwise to decrease the setting. Hold the adjusting screw and tighten the lock nut when the proper setting has been obtained.

NOTICE: Set the bellows disengagement pressure as near as possible to the high end of the pressure range for the low engine speed specified for the engine.

Check the operation of the engine coolant temperature–sensing valve by placing a cover over the radiator while the engine is operating at part load and note the coolant outlet temperature at which the bellows disengages the air shutdown latch. The air shutdown valve should close and stop the engine within a temperature range of 200°–210°F (93°–99°C). If the engine is not shutdown in this range, replace the temperature–sensing valve. If the engine is shutdown below 200°F (93°C), check the coolant flow through the plug and adaptor assembly and, if circulation is satisfactory, replace the temperature–sensing valve.

NOTICE: If the temperature sensing valve is removed, examine the temperature shutdown valve plunger in the copper probe (Fig. 3). If it is not free in the probe and adaptor, install a new plunger, spring and adaptor. Deposits from the engine coolant building up between the plunger, spring and plug can cause the plunger to stick in the probe.

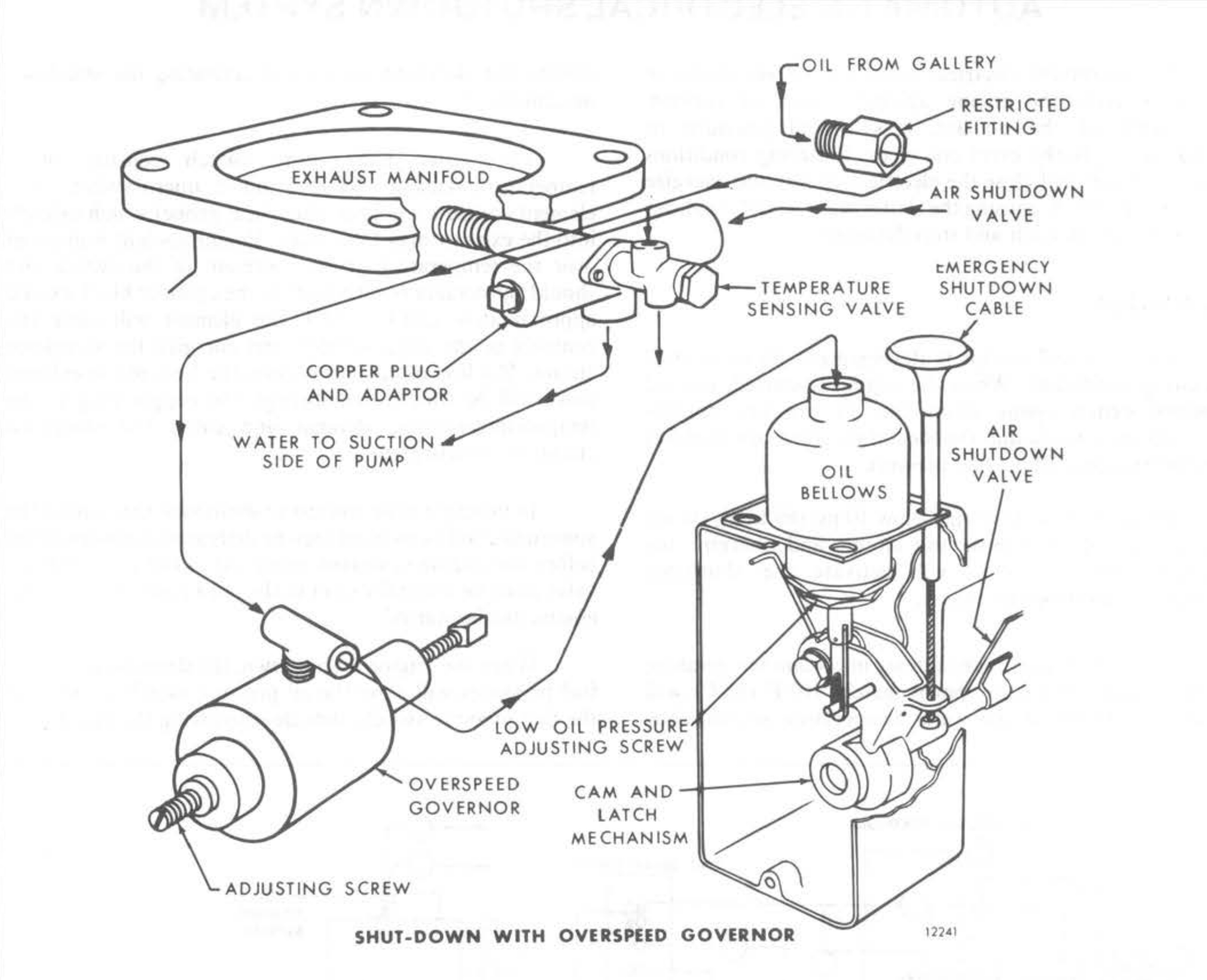


Fig. 3 – Schematic Drawing of Automatic Mechanical Shutdown System with Overspeed Governor

The temperature–sensing valve can be bench tested by attaching an air hose (40 psi or 276 kPa) air supply to the oil inlet side and installing a tube from the outlet side to a can of water. Then immerse the power element of the valve in a container of water that is heated and agitated. Check the temperature of the water with a thermometer. Apply air to the valve. The valve should be open, as indicated by the flow of air, at a water temperature of 195°–206°F (91°–96°C).

To adjust the overspeed governor, run the engine until normal operating temperature is reached. Then increase the engine speed to the desired overspeed shutdown speed. At this speed, the bellows should disengage the air shutdown latch and stop the engine. If necessary, adjust the overspeed governor setting by loosening the lock nut on the adjusting screw at the rear of the governor and turn the screw clockwise to increase the shutdown speed or counterclockwise to decrease the shutdown speed. Then tighten the lock nut, while holding the adjusting screw, when the proper setting is obtained.

AUTOMATIC ELECTRICAL SHUTDOWN SYSTEM

The automatic electrical shutdown system shown in Fig. 4 protects the engine against a loss of coolant, overheating of the coolant, loss of oil pressure or overspeeding. In the event one of the foregoing conditions arises, a switch will close the electrical circuit and energize the solenoid switch, causing the shutdown solenoid to release the air shutdown latch and stop the engine.

Operation

The electrical circuit is de–energized under normal operating conditions. When the engine is started, one oil pressure switch opens when the oil pressure reaches approximately 10 psi and the fuel oil pressure switch closes at approximately 20 psi fuel pressure.

If the oil pressure drops below 10 psi (69 kPa), the oil pressure switch will close the circuit and energize the shutdown solenoid. This will activate the shutdown mechanism and stop the engine.

A loss of coolant or an increase in coolant temperature in the cylinder block to approximately 203°F (95°C) will close the contacts in the water temperature switch, thus closing the electrical circuit and activating the shutdown mechanism.

The water temperature switch consists of a temperature–sensing element and a micro–switch. The element contacts a copper plug (heat probe) which extends into the exhaust manifold outlet. Engine coolant is directed over the temperature–sensing element of the switch and should the coolant temperature in the cylinder block exceed approximately 203°F (95°C), the element will close the contacts in the micro–switch and energize the shutdown circuit. If a loss of coolant occurs, the heat of the exhaust gases will be transmitted through the copper plug to the temperature–sensing element and cause the shutdown circuit to be activated.

In the event of an automatic shutdown, the cause of the abnormal conditions must then be determined and corrected before the engine is started again. Also, the air shutdown valve must be manually reset in the open position before the engine can be started.

When the engine is shutdown, the decrease in oil and fuel pressures will close the oil pressure switches and open the fuel pressure switch, thus de–energizing the circuit.

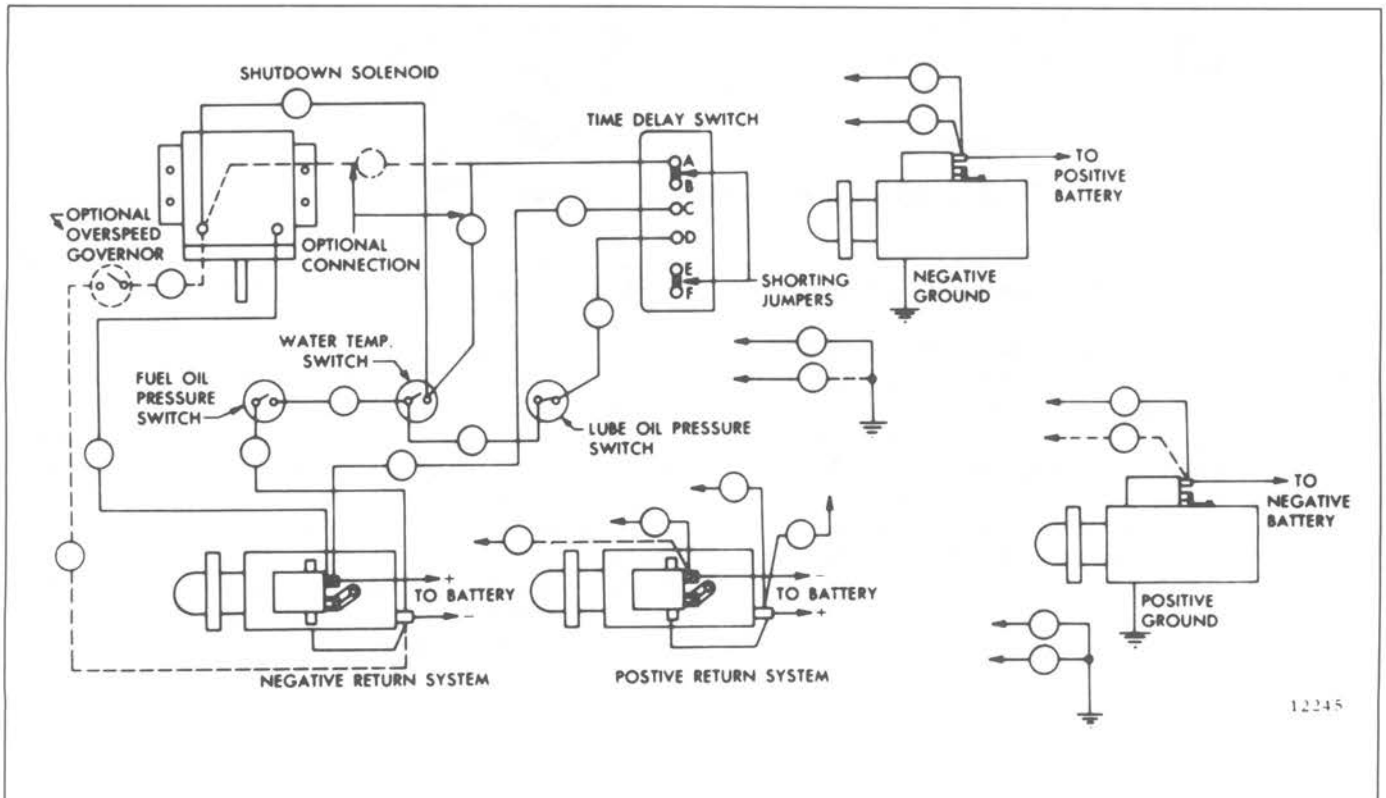


Fig. 4 – Automatic Electrical Shutdown System Diagram

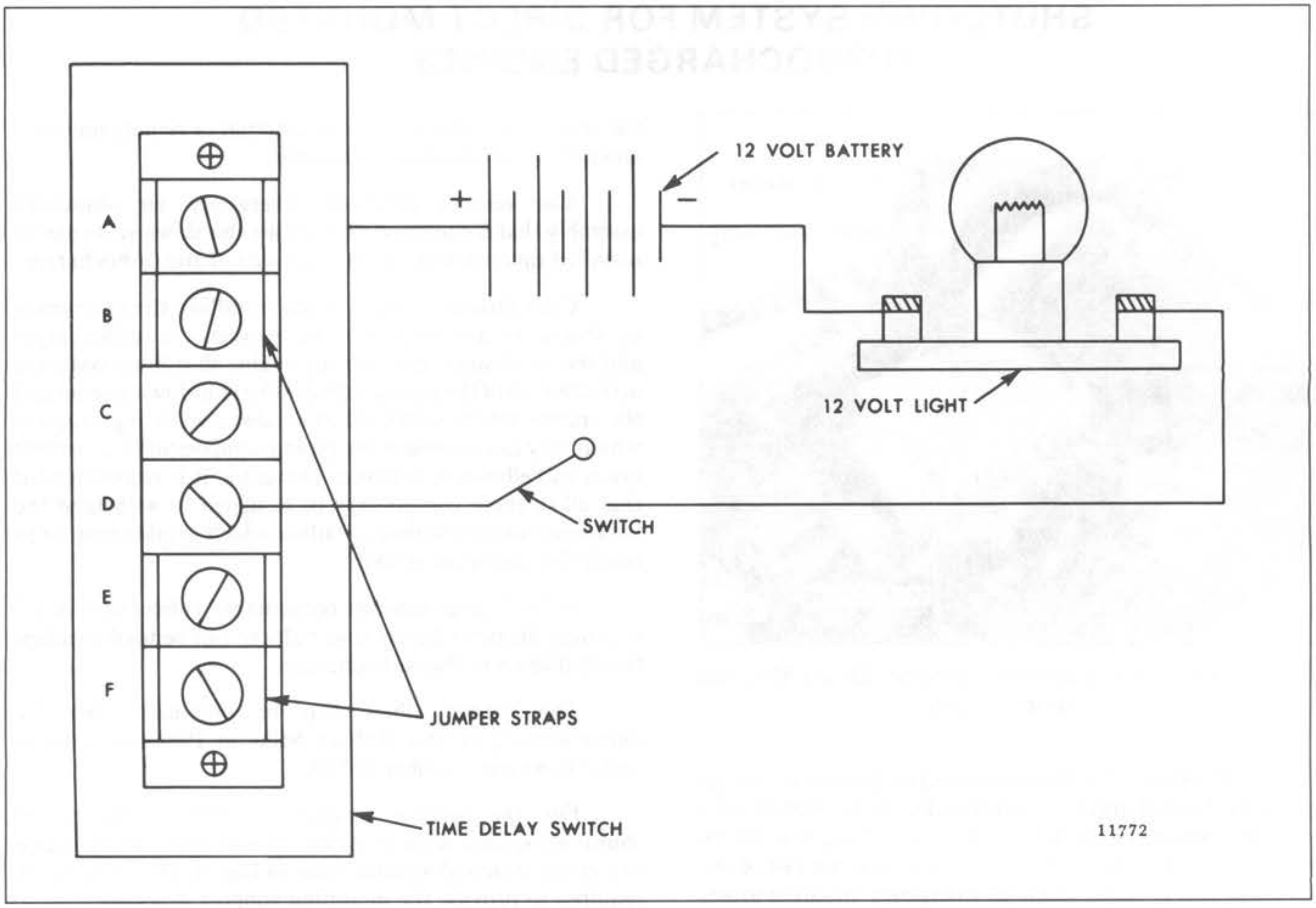


Fig. 5 – Solid State Time Delay Switch Testing Diagram

Some engines are equipped with an electrically operated automatic shutdown system which incorporates a time delay switch (Fig. 4).

Since the fuel pressure builds up rapidly, the fuel oil pressure switch could close before the lubricating oil pressure switch opens, thereby effecting a shutdown of the engine. The time delay switch, however, delays operation of the solenoid for 3 to 10 seconds to enable the lubricating oil pressure to build up and open the oil pressure switch contacts.

When the lubricating oil pressure falls below 10± 2 psi 69 ± 7 kPa), the contacts in the oil pressure switch used in this system will close and current will flow to the time delay switch. The few seconds required to heat the time delay switch provides sufficient delay to avoid an engine shutdown when low oil pressure is caused by a temporary condition such as an air bubble or a temporary overlap in the operation of the oil pressure switch and the fuel oil pressure switch when starting or stopping the engine.

Solid State Time Delay Switch

A bench test procedure for the solid state time delay switch is as follows:

1. Refer to Fig. 4 and remove the time delay switch from the engine.
2. Refer to Fig. 5 and install the jumper straps on terminals A to B and E to F.
3. Install a positive battery lead to terminal A.
4. Install a negative battery lead to one side of a 12 volt light.
5. Install a lead from the opposite side of the light to terminal D. A switch may be used in this lead, if desired.
6. After the negative lead is connected to terminal D or the switch is closed, the lamp should light in 8 to 10 seconds. If not, the time delay switch must be replaced.

SHUTDOWN SYSTEM FOR DIRECT MOUNTED TURBOCHARGED ENGINES

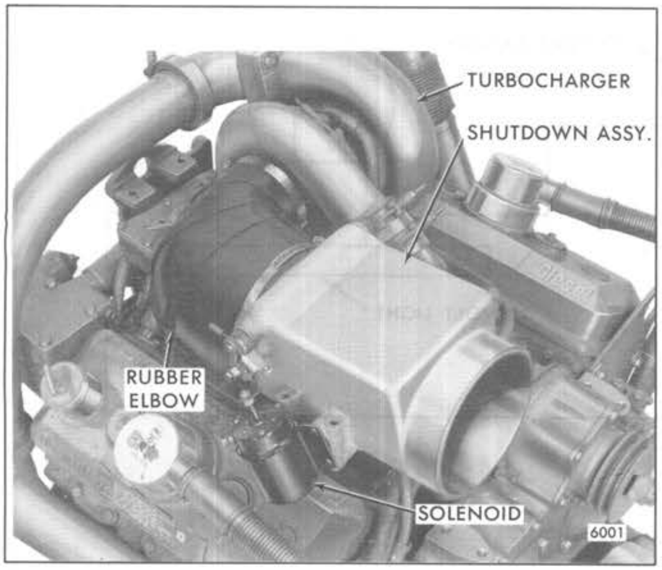


Fig. 6 – Emergency Shutdown Assembly (Direct Mounted Turbocharger)

With the use of a direct mounted turbocharger and the spring loaded fuel injector control racks, the air shutoff valve was eliminated from the air inlet housing. The spring loaded injector control racks enable the engine to come out of any advanced fuel position when an emergency situation arises.

When an engine is operating in an atmosphere subject to volatile fuel and is equipped with an air inlet housing without the air shutdown valve, a customer may request that the engine be equipped with an external or remote mounted emergency air shutdown assembly.

The remote mounted emergency air shutdown assembly that is equipped with the air shutdown valve can be installed upstream of the air inlet side of the turbocharger.

Care should be taken when installing the emergency air shutdown assembly (Fig. 6) between the turbocharger and the air cleaner. Because the engine shutdown system is activated, all of the piping between the shutdown system and the engine will be subjected to an abnormally high suction which may cause some of the piping components, i.e., rubber hoses and elbows to collapse. Therefore, it is recommended that all of these components be designed to withstand the maximum suction without a failure which would allow air to reach the engine air intake.

A 7 to 5 inch diameter reducing 90° rubber hose or a 7 to 5 inch diameter hump hose reducer can be used to adapt the shutdown to the turbocharger.

The rubber elbow can be obtained from the manufacturer; Griffin Rubber Mills in Portland, Oregon under their part number 51759.

For the relative position of the emergency air shutdown system when installed on a Detroit Diesel engine in a direct mounted location refer to Fig. 6. The customer is required to provide the mounting support brackets.

The emergency air shutdown assembly is manually operated. To be an automatic shutdown system, it will be necessary to install a solenoid.

ALARM SYSTEM

The alarm system shown in Figs. 1 and 2 is similar to the automatic electrical shutdown system, but uses a warning bell in place of the air shutdown valve solenoid. The bell warns the engine operator if the engine coolant overheats or the oil pressure drops below the oil pressure switch setting.

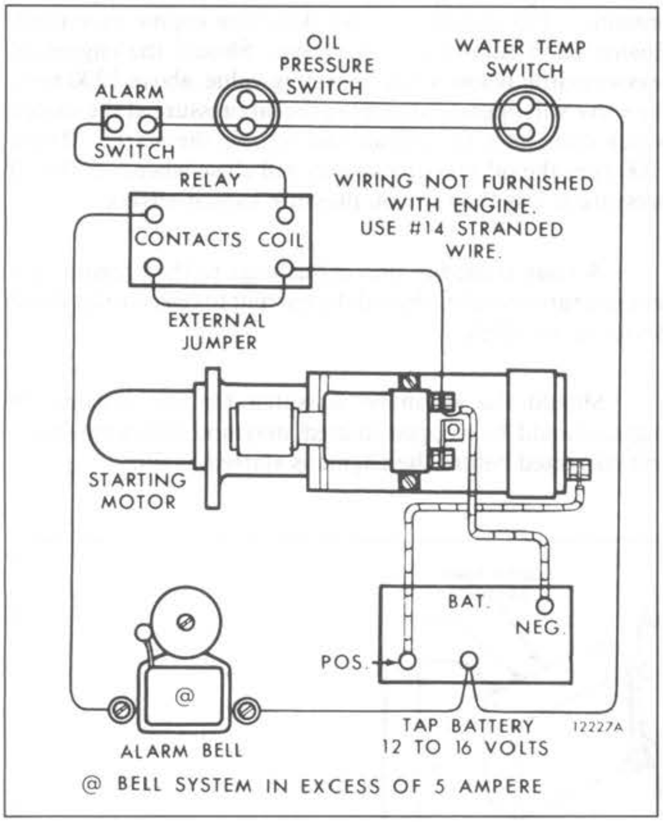


Fig. 1 – Former Alarm System Wiring Diagram

When the engine is started and the oil pressure is sufficient to open the oil pressure switch contacts (opening pressure is stamped on the switch cover), the alarm switch must be turned on manually to put the system in operation. The water temperature switch is normally open. Should the engine coolant exceed 215$\pm$5°F (102 $\pm$ 3°C), the water temperature switch will close the electrical circuit and sound the alarm bell. Likewise, if the oil pressure drops below the setting of the oil pressure switch, the switch will close and cause the bell to ring. The bell will continue to ring until the engine operator turns the alarm switch off. The alarm switch must also be turned off before a routine stop since the decreasing oil pressure will close the oil pressure switch and cause the bell to ring.

Current Bell System requires less than 5 ampheres to ring the bell (Fig. 2). The former Bell System requires more than 5 ampheres to ring the bell (Fig. 1).

If the alarm bell rings during engine operation, stop the engine immediately and determine the cause of the abnormal condition. Make the necessary corrections before starting the engine again.

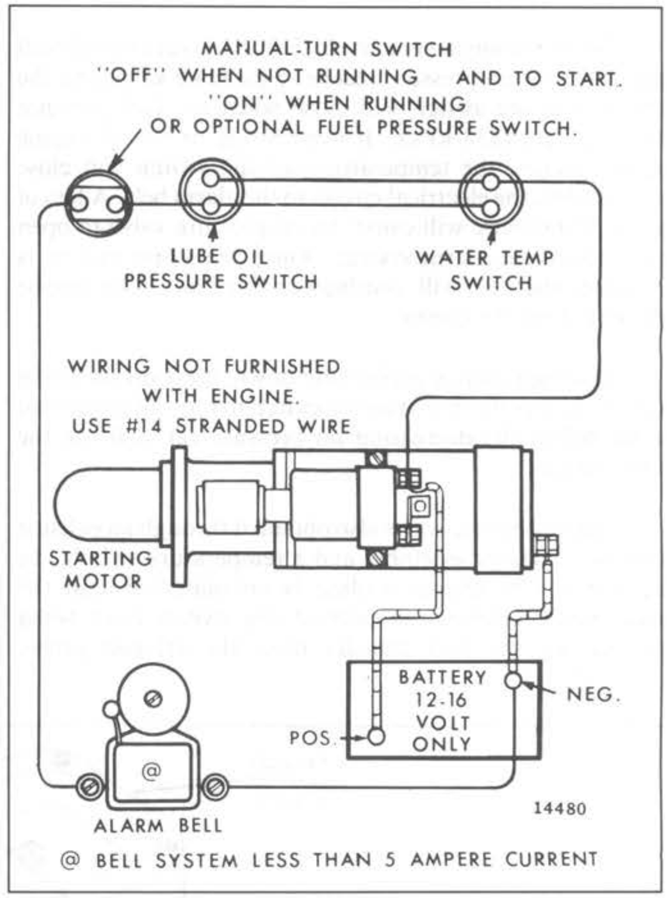


Fig. 2 – Current Alarm System Wiring Diagram

An alarm bell may be connected to the electrical shutdown system (Fig. 3). In this system, if an abnormal condition occurs, the engine will be stopped automatically and the alarm bell will ring to notify the operator. The bell will continue to ring until the operator pushes the reset button on the drop relay.

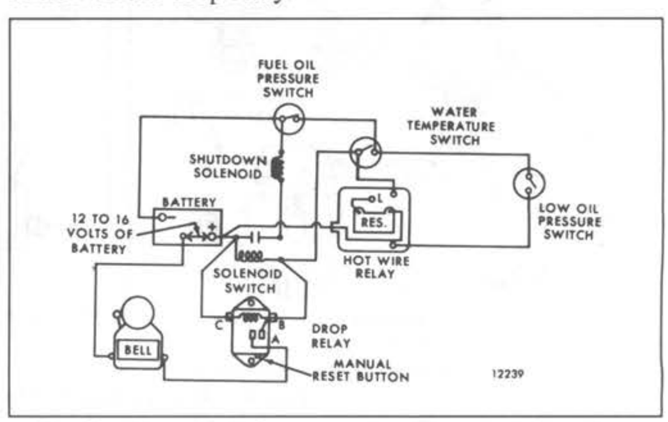


Fig. 3 – Alarm Bell Connected to Electrical Shutdown System

The alarm system illustrated in Fig. 4 utilizes the temperature–sensing switch and the low oil pressure valve.

When the engine is started, the oil pressure switch will open when the oil pressure reaches 5 psi (34.5 kPa), and the fuel oil pressure switch will close when the fuel pressure reaches 20 psi (138 kPa). If overheating or loss of engine coolant occurs, the temperature–sensing switch will close and complete the electrical circuit to the alarm bell. A loss of engine oil pressure will cause the oil pressure valve to open and activate the alarm system. Once the alarm system is activated, the bell will continue to ring until the engine operator stops the engine.

During a routine engine shut down, the decreasing fuel pressure causes the fuel pressure switch to open the electrical circuit before the decreasing oil pressure can activate the alarm system.

Coolant protection is also obtained through an exhaust probe and adaptor assembly and a temperature switch. In this system, the engine coolant is circulated around the switch power element to prevent the switch from being activated by the heat transfer from the exhaust probe. Therefore, an alarm will occur if coolant flow through the adaptor is interrupted for any reason. The switch will also operate when the engine coolant discharge temperature exceeds 205°–215°F (96°–102°C).

The oil pressure switch, mounted in the low oil pressure valve (Fig. 5), will be activated to sound the alarm when the engine oil pressure drops below the safe operating pressure. The switch will also detect an engine overspeed. Engine oil is supplied to the valve. Should the engine oil pressure drop below a safe operating value, above 1200 rpm, the valve will operate, dropping the oil pressure at the switch which completes the circuit and sounds the alarm. Below 1200 rpm the oil pressure switch will close whenever the oil pressure is less than the oil pressure switch setting.

A relay is used to prevent damage to the pressure and temperature switches should the current to operate the alarm device be too high.

Should the alarm be activated for any reason, the engine should be stopped immediately and the cause found and corrected before the engine is started again.

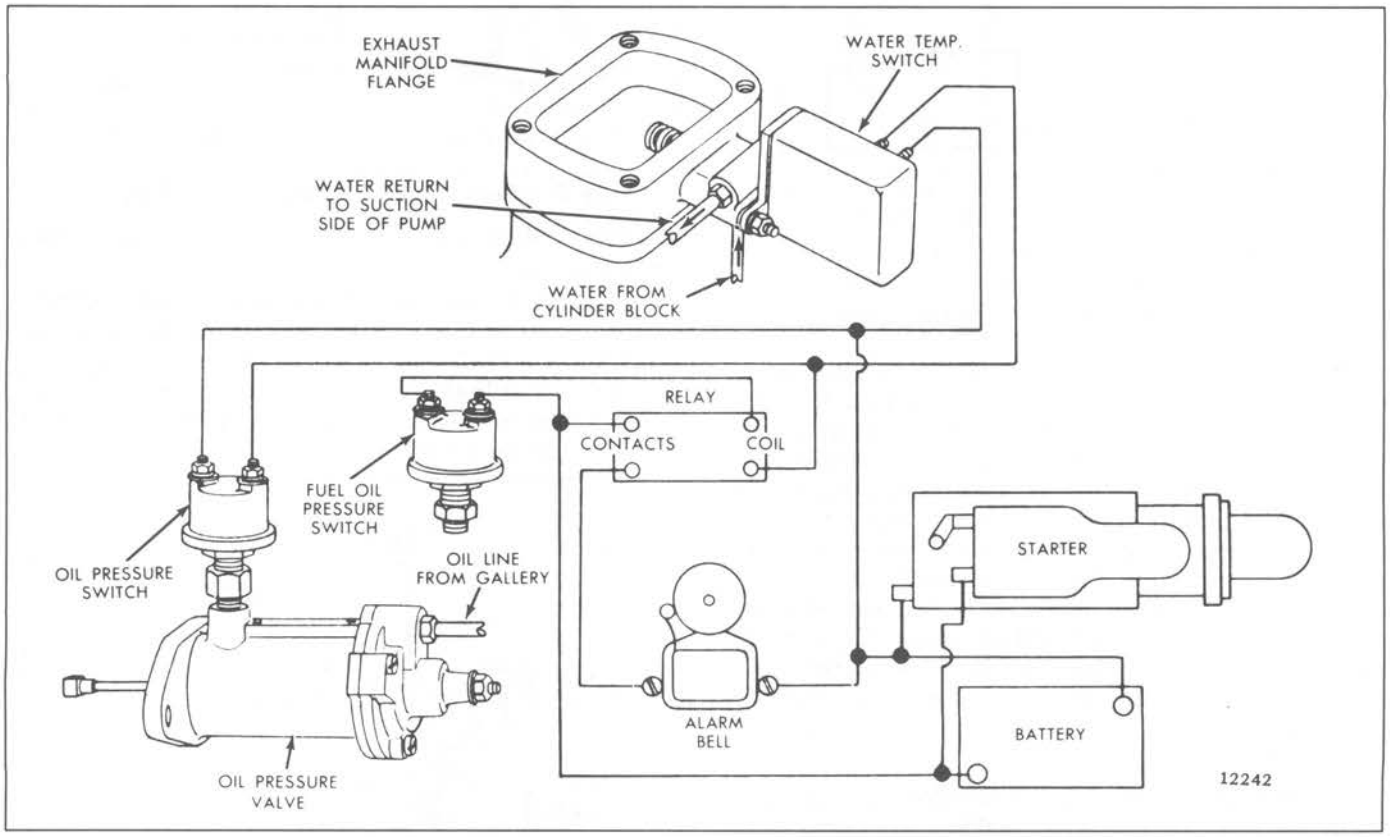


Fig. 4 – Alarm System With Mechanical Sensing Units

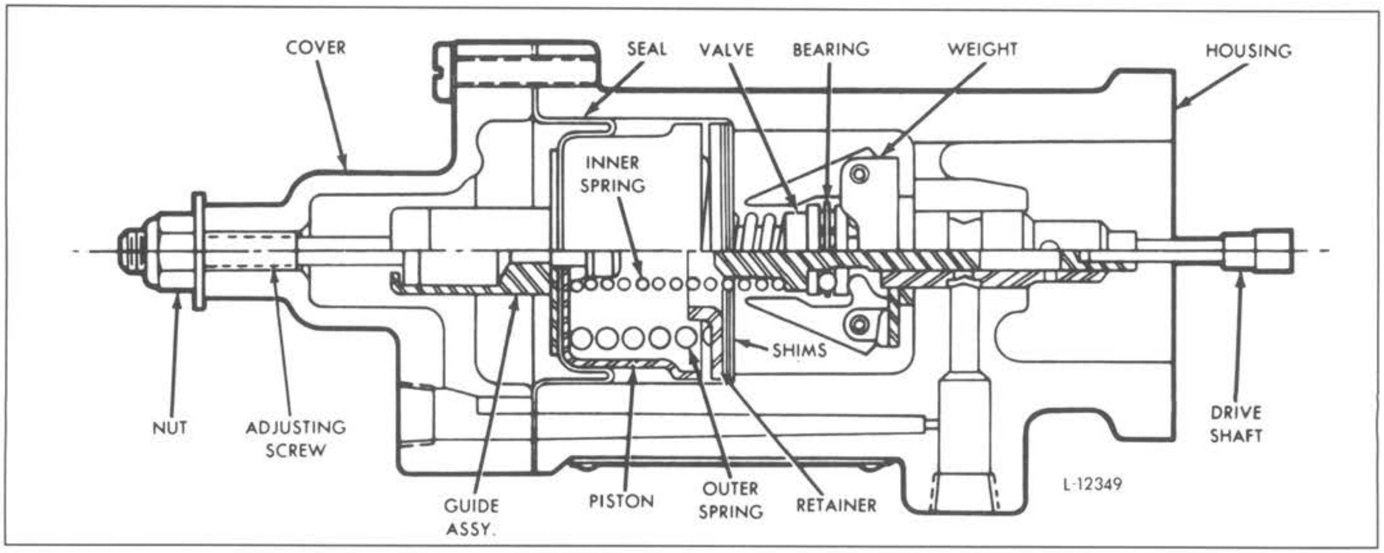


Fig. 5 – Typical Low Oil Pressure Valve

OVERSPEED GOVERNOR

The series GW–2 Synchro–Start overspeed governor (Fig. 1) contains two separate snap action switches with single–pole double–throw contacts which operate at two different speeds. The governor is adjusted by the manufacturer to trip at the speeds required as indicated on the name plate. Unless otherwise specified, the name plate indicates trip points on increasing speed. The contacts will return to normal when the speed is decreased approximately 100 rpm below the trip speed, except on the high speed switch of those models having a manual reset button. The letter "M" after any model number indicates the high speed switch must be reset manually.

Service

1. The snap action switches may be replaced as follows:
   a. Mark the position of the dust cover and remove both hold–down screws.
   b. Observe the position of the switches. Usually they are positioned with 1/64" clearance between the switch button and the lifters. If the lifters are replaced, make certain that the long lifter is placed beneath the low speed switch and the short lifter is placed beneath the high speed switch.
   c. Install the new switches by reversing the above procedure.

   NOTICE: When replacing the dust cover on a governor with a manual reset, make certain the switch wiring does not interfere with the reset mechanism.

   d. Adjust the speed as outlined under *Speed Adjustment*.
2. Remove the governor cap as follows:
   a. Observe the marking on the cap and the body and remove the three holding screws.
   b. Remove the cap assembly, being careful not to damage the seal ring.
   c. Replace any internal parts as required and reassemble and return the cap to the original position. A light coat of grease will facilitate assembly of the seal ring to the body.

   NOTICE: The position of the cap is very critical on governors in which the difference in trip points between the two switches is more than 1000 rpm and the trip point of the high speed switch is above 2100 rpm. These governors use elongated loop flyweight springs.

   If, after assembly, the No. 1 switch trips at a far higher point than normal, lower the cap position slightly. If the No. 2 switch trips at a very low speed, raise the cap position slightly. If difficulty arises, refer to step 5 below.

   d. Adjust the speed as outlined under *Speed Adjustment*.
3. Replace the speed adjusting springs as follows:
   a. Hold the speed adjusting stud with a 5/16" open end wrench and loosen the adjusting stud nut with a 3/8" open end wrench.
   b. After the above nut is removed, the adjusting spring and related parts may be removed and replaced as necessary. Exercise care to prevent particles of dirt from accumulating on the parts.
4. Replace the flexible drive shaft as follows:
   a. Insert a sharp pointed instrument in the loop of the spring clip and pull it from the shaft as far as possible and remove the shaft assembly.
   b. Upon reassembly, first install the spring clip in the groove of the fitting on the end of the governor shaft.
   c. Push the shaft assembly into the square end of the governor shaft and the spring clip will snap in place.

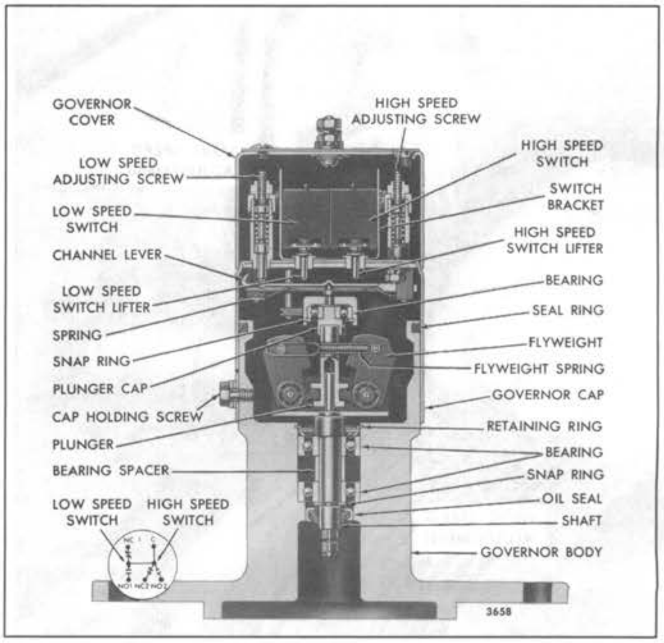


Fig. 1 – Cross–Section of Overspeed Governor

NOTICE: Check the position of the spring clip. If the clip has sprung out of position, use a small screwdriver and push it into place.

5. Adjust the governor cap (with the dust cover in place):

   a. Turn the low speed adjusting screw out for minimum speed adjustment. In this position, the top of the adjusting screw is approximately 1/8" from the top of the dust cover.

   b. Turn the high speed adjusting screw in for almost maximum speed adjustment. In this position, the top of the adjusting screw is approximately 5/16" from the top of the dust cover.

   c. With partial tension on the cap holding screws, turn the governor cap to the maximum extended position.

   d. Operate the governor at 200 rpm above the trip point of the low speed switch.

   e. Rotate the cap slowly in a clockwise direction until the low speed switch trips, mark the cap position and stop the governor. Then turn the cap another 1/16" and lock the holding screws securely.

   f. Complete the operation as outlined under *Speed Adjustment.* Generally, the trip point of the low speed switch will have to be increased and the high speed switch decreased.

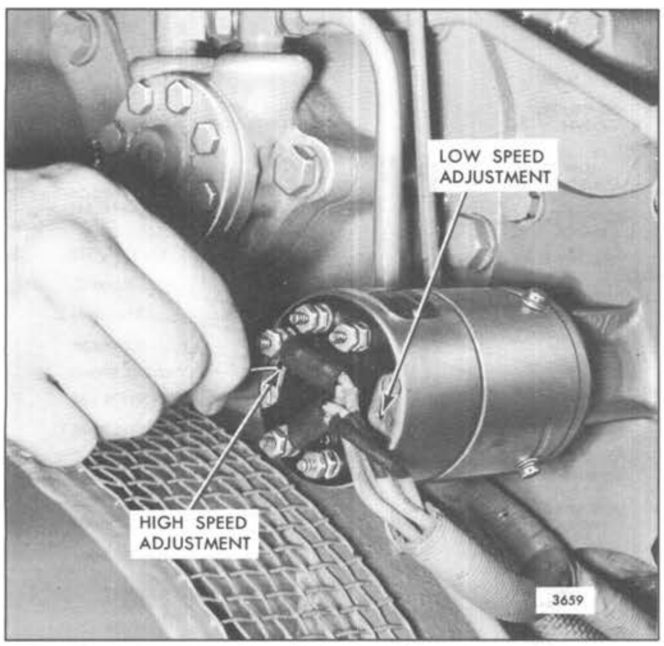


Fig. 2 – Adjusting Trip Speed of Overspeed Governor

Maintenance

- All Synchro–Start two switch electric overspeed governors contain sealed ball bearings which have sufficient grease for their useful life, except Model GT governors. *For GT units only,* add Aeroshell 7A grease (or equivalent) to the open upper shaft bearing every 2500 operating hours. Apply grease sparingly with a hand operated low pressure gun. Grease the upper governor shaft bearing as follows:

1. Remove the governor cap.

2. Apply grease sparingly to the bearing.

   NOTICE: Do not overgrease or use a power gun, since the bearing seals will be damaged, forcing grease onto the weights and springs.

3. Replace the cap.

4. The oil seal may be inspected and if necessary replaced as follows:

   1. Place the governor body in an arbor press with the mounting flange toward the bottom and use a 9/16" diameter rod to press out the oil seal.

   2. Press a new oil seal in place 3/64" from the bottom of the bearing cavity.

   3. Reassemble the governor by reversing the procedure for disassembly and adjust the trip speeds as outlined below.

Speed Adjustment

Both switches may be individually adjusted. Dust cover screw marked "1" covers the low speed adjuster; screw marked "2" covers the high speed adjuster. Proceed as follows:

1. Remove the appropriate dust cover screw.

2. Insert a 1/16" Allen wrench into the adjusting screw.

3. Turn the screw clockwise to increase the trip speed, or counterclockwise to decrease.

   NOTICE: If the adjusting screws are turned in too far, the switch will no longer operate. Do not attempt to use the slots in the cap for normal speed adjustments. This position is set and marked by the manufacturer for operation in the speed range required.

HYDRAULIC OVERSPEED GOVERNOR

The hydraulic governor which contains a set of spring loaded weights, prevents excessive engine speeds.

The overspeed governor is mounted in an adaptor which is mounted on the rear of the flywheel housing. A seal ring in the adaptor end of the governor housing prevents oil seepage from the flywheel housing. The governor is driven by a flexible drive assembly from the blower drive shaft. Oil under pressure is supplied to the governor by a tube which is connected to the oil gallery in the cylinder block.

Operation

When the engine speed reaches the value for which the overspeed governor is set, the centrifugal force of the weights in the overspeed governor overcomes the spring tension and opens a pilot valve in the governor. The pilot valve dumps oil from the oil tube, lowering the pressure at the engine oil pressure switch, thus closing the switch and energizing the shutdown solenoid and closing the shutdown valve.

Lubrication

The overspeed governor is lubricated by oil from the engine crankcase.

Adjustment

The engine shutdown speed is determined by the position of the adjusting screw in the overspeed governor cover. To change the setting, loosen the locknut and turn the adjusting screw in to increase the speed and out to decrease the speed. When the proper setting is obtained, tighten the adjusting screw locknut.

SHOP NOTES - TROUBLESHOOTING SPECIFICATIONS - SERVICE TOOLS

SHOP NOTES

PROPER OPERATION OF THE SWITCHES OR ALARM SYSTEM FOR TESTING THE ELECTRICAL SHUTDOWN

The protective system is activated whenever low lubricating oil pressure, high coolant temperature, engine overspeed or any other abnormal condition develops that could damage the engine.

In a properly maintained installation, the shutdown system seldom has cause to function. Therefore, it is advisable to check the system periodically to be sure that it will function when needed.

Check each component of the shutdown system as outlined below. It is important to thoroughly warm-up the engine before any component of the shutdown system is checked.

Overspeed Governor

1. Remove the valve rocker cover. Discard the gasket.
2. Start the engine and move the speed control lever to the *full-speed* position.
3. While watching a tachometer, manually move the control tube slowly towards the *increased fuel* position until the air shutoff valve closes, stopping the engine. Do not exceed the engine no-load operating speed by more than 10%.
4. Note the speed at which the engine stops and adjust the overspeed governor, if necessary, as outlined in Section 7.4.3.
5. Using new gaskets reinstall the valve rocker cover.

Water Temperature Switch

The terminals of the water temperature switch are connected into the shutdown system and when the engine water temperature reaches 210°F (99°C), the switch closes and completes the circuit in the shutdown or alarm system.

1. Cover the radiator with a sheet of cardboard to prevent circulation of air.
2. Remove the radiator cap, if the engine is operating near sea level, and insert a steel jacketed thermometer.

The boiling point of water lowers approximately 2° for each 1000 foot rise in altitude. As an example, water boils at approximately 203°F (95°C) at 5000 feet and at 195°F (91°C) at 9000 feet altitude. It is necessary to retain the radiator pressure cap on engines which operate in excess of 1000 feet altitude to prevent the coolant from boiling while performing this test. The engine temperature gage, if it is found to be accurate, may be used when performing this test.

Do not exceed 210°F (99°C) when performing this test.

3. Start and run the engine at rated speed and with enough load to raise the water temperature gradually until the air shutoff valve closes. The water temperature switch will usually be set at 210°F (99°C).
4. Note the temperature at which the air shutoff valve closed.
5. Remove the radiator cover and start the engine without load immediately after the engine stops. This will permit the engine to cool down to normal operating temperature.

Fuel Oil Pressure Switch

The fuel oil pressure switch is set to make contact at an increasing fuel pressure of 20 psi (138 kPa), and the phrase "20-MAKE" is stamped on the switch cover.

As the fuel pressure increases upon starting the engine, a diaphragm in the switch body expands and forces the plunger upwards (Fig. 1). Since the bottom of the adjusting screw bears against this plunger, the adjusting screw and the lower breaker point are also forced upwards. When the fuel pressure reaches 20 psi (138 kPa), the breaker points close and current flows to the terminals of the lubricating oil pressure switch and the water temperature switch.

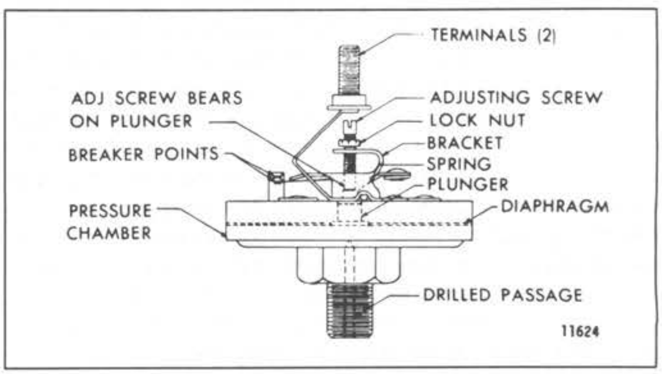


Fig. 1 - Fuel Oil Pressure Switch

When the engine is stopped, the fuel pressure decreases and the diaphragm in the switch body contracts. This action causes the plunger to lower and, when the fuel pressure decreases to 20 psi (138 kPa), permits the lower breaker point arm to lower and break the electrical circuit. The bracket to which the lower breaker point arm and the adjusting screw are attached is spring–loaded, which provides for positive breaking of the connection when the fuel pressure decreases sufficiently.

1. Insert a pressure gage on the discharge side of the fuel strainer.
2. Remove one of the leads from the lubricating oil pressure switch while this test is being performed, to prevent the engine from being shut down.
3. Start and run the engine at idle speed.
4. Slow the engine down by moving the speed control lever towards the *no–fuel* position until the fuel pressure is approximately 15 psi (103 kPa), with the engine barely turning over.
5. Place a jumper wire across the water temperature switch terminals.
6. Raise the engine speed slowly and watch the fuel oil pressure gage until the air shutoff valve closes.
7. Note the fuel pressure at which the air shutoff valve closed and, if necessary, replace the switch.
8. Remove the jumper wire from the water temperature switch and reconnect the lubricating oil pressure switch.

Lubricating Oil Pressure Switch

The construction of the lubricating oil pressure switch is very similar to that of the fuel oil pressure switch, except that the lubricating oil pressure switch is calibrated to break contact when the lubricating oil pressure increases to 10 psi (69 kPa). The phrase "10 BREAK" is stamped on the switch cover.

A 20 psi (138 kPa) break switch is used on some engines whose predominant operation is constant speed.

As the lubricating oil pressure increases upon starting, the diaphragm in the switch body expands and forces the plunger upwards (Fig. 2). Since the bottom of the adjusting screw bears against the plunger, and the adjusting screw is attached to the bracket which controls the upper breaker point arm, the arm is also forced upwards. When the lubricating oil pressure increases to 10 psi (69 kPa), the points separate. Current flows to the lubricating oil pressure switch only after the fuel oil pressure switch closes, at which time the points of the lubricating oil switch are open. Should the lubricating oil pressure decrease to 10 psi (69 kPa) during operation, the breaker point will close and either the alarm bell or shutdown solenoid will be energized.

1. Start and run the engine at idle speed.

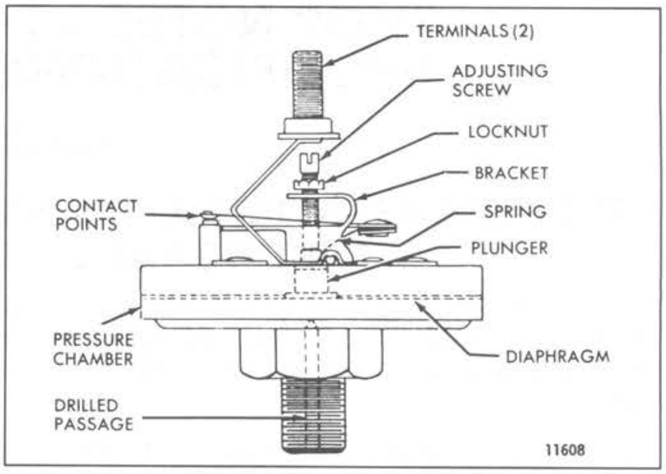


Fig. 2 – Lubricating Oil Pressure Switch

2. Place a jumper wire on the hot wire relay between the "1" and "S" terminals.
3. Place a jumper wire across the fuel oil pressure switch terminals.
4. Reduce the engine speed by moving the control lever towards the *no–fuel* position while watching the lubricating oil pressure gage.
5. Note the oil pressure at which the switch stops the engine and, if necessary, replace the switch.
6. Remove the jumper wire.

Hot Wire Relay

1. Start and operate the engine at idle speed.
2. Place the jumper wire across the terminals of the lubricating oil pressure switch while watching a second hand of a clock.
3. Not more than three (3) to ten (10) seconds should elapse between the time the jumper wire is placed across the terminals of the lubricating oil pressure switch and the air shutoff valve closes.

The above procedures completely test the normally open electrical shutdown system on an engine.

> **NOTICE:** When the engine is operating at idle speed or above, the air shutoff valve will completely close off the air from the engine causing it to stop. However, when the engine is operating at the very low speeds that are necessary when performing the test on the fuel shutdown switch and the lubricating oil shutdown switch, the air damper solenoid will close the air shutoff valve, but the engine may continue to run very slowly. This may be due to insufficient force exerted by the low air flow on the back of the shutoff valve to completely close it.

Solid State Time Delay Switch 12, 24 or 32 Volts–Direct Current

A solid state time delay switch is used on current engines in place of the former hot wire relay.

A bench test procedure for the solid state time delay switch (Fig. 3) is as follows:

1. Remove the time delay switch from the engine.
2. Install the jumper straps on terminals "A" to "B" and "E" to "F", if they have been removed. Normally, the jumper straps are on the Time Delay Switches as supplied.
3. Install a positive battery lead to terminal "A".
4. Install a negative battery lead to one side of a 12 volt light which is a known good test lamp.
5. Install a lead from the opposite side of the light to terminal "D". A switch may be used in this lead, if desired.
6. After the negative lead is connected to "D" or the switch is closed, the lamp should light in eight (8) to ten (10) seconds. If not, the time delay switch must be replaced.

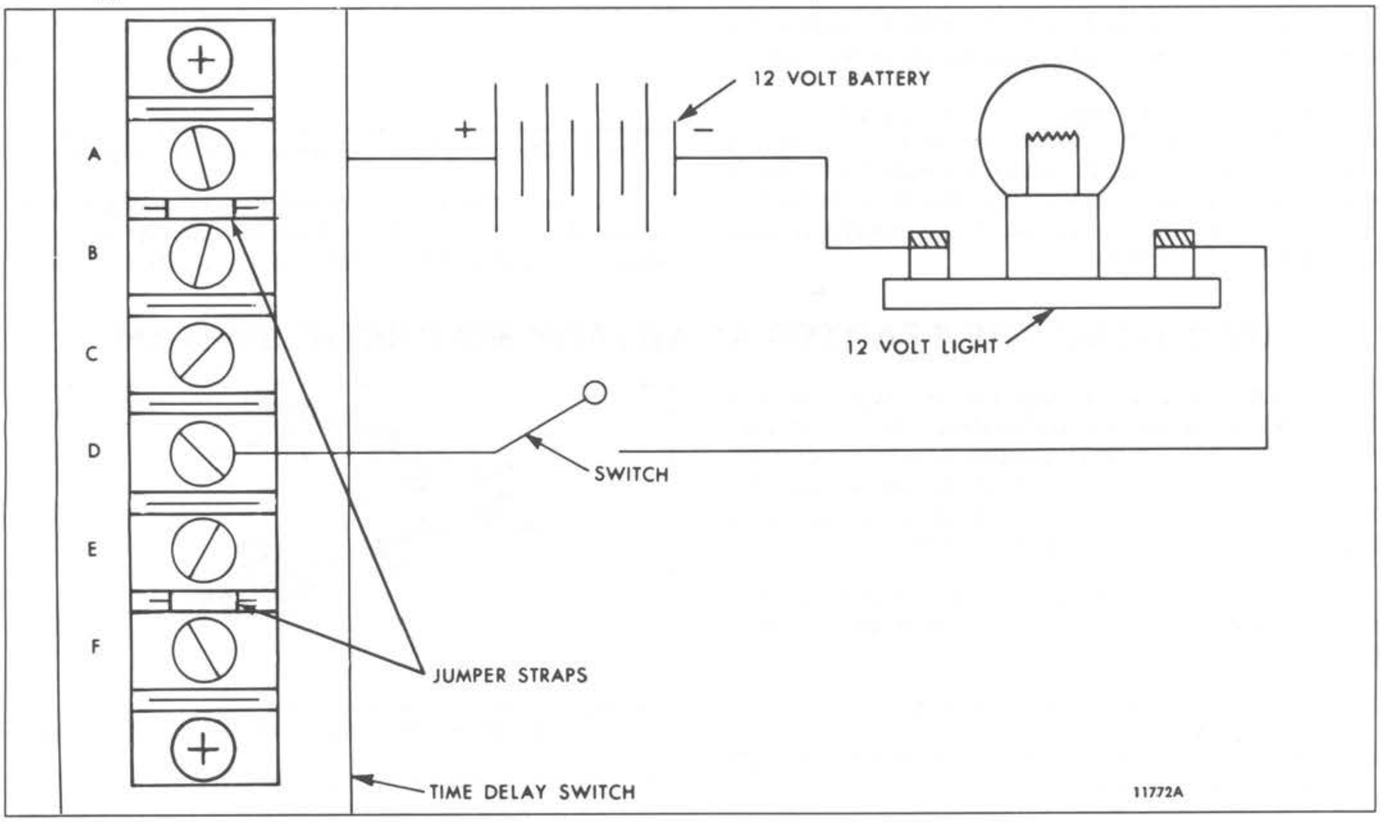


Fig. 3 – Time Delay Switch Testing Diagram

CHECK ENGINE STARTING SWITCH

If difficulty in starting motor engagement has been experienced in a vehicle which has been repowered by a diesel engine, check to see if the key–type starting switch on the instrument panel has been retained.

Key–type starting switches are usually not capable of carrying the current required for heavy–duty diesel engine starter solenoids. The excessive voltage drop in the solenoid circuit restricts the solenoid pull and results in failure of the starter to engage and crank. When tooth abutment occurs and the switch is turned off and on several times, breaking of the solenoid current causes burning or welding of the switch contacts.

Install a push button type starting switch which is capable of making, breaking and carrying the solenoid current without damage (refer to *Engine Starting Motor Switch* in Section 7.4). Otherwise, a heavy–duty magnetic switch should be used in the solenoid control circuit in addition to the key–type switch. The magnetic switch must be capable of making and breaking at least 90 amperes in a 12 volt system; the key switch would then carry no more than one ampere, which is sufficient to operate the magnetic switch.

ALIGNMENT TOOLS FOR TACHOMETER DRIVE COVERS AND ADAPTORS

Whenever a tachometer drive cover assembly or a tachometer drive adaptor is installed on a engine, it is important that the cover assembly or adaptor be aligned properly with the tachometer drive shaft.

Misalignment of a tachometer drive shaft can impose a side load on a tachometer drive cable adaptor resulting in possible gear seizure and damage to other related components.

Use one of three tools in set J 23068 to establish the proper alignment. Fig. 4 illustrates the use of the tools.

Because of the many different combinations of tachometer drive shafts, covers and adaptors, it is not practical to itemize specific usages for each tool. When confronted with an alignment job, test fit each tool to determine which provides the best fit and proceed to make the alignment with that tool.

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Fig. 4 – Checking Tachometer Drive Shaft Alignment

Correct alignment is established when there is no tachometer drive shaft bind on the inside diameter of the tool when one complete hand rotation of the engine is made.

MOUNTING THE STARTER AUXILIARY MAGNETIC SWITCH

On certain railcar and highway units equipped with Detroit Diesel engines and Delco–Remy starter auxiliary magnetic switches, no–start conditions may result from damage to the starter auxiliary magnetic switch caused by vibration. The vibration may result from improper mounting of the auxiliary magnetic switch.

The following guidelines should be followed when mounting a Delco–Remy starter auxiliary magnetic switch (Fig. 5):

1. Do not mount the switch on the engine.
2. Position the mounting pads of the switch vertically (one above the other).
3. Mount the switch on a rigid bracket, base rail or fire wall.

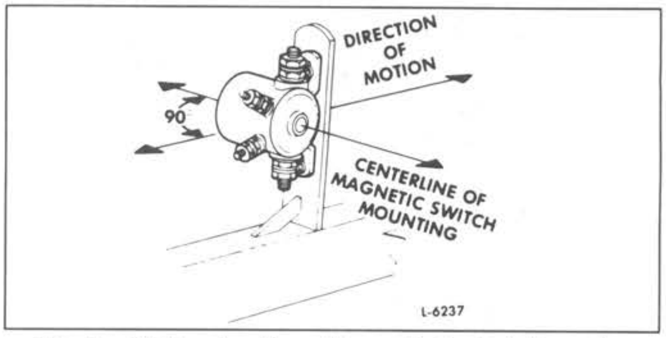

Fig. 5 – Starter Auxiliary Magnetic Switch Mounting

4. Mount the switch on a surface perpendicular (90°) to the forward motion of the vehicle so that contact disc movement is not in line with gravity or vehicle movement.

TROUBLESHOOTING

CHECKING ENGINE ELECTRICAL GENERATING SYSTEM

Whenever trouble is indicated in the electrical generating system, the following quick checks can be made to assist in localizing the cause.

A *fully charged battery and low charging rate* indicates normal alternator–regulator operation.

A *low battery and high charging rate* indicates normal alternator–regulator operation.

A *fully charged battery and high charging rate* condition usually indicates the voltage regulator is set too high or is not limiting the alternator output. A high charging rate to a fully charged battery will damage the battery and other electrical components.

A *low battery and low or no charging rate* condition could be caused by: Loose connections or damaged wiring, defective battery or alternator and defective regulator or improper regulator setting.

SPECIFICATIONS

STANDARD BOLT AND NUT TORQUE SPECIFICATIONS

THREAD SIZE	260M BOLTS TORQUE (lb-ft)	260M BOLTS TORQUE N•m	THREAD SIZE	280M OR BETTER TORQUE (lb-ft)	280M OR BETTER TORQUE N•m
1/4-20	5-7	7-9	1/4-20	7-9	10-12
1/4-28	6-8	8-11	1/4-28	8-10	11-14
5/16-18	10-13	14-18	5/16-18	13-17	18-23
5/16-24	11-14	15-19	5/16-24	15-19	20-26
3/8-16	23-26	31-35	3/8-16	30-35	41-47
3/8-24	26-29	35-40	3/8-24	35-39	47-53
7/16-14	35-38	47-51	7/16-14	46-50	62-68
7/16-20	43-46	58-62	7/16-20	57-61	77-83
1/2-13	53-56	72-76	1/2-13	71-75	96-102
1/2-20	62-70	84-95	1/2-20	83-93	113-126
9/16-12	68-75	92-102	9/16-12	90-100	122-136
9/16-18	80-88	109-119	9/16-18	107-117	146-159
5/8-11	103-110	140-149	5/8-11	137-147	186-200
5/8-18	126-134	171-181	5/8-18	168-178	228-242
3/4-10	180-188	244-254	3/4-10	240-250	325-339
3/4-16	218-225	295-305	3/4-16	290-300	393-407
7/8-9	308-315	417-427	7/8-9	410-420	556-569
7/8-14	356-364	483-494	7/8-14	475-485	644-657
1-8	435-443	590-600	1-8	580-590	786-800
1-14	514-521	697-705	1-14	685-695	928-942

Grade identification markings are normally stamped on the heads of the bolts. To aid identification of the various bolts used in Detroit Diesel engines, refer to the following chart.

Grade Identification Marking on Bolt Head	GM Number	SAE Grade Designation	Nominal Size Diameter (inch)	Tensile Strength Min. (psi)
None	GM 255-M	1	No. 6 thru 1 1/2	60,000
None	GM 260-M	2	No. 6 thru 3/4 over 3/4 to 1 1/2	74,000 60,000
Bolts and Screws	GM 280-M	5	No. 6 thru 1 over 1 to 1 1/2	120,000 105,000
Hex Head Sems Only	GM 275-M	5.1	No. 6 thru 3/8	120,000
Bolts and Screws	GM 290-M	7	1/4 thru 1 1/2	133,000
Bolts and Screws	GM 300-M	8	1/4 thru 1 1/2	150,000
Bolts and Screws	GM 455-M	None	No. 6 thru 1 1/2	55,000

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BOLT IDENTIFICATION CHART

EXCEPTIONS TO STANDARD BOLT AND NUT TORQUE SPECIFICATIONS

APPLICATION	THREAD	(lb–ft)	(N•m)
Flange mounted alternator adaptor nut	3/8–24	15–20	20–27
Tachometer drive cover bolt	7/16–14	30–35	41–47
Tachometer drive cover bolt	1/2–13	30–35	41–47
Tachometer drive shaft (blower)	1/2–20	55–65	75–88
Starting motor switch mounting nut	5/8–32	*	*
Starting motor attaching bolts (alum. flywheel hsg.)	5/8–11	95–105	129–143

*36–48 **lb–in** (4–5.5 N•m)

SERVICE TOOLS

TOOL NAME	TOOL NO.
Slide hammer	J 23907-1
Tachometer drive alignment tool set	J 23068
Tachometer drive shaft remover	J 5901-3

SECTION 8

POWER TAKE-OFF - TORQMATIC CONVERTER

For service and overhaul procedures covering the Power Take–Offs, refer to the *Power Take–Offs Manual, Form 6SE456.* Refer to this manual for the Rockford Front Disconnect Mechanical Clutch adjustment used with the Allison 800–900 Series Torque Converter.

For service and overhaul information covering the Torqmatic Converter, refer to the manufacturer's service manuals:

Allison 500 Series Torqmatic Converter Service Manual – Form SA 1058.

Allison 800–900 Series Torqmatic Converter Service Manual – Form SA 1054.

Refer to SA 1054 for the Industrial Clutch Company Front Disconnect Mechanical Clutch adjustment.

SECTION 9

TRANSMISSIONS

For service and overhaul procedures for Allison products, refer to the manufacturer:

Allison Transmission Division
General Motors Corporation
P.O. Box 894
Indianapolis, IN 46206

For service and overhaul procedures for the Twin Disc Marine Gear assembly, refer to the manufacturer:

Twin Disc, Inc.
1328 Racine Street
Racine, Wisc. 53403

SECTION 12

SPECIAL EQUIPMENT

CONTENTS

AIR COMPRESSOR

The air compressor (Fig. 1) may be mounted on a bracket attached to the cylinder block of the engine and belt–driven from the crankshaft pulley, or it may be flange–mounted to the flywheel housing and gear driven by means of an accessory drive attached to a camshaft gear.

A six bolt design air compressor mounting base, mounting bracket and gasket are used on engines equipped with a belt–driven air compressor.

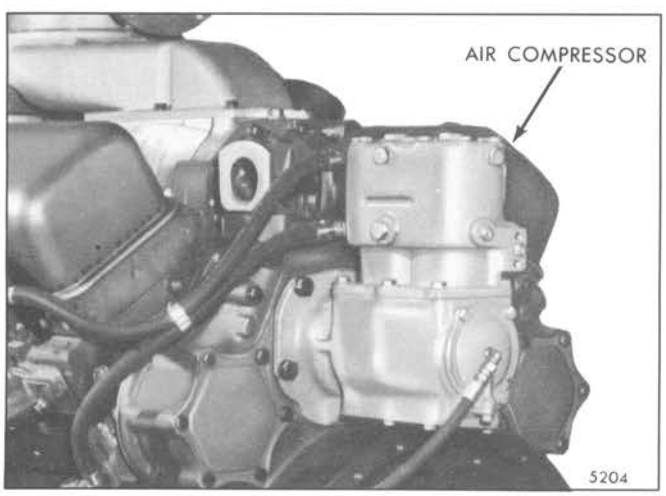
The air compressor runs continuously while the engine is running. While the compressor is running, actual compression of air is controlled by the compressor governor which acts in conjunction with the unloading mechanism in the compressor cylinder block. The governor starts and stops the compression of air by loading or unloading the compressor when the air pressure in the system reaches the desired minimum or maximum pressure.

During the down stroke of each piston, a partial vacuum is created above the piston which unseats the inlet valve and then allows air drawn from the air box in the engine cylinder block or through an intake strainer to enter the cylinder above the piston. As the piston starts the upward stroke, the air pressure on top of the inlet valves, plus the inlet valve return spring force, closes the inlet valve. The air above the piston is further compressed until the pressure lifts the discharge valve and the compressed air is discharged through the discharge line into the reservoir.

As each piston starts its downstroke, the discharge valve above it returns to its seat, preventing the compressed air from returning to the cylinder and the same cycle is repeated.

When the air pressure in the reservoir reaches the maximum setting of the governor, compressed air from the reservoir passes through the governor into the cavity below the unloading pistons in the compressor cylinder block. The air pressure lifts the unloading pistons which in turn lifts the inlet valves off their seats.

With the inlet valves held off their seats, the air during each upstroke of the piston is merely passed back through the air inlet cavity and to the other cylinder where the piston is on the downstroke. When the air pressure in the reservoir drops to the minimum setting of the governor, the governor releases the air pressure beneath the unloading pistons. The unloading piston return spring then forces the piston down and the inlet valve springs return the inlet valves to their seats and compression is resumed.



1 – Air Compressor Mounting

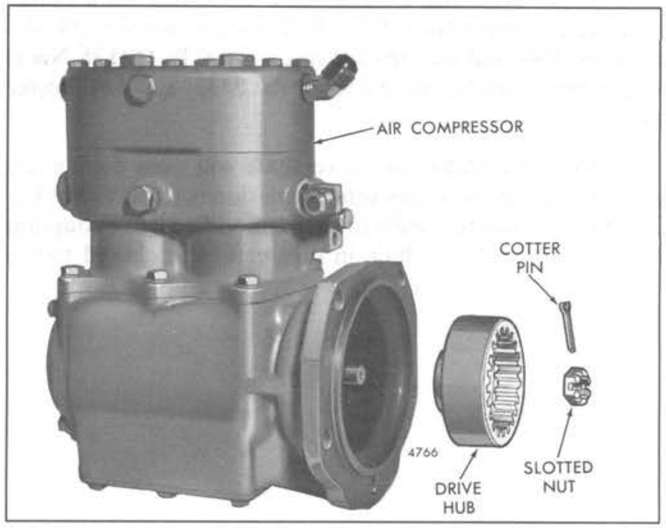


Fig. 2 – Typical Air Compressor with Drive Hub

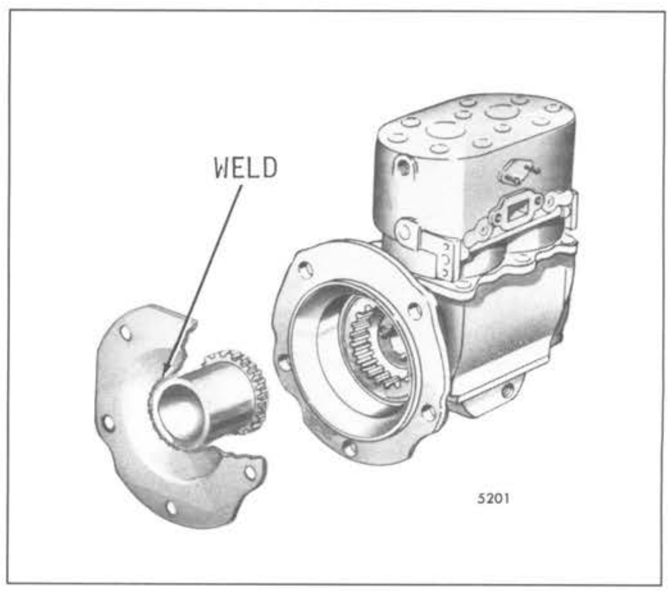


Fig. 3 – Fixture for Holding Drive While Installing or Removing Slotted Nut

Service Note

When installing a pulley or a drive hub on a flange mounted air compressor (Fig. 2), it is important the 3/4"–16 drive shaft slotted nut be tightened to 100 lb–ft (136 N•m) torque minimum before installing the 3/32" x 1–1/4" cotter pin.

The air compressor drive shaft will turn during the torquing operation unless some provision is made to hold it. One way this can be done is to weld a modified drive coupling to a support or base which in turn can be anchored to the mounting flange of the compressor. An old flywheel housing cover that matches the flange of the compressor makes an ideal base for the modified coupling. With the exterior splines of the coupling in mesh with the internal splines of the drive hub and the entire assembly secured to the compressor housing, the hub and shaft are kept from rotating when the torque is applied. That part of the base within the inner diameter of the coupling must be removed to permit placement of the wrench socket on the nut. Two bolts will secure the base to the compressor during the torquing operation (Fig. 3).

SERVICE TOOLS

TOOL NAME	TOOL NO.
Air Compressor Hub Remover	J 36309
Air Compressor Hub Installer	J 36311

SECTION 13

OPERATING INSTRUCTIONS

CONTENTS

ENGINE OPERATING INSTRUCTIONS

PREPARATION FOR STARTING ENGINE FIRST TIME

Before starting an engine for the first time, carefully read and follow the instructions in Sections 13 and 14 of this manual. Attempting to run the engine before studying these instructions may result in serious damage to the engine.

> **NOTICE:** When preparing to start a new or overhauled engine or an engine which has been in storage, perform all of the operations listed below. Before a routine start (at each shift), see *Daily Operations* in the *Lubrication and Preventive Maintenance Chart*, Section 15.1.

Cooling System

Install all of the drain cocks or plugs in the cooling system (drain cocks are removed for shipping).

Open the cooling system vents, if the engine is so equipped. Remove the filler cap and fill the cooling system with a coolant specified under *Coolant Specifications* in Section 13.3. Keep the liquid level about two inches below the filler neck to allow for fluid expansion.

Close the vents, if used, after filling the cooling system.

On marine installations, prime the raw water cooling system and open any sea cocks in the raw water pump intake line. Prime the raw water pump by removing the pipe plug or electrode provided in the pump outlet elbow and pour water in the pump.

> **NOTICE:** Failure to prime the raw water pump may result in damage to the pump impeller.

Lubrication System

The lubricating oil film on the rotating parts and bearings of a new or overhauled engine, or one which has been in storage, may be insufficient for proper lubrication when the engine is started for the first time. Insufficient lubrication at start–up can cause serious damage to the engine components.

To ensure an immediate flow of oil to all bearing surfaces at initial engine start–up, DDC recommends that the engine lubrication system be charged with a commercially available pressure pre–lubricator. Use the following procedure:

1. Remove the pipe plug from the engine main oil gallery and attach the pre–lubricator hose.
2. Remove the valve rocker cover(s) and, using a positive displacement pump set at 25–35 psi (172–241 kPa), pump in the recommended grade of engine lubricating oil until it is observed flowing from the rocker arms.
3. If the engine is turbocharged, disconnect the oil supply lines at the turbo bearing (center) housings and fill the bearing housing cavities with approximately one pint of the recommended grade of clean engine oil. Turn the rotating assemblies by hand to coat all internal surfaces with oil and reinstall the turbo oil supply lines (refer to Section 3.5).
4. After 20 minutes, check the crankcase oil level. Add enough oil to bring the level to the "full" mark on the dipstick. *Do not overfill.*
5. Disconnect the pre–lubricator hose, plug the main oil gallery hole and replace all components previously removed.
6. Before initial engine start–up, DDC also recommends cranking the engine with the governor in the no–fuel position until oil pressure registers on the gage.

For engine lubricating oil recommendations, see *Lubrication Specifications* in Section 13.3 or contact a Detroit Diesel Corporation distributor.

If a pressure prelubricator is not available, fill the crankcase to the proper level with *heavy–duty* lubricating oil as specified under *Lubrication Specifications* in Section 13.3. Then, prelubricate the upper engine parts by removing the valve rocker covers and pouring lubricating oil, of the same grade and viscosity as used in the crankcase, over the rocker arms.

Turbocharger

1. Clean the area and disconnect the oil inlet line at the bearing housing.
2. Fill the bearing housing cavity with clean engine oil. Turn the rotating assembly by hand to coat all of the internal surfaces with oil.
3. Add additional engine oil to completely fill the bearing housing cavity and reinstall the oil line. Clean off any spilled oil.

> **CAUTION: Do not hold the compressor wheel, for any reason, while the engine is running. This could result in personal injury.**

4. Start and run the engine at idle until oil pressure and supply has reached all of the turbocharger moving parts. A good indicator that all the moving parts are getting lubrication is when the oil pressure gage registers pressure (10 psi – 69 kPa at idle speed).

The free floating bearings in the turbocharger center housing require positive lubrication. This is provided by the above procedure *before the turbocharger reaches its maximum operating speed* which is produced by high engine speeds.

NOTICE: Starting any turbocharged engine and accelerating to any speed above idle before engine oil supply and pressure has reached the free floating bearings can cause severe damage to the shaft and bearings of the turbocharger.

Air Cleaner

If the engine is equipped with oil bath air cleaners, fill the air cleaner oil cups to the proper level with clean engine oil. *Do not overfill.*

Transmission

Check the oil level and, if necessary, fill the transmission case, marine gear or torque converter supply tank to the proper level with the lubricant specified under *Lubrication and Preventive Maintenance* in Section 15.1.

Fuel System

Fill the fuel tank with the fuel specified under *Fuel Specifications* in Section 13.3.

If the unit is equipped with a fuel valve, it must be opened.

To ensure prompt starting, fill the fuel system between the pump and the fuel return manifold with fuel. If the engine has been out of service for a considerable length of time, prime the fuel system between the fuel pump and the fuel return manifold. The fuel system may be primed by removing the plug in the top of the fuel filter cover and slowly filling the filter with fuel.

In addition to the above, on an engine equipped with a hydrostarter, use a priming pump to make sure the fuel lines and the injectors are full of fuel before attempting to start the engine.

NOTICE: The fuel system is filled with fuel before leaving the factory. If the fuel is still in the system when preparing to start the engine, priming should be unnecessary.

Lubrication Fittings

Fill all grease cups and lubricate at all fittings (except for fan hub pulley fitting — refer to Section 15.1) with an all purpose grease. Apply lubricating oil to the throttle linkage and other moving parts and fill the hinged cap oilers with a hand oiler.

Drive Belts

Adjust all drive belts as recommended under *Lubrication and Preventive Maintenance* in Section 15.1.

Storage Battery

Check the battery. The top should be clean and dry, the terminals tight and protected with a coat of petroleum jelly and the electrolyte must be at the proper level.

NOTICE: When necessary, check the battery with a hydrometer; the reading should be 1.265 or higher. However, hydrometer readings should always be corrected for the temperature of the electrolyte.

Generator Set

Where applicable, fill the generator end bearing housing with the same lubricating oil as used in the engine.

A generator set should be connected and grounded in accordance with the applicable local electrical codes.

NOTICE: The base of a generator set must be grounded.

Clutch

Disengage the clutch, if the unit is so equipped.

STARTING

Before starting the engine for the first time, perform the operations listed under *Preparation For Starting Engine First Time.*

Before a routine start, see *Daily Operations* in the *Lubrication and Preventive Maintenance Chart,* Section 15.1.

If a manual or an automatic shutdown system is incorporated in the unit, the control must be set in the open position before starting the engine. The blower will be seriously damaged if operated with the air shutoff valve in the closed position.

NOTICE: On engines with dual air shutdown housings, both air shutoff valves must be in the open position before starting the engine.

Starting at air temperatures below 40°F (4°C) requires the use of a cold weather starting aid.

CAUTION: Starting fluid used in capsules is highly inflammable, toxic and possesses sleep inducing properties.

The instructions for the use of a cold weather fluid starting aid will vary dependent on the type being used. Reference should be made to these instructions before attempting a cold weather start.

Initial Engine Start (Electric)

Start an engine equipped with an electric starting motor as follows: Set the speed control lever at part throttle, then bring it back to the desired no–load speed. In addition, on mechanical governors, make sure the stop lever on the governor cover is in the *run* position; on hydraulic governors, make sure the stop knob is pushed all the way in. Then, press the starting motor switch firmly. If the engine fails to start within 30 seconds, release the starting switch and allow the starting motor to cool a few minutes before trying again. If the engine fails to start after four attempts, an inspection should be made to determine the cause.

NOTICE: To prevent serious damage to the starter, if the engine does not start, do not press the starting switch again while the starting motor is running.

Initial Engine Start (Hydrostarter)

Start an engine equipped with a hydrostarter as follows:

Use the priming pump to make sure the fuel filter, fuel lines and injectors are full of fuel before attempting to start the engine.

Raise the hydrostarter accumulator pressure with the hand pump until the gage reads as indicated in Table 1.

Set the engine controls for starting with the throttle at least half open.

NOTICE: During cold weather, add starting fluid at the same time the hydrostarter motor lever is moved. Do not wait to add the fluid after the engine is turning over.

Push the hydrostarter control lever to simultaneously engage the starter pinion with the flywheel ring gear and to open the control valve. Close the valve as soon as the engine starts to conserve the accumulator pressure and to avoid excessive over–running of the starter drive clutch assembly.

RUNNING

Oil Pressure

Observe the oil pressure gage immediately after starting the engine. If there is no pressure indicated within 10 to 15 seconds, stop the engine and check the lubricating oil system. Refer to the *Troubleshooting Charts* in Section 15.2.

Warm–Up

Run the engine at part throttle and no–load for approximately five minutes, allowing it to warm–up before applying a load.

If the unit is operating in a closed room, start the room ventilating fan or open the windows, as weather conditions permit, so ample air is available for the engine.

Inspection

While the engine is running at operating temperature, check for coolant, fuel or lubricating oil leaks. Tighten the line connections where necessary to stop leaks.

Engine Temperature

See Section 13.2 for normal engine coolant temperature.

Ambient Temperature	Pressure Gage Reading	
	psi	kPa
Above 40° F (4.4° C)	1500	10 342
40 - 0° F (4.4 to -18° C)	2500	17 237
Below 0° F (-18° C)	3300	22 753

Table 1

Crankcase

If the engine crankcase was refilled, stop the engine after normal operating temperature has been reached, allow the oil to drain (approximately 20 minutes) back into the crankcase and check the oil level. Add oil, if necessary, to bring it to the proper level on the dipstick.

Use only the *heavy duty* lubricating oil specified under *Lubrication Specifications* in Section 13.3.

Clutch

Do not engage the clutch (with a sintered iron clutch plate) at engine speeds over 850 rpm. A clutch with an asbestos or vegetable fiber material clutch plate must not be engaged at speeds over 1000 rpm.

Cooling System

Remove the radiator or heat exchanger tank cap *slowly* after the engine has reached normal operating temperature and check the engine coolant level. The coolant level should be near the top of the opening. If necessary, add clean soft water or an ethylene glycol base antifreeze.

Transmission

Check the marine gear oil pressure. The operating oil pressure range at operating speed is 90–150 psi (621–1034 kPa) (Allison Torqmatic gear). The operating oil pressure varies with the different Twin Disc gears as noted in Table 2. Check and, if necessary, replenish the oil supply in the transmission.

Turbocharger

Make a visual inspection of the turbocharger for leaks and excessive vibration. Stop the engine immediately if there is an unusual noise in the turbocharger.

Avoid Unnecessary Engine Idling

During long engine idling periods, the engine coolant temperature will fall below the normal operating range. The incomplete combustion of fuel in a cold engine will cause crankcase dilution, formation of lacquer or gummy deposits on the valves, pistons and rings and rapid accumulation of sludge in the engine.

NOTICE: When prolonged engine idling is necessary, maintain at least 800 rpm.

Operating Oil Pressure at 180° F (82° C)*

Marine Gear	Position	† Test rpm	Test Pressure	
			psi	kPa
MG-506 (except 1.5:1 and 2:1 ratios)	Neutral and Engaged	600	280-315	1930-2170
	Neutral and Engaged	1800	300-320	2067-2205
	Cruising	Min.	270	1861
MG-506 (only 1.5:1 and 2:1 ratios)	Neutral and Engaged	600	330-365	2274-2515
	Neutral and Engaged	1800	350-370	2412-2550
	Cruising	Min.	335	2308
MG-509	Neutral	600	35-70	241-483
	Neutral	1800	50-85	345-586
	Engaged	600	187-215	1289-1481
	Engaged	1800	193-220	1330-1516
	Cruising	Min.	165	1137
MG-512	Neutral	600	45-70	310-483
	Neutral	1800	60-90	414-621
	Engaged	600	185-215	1275-1481
	Engaged	1800	195-220	1344-1516
	Cruising	Min.	185	1275
MG-513	Neutral	600	70-110	483-758
	Neutral	1800	90-130	621-896
	Engaged	600	230-270	1585-1861
	Engaged	1800	240-280	1654-1930
	Cruising	Min.	234	1612

Marine Gear	Position	† Test rpm	Test Pressure	
			psi	kPa
MG-514 (less than 4:1 ratio) (shallow case)	Neutral	600	20-65	138-448
	Neutral	1800	45-92	310-634
	Engaged	600	210-235	1447-1619
	Engaged	1800	228-237	1571-1633
	Cruising	Min.	215	1481
MG-514 (4:1 and greater ratio) (deep case)	Neutral	600	35-65	241-448
	Neutral	1800	50-85	379-586
	Engaged	600	187-215	1289-1481
	Engaged	1800	193-220	1330-1516
	Cruising	Min.	185	1275
MG-521	Neutral	600	45-85	310-586
	Neutral	1800	75-100	517-689
	Engaged	600	180-215	1241-1481
	Engaged	1800	188-220	1296-1516
	Cruising	Min.	165	1137
MG-527	Neutral	600	45-85	310-586
	Neutral	1800	65-100	448-689
	Engaged	600	180-215	1241-1481
	Engaged	1800	188-220	1296-1516
	Cruising	Min.	165	1137

* Sump or heat exchanger inlet 210° F (99° C) maximum. Normal operating range desired 140-180° F (60-82° C) minimum continuous duty.

† Sump or heat exchanger inlet 225° F (107° C) maximum intermittent permissable in pleasure craft.

TABLE 2 – Twin Disc Marine Gear Operating Conditions

STOPPING

Normal Stopping

1. Release the load and decrease the engine speed. Put all shift levers in the *neutral* position.

2. Allow the engine to run at half speed or slower with no load for four or five minutes, then move the stop lever to the *stop* position to stop the engine.

Emergency Stopping

To stop an engine (normal or emergency) equipped with the spring–loaded (one screw) design injector control tube, pull the governor stop lever to the stop position. If an engine equipped with the non–spring loaded (two screw) design injector control tube does not stop after using the normal stopping procedure, pull the *Emergency Stop* knob all the way out. This control cuts off the air to the engine. Do not try to restart again until the cause for the malfunction has been found and corrected.

NOTICE: The emergency shutdown system should never be used except in an emergency. Use of the emergency shutdown can cause oil to be sucked past the oil seals and into the blower housing.

The air shutoff valve, located on the blower air inlet housing, must be reset by hand and the *Emergency Stop* knob pushed in before the engine is ready to start again.

Fuel System

If the unit is equipped with a fuel valve, close it. Fill the fuel tank; a full tank minimizes condensation.

Exhaust System

Drain the condensation from the exhaust line or silencer.

Cooling System

Drain the cooling system if it is not protected with antifreeze and freezing temperatures are expected. Leave the drains open. Open the raw water drains of a heat exchanger cooling system.

Crankcase

Check the oil level in the crankcase. Add oil, if necessary, to bring it to the proper level on the dipstick.

Transmission

Check and, if necessary, add sufficient oil to bring it to the proper level.

Inspection

Make a visual check for leaks in the fuel, lubricating and cooling systems.

Clean Engine

Clean and check the engine thoroughly to make certain it will be ready for the next run.

Refer to the *Lubrication and Preventive Maintenance Chart* in Section 15.1 and perform all of the daily maintenance operations. Also, perform the operations required for the number of hours or miles the engine has been in operation.

Make the necessary adjustments and minor repairs to correct difficulties which became apparent to the operator during the last run.

OPERATING CONDITIONS

The following charts are included as an aid to trouble shooting. Any variations from the conditions as listed may be indicative of an abnormal situation demanding correction. Make sure that readings represent true values and that instruments are accurate, before attempting to make corrections to the engine.

V-92 ALL (EXCEPT TURBOCHARGED) ENGINES

	1200 rpm	1800 rpm	2100 rpm
Lubrication System			
Lubricating oil pressure (psi):			
Normal	32–47	50–70	50–70
Minimum for safe operation	25	28	30
†Lubricating oil temperature (deg. F) – Normal	200–235	200–235	200–235
Air System			
Air box pressure (inches mercury) – full load min.:			
At zero exhaust back pressure	1.1	3.8	5.0
At max. full-load exhaust back pressure	2.3	6.4	8.2
Air inlet restriction (inches water) – full load max.:			
Dirty air cleaner – oil bath or dry type	12.4	25.0	25.0
Clean air cleaner:			
Oil bath type	8.7	13.4	15.9
Dry type with precleaner	8.7	13.4	15.9
Dry type less precleaner	5.2	9.1	11.5
Crankcase pressure (inches water) – max.	1.0	2.2	3.0
Exhaust back pressure (inches mercury) – max.:			
Full load	1.5	3.3	4.0
No load	1.0	2.1	2.6
Fuel System			
Fuel pressure at inlet manifold (psi):			
Normal with .080" restriction fitting (6, 8V)	45–70	45–70	45–70
Normal with .070" restriction fitting (12, 16V)	30–65	30–65	30–65
Minimum	30	30	30
Fuel spill (gpm) – min. at no load:			
6 and 8V engines	0.8	0.9	0.9
12 and 16V engines	1.2	1.4	1.4
Pump suction at inlet (inches mercury) – max.:			
Clean system	6.0	6.0	6.0
Dirty system	12.0	12.0	12.0
Cooling System			
Coolant temperature (deg. F) – Normal	160–185	160–185	160–185
Vehicle engines built 1976 and later	170–195	170–195	170–195
Compression			
Compression pressure (psi at sea level):			
Average – new engine – at 600 rpm ... 550			
Minimum – at 600 rpm ... 500			

†The lubricating oil temperature range is based on the temperature measurement in the oil pan at the oil pump inlet. When measuring the oil temperature at the cylinder block oil gallery, it will be approximately 10° lower than the oil pan temperature.

6V–92T ENGINE (with T18A40 TURBOCHARGER) (1.14 A/R* Turbine Housing)

	1800 rpm	2000 rpm	2100 rpm
Lubrication System			
Lubricating oil pressure (psi):			
Normal	50–70	50–70	50–70
Minimum for safe operation	28	30	30
†Lubricating oil temperature (deg. F) – Normal	200–250	200–250	200–250
Air System			
Air box pressure (inches mercury) – full load min.:			
At zero exhaust back pressure:			
9280 injector	21.0	25.5	28.0
9285 injector	22.5	27.0	29.5
9290 injector	24.0	29.0	31.5
9295 injector	25.5		
At max. full–load exhaust back pressure (clean ports):			
9280 injector	19.5	23.7	26.0
9285 injector	20.9	25.1	27.4
9290 injector	22.3	27.0	29.3
9295 injector	23.4		
Air inlet restriction (inches water) – full load max.:			
Dirty air cleaner – dry type	14.5	18.0	20.0
Clean air cleaner:			
Dry type with precleaner	8.7	10.8	12.0
Dry type less precleaner	5.8	7.2	8.0
Crankcase pressure (inches water) – max.	2.2	2.7	3.0
Exhaust back pressure (inches mercury) – max.:			
Full load	1.8	2.2	2.5
No load	1.3	1.6	1.8
Fuel System			
Fuel pressure at inlet manifold (psi):			
Normal with .080" restriction fitting	50–70	50–70	50–70
Minimum	30	30	30
Fuel spill (gpm) – min. at no load:			
.080" restriction fitting	0.9	0.9	0.9
Pump suction at inlet (inches mercury) – max.:			
Clean system	6.0	6.0	6.0
Dirty system	12.0	12.0	12.0
Cooling System			
Coolant temperature (deg. F) – Normal	160–185	160–185	160–185
Vehicle engines built 1976 and later	170–195	170–195	170–195
Compression			
Compression pressure (psi at sea level):			
Average – new engine – at 600 rpm	500		
Minimum – at 600 rpm	450		

*Turbine housing designation (area over radius).

†The lubricating oil temperature range is based on the temperature measurement in the oil pan at the oil pump inlet. When measuring the oil temperature at the cylinder block oil gallery, it will be approximately 10° lower than the oil pan temperature.

6V-92T (OTM) ENGINE (with TV8102 TURBOCHARGER) (1.23 A/R* Turbine Housing) – 9290 INJECTORS

	1200 rpm	1800 rpm	2100 rpm
Lubrication System			
Lubricating oil pressure (psi):			
Normal	32–52	49–70	49–70
Minimum for safe operation	25	28	30
†Lubricating oil temperature (deg. F) – Normal	200–235	200–235	200–235
Air System			
Air box pressure (inches mercury) – full load min.:			
At zero exhaust back pressure	12.5	25.9	33.9
At max. exhaust back pressure (clean ports)	11.8	24.4	32.0
Air inlet restriction (inches water) – max.:			
Dirty air cleaner – dry type:			
Full–load speed	6.5	14.4	20.0
No–load speed	4.0	8.7	12.0
Clean air cleaner – dry type:			
Full–load speed	4.0	8.7	12.0
No–load speed	2.0	5.1	7.2
Crankcase pressure (inches water) – max.	1.3	2.1	3.0
Exhaust back pressure (inches mercury) – max.:			
Full load	0.7	2.0	2.5
No load	0.7	1.4	1.8
Fuel System			
Fuel pressure at inlet manifold (psi):			
Normal	50–70	50–70	50–70
Minimum	30	30	30
Fuel spill (gpm) – min. at no load	0.9	0.9	0.9
Pump suction at inlet (inches mercury) – max.:			
Clean system	6.0	6.0	6.0
Dirty system	12.0	12.0	12.0
Cooling System			
Coolant temperature (deg. F) – Normal	160–185	160–185	160–185
Vehicle engines built 1976 and later	170–195	170–195	170–195
Compression			
Compression pressure (psi at sea level):			
Average – new engine – at 600 rpm 500			
Minimum – at 600 rpm 450			

*Turbine housing designation (area over radius).

†The lubricating oil temperature range is based on the temperature measurement in the oil pan at the oil pump inlet. When measuring the oil temperature at the cylinder block oil gallery, it will be approximately 10° lower than the oil pan temperature.

6V-92TA and 6V-92TAC ENGINE (with TV7101 TURBOCHARGER) (1.23 A/R* Turbine Housing) – California Coach

	1900 rpm	2000 rpm	2100 rpm
Lubrication System			
Lubricating oil pressure (psi):			
Normal	49–70	49–70	49–70
Minimum for safe operation	28	29	30
†Lubricating oil temperature (deg. F) – Normal	200–250	200–250	200–250
Air System			
Air box pressure (inches mercury) – full load min.:			
At zero exhaust back pressure:			
9E65 injector – No. 1 Fuel	35.3	38.4	41.5
9E70 injector – No. 1 Fuel	37.3	40.5	43.7
9E65 injector – No. 2 Fuel	34.6	41.1	44.3
9E70 injector – No. 2 Fuel	37.0	43.7	47.0
At max. exhaust back pressure (clean ports):			
9E65 injector – No. 1 Fuel	33.0	36.1	39.2
9E70 injector – No. 1 Fuel	35.0	38.2	41.4
9E65 injector – No. 2 Fuel	32.3	38.8	42.0
9E70 injector – No. 2 Fuel	34.7	41.4	44.7
Air inlet restriction (inches water) – full load max.:			
Dirty air cleaner – dry type	20.0	20.0	20.0
Clean air cleaner – dry type	12.0	12.0	12.0
Crankcase pressure (inches water) – max.:			
Both breathers	2.1	2.3	3.0
Left bank breather	2.6	2.8	3.0
Exhaust back pressure (inches mercury) – max.:			
Full load	3.0	3.0	3.0
Fuel System			
Fuel pressure at inlet manifold (psi) – Normal	50–70	50–70	50–70
Fuel spill (gpm) – min. at no load	0.9	0.9	0.9
Pump suction at inlet (inches mercury) – max.:			
Clean system	6.0	6.0	6.0
Dirty system	12.0	12.0	12.0
Cooling System			
Coolant temperature (deg. F) – Normal	170–195	170–195	170–195
Compression			
Compression pressure (psi at sea level):			
Average – new engine – at 600 rpm ... 500			
Minimum – at 600 rpm ... 450			

*Turbine housing designation (area over radius).

†The lubricating oil temperature range is based on the temperature measurement in the oil pan at the oil pump inlet. When measuring the oil temperature at the cylinder block oil gallery, it will be approximately 10° lower than the oil pan temperature.

6V-92TA and 6V-92TAC ENGINE (with TV7101 TURBOCHARGER) (1.39 A/R* Turbine Housing) - Coach

	1800 rpm	2000 rpm	2100 rpm
Lubrication System			
Lubricating oil pressure (psi):			
Normal	49–70	49–70	49–70
Minimum for safe operation	28	29	30
†Lubricating oil temperature (deg. F) – Normal	200–250	200–250	200–250
Air System			
Air box pressure (inches mercury) – full load min.:			
At zero exhaust back pressure:			
7G65 injector – Fed. – No. 1 Fuel	24.4	30.1	33.0
7G70 injector – Fed. – No. 1 Fuel	26.4	32.1	34.9
7G75 injector – Fed. – No. 1 Fuel	28.3	33.9	36.8
7G65 injector – Fed. – No. 2 Fuel	26.3	31.7	34.4
7G70 injector – Fed. – No. 2 Fuel	28.3	33.7	36.4
7G75 injector – Fed. – No. 2 Fuel	30.3	35.7	38.4
7G65 injector – Calif. – No. 1 Fuel	30.7	33.7	36.8
7G70 injector – Calif. – No. 1 Fuel	32.8	35.9	39.0
7G75 injector – Calif. – No. 1 Fuel	34.9	38.0	41.2
7G65 injector – Calif. – No. 2 Fuel	31.9	34.9	38.0
7G70 injector – Calif. – No. 2 Fuel	33.9	36.9	40.0
7G75 injector – Calif. – No. 2 Fuel	35.9	38.9	42.0
At max. exhaust back pressure (clean ports):			
7G65 injector – Fed. – No. 1 Fuel	22.1	27.8	30.7
7G70 injector – Fed. – No. 1 Fuel	24.1	29.8	32.6
7G75 injector – Fed. – No. 1 Fuel	26.0	31.6	34.5
7G65 injector – Fed. – No. 2 Fuel	24.0	29.4	32.1
7G70 injector – Fed. – No. 2 Fuel	26.0	31.4	34.1
7G75 injector – Fed. – No. 2 Fuel	28.0	33.4	36.1
7G65 injector – Calif. – No. 1 Fuel	28.4	31.4	34.5
7G70 injector – Calif. – No. 1 Fuel	30.5	33.6	36.7
7G75 injector – Calif. – No. 1 Fuel	32.6	35.7	38.9
7G65 injector – Calif. – No. 2 Fuel	29.6	32.6	35.7
7G70 injector – Calif. – No. 2 Fuel	31.6	34.6	37.7
7G75 injector – Calif. – No. 2 Fuel	33.6	36.6	39.7
Air inlet restriction (inches water) – full load max.:			
Dirty air cleaner – dry type	20.0	20.0	20.0
Clean air cleaner – dry type	12.0	12.0	12.0
Crankcase pressure (inches water) – max.	2.1	2.3	3.0
Exhaust back pressure (inches mercury) – max.:			
Full load	3.0	3.0	3.0
Fuel System			
Fuel pressure at inlet manifold (psi) – Normal	50–70	50–70	50–70
Fuel spill (gpm) – min. at no load	0.9	0.9	0.9
Pump suction at inlet (inches mercury) – max.:			
Clean system	6.0	6.0	6.0
Dirty system	12.0	12.0	12.0

6V–92TA and 6V–92TAC ENGINE (with TV7101 TURBOCHARGER) (1.39 A/R* Turbine Housing) – Coach (Cont'd.)

	1800 rpm	2000 rpm	2100 rpm
Cooling System			
Coolant temperature (deg. F) – Normal	170–195	170–195	170–195
Compression			
Compression pressure (psi at sea level):			
Average – new engine – at 600 rpm 500			
Minimum – at 600 rpm 450			

*Turbine housing designation (area over radius).

†The lubricating oil temperature range is based on the temperature measurement in the oil pan at the oil pump inlet. When measuring the oil temperature at the cylinder block oil gallery, it will be approximately 10° lower than the oil pan temperature.

6V–92TA and 6V–92TAC ENGINE (with TV7111 TURBOCHARGER) (1.23 A/R* Turbine Housing) – 1981 and 1982 Automotive

	1800 rpm	1950 rpm	2100 rpm
Lubrication System			
Lubricating oil pressure (psi):			
Normal	49–70	49–70	49–70
Minimum for safe operation	28	29	30
†Lubricating oil temperature (deg. F) – Normal	200–250	200–250	200–250
Air System			
Air box pressure (inches mercury) – full load min.:			
At zero exhaust back pressure:			
9B90 injector – 1.470 timing – Fed.	34.4	40.3	46.4
9F90 injector – 1.520 timing – Calif.	38.1	43.9	49.8
At max. exhaust back pressure (clean ports):			
9B90 injector – 1.470 timing – Fed.	32.2	38.1	44.2
9F90 injector – 1.520 timing – Calif.	35.8	41.6	47.5
Air inlet restriction (inches water) – full load max.:			
Dirty air cleaner – dry type	20.0	20.0	20.0
Clean air cleaner – dry type	12.0	12.0	12.0
Crankcase pressure (inches water) – max.	2.1	2.3	3.0
Exhaust back pressure (inches mercury) – max.:			
Full load	3.0	3.0	3.0
Fuel System			
Fuel pressure at inlet manifold (psi) – Normal	50–70	50–70	50–70
Fuel spill (gpm) – min. at no load	0.9	0.9	0.9
Pump suction at inlet (inches mercury) – max.:			
Clean system	6.0	6.0	6.0
Dirty system	12.0	12.0	12.0
Cooling System			
Coolant temperature (deg. F) – Normal	170–195	170–195	170–195
Compression			
Compression pressure (psi at sea level):			
Average – new engine – at 600 rpm	500		
Minimum – at 600 rpm	450		

*Turbine housing designation (area over radius).

†The lubricating oil temperature range is based on the temperature measurement in the oil pan at the oil pump inlet. When measuring the oil temperature at the cylinder block oil gallery, it will be approximately 10° lower than the oil pan temperature.

6V–92TA ENGINE (with TV7301 TURBOCHARGER) (1.08 A/R* Turbine Housing) – 9B90 – 1.464 Timing

	1800 rpm	1950 rpm	2100 rpm
Lubrication System			
Lubricating oil pressure (psi):			
Normal	49–70	49–70	49–70
Minimum for safe operation	28	29	30
†Lubricating oil temperature (deg. F) – Normal	200–250	200–250	200–250
Air System			
Air box pressure (inches mercury) – full load min.:			
At zero exhaust back pressure	36.3	39.9	43.2
At max. exhaust back pressure	34.8	38.2	41.3
Air inlet restriction (inches water) – full load max.:			
Dirty air cleaner	20.0	20.0	20.0
Clean air cleaner	12.0	12.0	12.0
Crankcase pressure (inches water) – max.:			
Both breather	2.1	2.3	3.0
Left bank breather	2.6	2.8	3.0
Exhaust back pressure (inches mercury) – max.:			
Full load	2.0	2.3	2.5
Fuel System			
Fuel pressure at inlet manifold (psi) – Normal	50–70	50–70	50–70
Fuel spill (gpm) – min. at no load	0.9	0.9	0.9
Pump suction at inlet (inches mercury) – max.:			
Clean system	6.0	6.0	6.0
Dirty system	12.0	12.0	12.0
Cooling System			
Coolant temperature (deg. F) – Normal	170–195	170–195	170–195
Compression			
Compression pressure (psi at sea level):			
Average – new engine – at 600 rpm	500		
Minimum – at 600 rpm	450		

*Turbine housing designation (area over radius).

†The lubricating oil temperature range is based on the temperature measurement in the oil pan at the oil pump inlet. When measuring the oil temperature at the cylinder block oil gallery, it will be approximately 10° lower than the oil pan temperature.

6V-92TA ENGINE (with TV8102 TURBOCHARGER) (1.08 A/R* Turbine Housing) – 9A90 INJECTORS

	1200 rpm	1800 rpm	2100 rpm
Lubrication System			
Lubricating oil pressure (psi):			
Normal	32–52	49–70	49–70
Minimum for safe operation	25	28	30
†Lubricating oil temperature (deg. F) – Normal	200–235	200–235	200–235
Air System			
Air box pressure (inches mercury) – full load min.:			
At zero exhaust back pressure	16.1	32.2	40.4
At max. exhaust back pressure (clean ports)	15.4	30.7	38.5
Air inlet restriction (inches water) – max.:			
Dirty air cleaner – dry type:			
Full–load speed	6.5	20.0	20.0
No–load speed	4.0	8.7	12.0
Clean air cleaner – dry type:			
Full–load speed	4.0	12.0	12.0
No–load speed	2.0	5.1	7.2
Crankcase pressure (inches water) – max.	1.3	2.1	3.0
Exhaust back pressure (inches mercury) – max.:			
Full load	0.9	3.0	3.0
No load	0.7	1.4	1.8
Fuel System			
Fuel pressure at inlet manifold (psi):			
Normal	50–70	50–70	50–70
Minimum	25	28	30
Fuel spill (gpm) – min. at no load	0.9	0.9	0.9
Pump suction at inlet (inches mercury) – max.:			
Clean system	6.0	6.0	6.0
Dirty system	12.0	12.0	12.0
Cooling System			
Coolant temperature (deg. F) – Normal	160–185	160–185	160–185
Vehicle engines built 1976 and later	170–195	170–195	170–195
Compression			
Compression pressure (psi at sea level):			
Average – new engine – at 600 rpm ... 500			
Minimum – at 600 rpm ... 450			

*Turbine housing designation (area over radius).

†The lubricating oil temperature range is based on the temperature measurement in the oil pan at the oil pump inlet. When measuring the oil temperature at the cylinder block oil gallery, it will be approximately 10° lower than the oil pan temperature.

6V–92TA and 6V–92TAC ENGINE (with TV8102 TURBOCHARGER) (1.23 A/R* Turbine Housing) – 1979 Federal and California

	1800 rpm	1950 rpm	2100 rpm
Lubrication System			
Lubricating oil pressure (psi):			
Normal	49–70	49–70	49–70
Minimum for safe operation	28	29	30
†Lubricating oil temperature (deg. F) – Normal	200–250	200–250	200–250
Air System			
Air box pressure (inches mercury) – full load min.:			
At zero exhaust back pressure (clean ports):			
9B80 injector – 1.470 timing – Fed.	26.5	31.7	37.2
9B85 injector – 1.470 timing – Fed.	28.1	33.4	38.9
9B90 injector – 1.470 timing – Fed.	29.7	35.1	40.5
9B80 injector – 1.470 timing – Calif.	26.9	32.2	37.5
9B85 injector – 1.470 timing – Calif.	28.7	34.0	39.4
9B90 injector – 1.470 timing – Calif.	30.3	35.8	41.3
At max. exhaust back pressure (clean ports):			
9B80 injector – 1.470 timing – Fed.	24.2	29.4	34.9
9B85 injector – 1.470 timing – Fed.	25.8	31.1	36.6
9B90 injector – 1.470 timing – Fed.	27.4	32.8	38.2
9B80 injector – 1.470 timing – Calif.	24.6	29.9	35.2
9B85 injector – 1.470 timing – Calif.	26.4	31.7	37.1
9B90 injector – 1.470 timing – Calif.	28.0	33.5	39.0
Air inlet restriction (inches water) – full load max.:			
Dirty air cleaner – dry type	20.0	20.0	20.0
Clean air cleaner – dry type	12.0	12.0	12.0
Crankcase pressure (inches water) – max.	2.1	2.3	3.0
Exhaust back pressure (inches mercury) – max.:			
Full load	3.0	3.0	3.0
Fuel System			
Fuel pressure at inlet manifold (psi):			
Normal	50–70	50–70	50–70
Minimum	30	30	30
Fuel spill (gpm) – min. at no load	0.9	0.9	0.9
Pump suction at inlet (inches mercury) – max.:			
Clean system	6.0	6.0	6.0
Dirty system	12.0	12.0	12.0
Cooling System			
Coolant temperature (deg. F) – Normal	170–195	170–195	170–195
Compression			
Compression pressure (psi at sea level):			
Average – new engine – at 600 rpm ... 500			
Minimum – at 600 rpm ... 450			

*Turbine housing designation (area over radius).

†The lubricating oil temperature range is based on the temperature measurement in the oil pan at the oil pump inlet. When measuring the oil temperature at the cylinder block oil gallery, it will be approximately 10° lower than the oil pan temperature.

6V–92TT ENGINE (with TV8102 TURBOCHARGER) (1.23 A/R* Turbine Housing) – 9290 INJECTORS

	1200 rpm	1800 rpm	1950 rpm
Lubrication System			
Lubricating oil pressure (psi):			
Normal	32–52	49–70	49–70
Minimum for safe operation	25	28	30
†Lubricating oil temperature (deg. F) – Normal	200–235	200–235	200–235
Air System			
Air box pressure (inches mercury) – full load min.:			
At zero exhaust back pressure:			
270 BHP	12.5	22.2	25.4
240 BHP	12.5	20.4	23.4
At max. exhaust back pressure (clean ports):			
270 BHP	11.8	20.7	23.7
240 BHP	11.8	18.9	21.7
Air inlet restriction (inches water) – max.:			
Dirty air cleaner – dry type:			
Full–load speed	6.5	14.5	17.0
No–load speed	4.0	8.7	10.3
Clean air cleaner – dry type:			
Full–load speed	4.0	8.7	10.2
No–load speed	2.0	5.1	6.0
Crankcase pressure (inches water) – max.	1.3	2.1	3.0
Exhaust back pressure (inches mercury) – max.:			
Full load	0.9	2.0	2.4
No load	0.7	1.4	1.7
Fuel System			
Fuel pressure at inlet manifold (psi):			
Normal	50–70	50–70	50–70
Minimum	30	30	30
Fuel spill (gpm) – min. at no load	0.9	0.9	0.9
Pump suction at inlet (inches mercury) – max.:			
Clean system	6.0	6.0	6.0
Dirty system	12.0	12.0	12.0
Cooling System			
Coolant temperature (deg. F) – Normal	160–185	160–185	160–185
Vehicle engines built 1976 and later	170–195	170–195	170–195
Compression			
Compression pressure (psi at sea level):			
Average – new engine – at 600 rpm ... 500			
Minimum – at 600 rpm ... 450			

*Turbine housing designation (area over radius).

†The lubricating oil temperature range is based on the temperature measurement in the oil pan at the oil pump inlet. When measuring the oil temperature at the cylinder block oil gallery, it will be approximately 10° lower than the oil pan temperature.

6V–92TTA and 6V–92TTAC ENGINE (with TV7111 TURBOCHARGER) (1.23 A/R* Turbine Housing) – 1981 and 1982 Automotive

	1800 rpm	1900/1950 rpm	2100 rpm
Lubrication System			
Lubricating oil pressure (psi):			
Normal	49–70	49–70	49–70
Minimum for safe operation	28	29	30
†Lubricating oil temperature (deg. F) – Normal	200–250	200–250	200–250
Air System			
Air box pressure (inches mercury) – full load min.:			
At zero exhaust back pressure:			
9B90 injector – 1.470 timing – Fed.:			
270 BHP	30.1	33.2/—	39.5
307 BHP	34.4	37.5/—	43.6
9F90 injector – 1.520 timing – Calif.:			
270 BHP	30.6	—/35.1	39.3
307 BHP	34.0	—/38.6	42.9
At max. exhaust back pressure (clean ports):			
9B90 injector – 1.470 timing – Fed.:			
270 BHP	27.8	20.9/—	37.2
307 BHP	32.1	35.2/—	41.3
9F90 injector – 1.520 timing – Calif.:			
270 BHP	28.3	—/32.8	37.0
307 BHP	31.7	—/36.3	40.6
Air inlet restriction (inches water) – full load max.:			
Dirty air cleaner – dry type	20.0	20.0	20.0
Clean air cleaner – dry type	12.0	12.0	12.0
Crankcase pressure (inches water) – max.	2.1	2.2/2.3	3.0
Exhaust back pressure (inches mercury) – max.:			
Full load	3.0	3.0	3.0
Fuel System			
Fuel pressure at inlet manifold (psi) – Normal	50–70	50–70	50–70
Fuel spill (gpm) – min. at no load	0.9	0.9	0.9
Pump suction at inlet (inches mercury) – max.:			
Clean system	6.0	6.0	6.0
Dirty system	12.0	12.0	12.0
Cooling System			
Coolant temperature (deg. F) – Normal	170–195	170–195	170–195
Compression			
Compression pressure (psi at sea level):			
Average – new engine – at 600 rpm	500		
Minimum – at 600 rpm	450		

*Turbine housing designation (area over radius).

†The lubricating oil temperature range is based on the temperature measurement in the oil pan at the oil pump inlet. When measuring the oil temperature at the cylinder block oil gallery, it will be approximately 10° lower than the oil pan temperature.

6V–92TTA ENGINE (with TV7301 TURBOCHARGER) (1.08 A/R* Turbine Housing) – 9B90 – 1.470 Timing

	1800 rpm	1900 rpm	2100 rpm
Lubrication System			
Lubricating oil pressure (psi):			
Normal	49–70	49–70	49–70
Minimum for safe operation	28	29	30
†Lubricating oil temperature (deg. F) – Normal	200–250	200–250	200–250
Air System			
Air box pressure (inches mercury) – full load min.:			
At zero exhaust back pressure (clean ports):			
270 BHP	30.1	30.5	33.3
307 BHP	36.3	36.5	38.2
At max. exhaust back pressure (clean ports):			
270 BHP	28.6	28.8	31.4
307 BHP	34.8	34.8	36.3
Air inlet restriction (inches water) – full load max.:			
Dirty air cleaner	20.0	20.0	20.0
Clean air cleaner	12.0	12.0	12.0
Crankcase pressure (inches water) – max.:			
Both breather	2.1	2.2	3.0
Left bank breather	2.6	2.8	3.0
Exhaust back pressure (inches mercury) – max.:			
Full load	2.0	2.2	2.5
Fuel System			
Fuel pressure at inlet manifold (psi) – Normal	50–70	50–70	50–70
Fuel spill (gpm) – min. at no load	0.9	0.9	0.9
Pump suction at inlet (inches mercury) – max.:			
Clean system	6.0	6.0	6.0
Dirty system	12.0	12.0	12.0
Cooling System			
Coolant temperature (deg. F) – Normal	170–195	170–195	170–195
Compression			
Compression pressure (psi at sea level):			
Average – new engine – at 600 rpm	500		
Minimum – at 600 rpm	450		

*Turbine housing designation (area over radius).

†The lubricating oil temperature range is based on the temperature measurement in the oil pan at the oil pump inlet. When measuring the oil temperature at the cylinder block oil gallery, it will be approximately 10° lower than the oil pan temperature.

6V–92TTA ENGINE (with TV8102 TURBOCHARGER) (1.08 A/R* Turbine Housing) – 9A90 INJECTORS

	1200 rpm	1800 rpm	1950 rpm
Lubrication System			
Lubricating oil pressure (psi):			
Normal	32–52	49–70	49–70
Minimum for safe operation	25	28	30
†Lubricating oil temperature (deg. F) – Normal	200–235	200–235	200–235
Air System			
Air box pressure (inches mercury) – full load min.:			
At zero exhaust back pressure	16.1	28.5	31.7
At max. exhaust back pressure (clean ports)	15.4	27.0	30.0
Air inlet restriction (inches water) – max.:			
Dirty air cleaner – dry type:			
Full–load speed	6.5	20.0	20.0
No–load speed	4.0	8.7	10.2
Clean air cleaner – dry type:			
Full–load speed	4.0	12.0	12.0
No–load speed	2.0	5.1	7.2
Crankcase pressure (inches water) – max.	1.3	2.1	3.0
Exhaust back pressure (inches mercury) – max.:			
Full load	0.9	3.0	3.0
No load	0.7	1.4	1.7
Fuel System			
Fuel pressure at inlet manifold (psi):			
Normal	50–70	50–70	50–70
Minimum	30	30	30
Fuel spill (gpm) – min. at no load	0.9	0.9	0.9
Pump suction at inlet (inches mercury) – max.:			
Clean system	6.0	6.0	6.0
Dirty system	12.0	12.0	12.0
Cooling System			
Coolant temperature (deg. F) – Normal	160–185	160–185	160–185
Vehicle engines built 1976 and later	170–195	170–195	170–195
Compression			
Compression pressure (psi at sea level):			
Average – new engine – at 600 rpm ... 500			
Minimum – at 600 rpm ... 450			

*Turbine housing designation (area over radius).

†The lubricating oil temperature range is based on the temperature measurement in the oil pan at the oil pump inlet. When measuring the oil temperature at the cylinder block oil gallery, it will be approximately 10° lower than the oil pan temperature.

6V–92TTA AND 6V–92TTAC ENGINE (WITH TV8102 TURBOCHARGER) (1.23 A/R* TURBINE HOUSING) – 9B90 INJECTOR

	1800 rpm	1950 rpm	2100 rpm
Lubrication System			
Lubricating oil pressure (psi):			
Normal	49–70	49–70	49–70
Minimum for safe operation	28	29	30
†Lubricating oil temperature (deg. F) – Normal	200–250	200–250	200–250
Air System			
Air box pressure (inches mercury) – full load min.:			
At zero exhaust back pressure (clean ports):			
240 (Fed.) – 1.470 timing	23.1	—	—
270 (Fed.) – 1.470 timing	25.7	31.3	35.3
307 (Fed.) – 1.470 timing	29.7	34.5	38.3
240 (Calif.) – 1.490 timing	24.1	—	—
270 (Calif.) – 1.490 timing	26.6	31.4	35.6
307 (Calif.) – 1.490 timing	30.3	34.8	38.8
At max. exhaust back pressure (clean ports):			
240 (Fed.) – 1.470 timing	20.8	—	—
270 (Fed.) – 1.470 timing	23.4	29.0	33.0
307 (Fed.) – 1.470 timing	27.4	32.2	36.0
240 (Calif.) – 1.490 timing	21.8	—	—
270 (Calif.) – 1.490 timing	24.3	29.1	33.3
307 (Calif.) – 1.490 timing	28.0	32.5	36.5
Air inlet restriction (inches water) – full load max.:			
Dirty air cleaner – dry type	20.0	20.0	20.0
Clean air cleaner – dry type	12.0	12.0	12.0
Crankcase pressure (inches water) – max.	2.1	2.3	3.0
Exhaust back pressure (inches mercury) – max.:			
Full load	3.0	3.0	3.0
Fuel System			
Fuel pressure at inlet manifold (psi):			
Normal	50–70	50–70	50–70
Minimum	30	30	30
Fuel spill (gpm) – min. at no load	0.9	0.9	0.9
Pump suction at inlet (inches mercury) – max.:			
Clean system	6.0	6.0	6.0
Dirty system	12.0	12.0	12.0
Cooling System			
Coolant temperature (deg. F) – Normal	170–195	170–195	170–195
Compression			
Compression pressure (psi at sea level):			
Average – new engine – at 600 rpm	500		
Minimum – at 600 rpm	450		

*Turbine housing designation (area over radius).

†The lubricating oil temperature range is based on the temperature measurement in the oil pan at the oil pump inlet. When measuring the oil temperature at the cylinder block oil gallery, it will be approximately 10° lower than the oil pan temperature.

8V–92T AND 16V–92T ENGINE (WITH T18A90 TURBOCHARGER) (1.50 A/R* TURBINE HOUSING)

	1800 rpm	2000 rpm	2100 rpm
Lubrication System			
Lubricating oil pressure (psi):			
Normal	50–70	50–70	50–70
Minimum for safe operation	28	30	30
†Lubricating oil temperature (deg. F) – Normal	200–250	200–250	200–250
Air System			
Air box pressure (inches mercury) – full load min.:			
At zero exhaust back pressure:			
9280 injector	22.5	27.5	29.5
9285 injector	24.0	29.0	31.0
9290 injector	25.5	31.0	33.0
9295 injector	27.5		
At max. full–load exhaust back pressure (clean ports):			
9280 injector	20.9	25.6	27.4
9285 injector	22.3	27.0	28.8
9290 injector	23.7	28.8	30.7
9295 injector	25.6		
Air inlet restriction (inches water) – full load max.:			
Dirty air cleaner – dry type	14.5	18.0	20.0
Clean air cleaner:			
Dry type with precleaner	8.7	10.8	12.0
Dry type less precleaner	6.3	7.7	8.5
Crankcase pressure (inches water) – max.	2.2	2.7	3.0
Exhaust back pressure (inches mercury) – max.:			
Full load	2.0	2.5	2.5
No load	1.3	1.6	1.8
Fuel System			
Fuel pressure at inlet manifold (psi):			
Normal with .080" restriction fitting (8V)	50–70	50–70	50–70
Normal with .070" restriction fitting (two for 16V)	50–70	50–70	50–70
Minimum	30	30	30
Fuel spill (gpm) – min. at no load:			
.080" restriction fitting (8V)	0.9	0.9	0.9
.070" restriction fitting (two for 16V)	1.4	1.4	1.4
Pump suction at inlet (inches mercury) – max.:			
Clean system	6.0	6.0	6.0
Dirty system	12.0	12.0	12.0
Cooling System			
Coolant temperature (deg. F) – Normal	160–185	160–185	160–185
Vehicle engines built 1976 and later	170–195	170–195	170–195

8V–92T AND 16V–92T ENGINE (WITH T18A90 TURBOCHARGER) (1.50 A/R* TURBINE HOUSING) (Cont'd.)

	1800 rpm	2000 rpm	2100 rpm
Compression			
Compression pressure (psi at sea level):			
Average – new engine – at 600 rpm 500			
Minimum – at 600 rpm 450			

*Turbine housing designation (area over radius).

†The lubricating oil temperature range is based on the temperature measurement in the oil pan at the oil pump inlet. When measuring the oil temperature at the cylinder block oil gallery, it will be approximately 10° lower than the oil pan temperature.

8V–92T (OTM) ENGINE (with TV8101 TURBOCHARGER) (1.84 A/R* Turbine Housing) – 9290 INJECTORS

	1200 rpm	1800 rpm	2100 rpm
Lubrication System			
Lubricating oil pressure (psi):			
Normal	32–52	49–70	49–70
Minimum for safe operation	25	28	30
†Lubricating oil temperature (deg. F) – Normal	200–235	200–235	200–235
Air System			
Air box pressure (inches mercury) – full load min.:			
At zero exhaust back pressure	13.6	27.0	35.0
At max. full–load exhaust back pressure (clean ports)	12.9	25.5	33.1
Air inlet restriction (inches water) – max.:			
Dirty air cleaner – dry type:			
Full–load speed	6.5	14.4	20.0
No–load speed	4.0	8.7	12.0
Clean air cleaner – dry type:			
Full–load speed	4.0	8.7	12.0
No–load speed	2.0	5.1	7.2
Crankcase pressure (inches water) – max.	2.3	3.1	3.5
Exhaust back pressure (inches mercury) – max.:			
Full load	0.7	2.0	2.5
No load	0.7	1.4	1.8
Fuel System			
Fuel pressure at inlet manifold (psi):			
Normal	50–70	50–70	50–70
Minimum	30	30	30
Fuel spill (gpm) – min. at no load	0.9	0.9	0.9
Pump suction at inlet (inches mercury) – max.:			
Clean system	6.0	6.0	6.0
Dirty system	12.0	12.0	12.0
Cooling System			
Coolant temperature (deg. F) – Normal	160–185	160–185	160–185
Vehicle engines built 1976 and later	170–195	170–195	170–195
Compression			
Compression pressure (psi at sea level):			
Average – new engine – at 600 rpm ... 500			
Minimum – at 600 rpm ... 450			

*Turbine housing designation (area over radius).

†The lubricating oil temperature range is based on the temperature measurement in the oil pan at the oil pump inlet. When measuring the oil temperature at the cylinder block oil gallery, it will be approximately 10° lower than the oil pan temperature.

8V-92TA and 8V-92TAC ENGINE (with TV7111 TURBOCHARGER) (1.39 A/R* Turbine Housing) – 1981 and 1982 Automotive

	1800 rpm	2000 rpm	2100 rpm
Lubrication System			
Lubricating oil pressure (psi):			
Normal	49–70	49–70	49–70
Minimum for safe operation	28	29	30
†Lubricating oil temperature (deg. F) – Normal	200–250	200–250	200–250
Air System			
Air box pressure (inches mercury) – full load min.:			
At zero exhaust back pressure:			
7G75 injector – 1.470 timing – Fed.	38.1	—	—
7G75 injector – 1.508 timing – Calif.	39.2	—	—
9E65 injector – 1.466 timing – Fed. Transit	32.7	37.9	40.4
9E70 injector – 1.466 timing – Fed. Transit	35.0	40.1	41.4
At max. exhaust back pressure (clean ports):			
7G75 injector – 1.470 timing – Fed.	35.8	—	—
7G75 injector – 1.508 timing – Calif.	36.9	—	—
9E65 injector – 1.466 timing – Fed. Transit	30.4	35.6	38.1
9E70 injector – 1.466 timing – Fed. Transit	32.7	37.8	39.1
Air inlet restriction (inches water) – full load max.:			
Dirty air cleaner – dry type	20.0	20.0	20.0
Clean air cleaner – dry type	12.0	12.0	12.0
Crankcase pressure (inches water) – max.	3.1	3.3	3.5
Exhaust back pressure (inches mercury) – max.:			
Full load	3.0	3.0	3.0
Fuel System			
Fuel pressure at inlet manifold (psi) – normal	50–70	50–70	50–70
Fuel spill (gpm) – min. at no load	0.9	0.9	0.9
Pump suction at inlet (inches mercury) – max.:			
Clean system	6.0	6.0	6.0
Dirty system	12.0	12.0	12.0
Cooling System			
Coolant temperature (deg. F) – Normal	170–195	170–195	170–195
Compression			
Compression pressure (psi at sea level):			
Average – new engine – at 600 rpm 500			
Minimum – at 600 rpm 450			

*Turbine housing designation (area over radius).

†The lubricating oil temperature range is based on the temperature measurement in the oil pan at the oil pump inlet. When measuring the oil temperature at the cylinder block oil gallery, it will be approximately 10° lower than the oil pan temperature.

8V–92TA and 8V–92TAC ENGINE (with TV7301 TURBOCHARGER) (1.39 A/R* Turbine Housing) – 355 BHP

	1800 rpm
Lubrication System	
Lubricating oil pressure (psi):	
Normal	49–70
Minimum for safe operation	28
†Lubricating oil temperature (deg. F) – Normal	200–250
Air System	
Air box pressure (inches mercury) – full load min.:	
At zero exhaust back pressure:	
9E70 injector – 1.470 timing – Fed.	39.5
9G75 injector – 1.508 timing – Calif.	41.0
At max. exhaust back pressure (clean ports)	
9E70 injector – 1.470 timing – Fed.	37.7
9G75 injector – 1.508 timing – Calif.	39.2
Air inlet restriction (inches water) – full load max.:	
Dirty air cleaner	20.0
Clean air cleaner	12.0
Crankcase pressure (inches water) – max.	3.1
Exhaust back pressure (inches mercury) – max.:	
Full load	2.4
Fuel System	
Fuel pressure at inlet manifold (psi) – Normal	50–70
Fuel spill (gpm) – min. at no load	0.9
Pump suction at inlet (inches mercury) – max.:	
Clean system	6.0
Dirty system	12.0
Cooling System	
Coolant temperature (deg. F) – Normal	170–195
Compression	
Compression pressure (psi at sea level):	
Average – new engine – at 600 rpm 500	
Minimum – at 600 rpm 450	

*Turbine housing designation (area over radius).

†The lubricating oil temperature range is based on the temperature measurement in the oil pan at the oil pump inlet. When measuring the oil temperature at the cylinder block oil gallery, it will be approximately 10° lower than the oil pan temperature.

8V–92TA ENGINE (with TV8101 TURBOCHARGER) (1.60 A/R* Turbine Housing)

	1200 rpm	1800 rpm	1950/2100 rpm
Lubrication System			
Lubricating oil pressure (psi):			
Normal	32–52	49–70	49–70
Minimum for safe operation	25	28	30
†Lubricating oil temperature (deg. F) – Normal	200–235	200–235	200–235
Air System			
Air box pressure (inches mercury) – full load min.:			
At zero exhaust back pressure:			
9290 Injector	15.0	29.8	—/36.9
9A90 Injector	18.7	35.4	44.0/—
At max. exhaust back pressure (clean ports):			
9290 Injector	14.3	28.3	—/35.0
9A90 Injector	18.0	33.9	42.1/—
Air inlet restriction (inches water) – full load max.:			
Dirty air cleaner – dry type:			
Full–load speed	6.5	20.0	20.0
No–load speed	4.0	8.7	12.0
Clean air cleaner – dry type:			
Full–load speed	4.0	12.0	12.0
No–load speed	2.0	5.1	7.2
Crankcase pressure (inches water) – max.	2.3	3.1	3.5
Exhaust back pressure (inches mercury) – max.:			
Full load	0.9	3.0	3.0
No load	0.7	1.4	1.8
Fuel System			
Fuel pressure at inlet manifold (psi):			
Normal	50–70	50–70	50–70
Minimum	30	30	30
Fuel spill (gpm) – min. at no load	0.9	0.9	0.9
Pump suction at inlet (inches mercury) – max.:			
Clean system	6.0	6.0	6.0
Dirty system	12.0	12.0	12.0
Cooling System			
Coolant temperature (deg. F) – Normal	170–195	170–195	170–195
Compression			
Compression pressure (psi at sea level):			
Average – new engine – at 600 rpm 500			
Minimum – at 600 rpm 450			

*Turbine housing designation (area over radius).

†The lubricating oil temperature range is based on the temperature measurement in the oil pan at the oil pump inlet. When measuring the oil temperature at the cylinder block oil gallery, it will be approximately 10° lower than the oil pan temperature.

8V–92TA ENGINE (with TV8101 TURBOCHARGER) (1.60 A/R* Turbine Housing)1979 Federal and California

	1800 rpm	1950 rpm	2100 rpm
Lubrication System			
Lubricating oil pressure (psi):			
Normal	49–70	49–70	49–70
Minimum for safe operation	28	29	30
†Lubricating oil temperature (deg. F) – Normal	200–250	200–250	200–250
Air System			
Air box pressure (inches mercury) – full load min.:			
At zero exhaust back pressure (clean ports):			
9A80 injector – Fed.	29.3	33.1	36.8
9A80 injector – Calif.	31.0	34.8	38.6
9A85 injector – Fed.	31.2	35.1	38.7
9A85 injector – Calif.	32.8	36.7	40.6
9A90 injector – Fed.	33.1	37.0	40.6
9A90 injector – Calif.	34.6	38.7	42.6
At max. exhaust back pressure (clean ports):			
9A80 injector – Fed.	27.0	30.8	34.5
9A80 injector – Calif.	28.7	32.5	36.3
9A85 injector – Fed.	28.9	32.8	36.4
9A85 injector – Calif.	30.5	34.4	38.3
9A90 injector – Fed.	30.8	34.7	38.3
9A90 injector – Calif.	32.3	36.4	40.3
Air inlet restriction (inches water) – full load max.:			
Dirty air cleaner – dry type	20.0	20.0	20.0
Clean air cleaner – dry type	12.0	12.0	12.0
Crankcase pressure (inches water) – max.	3.1	3.3	3.5
Exhaust back pressure (inches mercury) – max.:			
Full load	3.0	3.0	3.0
Fuel System			
Fuel pressure at inlet manifold (psi):			
Normal	50–70	50–70	50–70
Minimum	30	30	30
Fuel spill (gpm) – min. at no load	0.9	0.9	0.9
Pump suction at inlet (inches mercury) – max.:			
Clean system	6.0	6.0	6.0
Dirty system	12.0	12.0	12.0
Cooling System			
Coolant temperature (deg. F) – Normal	170–195	170–195	170–195
Compression			
Compression pressure (psi at sea level):			
Average – new engine – at 600 rpm	500		
Minimum – at 600 rpm	450		

*Turbine housing designation (area over radius).

†The lubricating oil temperature range is based on the temperature measurement in the oil pan at the oil pump inlet. When measuring the oil temperature at the cylinder block oil gallery, it will be approximately 10° lower than the oil pan temperature.

8V–92TA and 8V–92TAC ENGINE (with TV8117 TURBOCHARGER) (1.39 A/R* Turbine Housing) – 1981 and 1982 Automotive

	1800 rpm	1950 rpm	2100 rpm
Lubrication System			
Lubricating oil pressure (psi):			
Normal	49–70	49–70	49–70
Minimum for safe operation	28	29	30
†Lubricating oil temperature (deg. F) – Normal	200–250	200–250	200–250
Air System			
Air box pressure (inches mercury) – full load min.:			
At zero exhaust back pressure:			
9A90 injector – 1.466 timing – Fed.	29.8	34.0	38.2
9F90 injector – 1.520 timing – Calif.	36.9	40.8	44.7
At max. exhaust back pressure (clean ports):			
9A90 injector – 1.466 timing – Fed.	27.5	31.7	35.9
9F90 injector – 1.520 timing – Calif.	34.6	38.5	42.4
Air inlet restriction (inches water) – full load max.:			
Dirty air cleaner – dry type	20.0	20.0	20.0
Clean air cleaner – dry type	12.0	12.0	12.0
Crankcase pressure (inches water) – max.	3.1	3.3	3.5
Exhaust back pressure (inches mercury) – max.:			
Full load	3.0	3.0	3.0
Fuel System			
Fuel pressure at inlet manifold (psi) – Normal	50–70	50–70	50–70
Fuel spill (gpm) – min. at no load	0.9	0.9	0.9
Pump suction at inlet (inches mercury) – max.:			
Clean system	6.0	6.0	6.0
Dirty system	12.0	12.0	12.0
Cooling System			
Coolant temperature (deg. F) – Normal	170–195	170–195	170–195
Compression			
Compression pressure (psi at sea level):			
Average – new engine – at 600 rpm 500			
Minimum – at 600 rpm 450			

*Turbine housing designation (area over radius).

†The lubricating oil temperature range is based on the temperature measurement in the oil pan at the oil pump inlet. When measuring the oil temperature at the cylinder block oil gallery, it will be approximately 10° lower than the oil pan temperature.

8V–92TA and 8V–92TAC ENGINE (with TV8301 TURBOCHARGER) (1.39 A/R* Turbine Housing)

	1800 rpm	1950 rpm	2100 rpm
Lubrication System			
Lubricating oil pressure (psi):			
Normal	49–70	49–70	49–70
Minimum for safe operation	28	29	30
†Lubricating oil temperature (deg. F) – Normal	200–250	200–250	200–250
Air System			
Air box pressure (inches mercury) – full load min.:			
At zero exhaust back pressure:			
TTA 365 BHP – 9A90 – 1.460 timing	24.6	26.8	29.0
TA 445 BHP – 9A90 – 1.460 timing	29.1	34.7	36.4
TTAC 365 BHP – 9F90 – 1.515 timing	26.4	28.2	30.4
TAC 440 BHP – 9F90 – 1.515 timing	31.6	34.6	37.2
At max. exhaust back pressure (clean ports):			
TTA 365 BHP – 9A90 – 1.460 timing	22.8	24.8	26.7
TA 445 BHP – 9A90 – 1.460 timing	27.3	32.7	34.1
TTAC 365 BHP – 9F90 – 1.515 timing	24.6	26.2	28.1
TAC 440 BHP – 9F90 – 1.515 timing	29.8	32.6	34.9
Air inlet restriction (inches water) – full load max.:			
Dirty air cleaner – dry type	20.0	20.0	20.0
Clean air cleaner – dry type	12.0	12.0	12.0
Crankcase pressure (inches water) – max.	3.1	3.3	3.5
Exhaust back pressure (inches mercury) – max.:			
Full load	2.4	2.7	3.0
Fuel System			
Fuel pressure at inlet manifold (psi) – Normal	50–70	50–70	50–70
Fuel spill (gpm) – min. at no load	0.9	0.9	0.9
Pump suction at inlet (inches mercury) – max.:			
Clean system	6.0	6.0	6.0
Dirty system	12.0	12.0	12.0
Cooling System			
Coolant temperature (deg. F) – Normal	170–195	170–195	170–195
Compression			
Compression pressure (psi at sea level):			
Average – new engine – at 600 rpm	500		
Minimum – at 600 rpm	450		

*Turbine housing designation (area over radius).

†The lubricating oil temperature range is based on the temperature measurement in the oil pan at the oil pump inlet. When measuring the oil temperature at the cylinder block oil gallery, it will be approximately 10° lower than the oil pan temperature.

8V-92TT ENGINE (WITH TV8101 TURBOCHARGER) (1.84 A/R* TURBINE HOUSING) – 9290 INJECTORS

	1200 rpm	1800 rpm	1950 rpm
Lubrication System			
Lubricating oil pressure (psi):			
Normal	32–52	49–70	49–70
Minimum for safe operation	25	28	30
†Lubricating oil temperature (deg. F) – Normal	200–235	200–235	200–235
Air System			
Air box pressure (inches mercury) – full load min.:			
At zero exhaust back pressure	13.6	25.4	28.6
At max. exhaust back pressure (clean ports)	12.9	23.9	26.9
Air inlet restriction (inches water) – max.:			
Dirty air cleaner – dry type:			
Full–load speed	6.5	14.5	17.0
No–load speed	4.0	8.7	10.3
Clean air cleaner – dry type:			
Full–load speed	4.0	8.7	10.2
No–load speed	2.0	5.1	6.0
Crankcase pressure (inches water) – max.	2.3	3.1	3.3
Exhaust back pressure (inches mercury) – max.:			
Full load	0.9	2.0	2.4
No load	0.7	1.4	1.7
Fuel System			
Fuel pressure at inlet manifold (psi):			
Normal	50–70	50–70	50–70
Minimum	30	30	30
Fuel spill (gpm) – min. at no load	0.9	0.9	0.9
Pump suction at inlet (inches mercury) – max.:			
Clean system	6.0	6.0	6.0
Dirty system	12.0	12.0	12.0
Cooling System			
Coolant temperature (deg. F) – Normal	160–185	160–185	160–185
Vehicle engines built 1976 and later	170–195	170–195	170–195
Compression			
Compression pressure (psi at sea level):			
Average – new engine – at 600 rpm ... 500			
Minimum – at 600 rpm ... 450			

*Turbine housing designation (area over radius).

†The lubricating oil temperature range is based on the temperature measurement in the oil pan at the oil pump inlet. When measuring the oil temperature at the cylinder block oil gallery, it will be approximately 10° lower than the oil pan temperature.

8V–92TTA ENGINE (with TV8101 TURBOCHARGER) (1.60 A/R* Turbine Housing)

	1200 rpm	1800 rpm	1950 rpm
Lubrication System			
Lubricating oil pressure (psi):			
Normal	32–52	49–70	49–70
Minimum for safe operation	25	28	30
†Lubricating oil temperature (deg. F) – Normal	200–235	200–235	200–235
Air System			
Air box pressure (inches mercury) – full load min.:			
At zero exhaust back pressure:			
9290 injector	15.0	27.0	29.3
9A90 injector	18.7	35.4	39.5
At max. exhaust back pressure (clean ports):			
9290 injector	14.3	25.5	27.6
9A90 injector	18.0	33.9	37.8
Air inlet restriction (inches water) – max.:			
Dirty air cleaner – dry type:			
Full–load speed	6.5	20.0	20.0
No–load speed (9290 injector)	4.0	8.7	12.0
No–load speed (9A90 injector)	4.0	8.7	10.3
Clean air cleaner – dry type:			
Full–load speed	4.0	12.0	12.0
No–load speed (9290 injector)	2.0	5.1	7.2
No–load speed (9A90 injector)	2.0	5.1	6.0
Crankcase pressure (inches water) – max.	2.3	3.1	3.3
Exhaust back pressure (inches mercury) – max.:			
Full load	0.9	3.0	3.0
No load	0.7	1.4	1.7
Fuel System			
Fuel pressure at inlet manifold (psi):			
Normal	50–70	50–70	50–70
Minimum	30	30	30
Fuel spill (gpm) – min. at no load	0.9	0.9	0.9
Pump suction at inlet (inches mercury) – max.:			
Clean system	6.0	6.0	6.0
Dirty system	12.0	12.0	12.0
Cooling System			
Coolant temperature (deg. F) – Normal	170–195	170–195	170–195
Compression			
Compression pressure (psi at sea level):			
Average – new engine – at 600 rpm 500			
Minimum – at 600 rpm 450			

*Turbine housing designation (area over radius).

†The lubricating oil temperature range is based on the temperature measurement in the oil pan at the oil pump inlet. When measuring the oil temperature at the cylinder block oil gallery, it will be approximately 10° lower than the oil pan temperature.

8V-92TTA and 8V-92TTAC ENGINE (with TV8101 TURBOCHARGER) (1.60 A/R* Turbine Housing) – 9A90 INJECTOR

	1800 rpm	1950 rpm	2100 rpm
Lubrication System			
Lubricating oil pressure (psi):			
Normal	49–70	49–70	49–70
Minimum for safe operation	28	29	30
†Lubricating oil temperature (deg. F) – Normal	200–250	200–250	200–250
Air System			
Air box pressure (inches mercury) – full load min.:			
At zero exhaust back pressure (clean ports):			
335 BHP (Fed.) – 1.480 timing	27.7	—	—
335 BHP (Calif.) – 1.500 timing	30.7	—	—
365 BHP (Fed.) – 1.480 timing	30.1	32.4	35.6
365 BHP (Calif.) – 1.500 timing	33.3	34.7	37.8
At max. exhaust back pressure (clean ports):			
335 BHP (Fed.) – 1.480 timing	25.4	—	—
335 BHP (Calif.) – 1.500 timing	28.4	—	—
365 BHP (Fed.) – 1.480 timing	27.8	30.1	33.3
365 BHP (Calif.) – 1.500 timing	31.0	32.4	35.5
Air inlet restriction (inches water) – full load max.:			
Dirty air cleaner – dry type	20.0	20.0	20.0
Clean air cleaner – dry type	12.0	12.0	12.0
Crankcase pressure (inches water) – max.	2.1	3.3	3.5
Exhaust back pressure (inches mercury) – max.:			
Full load	3.0	3.0	3.0
Fuel System			
Fuel pressure at inlet manifold (psi):			
Normal	50–70	50–70	50–70
Minimum	30	30	30
Fuel spill (gpm) – min. at no load	0.9	0.9	0.9
Pump suction at inlet (inches mercury) – max.:			
Clean system	6.0	6.0	6.0
Dirty system	12.0	12.0	12.0
Cooling System			
Coolant temperature (deg. F) – Normal	170–195	170–195	170–195

Compression

Compression pressure (psi at sea level):

Average – new engine – at 600 rpm 500

Minimum – at 600 rpm 450

*Turbine housing designation (area over radius).

†The lubricating oil temperature range is based on the temperature measurement in the oil pan at the oil pump inlet. When measuring the oil temperature at the cylinder block oil gallery, it will be approximately 10° lower than the oil pan temperature.

8V-92TTA and TTAC ENGINE (with TV8117 TURBOCHARGER) (1.39 A/R* Turbine Housing) – 1981 and 1982 Automotive

	1800 rpm	1950 rpm	2100 rpm
Lubrication System			
Lubricating oil pressure (psi):			
Normal	49–70	49–70	49–70
Minimum for safe operation	28	29	30
†Lubricating oil temperature (deg. F) – Normal	200–250	200–250	200–250
Air System			
Air box pressure (inches mercury) – full load min.:			
At zero exhaust back pressure:			
9A90 injector – 1.466 timing – Fed.	26.4	29.1	31.0
9F90 injector – 1.520 timing – Calif.	32.5	34.3	37.3
At max. exhaust back pressure (clean ports):			
9A90 injector – 1.466 timing – Fed.	24.1	26.8	28.7
9F90 injector – 1.520 timing – Calif.	30.2	32.0	35.0
Air inlet restriction (inches water) – full load max.:			
Dirty air cleaner – dry type	20.0	20.0	20.0
Clean air cleaner – dry type	12.0	12.0	12.0
Crankcase pressure (inches water) – max.	—	—	—
Exhaust back pressure (inches mercury) – max.:			
Full load	3.0	3.0	3.0
Fuel System			
Fuel pressure at inlet manifold (psi) – Normal	50–70	50–70	50–70
Fuel spill (gpm) – min. at no load	0.9	0.9	0.9
Pump suction at inlet (inches mercury) – max.:			
Clean system	6.0	6.0	6.0
Dirty system	12.0	12.0	12.0
Cooling System			
Coolant temperature (deg. F) – Normal	170–195	170–195	170–195
Compression			
Compression pressure (psi at sea level):			
Average – new engine – at 600 rpm 500			
Minimum – at 600 rpm 450			

*Turbine housing designation (area over radius).

†The lubricating oil temperature range is based on the temperature measurement in the oil pan at the oil pump inlet. When measuring the oil temperature at the cylinder block oil gallery, it will be approximately 10° lower than the oil pan temperature.

8V-92T and 16V-92T ENGINE (with TV8101 TURBOCHARGER) (1.39 A/R* Turbine Housing) – GEN SET

	1200 rpm	1500 rpm	1800 rpm
Lubrication System			
Lubricating oil pressure (psi):			
Normal (8V-92)	32–52	41–61	49–70
Normal (16V-92)	40–60	46–66	50–70
Minimum for safe operation	20	27	28
†Lubricating oil temperature (deg. F) – Normal	200–250	200–250	200–250
Air System			
Air box pressure (inches mercury) – full load min.:			
At zero exhaust back pressure:			
9285 injector	15.5	26.0	35.0
9200 injector	20.8	31.4	40.5
9215 injector	25.6	36.3	45.2
At max. exhaust back pressure (clean ports):			
9285 injector	14.8	25.0	33.5
9200 injector	20.1	30.4	39.0
9215 injector	24.9	35.3	43.7
Air inlet restriction (inches water) – full load max.:			
Dirty air cleaner – dry type:			
Full-load speed	6.5	10.3	14.4
No-load speed	4.0	6.1	8.7
Clean air cleaner – dry type:			
Full-load speed	4.0	6.2	8.7
No-load speed	2.0	3.4	5.1
Crankcase pressure (inches water) – max.	2.3	2.7	3.1
Exhaust back pressure (inches mercury) – max.:			
Full load	0.9	1.4	2.0
No load	0.7	1.0	1.45
Fuel System			
Fuel pressure at inlet manifold (psi):			
Normal	50–70	50–70	50–70
Minimum	30	30	30
Fuel spill (gpm) – min. at no load:			
(8V-92)	0.9	0.9	0.9
(16V-92)	1.4	1.4	1.4
Pump suction at inlet (inches mercury) – max.:			
Clean system	6.0	6.0	6.0
Dirty system	12.0	12.0	12.0
Cooling System			
Coolant temperature (deg. F) – Normal	160–185	160–185	160–185
Compression			
Compression pressure (psi at sea level):			
Average – new engine – at 600 rpm	500		
Minimum – at 600 rpm	450		

*Turbine housing designation (area over radius).

†The lubricating oil temperature range is based on the temperature measurement in the oil pan at the oil pump inlet. When measuring the oil temperature at the cylinder block oil gallery, it will be approximately 10° lower than the oil pan temperature.

8V–92TI ENGINE (with TH08A TURBOCHARGER) (.096 A/R* Turbine Housing) – MARINE

	1800 rpm	2100 rpm	2300 rpm
Lubrication System			
Lubricating oil pressure (psi):			
Normal	49–70	49–70	49–70
Minimum for safe operation	28	30	31
†Lubricating oil temperature (deg. F) – Normal	200–250	200–250	200–250
Air System			
Air box pressure (inches mercury) – full load min.:			
At zero exhaust back pressure:			
9290 injector	20.0	27.9	33.3
9200 injector	23.0	31.3	37.0
9215 injector	26.2	35.3	41.5
At max. exhaust back pressure (clean ports):			
9290 injector	17.7	25.6	31.0
9200 injector	20.7	29.0	34.7
9215 injector	23.9	33.0	39.2
Air inlet restriction (inches water) – full load max.:			
Dirty air cleaner – dry type	20.0	20.0	20.0
Clean air cleaner – dry type	12.0	12.0	12.0
Crankcase pressure (inches water) – max.	2.5	2.8	3.0
Exhaust back pressure (inches mercury) – max.:			
Full load	3.0	3.0	3.0
Fuel System			
Fuel pressure at inlet manifold (psi):			
Normal	50–70	50–70	50–70
Minimum	30	30	30
Fuel spill (gpm) – min. at no load	0.9	0.9	0.9
Pump suction at inlet (inches mercury) – max.:			
Clean system	6.0	6.0	6.0
Dirty system	12.0	12.0	12.0
Cooling System			
Coolant temperature (deg. F) – Normal	160–185	160–185	160–185
Compression			
Compression pressure (psi at sea level):			
Average – new engine – at 600 rpm ... 500			
Minimum – at 600 rpm ... 450			

*Turbine housing designation (area over radius).

†The lubricating oil temperature range is based on the temperature measurement in the oil pan at the oil pump inlet. When measuring the oil temperature at the cylinder block oil gallery, it will be approximately 10° lower than the oil pan temperature.

12V–92TAB ENGINE (with TW–83 TURBOCHARGER) (1.19 A/R* Turbine Housing) – MARINE

	2300 rpm
Lubrication System	
Lubricating oil pressure (psi):	
Normal	Greater than 60
Minimum for safe operation	40
†Lubricating oil temperature (deg. F) – max.	
Full load	250
Air System	
Air box pressure (inches mercury) – full load min.:	
145 injector	
Front block	54.0
Rear block	51.0
Turbocharger pressure (inches mercury) – full load min.:	
Front block	44.0
Rear block	41.0
Air inlet restriction (inches water) – full load max.:	
Dirty air cleaner – dry type	14.5
Crankcase pressure (inches water) – full load max.	3.0
Exhaust back pressure (inches mercury) – max.:	
Full load	2.5
Exhaust temperature at full load (approx.) (deg. F) (taken at turbo outlet)	650
Fuel System	
Fuel pressure at inlet manifold (psi):	
Normal	50–70
Fuel spill (gpm) – min. at no load	1.4
Pump suction at inlet (inches mercury) – no load max.:	
Clean system	6.0
Dirty system	12.0
Cooling System	
Coolant temperature (deg. F) – Normal–full load	185
Max.	200
Compression	
Compression pressure (psi at sea level):	
Average – new engine – at 600 rpm	500
Minimum – at 600 rpm	450

*Turbine housing designation (area over radius).

†The lubricating oil temperature range is based on the temperature measurement in the oil pan at the oil pump inlet. When measuring the oil temperature at the cylinder block oil gallery, it will be approximately 10° lower than the oil pan temperature.

16V–92TA ENGINE (with T18A90 TURBOCHARGERS) (1.32 A/R* Turbine Housing) – 9290 INJECTORS

	1800 rpm	2000 rpm	2100 rpm
Lubrication System			
Lubricating oil pressure (psi):			
Normal	50–70	50–70	50–70
Minimum for safe operation	28	30	30
†Lubricating oil temperature (deg. F) – Normal	200–250	200–250	200–250
Air System			
Air box pressure (inches mercury) – full load min.:			
At zero exhaust back pressure	18.3	42.6	45.6
At max. exhaust back pressure (clean ports)	16.8	40.7	43.7
Air inlet restriction (inches water) – full load max.:			
Dirty air cleaner – dry type	14.5	18.0	20.0
Clean air cleaner:			
Dry type with precleaner	8.7	10.8	12.0
Dry type less precleaner	6.3	7.7	8.5
Crankcase pressure (inches water) – max.	2.6	2.9	3.0
Exhaust back pressure (inches mercury) – max.:			
Full load	2.0	2.5	2.5
No load	1.3	1.6	1.8
Fuel System			
Fuel pressure at inlet manifold (psi):			
Normal with .080" restriction fitting	50–70	50–70	50–70
Minimum	30	30	30
Fuel spill (gpm) – min. at no load	1.4	1.4	1.4
Pump suction at inlet (inches mercury) – max.:			
Clean system	6.0	6.0	6.0
Dirty system	12.0	12.0	12.0
Cooling System			
Coolant temperature (deg. F) – Normal	160–185	160–185	160–185
Compression			
Compression pressure (psi at sea level):			
Average – new engine – at 600 rpm	500		
Minimum – at 600 rpm	450		

*Turbine housing designation (area over radius).

†The lubricating oil temperature range is based on the temperature measurement in the oil pan at the oil pump inlet. When measuring the oil temperature at the cylinder block oil gallery, it will be approximately 10° lower than the oil pan temperature.

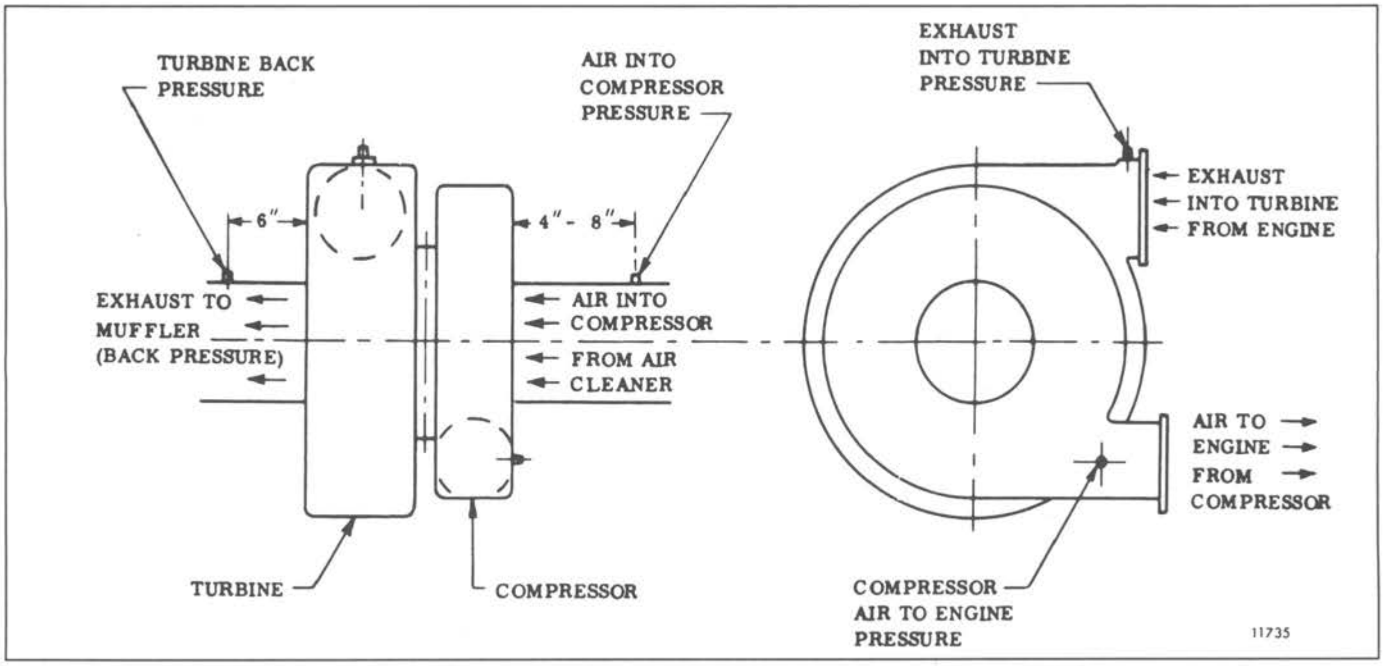


Fig. 1 – Points to Measure Intake and Exhaust Restriction

ENGINE RUN-IN INSTRUCTIONS

Following a complete overhaul or any major repair job involving the installation of piston rings, pistons, cylinder liners or bearings, the engine should be "Run-In" on a dynamometer prior to release for service.

The dynamometer is a device for applying specific loads to an engine. It permits the serviceman to physically and visually inspect and check the engine while it is operating. It is an excellent method of detecting improper tune-up, misfiring injectors, low compression and other malfunctions, and may save an engine from damage at a later date.

The operating temperature within the engine affects the operating clearances between the various moving parts of the engine and determines to a degree how the parts will wear. Normal coolant temperature (see section 13.2) should be maintained throughout the Run-In.

The rate of water circulation through the engine on a dynamometer should be sufficient to avoid having the engine outlet water temperature more than 10°F or 6°C higher than the water inlet temperature. Though a 10°F or 6°C rise across an engine is recommended, it has been found that a 15°F or 8°C temperature rise maximum can be permitted.

Thermostats are used in the engine to control the coolant flow. Therefore, be sure they are in place and fully operative or the engine will overheat during the Run-In. However, if the dynamometer has a water standpipe with a temperature control regulator, such as a Taylor valve or equivalent, the engine should be tested without thermostats.

NOTICE: Because of the wet cylinder liners in the V-92 engine, it is desirable that the engine Run-In be made on a closed (heat exchanger type) cooling system where the coolant can be treated with a rust inhibitor (refer to Section 13.3). Use of a good rust inhibitor in the coolant system during engine Run-In will prevent the rusting of the outside diameter of the cylinder liners after the engine has been removed from the dynamometer test stand.

The Run-In Schedules are shown in Tables 1 and 2. The horsepower shown is at SAE conditions: dry air density .0705 lb/cu. ft. (1.129 Kg/cu. m), air temperature of 85°F (29.4°C) and 500 ft. elevation.

DYNAMOMETER TEST AND RUN-IN PROCEDURES

The Basic Engine

The great number of engine applications make any attempt to establish comparisons for each individual model impractical. For this reason, each model has a basic engine rating for comparison purposes.

A basic engine includes only those items actually required to run the engine. The addition of any engine driven accessories will result in a brake horsepower figure less than the values shown in the *Basic Engine Run-In Schedule*. The following items are included on the basic engine: blower, fuel pump, water pump and governor. The fan and battery-charging alternator typify accessories not considered on the basic engine.

In situations where other than basic engine equipment is used during the test, proper record of this fact should be made on the *Engine Test Report*. The effects of this additional equipment on engine performance should then be considered when evaluating test results.

Dynamometer

The function of the dynamometer is to absorb and measure the engine output. Its basic components are a frame, engine mounts, the absorption unit, a heat exchanger, and a torque loading and measuring device.

The engine is connected through a universal coupling to the absorption unit. The load on the engine may be varied from zero to maximum by decreasing or increasing the resistance in the unit. The amount of power absorbed in a water brake type dynamometer, as an example, is governed by the volume of fluid within the working system. The fluid offers resistance to a rotating motion. By controlling the volume of water in the absorption unit, the load may be increased or decreased as required.

The power absorbed is generally measured in torque (lb-ft) on a suitable scale. This value for a given engine speed will show the brake horsepower developed in the engine by the following formula:

$$BHP = (T \times RPM)/5250$$

Where:

BHP = brake horsepower

T = torque in lb-ft

RPM = revolutions per minute

BASIC ENGINE RUN-IN SCHEDULE

Time Minutes	Speed RPM	Injectors	Engine Brake Horsepower					
			6V	6VT	8V	8VT	16V	16VT
10	1200	All	54	54	72	72	144	144
30	1800	All	195	225	260	300	520	600
30*	2100	70	216	—	288	—	576	—
30*	2100	75	230	—	306	—	612	—
30*	2100	80	243	—	324	—	648	—
30*	2100	85	257	—	342	—	684	—
30*	2100	80	—	252	—	338	—	675
30*	2100	85	—	270	—	360	—	720
30*	2100	90	—	290	—	387	—	774

*Use speed-injector combination applicable to engine on test.

TABLE 1

Some dynamometers indicate direct brake horsepower readings. Therefore, the use of the formula is not required when using these units.

During the actual operation, all data taken should be recorded immediately on an *Engine Test Report* (see sample in this section).

Instrumentation

Certain instrumentation is necessary so that data required to complete the *Engine Test Report* may be obtained. The following list contains both the minimum amount of instruments and the proper location of the fittings on the engine so that the readings represent a true evaluation of engine conditions.

a. Oil pressure gage installed in one of the engine main oil galleries.

b. Oil temperature gage installed in the oil pan, or thermometer installed in the dipstick hole in the oil pan.

c. Adaptor for connecting a pressure gage or mercury manometer to the engine air box.

d. Water temperature gage installed in the thermostat housing or water outlet manifold.

e. Adaptor for connecting a pressure gage or water manometer to the crankcase.

FINAL ENGINE RUN-IN SCHEDULE

Time Minutes	Speed RPM	Injectors	+ Engine Brake Horsepower					
			6V	6VT	8V	8VT	16V	16VT
30*	2100	70	240	—	320	—	640	—
30*	2100	75	255	—	340	—	680	—
30*	2100	80	270	280	360	375	720	750
30*	2100	85	285	300	380	400	760	800
30*	2100	90	—	322	—	430	—	860

*Use speed-injector combination applicable to engine on test.
+ Within 5% of brake horsepower rating shown above at governor speed.

TABLE 2

ENGINE TEST REPORT

Date ________________ Unit Number ________________

Repair Order Number ________________ Model Number ________________

A PRE-STARTING

1. PRIME LUBE OIL SYSTEM	2. PRIME FUEL SYSTEM	3. ADJUST VALVES	4. TIME INJ.	5. ADJ. GOV.	6. ADJUST INJ. RACKS

B BASIC ENGINE RUN-IN

TIME AT SPEED	TIME		RPM	BHP	WATER TEMP.	LUBE OIL PRESS.
	START	STOP				

C BASIC RUN-IN INSPECTION

1. Check oil at rocker arm mechanism	
2. Inspect for lube oil leaks	
3. Inspect for fuel oil leaks	
4. Inspect for water leaks	
5. Check and tighten all external bolts	
6.	

D INSPECTION AFTER BASIC RUN-IN

1. Tighten Cylinder Head & Rocker Shaft Bolts	
2. Adjust Valves (Hot)	
3. Time Injectors	
4. Adjust Governor Gap	
5. Adjust Injector Racks	
6.	

E FINAL RUN-IN

TIME		TOP RPM		BHP	AIR BOX PRESSURE FULL LOAD	EXHAUST BACK PRESSURE F/L	CRANKCASE PRESSURE F/L
START	STOP	NO LOAD	FULL LOAD				

BLOWER INTAKE RES. - F/L	FUEL OIL PRESSURE RET. MAN. F/L	WATER TEMP. FULL LOAD	LUBE OIL TEMP. F/L	LUBE OIL PRESSURE		IDLE SPEED
				FULL LOAD	IDLE	

F INSPECTION AFTER FINAL RUN

1. Inspect Air Box, Pistons, Liners, Rings	6. Tighten Oil Pump Bolts
2. Inspect Blower	7. Inspect Oil Pump Drive
3. Check Generator Charging Plate	8. Replace Lube Filter Elements
4. Wash Oil Pan, Check Gasket	9. Tighten Flywheel Bolts
5. Clean Oil Pump Screen	10. Rust Proof Cooling System

REMARKS:

Final Run OK'd ________________ Dynamometer Operator ________________ Date ________________

NOTE: Operator must initial each check and sign this report.

f. Adaptor for connecting a pressure gage or mercury manometer to the exhaust manifold at the flange.

g. Adaptor for connecting a vacuum gage or water manometer to the blower inlet.

h. Adaptor for connecting a fuel pressure gage to the fuel manifold inlet passage.

i. Adaptor for connecting a pressure gage or mercury manometer to the turbocharger.

In some cases, gages reading in pounds per square inch are used for determining pressures while standard characteristics are given in inches of mercury or inches of water. It is extremely important that the scale of such a gage be of low range and finely divided if accuracy is desired. This is especially true of a gage reading in psi, the reading of which is to be converted to inches of water. The following conversion factors may be helpful.

Inches of water = psi x 27.7"

Inches of mercury = psi x 2.04"

Inches of water = kPa x 4.02"

Inches of mercury = kPa x 0.30"

NOTICE: Before starting the Run–In or starting the engine for any reason following an overhaul, it is of extreme importance to observe the instructions on *Preparation for Starting Engine First Time* in Section 13.1.

•Block Oil Filter Bypass Before Initial Start–Up and Dynamometer Test of Rebuilt Engines

Cold engine start–up causes the lubricating oil filter bypass valve to open until oil temperature increases. When an engine is rebuilt and then dynamometer tested, this bypass condition may result in the circulation of abrasive (harmful) debris introduced into the engine during rebuild.

To prevent unnecessary circulation of debris through the lube oil system, DDC recommends plugging the filter bypass before start–up and during basic engine run–in. This allows all the lube oil to flow through the filter(s), trapping contaminants. To plug the bypass, proceed as follows:

Drill and tap a 1/4" – 20 hole in a filter bypass valve plug. Install a bolt long enough to contact the valve and keep it from opening and a nut to lock the bolt in position (Fig. 1). When the dynamometer test is completed, replace the modified plug with a standard plug and change the filter(s).

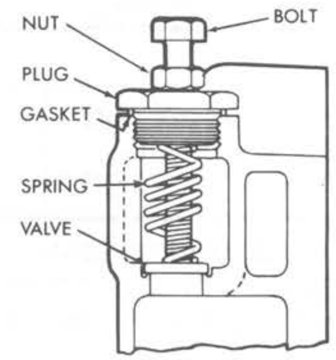


Fig. 1 – Bypass Valve with Modified Valve Plug Installed

NOTICE: To avoid damaging the phenolic bypass valve, the bolt should be finger–tightened only and then secured in place with the lock nut. On filter adaptors with more than one bypass valve, install modified valve plugs in all valve openings before starting or dynamometer testing the engine.

DDC recommends bringing lube oil temperature up to at least 60°F (15.6°C) before starting the engine prior to testing. If the lube oil is too cold when the engine is started, the resistance to the flow of the heavier oil may cause filter gasket leakage or bearing surface damage from inadequate oil film.

Run–In Procedure

The procedure outlined below will follow the order of the sample *Engine Test Report.*

A. PRE–STARTING

1. Fill the lubrication system as outlined under *Lubrication System — Preparation for Starting Engine First Time* in Section 13.1.

2. Prime the fuel system as outlined under *Fuel System — Preparation for Starting Engine First Time* in Section 13.1.

3. A preliminary valve clearance adjustment must be made before the engine is started. See *Valve Clearance Adjustment* in Section 14.1.

4. A preliminary injector timing check must be made before starting the engine. See *Fuel Injector Timing* in Section 14.2.

5. Preliminary governor adjustments must be made as outlined in Section 14.

6. Preliminary injector rack adjustment must be made (Section 14).

NOTICE: Prior to starting a turbocharged engine, remove the oil supply line at each turbocharger and add clean engine oil to the oil inlet to ensure pre–lubrication of the turbochargers. Reconnect the oil lines and idle the engine for at least one minute after starting and before increasing the speed.

B. BASIC ENGINE RUN–IN

The operator should be observant at all times, so that any malfunction which may develop will be detected. Since the engine has just been reconditioned, this Run–In will be a test of the workmanship of the serviceman who performed the overhaul. Minor difficulties should be detected and corrected so that a major problem will not develop.

After performing the preliminary steps, be sure all water valves, fuel valves, etc. are open. Also inspect the exhaust system, air cleaner and air inlet piping to insure that it is properly connected to the engine. Always start the engine with minimum dynamometer resistance.

After the engine starts, if using a water brake type dynamometer, allow sufficient water, by means of the control loading valves, into the dynamometer absorption unit to show a reading of approximately 5 lb–ft (7 N•m) on the torque gage (or 10–15 HP on a horsepower gage). This is necessary, on some units, to lubricate the absorption unit seals and to protect them from damage.

Set the engine throttle at idle speed, check the lubricating oil pressure and check all connections to be sure there are no leaks.

Refer to the *Engine Test Report* sample which establishes the sequence of events for the Test and Run–In, and to the *Basic Engine Run–In Schedule* which indicates the speed (rpm), length of time and the brake horsepower required for each phase of the test. Also refer to the *Operating Conditions* in Section 13.2 which presents the engine operating characteristics. These characteristics will be a guide for tracing faulty operation or lack of power.

Engine governors in most cases must be reset at the maximum full–load speed designated for the Run–In. If a governor is encountered which cannot be adjusted to this speed, a stock governor should be installed for the Run–In.

After checking the engine performance at idle speed and being certain the engine and dynamometer are operating properly, increase the engine speed to half speed and apply the load indicated on the *Basic Engine Run–In Schedule.*

The engine should be run at this speed and load for 10 minutes to allow sufficient time for the coolant temperature to reach the normal operating range. Record length of time, speed, brake horsepower, coolant temperature and lubricating oil pressure on the *Engine Test Report.*

Run the engine at each speed and rating for the length of time indicated in the *Basic Engine Run–In Schedule.* This is the Basic Run–In. During this time, engine performance will improve as new parts begin to "seat in". Record all of the required data.

C. BASIC RUN–IN INSPECTION

While the engine is undergoing the Basic Run–In, check each item indicated in Section "C" of the *Engine Test Report.* Check for fuel oil or water leaks in the rocker arm compartment.

During the final portion of the Basic Run–In, the engine should be inspected for fuel oil, lubricating oil and water leaks.

Upon completion of the Basic Run–In and Inspection, remove the load from the dynamometer and reduce the engine speed gradually to idle and then stop the engine.

D. INSPECTION AFTER BASIC RUN–IN

The primary purpose of this inspection is to provide a fine engine tune–up. First, tighten the cylinder head and rocker arm shaft bolts to the proper torque. Next, complete the applicable tune–up procedure. Refer to Section 14.

E. FINAL RUN–IN

After all of the tests have been made and the *Engine Test Report* is completed through Section "D", the engine is ready for final test. This portion of the test and Run–in procedure will assure the engine owner that his engine has been rebuilt to deliver factory rated performance at the same maximum speed and load which will be experienced in the installation.

If the engine has been shut down for one hour or longer, it will be necessary to have a warm–up period of 10 minutes at the same speed and load used for warm–up in the Basic Run–In. If piston rings, cylinder liners or bearings have been replaced as a result of findings in the Basic Run–In, the entire Basic Run–In must be repeated as though the Run–In and test procedure were started anew.

All readings observed during the Final Run–In should fall within the range specified in the *Operating Conditions* in Section 13.2 and should be taken at full load unless otherwise specified. Following is a brief discussion of each condition to be observed.

The engine *water temperature* should be taken during the last portion of the Basic Run–In at full load. It should be recorded and should be within the specified range.

The *lubricating oil temperature* reading must be taken while the engine is operating at full load and after it has been operating long enough for the temperature to stabilize. This temperature should be recorded and should be within the specified range.

The *lubricating oil pressure* should be recorded in *psi* after being taken at engine speeds indicated in the *Operating Conditions,* Section 13.2.

The *fuel oil pressure* at the fuel manifold inlet passage should be recorded and should fall within the specified range. Fuel pressure should be recorded at maximum engine speed during the Final Run–In.

Check the *air box pressure* while the engine is operating at maximum speed and load. This check may be made by attaching a suitable gage (0–15 psi) or manometer (15–0–15) to an air box drain or to a hand hole plate prepared for this purpose. If an air box drain is used as a source for this check, it must be clean. The air box pressure should be recorded in inches of mercury.

Check the *crankcase pressure* while the engine is operating at maximum Run–In speed. Attach a manometer, calibrated to read in inches of water, to the oil level dipstick opening. Normally, crankcase pressure should decrease during the Run–In indicating that new rings are beginning to "seat–in".

Check the *air inlet restriction* with a water manometer connected to a fitting in the air inlet ducting located 2" above the air inlet housing. When practicability prevents the insertion of a fitting at this point, the manometer may be connected to a fitting installed in the 1/4" pipe tapped hole in the engine air inlet housing on naturally aspirated engines. If a hole is not provided, a stock housing should be drilled, tapped and kept on hand for future use.

The restriction at this point should be checked at full–load engine speed. Then the air cleaner and ducting should be removed from the air inlet housing and the engine again operated at the same speed while noting the manometer reading. On turbocharged engines, take the reading on the inlet side of one of the turbochargers (see Chart at the end of Section 13.2). The difference between the two readings, with and without the air cleaner and ducting, is the actual restriction caused by the air cleaner and ducting.

Check the normal *air intake vacuum* at various speeds (at no–load) and compare the results with the *Engine Operating Conditions* in section 13.2. Record these readings on the *Engine Test Report.*

Check the *exhaust back pressure* (except turbocharged engines) at the exhaust manifold companion flange or within one inch of this location. This check should be made with a mercury manometer through a tube adaptor installed at the tapped hole. If the exhaust manifold does not provide a 1/8" pipe tapped hole, such a hole can be incorporated by reworking the exhaust manifold. Install a fitting for a pressure gage or manometer in this hole. Care should be exercised so that the fitting does not protrude into the stack. On turbocharged engines, check the exhaust back pressure in the exhaust piping 6" to 12" from the turbine outlet. The tapped hole must be in a comparatively straight area for an accurate measurement. The manometer check should produce a reading in inches that is below the *Maximum Exhaust Back Pressure* for the engine (refer to Section 13.2).

Turbocharger compressor outlet pressure and turbine inlet pressures are taken at full–load and no–load speeds.

Refer to the *Final Engine Run–In Schedule* and determine the maximum rated brake horsepower and the full–load speed to be used during the Final Run–In. Apply the load thus determined to the dynamometer. If a hydraulic governor is used, the droop may be adjusted at this time by following the prescribed procedure. The engine should be run at this speed and load for 1/2 hour. While making the Final Run–In, the engine should develop, within 5%, the maximum rated brake horsepower indicated for the speed at which it is operating. If this brake horsepower is not developed, the cause should be determined and corrections made.

When the above conditions have been met, adjust the maximum no–load speed to conform with that specified for the particular engine. This speed may be either higher or lower than the maximum speed used during the Basic Run–In. This will ordinarily require a governor adjustment.

All information required in Section "E", Final Run–In, of the *Engine Test Report* should be determined and filled in. After the prescribed time for the Final Run–In has elapsed, remove the load from the dynamometer and reduce the engine speed gradually to idle speed and then stop the engine. The Final Run–In is complete.

F. INSPECTION AFTER FINAL RUN–IN

After the Final Run–In and before the *Engine Test Report* is completed, a final inspection must be made. This inspection will provide final assurance that the engine is in proper working order. During this inspection, the engine is also made ready for any brief delay in delivery or installation which may occur. This is accomplished by rustproofing the fuel system as outlined in Section 15.3 and adding a rust inhibitor into the cooling system (refer to Section 13.3). The lubricating oil filters should also be changed.

> **NOTICE:** A rust inhibitor in the coolant system of the V–92 engine is particularly important because of the wet cylinder liners. Omission of a rust inhibitor will cause rusting of the outside diameter of the cylinder liners and interference with liner heat transfer.

.AUTOMOTIVE ENGINE CHARGE COOLING SYSTEMS

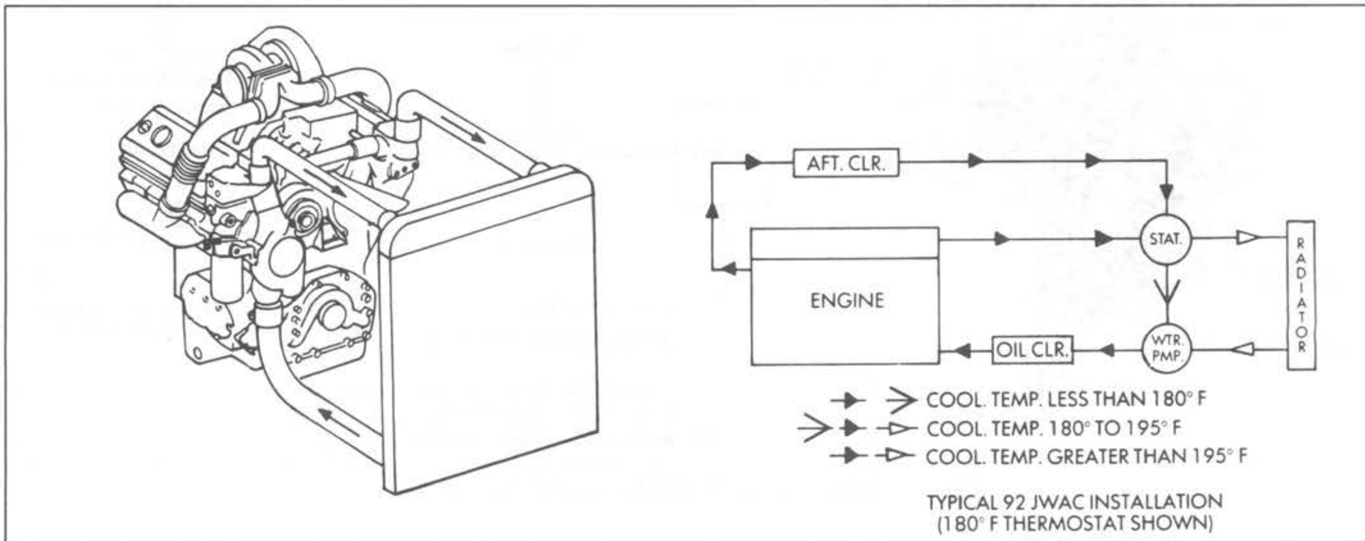


Fig. 2 – 92 TA JWAC Coolant Flow Path

The emphasis placed on improved fuel economy and the need to meet lower emissions levels both now and in the future has resulted in the development of two new "charge cooling" systems on Detroit Diesel engines. In addition to current JWAC (jacket water aftercooled) engines released in 1979, ALCC (advanced liquid charge cooled) and AACC (air–to–air charge cooled) engines have been added to the lineup.

The objective of these systems is to substantially reduce the temperature of the air supplied to the engine for combustion. Cooler, denser air provides improved air/fuel ratios and, when coupled with engine component changes, improved fuel economy.

Jacket Water Aftercooling (JWAC)

In JWAC V–92 models, coolant circulates from the water pump through the oil cooler, to the cylinder block where approximately 10% is shunted to the aftercooler and returned to the left–bank thermostat housing (see Fig. 2).

Inlet air is compressed by the turbocharger and directed to the blower. After passing through the blower, the air travels through the aftercooler. "Air in" is cooled from over 300°F (148°C) to approximately 200°F (93.3°C) at 85°F (29.4°C) ambient temperature under full–load conditions. The cool, dense air then travels from the aftercooler into the air box and cylinders for combustion. Other aspects of the JWAC cooling systems are identical to the standard non–aftercooled engines.

Advanced Liquid Charge Cooling (ALCC)

The ALCC cooling system is designed to provide cool charge air to Series 92TA engine cylinders using a single radiator or heat exchanger. Principally, this is accomplished by reducing the radiator coolant flow to increase its temperature drop and supplying the cooled coolant from the radiator directly to the aftercooler for maximum charge air cooling.

V–92TA ALCC Operation

The 6V–92TA ALCC cooling system (Fig. 3) consists of a water pump that flows coolant past the non–blocking thermostat S1 (160°F or 71°C) and through the engine oil cooler, cylinder block, and head and then past the S2 full blocking stat (180°F or 82°C) under cold or hot conditions. When the water temperature reaches 160°F (71°C), the S1 thermostat begins to open, flowing some coolant through the radiator to the aftercooler and into the inlet of the water pump where it mixes with coolant flowing through the engine. As the S1 thermostat opens more with the rise in engine water temperature, the flow of coolant through the radiator and aftercooler is increased, while the bypass flow through the oil cooler and engine is decreased slightly. At no time does the bypass flow fall below 84%.

At high load and under high ambient temperature conditions when engine coolant–out temperature exceeds the opening temperature of the S2 thermostat (180°F or 82°C), this thermostat will open, allowing part of the coolant from radiator discharge to flow into the water pump inlet, bypassing the aftercooler. The addition of this flow path lowers the radiator discharge pressure, resulting in a higher radiator flow which enhances engine cooling.

ALCC System Design Requirements

Rapid warm–up cooling systems with either an integral or separate surge tank *must* be used with all ALCC engines to ensure positive water pump inlet pressure under

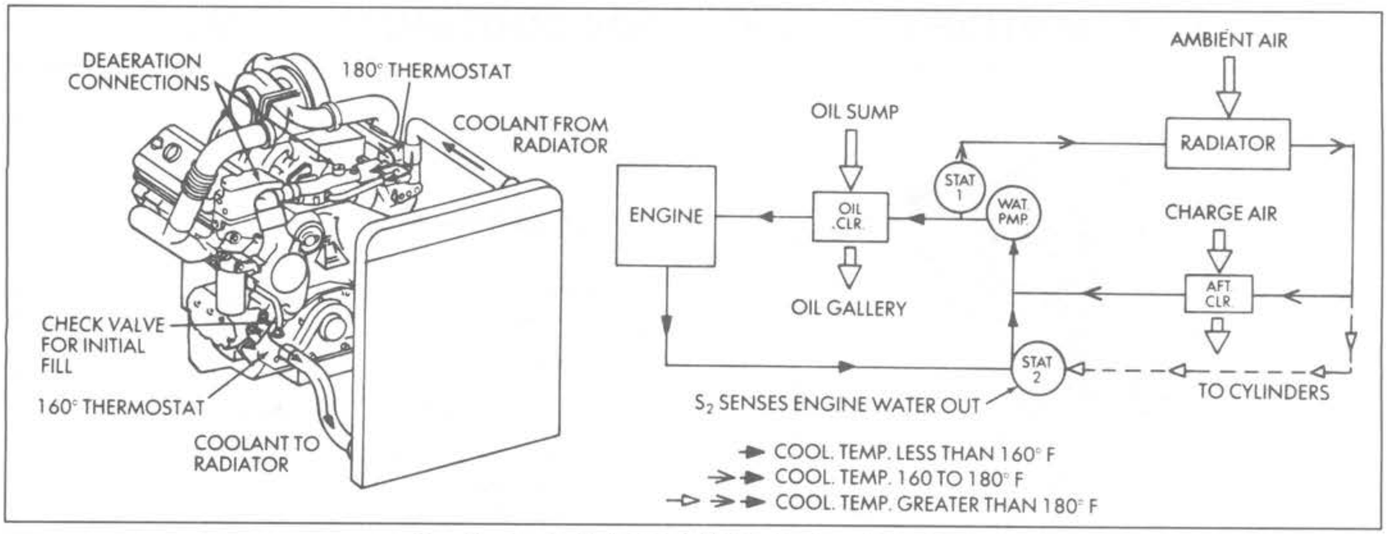


Fig. 3 – Typical V–92TA ALCC Coolant Flow Path

all conditions. The system must meet all the present cooling requirements of on–highway vehicle engines regarding fill, drawdown, and deaeration. The maximum engine water temperature and air–to–water temperature differential remain at 210°F (98.8°C) and 100°F (73.7°C), respectively, when both thermostats are fully open. A maximum temperature differential between the *radiator* coolant–out temperature and the ambient temperature (60°F or 15.6°C for 92TA engines) must also be met with both thermostats open to assure adequate charge air cooling under all conditions.

ALCC Radiators

The radiators used with ALCC cooling systems are designed for high effectiveness with low coolant flow when compared to conventional radiators. Presently, this is accomplished with the use of turbulated radiator tubes that have dimples or ridges in the tubes to increase scrubbing and/or a multi–pass radiator design that increases flow velocity and lengthens the flow path.

NOTICE: Radiators with turbulated tubes cannot be conventionally cleaned or rodded, because the dimple design results in narrower tubes. Radiators *must* be ultrasonically cleaned. Failure to observe this precaution can result in radiator damage.

Different vehicle installations may have peculiarities because of installation constraints or the type of radiator used. These should be addressed on an individual basis.

Series 92 Air–to–Air Charge Cooling (AACC)

An air–to–air charge cooling system provides much cooler charge air than an ALCC system by directing the turbocharger compressor discharge air through a heat exchanger which is cooled by ambient air. The heat exchanger is chassis mounted, most commonly in front of the conventional coolant radiator (Fig. 4). Since the AACC system eliminates the need for an intercooler or in–block aftercooler, its space in the cylinder block air box is occupied by an air deflector which improves air flow into the cylinders.

The AACC system cools the compressor air from over 250°F (121°C) to 110°F (43.3°C) at an ambient air temperature of 77°F (25°C) under full–load conditions. Air–to–air charge cooling offers the greatest improvement in fuel economy when compared to conventional jacket water aftercooling.

NOTICE: Radiator winter fronts are not recommended with air–to–air charge cooling systems, because they adversely affect engine performance.

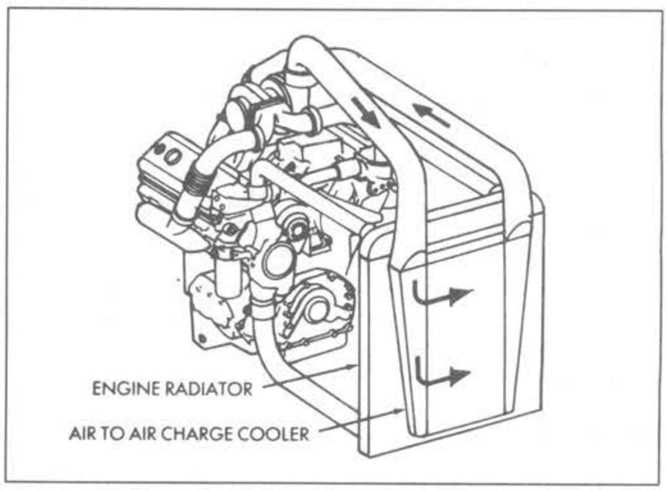


Fig. 4 – 6V–92 AACC Engine Showing Air Flow Through Heat Exchanger

.COOLING SYSTEM REQUIREMENTS FOR TESTING JWAC, ALCC AND AACC ENGINES ON A DYNAMOMETER

Jacket Water Aftercooled (JWAC) Engine

The cooling system needed to cool a JWAC engine on an engine dynamometer is the same as a standard engine. No special connections are required, and all of the aftercooler piping is built into the engine.

Advanced Liquid Charge Cooled (ALCC) Engine

The cooling system required to cool an ALCC engine dynamometer must meet the following requirements:

- To properly fill a Series 92 ALCC cooling system, a 1" fill line *must* be connected from the heat exchanger or radiator to the 3/4" NPTF boss on the water pump.
- To properly vent a Series 92 ALCC cooling system, 1/4" tubes or No. 4 flexible hose lines must be connected as follows: one line should run from the deaeration housing* on the front of the right–bank cylinder head to the heat exchanger or radiator surge tank. A second line should be connected from the water crossover tube connector (between the left–bank and right–bank) to the heat exchanger or radiator surge tank. *Do not tee the two bleed lines together.*

There are no air vents or bleed holes in the thermostats or thermostat housings used on any DDC automotive engines. Therefore, a deaeration line is required to provide air venting during initial system fill and engine operation.

*Previously R.B. thermostat housing.

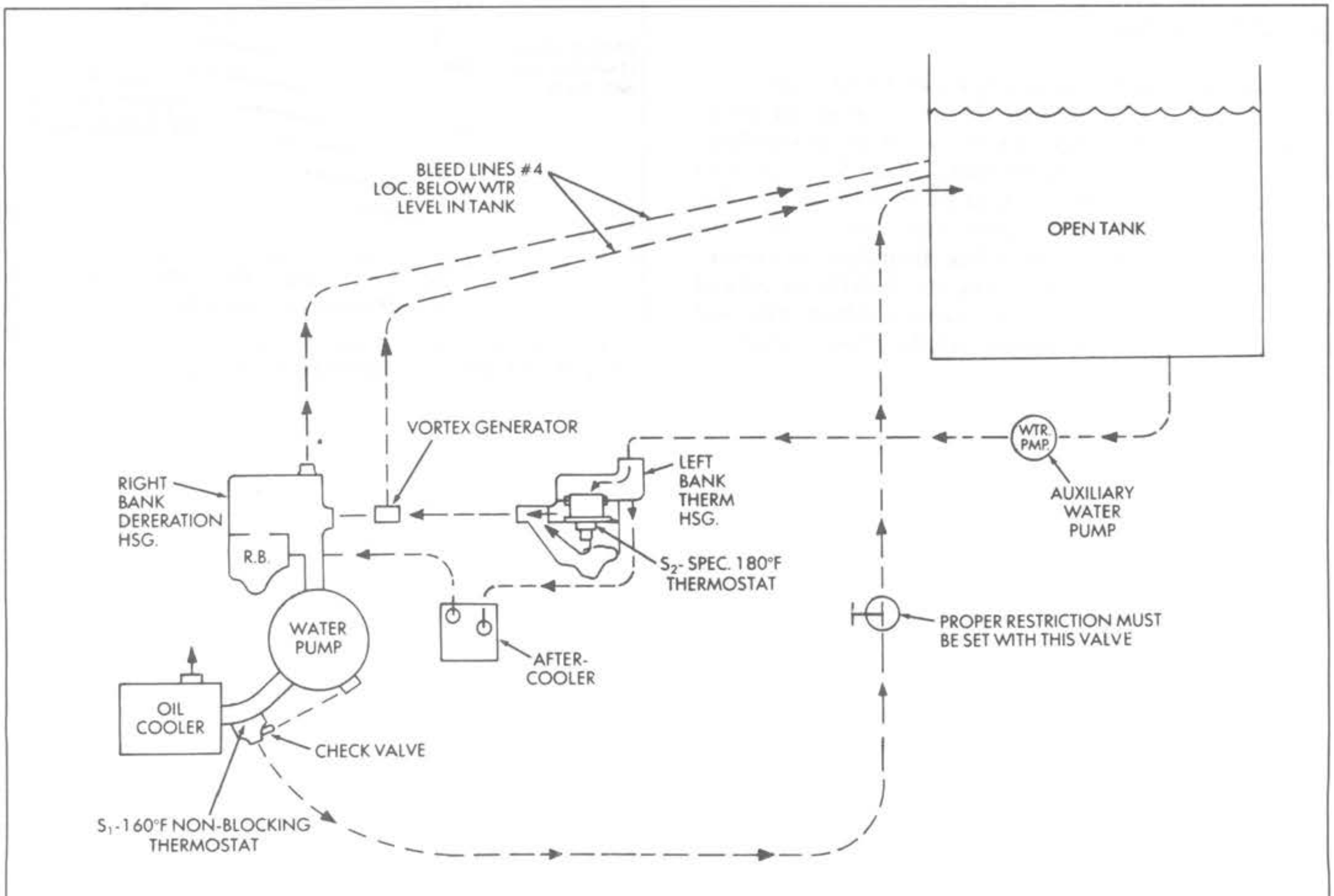


Fig. 5 – V–92TA ALCC Open Loop Test Stand Cooling System

92TA ALCC Engine

A *closed loop cooling system is preferred* because it will maintain the required positive coolant pressure at the engine coolant inlet (left–bank thermostat housing).

If an open loop cooling system (one that is open to atmosphere or dumps into a day tank) is used, *a restriction is required* at the engine water outlet connection (oil cooler elbow – see Fig. 5). The restriction should be sized to provide 11–12 psi (76–83 kPa) coolant pressure in the oil cooler elbow at 1800 RPM. This simulates the restriction of a cooling system installed in a vehicle or machine. *This is very important since, otherwise, an engine overheat condition is likely to occur during engine testing.*

A 10 psi (69 kPa) coolant pressure into the left–bank thermostat housing is required on open loop cooling systems. An auxiliary water pump must be used to meet this requirement.

A power evaluation of 92TA ALCC engines in a vehicle/machine is run identical to the JWAC engine.

Air–to–Air Charge Cooled (AACC) Engine

The same cooling system used with JWAC engines can be used with AACC engines. However, if an air–to–air chassis–mounted cooler cannot be used, it can be simulated by bolting two DDC intercoolers (Part No. 5148426) together, side by side, with air inlet elbows such as Part Nos. 5148026 or 5148329. Intercooler Part. Nos. 5124107 or 5144485 are also suitable from a heat dissipation standpoint. The air piping from the turbo compressor to the cooler and back to the engine should be 4" diameter tubing. This will have to be reduced at the cooler air inlet elbows, which are 3 1/2" diameter.

The air restriction of the two intercoolers is comparable to a chassis–mounted cooler. However, tubing and tubing bends should be kept to a minimum.

The water side of the two intercooler cores should be piped in series or in parallel with a source of cool coolant. The coolant temperature/flow requirement for the intercoolers is 80°F (26.6°C) maximum at 55 GPM.

The performance of the charge air cooler system should meet the guidelines shown on the DDC charge air cooler performance chart (Fig. 6).

A power evaluation of an air–to–air charge cooled engine in a vehicle is run identical to a standard or JWAC engine.

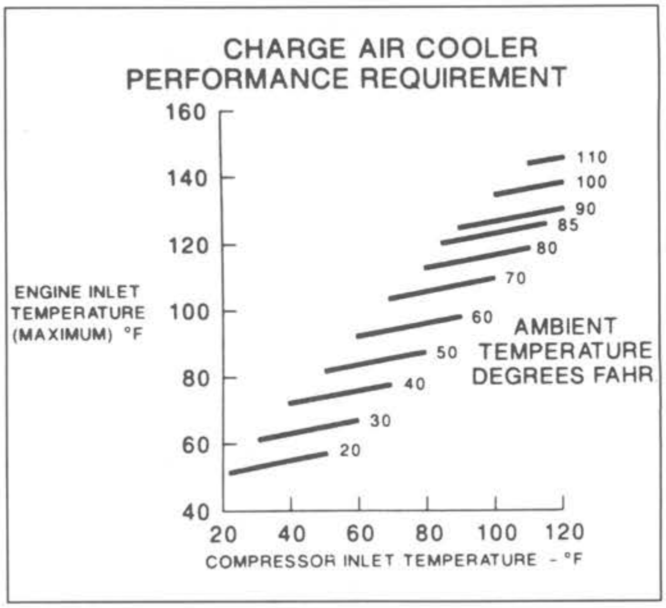


Fig. 6 – Charge Air Cooler Performance Requirement

LUBRICATING OIL, FUEL OIL AND FILTER RECOMMENDATIONS

Selection of the proper quality of fuel and lubricating oil is important to achieve the long and trouble–free service for which Detroit Diesel engines are designed. Conversely, operation with improper fuels and lubricants can cause problems. The manufacturer's warranty applicable to Detroit Diesel engines provides, in part, that warranty shall not apply to any engine which has been subject to misuse, negligence or accident. Accordingly, malfunctions attributable to neglect or failure to follow manufacturer's fuel or lubricating recommendations may not be covered by the warranty.

A requirement of Detroit Diesel Corporation's extended warranty program (Power Protection Plan) is that the customer use the lubricants, fuels and filters recommended in this publication.

It is Detroit Diesel's policy to build engines which will operate satisfactorily with fuels and lubricants available in the commercial market. However, not all fuels and lubricants are adequate. Product selection should be made based on these recommendations and in consultation with a reliable supplier who understands the equipment and its application.

LUBRICATING OIL

Engine service life depends upon selecting the proper lubricating oil and maintaining proper oil drain and filter change intervals.

LUBRICANT SELECTION

There are hundreds of commercial oils marketed today, but labeling terminology differs among suppliers and can be confusing. Some marketers may claim that their lubricant is suitable for all makes of diesel engines and may list engine makes and types, including Detroit Diesel, on their containers. Such claims by themselves are insufficient as a method of lubricant selection for Detroit Diesel engines.

The proper lubricating oil for all Detroit Diesel engines is selected based on SAE Viscosity Grade and API (American Petroleum Institute) Service Designation. Both of these properties are displayed on oil containers in the API symbol. In addition, military specifications may be used for selecting engine lubricants. Mil–L–2104D represents the most current military specification for diesel lubricants and the only one recommended for Detroit Diesel engines. For two–cycle Detroit Diesel engines, the proper lubricant must also possess a sulfated ash content below 1.0% mass. Refer to the following specific recommendations.

TWO–CYCLE ENGINES
Detroit Diesel Series 53, 71, 92, 149

LUBRICANT RECOMMENDATION

API Symbol:

SAE Viscosity Grade: 40
API Classification: CD–II
Military Spec.: Mil–L–2104D
Sulfated Ash: less than 1.0%

This is the only engine oil recommended for Detroit Diesel two–cycle engines. Lubricants meeting these criteria have provided maximum engine life when used in conjunction with recommended oil drain and filter maintenance schedules.

A more detailed description of each of these selection criteria may be found in a further section of this publication. Certain engine operating conditions may require exceptions to this recommendation. They are as follows:

1. For continuous high temperature operation (over 100°F ambient or 200°F Coolant Out) the use of an SAE grade 50 lubricant in all series two–cycle DDC engines is recommended.

2. At ambient temperatures below freezing where starting aids are not available or at very cold temperatures (0 to –25°F), the use of multiviscosity grade 15W–40 or monograde SAE 30 lubricants will improve startability. **Exception: Do not use these lubricants in two–cycle marine engines or DDC series 149 engines under any circumstances.**

3. The API category CD–II is relatively new and may not be fully in use at the time of this publication. API category CD may be used provided the recommended military specification is satisfied. Oils with API designation CE are not recommended in DDC two–cycle engines unless accompanied by CD–II.

4. When the use of high sulfur fuel is unavoidable, lubricants with a Total Base Number exceeding 10 are recommended. Such a lubricant may have a Sulfated Ash content above 1.0% mass. High sulfur fuels require modification to oil drain intervals. For further information refer to that section of this publication.

FOUR–CYCLE ENGINES
Detroit Diesel Series 60 and 8.2L

LUBRICANT RECOMMENDATION

API Symbol:

SAE Viscosity Grade: 15W–40
API Classification: CE
Military Spec.: Mil–L–2104D

This is the only engine oil recommended for Detroit Diesel Series 60 and 8.2L engines. Lubricants meeting these criteria have provided maximum engine life when used in conjunction with recommended oil drain and filter maintenance schedules.

When the use of high sulfur fuel is unavoidable, lubricants with a TBN exceeding 10 are recommended. High sulfur fuels require modification to oil drain intervals. For further information refer to that section of this publication.

LUBRICATING OIL SELECTION CRITERIA

SAE VISCOSITY GRADE

Viscosity is a measure of an oil's ability to flow at various temperatures. The SAE Viscosity Grade system is defined in SAE Standard J300 which designates a viscosity range with a grade number. Lubricants with two grade numbers separated by a "W" are classified as multigrade, while those with a single number are monograde. The higher the number the higher the viscosity.

API SERVICE CLASSIFICATION

The American Petroleum Institute has established a means of classifying lubricant performance suitable for different types of engines and types of service. The higher performance or quality API classifications for diesel engines include CD, CE (for four–cycle diesel engines) and CD–II (for two–cycle diesel engines). Detroit Diesel does not recommend the use of the older and lower performance classifications such as CC, CB and CA.

Multiple API Service Classifications such as "API SERVICE CD, CE" or "API SERVICE CE/CD–II" are frequently listed. Additional classifications not listed here may also be included. It is important that the DDC recommended classification be among those listed.

API SYMBOL

Lubricant marketers have adopted a uniform method of displaying the SAE viscosity grade and API service classification information on product containers and in product literature. The three segment "donut" contains the SAE grade number in the center, and the API service in the top segment. The lower segment is used to designate energy conserving status for gasoline engine use and has no significance for diesel engine use.

MILITARY SPECIFICATION

U.S. Military specifications are another means of classifying the performance of lubricants. As with the API system, lubricants must meet performance criteria before approval is given. The essential difference, however, is that lubricants meeting military specifications, particularly those possessing Qualified Products Listing (QPL) Numbers, have been reviewed by a committee consisting of engine manufacturers, including Detroit Diesel.

Military Specification Mil–L–2104D represents the current specification for heavy–duty diesel engines and the only one recommended by Detroit Diesel Corporation.

SULFATED ASH AND TOTAL BASE NUMBER

This is a lubricant property obtained by a laboratory test (ASTM D874) to determine potential for the formation of metallic ash. The ash residue is related to the oil's additive composition and is significant in predicting lubricants which may cause valve distress under certain operating conditions. Sulfated ash is related to Total Base Number (TBN), also a laboratory test (ASTM D2896) which measures an oil's ability to neutralize acids. As TBN increases, sulfated ash also increases to where lubricants with TBNs above 10 will likely have sulfated ash contents above 1.0% mass.

Total Base Number is important to deposit control in four–cycle diesel engines and to neutralize the effects of high sulfur fuel in all diesel engines. In general, Detroit Diesel recommends lubricants with sulfated ash contents below 1.0% mass and TBNs between 7 and 10 for all Series engines operating on low sulfur fuel.

UNIVERSAL OILS

Universal oils are designed for use in both gasoline and diesel engines and provide an operational convenience in mixed fuel engine fleets. These products are identified with combination API category designations such as SF/CD or SG/CE. Although such products can be used in Detroit Diesel engines (provided they satisfy all DDC requirements), their use is not as desirable as lubricants formulated specifically for diesel engines, and bearing only the API CD–II or CE designations.

SYNTHETIC OILS

Synthetic oils may be used in Detroit Diesel engines provided they meet the viscosity, performance classification and chemical recommendations listed for non–synthetic lubricants. Product information about synthetic oils should be reviewed carefully since these lubricants are often claimed to be of monograde viscosity. Their use does not permit extension of recommended oil drain intervals.

MARINE LUBRICANTS, RAILROAD DIESEL LUBRICANTS

The petroleum industry markets specialty lubricants for use in diesel engines designed specifically for marine propulsion or railroad locomotive use. These lubricants take into consideration the unique environments and operational characteristics of this type of duty, and consequently, they are formulated quite differently from the types of lubricants recommended by Detroit Diesel. Although in some cases they may be suitable in Detroit Diesel engines, they should not be used without specific consultation with your Detroit Diesel distributor or regional office and the lubricant supplier.

USE OF SUPPLEMENTAL ADDITIVES

Lubricants meeting the Detroit Diesel recommendations outlined in this publication already contain a balanced additive treatment. The use of supplemental additives, such as break–in oils, top oils, graphitizers, and friction–reducing compounds, is generally unnecessary and can even be harmful. Never use a lubricant supplement to "fix" a mechanical problem, and be cautious of products purporting to prevent one. The best approach is to follow DDC's lubricant recommendations.

EVIDENCE OF SATISFACTORY LUBRICANT PERFORMANCE

These recommendations are intended to provide a guideline for lubricating oil selection based on favorable service history in typical applications of Detroit Diesel engines. Specific situations may warrant consideration of a lubricant that does not fit these guidelines. Such a lubricant may perform satisfactorily in certain circumstances, and be inappropriate for others.

For such products, evidence of satisfactory performance should be obtained from the oil supplier on the specific lube oil blend being considered and compared with the performance of a DDC recommended lubricant as reference. Comparative performance evidence would include stationary engine tests and field testing in a similar application and severity.

The type of field test used by the oil supplier depends on the series engine in which the candidate oil will be used and the service application. The candidate test oil engines should all operate for the mileage/hours indicated in the table below. Any serious mechanical problems should be recorded. At the conclusion of the test, the engines should be disassembled and quantitatively compared with reference oil engines for:

- Ring conditions (broken, stuck and wear)
- Cylinder liner and piston skirt scuffing
- Exhaust valve face and seat deposits and distress
- Piston pin and slipper bushing wear
- Piston ring land deposits
- Overall valve train and bearing wear

Several stationary engine tests have been designed by and utilized by Detroit Diesel for evaluation of lubricants. These tests include:

100 Hour Series 92 Accelerated Engine Test
 – evaluates liners, rings and slipper bushings

Series 71 Valve Guttering Test
 – evaluates effects of high ash on valve distress

100 Hour Series 60 Truck Cycle Test
 – evaluates deposit and ring sticking

240 Hour 6V53T Endurance Test (FTM 355)
 – evaluates liner and ring wear (used for CD–II)

LUBRICATING OIL FIELD TESTING GUIDELINES

ENGINE SERIES	SERVICE APPLICATION	TEST DURATION	NO. ENGINES ON CANDIDATE TEST OIL	NO. ENGINES ON REFERENCE BASELINE OIL
53	Pickup & Delivery	50,000 Miles	5	5
60, 71, 92	Highway Truck, GVW 78,000 lbs	200,000 Miles	5	5
149	Off–Road 120 Ton Rear Dump	10,000 Hours	3	3

Although stationary engine testing provides important lubricant performance evaluation, it should be considered secondary to a properly conducted field test evaluation.

Upon completion of the field and stationary testing of products which meet or exceed the performance of lubricants recommended in this publication, Detroit Diesel will issue a written approval for their use in the application field tested. Such approval will be limited to the specific formulation (identical basestock and additive treatment) in which the testing was conducted.

OIL CHANGE INTERVALS

During use, engine lubricating oil undergoes deterioration from combustion by–products and contamination. For this reason, regular oil drain intervals are necessary. These intervals however, may vary in length depending upon engine operation, fuel quality, and lubricant quality. The oil drain interval may be established on recommendations of a Detroit Diesel Oil Analysis Program until the most practical oil change interval has been determined. Under no circumstances, however, should the drain intervals in the chart be exceeded. Refer to the "Used Lubricating Oil Analysis" section of this publication for more information. All engine oil filters should be changed when the lube oil is changed.

MAXIMUM RECOMMENDED OIL DRAIN INTERVALS (Normal Operation)

SERVICE APPLICATION	ENGINE SERIES	OIL DRAIN INTERVAL
Highway Truck	60, 71 & 92	20,000 Miles (32,000 kM)
City Transit Coaches	53, 71 & 92	6,000 Miles (9,600 kM)
Pick-up & Delivery, Stop & Go, Short Trip	53, 71, 92	12,000 Miles (19,000 kM)
	8.2L	6,000 Miles (9,600 kM)
Industrial, Agricultural and Marine	149NA	500 Hrs. or 1 Yr.
	149T	300 Hrs. or 1 Yr.
	53, 60, 71, 92 & 8.2L	150 Hrs.
Stationary Units Full Time	53, 71, 92 & 149	500 Hrs. or 1 Mo.
Standby	53, 71, 92, 149 & 8.2L	150 Hrs. or 1 Yr.

OIL CHANGE INTERVALS WHEN USING HIGH SULFUR FUEL

When the continuous use of high sulfur fuel (greater than 0.5%) is unavoidable, lubricant selection and oil drain interval must be modified. A lubricant with a Total Base Number (TBN per ASTM D 2896) above 10 is recommended. It is likely that such a lubricant will also exhibit a sulfated ash above 1.0%. The proper oil drain interval must be determined by oil analysis when operating on high sulfur fuel. A reduction in TBN (D 2896) to one third of the initial value provides a general drain interval guideline.

MAXIMUM RECOMMENDED OIL DRAIN INTERVALS

FUEL SULFUR 0.5% TO 1.0%
Use a lubricant with TBN (ASTM D 2896) 10 to 30

SERVICE APPLICATION	ENGINE SERIES	OIL DRAIN INTERVAL 10–19 TBN	OIL DRAIN INTERVAL 20–30 TBN
Highway Truck	60, 71 & 92	15,000 Mi. (24,000 kM)	20,000 Mi. (32,000 kM)
City Transit Coaches	53, 71 & 92	4,000 Mi. (6,400 kM)	6,000 Mi. (9,600 kM)
Pick-up & Delivery Stop & Go, Short Trip	53, 71 & 92	8,000 Mi. (12,500 kM)	12,000 Mi. (20,000 kM)
	8.2L	4,000 Mi. (6,400 kM)	6,000 Mi. (9,600 kM)
Industrial, Agricultural and Marine	149NA	300 Hrs.	500 Hrs.
	149T	200 Hrs.	300 Hrs.
		(or 1 Yr. Maximum)	
	53, 60, 71, 92 & 8.2L	100 Hrs.	150 Hrs.
Stationary Units Full Time	53, 71, 92 & 149	300 Hrs.	500 Hrs.
		(or 1 Mo. Maximum)	
Standby	53, 71, 92, 149 & 8.2L	100 Hrs.	150 Hrs.
		(or 1 Yr. Maximum)	

MAXIMUM RECOMMENDED OIL DRAIN INTERVALS

FUEL SULFUR ABOVE 1.0%
Use a lubricant with TBN (ASTM D 2896) 10 to 30

SERVICE APPLICATION	ENGINE SERIES	OIL DRAIN INTERVAL 10–19 TBN	OIL DRAIN INTERVAL 20–30 TBN
Highway Truck	60, 71 & 92	7,500 Mi. (12,000 kM)	15,000 Mi. (24,000 kM)
City Transit Coaches	53, 71 & 92	2,000 Mi. (3,000 kM)	4,000 Mi. (6,400 kM)
Pick-up & Delivery Stop & Go, Short Trip	53, 71 & 92	4,000 Mi. (6,500 kM)	8,000 Mi. (12,500 kM)
	8.2L	2,000 Mi. (3,000 kM)	4,000 Mi. (6,400 kM)
Industrial, Agricultural and Marine	149NA	150 Hrs.	300 Hrs.
	149T	100 Hrs.	200 Hrs.
		(or 6 Mos. Maximum)	
	53, 60, 71, 92 & 8.2L	50 Hrs.	100 Hrs.
Stationary Units Full Time	53, 71, 92 & 149	150 Hrs.	300 Hrs.
Standby	53, 71, 92, 149 & 8.2L	50 Hrs.	100 Hrs.
		(or 6 Mos. Maximum)	

USED LUBRICATING OIL ANALYSIS

A used lubricating oil analysis program such as the Detroit Diesel Oil Analysis Program is recommended for the monitoring of crankcase oil in all engines. Since an oil analysis indicates the condition of the engine, not the lubricating oil, it should not be used to extend oil drain intervals. The oil should be changed immediately if any contamination is present in concentrations exceeding the warning limits shown in the table. It should not however, be concluded that the engine is worn out based on *a single* measurement that exceeds the warning level. Imminent engine wearout can only be determined through a *continuous* oil analysis program wherein the change in data or deviation from baseline data can be used to interpret condition of engine parts.

Characteristics relating to lubricating oil dilution should trigger corrective action to identify and fix the source(s).

Confirmation of the need for engine overhaul should be based on operational data (increasing oil consumption and crankcase pressure, for example) and physical inspection of parts.

USED LUBRICATING OIL ANALYSIS WARNING LIMITS

These values indicate the need for an immediate oil change, but do not necessarily indicate internal engine problems requiring engine teardown.

WARNING LIMITS

	ASTM Designation	Two Cycle		Four Cycle
		53, 71, 92	149	60, 8.2
Pentane Insolubles Mass % Max.	D 893	1.0	1.0	1.0
Carbon (Soot) Content, TGA Mass % Max.	E 1131	0.8		1.5
Viscosity at 40°c St % Max. Increase % Max. Decrease	D 445 & D 2161	40.0 15.0	40.0 15.0	40.0 15.0
Total Base Number (TBN) Min. Min.	D 664 D 2986	1.0 2.0	1.0 2.0	1.0 2.0
Water Content (dilution) Vol. % Max.	D 95	0.30	0.30	0.30
Flash Point °C Reduction Max.	D 92	40.0	40.0	40.0
Fuel Dilution Vol. % Max.	*	2.5	1.0	2.5
Glycol Dilution PPM Max.	D 2982	1000	1000	1000
Iron Content PPM Fe Max.	**	150	35	60=150 8.2=250
Copper Content PPM Cu Max.	**	25	25	60=90 8.2=30
Sodium Content PPM Na Over Baseline Max.	**	50	50	50
Boron Content PPM B Over Baseline Max.	**	20	20	20

* No ASTM Designation

** Elemental Analysis are conducted using either emission or atomic absorption spectroscopy.
Neither method has an ASTM designation.

FUEL OIL

QUALITY AND SELECTION

The quality of fuel used is a very important factor in obtaining satisfactory engine performance, long engine life, and acceptable exhaust emission levels. DDC engines are designed to operate on most diesel fuels marketed today. In general, fuels meeting the properties of ASTM Designation D 975 (grades 1–D and 2–D) have provided satisfactory performance. The ASTM D 975 specification however does not in itself adequately define the fuel characteristics necessary for assurance of fuel quality. The properties listed in the Fuel Oil Selection Chart have provided optimum engine performance.

FUEL OIL SELECTION CHART

General Fuel Classification	ASTM Test	No. 1 ASTM 1-D	No. 2* ASTM 2-D
Gravity, °API #	D 287	40–44	33–37
Flash Point Min. °F (°C)	D 93	100 (38)	125 (52)
Viscosity, Kinematic cST @ 100°F (40°C)	D 445	1.3-2.4	1.9-4.1
Cloud Point °F #	D 2500	See Note 1	See Note 1
Sulfur Content wt%, Max.	D 129	0.5	0.5
Carbon Residue on 10%, wt%, Max.	D 524	0.15	0.35
Accelerated Stability Total Insolubles mg/100 ml, Max. #	D 2274	1.5	1.5
Ash, wt%, Max.	D 482	0.01	0.01
Cetane Number, Min. +	D 613	45	45
Distillation Temperature, °F (°C)	D 86		
IBP, Typical #		350 (177)	375 (191)
10% Typical #		385 (196)	430 (221)
50% Typical #		425 (218)	510 (256)
90% +		500 (260) Max.	625 (329) Max.
End Point #		550 (288) Max.	675 (357) Max.
Water & Sediment %, Max.	D 1796	0.05	0.05

\# Not specified in ASTM D 975
\+ Differs from ASTM D 975
* No. 1 diesel fuel is recommended for use in city coach engine models. No. 2 diesel fuel may be used in city coach engine models which have been certified to pass Federal and California emission standards.

Note 1: The cloud point should be 10°F (6°C) below the lowest expected fuel temperature to prevent clogging of fuel filters by wax crystals.

Note 2: When prolonged idling periods or cold weather conditions below 32°F (0°C) are encountered, the use of 1–D fuel is recommended. Number 1–D fuels should also be considered when operating continuously at altitudes above 5000 ft.

FUEL OIL SELECTION CRITERIA

DISTILLATION

The boiling range is a very important property in consideration of diesel fuel quality. The determination of boiling range is made using ASTM Test Method D 86. Many specifications contain a partial listing of the distillation results, ie., Distillation Temperature At 90% Recovered. Many diesel fuels are blended products which may contain constituents with boiling ranges much different than the majority of the fuel composition. The full boiling range as shown in the Fuel Oil Selection Chart should be used for proper selection.

FINAL BOILING POINT

Fuel can be burned in an engine only after it has been vaporized. The temperature at which fuel is completely vaporized is described as the End point Temperature in ASTM D 86 Distillation Test Method. This temperature must be low enough to permit complete vaporization at combustion chamber temperatures. The combustion chamber temperature depends on ambient temperature, engine speed and load. Poor vaporization is more apt to occur during severe cold weather, prolonged idling, and/or light load operation. Therefore engines operating under these conditions should utilize fuels with lower distillation end point temperatures.

COMPLETELY DISTILLED FLUID

Fuel selected should be completely distilled material. That is, the fuel should exhibit no less than 98% recovery when subjected to the ASTM D 86 Distillation Test Method.

CETANE NUMBER

Cetane Number is mistakenly used to indicate fuel quality. However, Cetane Number is most useful in predicting engine startup. A high Cetane Number should not be considered alone when evaluating fuel quality. Other properties such as end point distillation temperature and carbon residue should also be considered. Calculated Cetane Index is sometimes reported instead of Cetane Number. Cetane Index is an empirical property determined through the use of a mathematical equation whereas Cetane Number is determined through an engine test.

FUEL STABILITY

Diesel Fuel oxidizes in the presence of air and water, particularly if the fuel contains cracked products which are relatively unstable. The oxidation of fuel can result in the formation of undesirable gums and sediment. Such undesirable products can cause filter plugging, combustion chamber deposit formation and gumming or lacquering of injection system components with resultant sticking or wear.

ASTM Test Method D 2274 measures diesel fuel oxidative stability. Although the results of the test may vary with actual field storage, it does measure characteristics which will effect fuel storage stability for periods up to 12 months.

FUEL SULFUR CONTENT

The sulfur content of the fuel should be as low as possible to avoid premature wear and excessive deposit formation. Fuel containing no more than 0.5% sulfur are recommended. If the use of fuels with sulfur contents above 0.5% are unavoidable, lube oil drain intervals and lubricant selection need to be changed. Detroit Diesel recommends that the Total Base Number (TBN D 2896) of the lubricant be monitored and the oil drain interval be reduced.

FUEL OPERATING TEMPERATURE AND VISCOSITY

Since Diesel Fuel provides cooling of the injection system, the temperature of the fuel may vary considerably due to the ambient temperature, engine operating temperature, and the amount of fuel remaining in the tank. As fuel temperature increases, the fuel viscosity and therfore the lubrication capabilities of the fuel diminish. Maintaining proper fuel temperatures in combination with selection of fuels with the viscosity ranges shown in the Fuel Oil Selection Chart will assure proper injection system functioning.

DIESEL FUEL STORAGE

Fuel oil should be clean and free of contamination. Storage tanks and stored fuel should be inspected regularly for dirt, water, and sludge; and cleaned if contaminated. Diesel fuel tanks can be made of aluminum, monel stainless steel, black iron, welded steel or reinforced (non–reactive) plastic.

> **NOTICE:** Galvanized steel or sheet metal tanks and galvanized pipes or fittings should never be used in any diesel fuel storage, delivery or fuel system. The fuel oil will react chemically with the zinc coating, forming a compound which can clog the filters and can cause engine damage.

FUEL ADDITIVES

Detroit Diesel engines operate satisfactorily on a wide range of diesel fuels without the addition of supplemental additives. Such additives increase operating costs without providing benefit.

Fuel additives specifically NOT recommended include:

- Used Lubricating Oil
- Gasoline

Detroit Diesel does NOT recommend the use of drained lubricating oil or gasoline in diesel fuel. Furthermore Detroit Diesel Corporation will not be responsible for any detrimental effects which it determines resulted form this practice.

Some fuel additives provide temporary benefits but do not replace good fuel handling practices. Such additives are helpful when water contamination is suspected:

- Isopropyl Alcohol—1 pint per 125 gallons of fuel for winter freeze up protection.
- Biocide—For treatment of microbe growth or black "slime". Follow manufacturers' instructions for treatment.

Other fuel additives are of questionable benefit. These include a variety of independently marketed products which claim to be:

- Cetane Improvers
- Combustion Improvers
- Cold Weather Flow Improvers

These products should be accompanied with performance data supporting their merit. It is not the policy of Detroit Diesel Corporation to approve or endorse such products.

FILTER RECOMMENDATIONS

Filters make up an integral part of fuel and lubricating oil systems. Proper filter selection and maintenence are important to satisfactory engine operation and service life. Filters should be utilized for maintaining a clean system, not for cleaning up a contaminated system.

FUEL FILTER RECOMMENDATION
Regular Service

Filter Type	Micron Rating	Beta Ratio	Manufacturer	Filter No.
Primary	30	—	AC Spark Plug Div. GM	T552 T553 T541 T632 T915 T936 T958
Secondary	12	—	AC Spark Plug Div. GM	TP509 TP540X TP624 TP916 TP928 TP959

FUEL FILTER RECOMMENDATION
Severe Duty Service

Filter Type	Micron Rating	Beta Ratio	Manufacturer	Filter No.
Primary	—	—	Racor	B32002
Secondary	3	200	Pall Corp.	Head HH7400A12UPRBP Element HC7400SUP-4H
Secondary (Alternate)	5	—	AC Spark Plug	TP916L TP928L TP959L

LUBRICATING OIL FILTER RECOMMENDATION
Series 53, 71, 92, 149

Filter Type	Micron Rating	Beta Ratio	Manufacturer	Filter No.
Full Flow	12	75	AC Spark Plug Div. GM	PF911L P/N 25013192

LUBRICATING OIL FILTER RECOMMENDATION
Series 60

Filter Type	Micron Rating	Beta Ratio	Manufacturer	Filter No.
Full Flow	45	80	AC Spark Plug Div. GM	PF911 P/N 25010495
By–Pass	10	90	AC Spark Plug Div. GM	P–940 P/N 25011188

LUBRICATING OIL FILTER RECOMMENDATION
Series 8.2L

Filter Type	Micron Rating	Beta Ratio	Manufacturer	Filter No.
Full Flow	25	88	AC Spark Plug Div. GM	PF35 P/N 6438384

COOLANT SPECIFICATIONS

The coolant provides a medium for heat transfer and controls the internal temperature of the engine during operation. In an engine having proper coolant flow, the heat of combustion is conveyed through the cylinder walls and the cylinder head into the coolant. Without adequate coolant, normal heat transfer cannot take place within the engine, and engine temperature rapidly rises. In general, water containing various materials in solution is used for this purpose.

	PARTS PER MILLION	GRAINS PER GALLON
Chlorides (Maximum)	40	2.5
Sulfates (Maximum)	100	5.8
Total Dissolved Solids (Maximum)	340	20
Total Hardness (Maximum)	170	10

TABLE 1

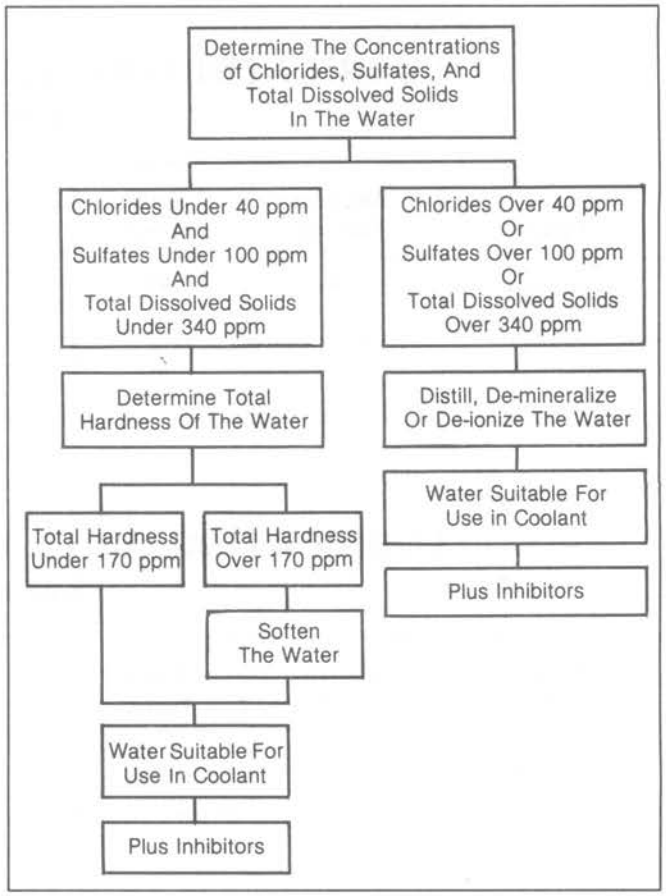


TABLE 2

COOLANT REQUIREMENTS

Coolant solutions used in Detroit Diesel engines must meet the following basic requirements:

1. Provide for adequate heat transfer.
2. Provide a corrosion–resistant environment within the cooling system.
3. Prevent formation of scale or sludge deposits in the cooling system.
4. Be compatible with the cooling system hose and seal materials.
5. Provide adequate freeze protection during cold weather operation and boil–over protection in hot weather.

The first four requirements are satisfied by combining a suitable water with reliable inhibitors. When freeze protection is required, a solution of suitable water and an antifreeze containing adequate inhibitors will provide a satisfactory coolant. Ethylene glycol–based antifreeze solutions are recommended for year–round use in Detroit Diesel engines.

WATER

Whether of drinking quality or not, any water will produce a corrosive environment in the cooling system, and the mineral content may permit scale deposits to form on internal cooling system surfaces. Therefore, water selected as a coolant must be properly treated with inhibitors to control corrosion and scale deposition.

To determine if a particular water is suitable for use as a coolant when properly inhibited, the following characteristics must be considered: the concentration of chlorides and sulfates, total hardness and dissolved solids.

Chlorides and/or sulfates tend to accelerate corrosion, while hardness (percentage of magnesium and calcium salts broadly classified as carbonates) causes deposits of scale. Total dissolved solids may cause scale deposits, sludge deposits, corrosion or a combination of these. Chlorides, sulfates, magnesium and calcium are among the materials which make up dissolved solids. Water within the limits specified in Table 1 is satisfactory as an engine coolant when proper inhibitors are added. The procedure for evaluating water intended for use in a coolant solution is shown in Table 2.

CORROSION INHIBITORS VITAL

A corrosion inhibitor is a water–soluble chemical compound which protects the metallic surfaces of the cooling system against corrosive attack. Some of the more commonly used corrosion inhibitors are chromates, borates, nitrates, nitrites and soluble oil. (Soluble oil is not recommended as a corrosion inhibitor). Depletion of all types of inhibitors occurs through normal operation.

Therefore, strength levels must be maintained by adding inhibitors as required after testing the coolant.

The importance of a properly inhibited coolant cannot be overstressed. A coolant which has insufficient inhibitors, the wrong inhibitors, or no inhibitors at all invites the formation of rust and scale deposits within the cooling system. Rust, scale, and mineral deposits can wear out water pump seals and coat the walls of the cylinder block water jackets and the outside walls of the cylinder liners. As these deposits build up, they insulate the metal and reduce the rate of heat transfer. For example, a 1/16" deposit of rust or scale on 1" of cast iron is equivalent to 4–1/4" of cast iron in heat transferability (Fig. 1).

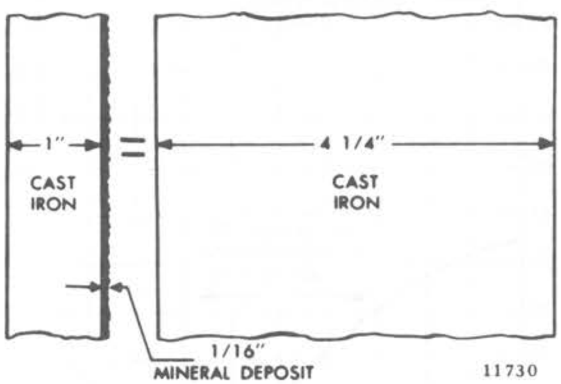


Fig. 1 – Heat Transfer Capacity

An engine affected in this manner overheats gradually over a period of weeks or months. Liner scuffing, scoring, piston seizure and cylinder head cracking are the inevitable results. An improperly inhibited coolant can also become corrosive enough to "eat away" coolant passages and seal ring grooves and cause coolant leaks to develop. If sufficient coolant accumulates on top of a piston, a hydrostatic lock can occur while the engine is being started. This, in turn, can result in a bent connecting rod.

An improperly inhibited coolant can also contribute to *cavitation erosion.* Cavitation erosion is caused by the collapse of bubbles (vapor pockets) formed at the coolant side of an engine component. The collapse results from a pressure differential in the liquid caused by the vibration of the engine part. As bubbles collapse, they form pin points of very high pressure. Over a period of time, the rapid succession of millions of tiny bursting bubbles can wear away (erode) internal engine surfaces.

Components such as fresh water pump impellers and cylinder liners are especially susceptible to cavitation erosion. In extreme cases their surfaces can become so deeply pitted that they appear to be spongy, and holes can develop completely through them.

Chromates

Sodium chromate and potassium dichromate are two of the best and most commonly used *water* system corrosion inhibitors. Care should be exercised in handling these materials due to their toxic nature.

Chromate inhibitors should *not* be used in antifreeze solutions. Chromium hydroxide, commonly called "green slime", can result from the use of chromate inhibitors with antifreeze. This material deposits on the cooling system passages, reducing the heat transfer rate (Fig. 1) and resulting in engine overheating. Engines which have operated with a chromate–inhibited water must be chemically cleaned before the addition of antifreeze. A commercial heavy–duty descaler should be used in accordance with the manufacturer's recommendation for this purpose.

Soluble Oil

Soluble oil has been used as a corrosion inhibitor for many years. It has, however, required very close attention relative to the concentration level due to adverse effects on heat transfer if the concentration exceeds 1% by volume. For example: 1.25% of soluble oil in the cooling system increases fire deck temperatures 6% and a 2.50% concentration raises fire deck temperatures up to 15%. *Soluble oil is not recommended as a corrosion inhibitor.*

Non–Chromates

Non–chromate inhibitors (borates, nitrates, nitrites, etc.) provide corrosion protection in the cooling system with the basic advantage that they can be used with either water or a water–and–antifreeze solution.

INHIBITOR SYSTEMS

An inhibitor system is a combination of chemical compounds which provide corrosion protection, pH control and water–softening ability. Corrosion protection is discussed under the heading *Corrosion Inhibitors Vital.* pH control is used to maintain an acid–free solution. The water–softening ability deters formation of mineral deposits. Inhibitor systems are available in various forms such as coolant filter elements, liquid and dry bulk inhibitor additives and as integral parts of antifreeze.

Coolant Filter Elements

Replaceable elements are available with various chemical inhibitor systems. Compatibility of the element with other ingredients of the coolant solution cannot always be taken for granted.

Problems have developed from the use of the magnesium lower support plate used by some manufacturers in their coolant filters. The magnesium plate will be attacked by solutions which will not be detrimental to other metals in the cooling system. The dissolved magnesium will be deposited in the hottest zones of the engine where heat transfer is most critical. The use of an aluminum or zinc support plate in preference to magnesium is recommended to eliminate the potential of this type of deposit.

High chloride coolants will have a detrimental effect on the water–softening capabilities of systems using ion–exchange resins. Accumulations of calcium and magnesium ions removed from the coolant and held captive by the zeolite resin can be released into the coolant by a regenerative process caused by high chloride–content solutions.

Inhibitor Additives

Commercially packaged inhibitor systems are available which can be added directly to the engine coolant. Both chromate and non–chromate systems are available and care should be taken regarding inhibitor compatibility with other coolant constituents.

Non–chromate inhibitor systems are recommended for use in Detroit Diesel engines. These systems can be used with either water or water–and–antifreeze solutions and provide corrosion protection, pH control and water softening. Most non–chromate inhibitor systems offer the additional advantage of a simple on–site test to determine protection level. Since they are added directly to the coolant, they require no additional hardware or plumbing.

All inhibitors become depleted through normal operation and additional inhibitor must be added to the coolant as required to maintain original strength levels.

NOTICE: Over–inhibiting antifreeze solutions can cause silicate dropout. Always follow the supplier's recommendations on inhibitor usage and handling.

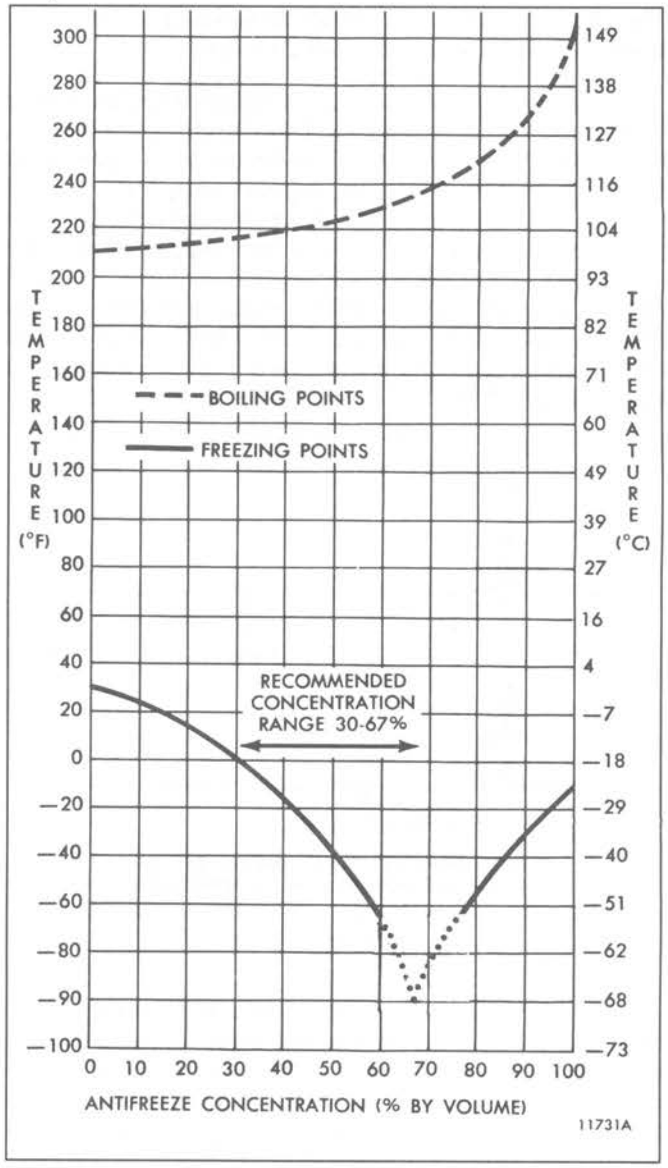


Fig. 2 – Coolant Freezing and Boiling Temperatures vs. Antifreeze Concentration (Sea Level)

TEST METHODS

Test kits and test strips are commercially available to check engine coolant for corrosion inhibitor strength level. Coolant should be tested to determine the need for corrosion inhibitor supplements and the amount required. Do not use one manufacturer's test to measure the inhibitor strength level of another manufacturer's product. Always follow the manufacturer's recommended test procedures.

ANTIFREEZE

When freeze protection is required, use an antifreeze that meets the GM 6038M formulation, which limits silicate to 0.15% maximum or an equivalent formulation meeting the 0.15% maximum silicate and GM 1899M performance requirements.

Solutions of less than 30% do not provide adequate corrosion protection. Concentrations over 67% adversely affect freeze protection, heat transfer rates and silicate stability. A 50% antifreeze solution is normally used as factory–fill.

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 non–metallic components of the cooling system and because of its low boiling point. Methoxy propanol base antifreeze is not recommended for use in Detroit Diesel engines due to the presence of fluoroelastomer seals in the cooling system.

Antifreeze solutions should be used year–round to provide freeze protection in the winter, boil–over protection in the summer and a stable environment for seals and hoses in the cooling system of the engine.

The inhibitors in antifreeze solutions should be replenished with a non–chromate corrosion inhibitor supplement when indicated by testing the coolant. Engine coolant should be checked at approximately 500 hour or 20,000 mile intervals.

A cooling system properly maintained and protected with supplemental corrosion inhibitors can be operated up to two years, 200,000 miles, or 6000 hours, whichever comes first. At this interval the antifreeze should be drained and the cooling system cleaned thoroughly. The cooling system should then be replenished with an ethylene glycol–base antifreeze/water solution in the required concentration (see graph).

NOTICE: Failure to maintain inhibitors at proper levels can result in damage to the cooling system and its related components. Conversely, *overinhibiting antifreeze solutions can cause silicate dropout.* Always follow the supplier's recommendations on inhibitor usage and handling.

SILICATE DROPOUT

Excessive amounts of chemicals in the engine coolant can cause silicate dropout, which creates a gel–type deposit that reduces heat transfer and coolant flow.

The gel takes on the color of the coolant solution in the wet state but appears as a white powdery deposit when dry. Although silica gel is non–abrasive, it can pick up solid particles in the coolant and become a gritty abrasive deposit that can cause excessive wear of water pump seals and other cooling system components. The wet gel can be removed by non–acid (alkali) type heavy–duty cleaners, while the dried silicate requires engine disassembly and caustic solution or mechanical cleaning of individual components.

The total amount of chemicals in the coolant can be minimized by using GM 6038M formulation antifreeze at the required freeze protection level, corrosion inhibitor supplements as needed to maintain protection and water that meets Detroit Diesel requirements.

GENERAL RECOMMENDATIONS

All Detroit Diesel engines incorporate pressurized cooling systems which permit operation at temperatures higher than non–pressurized systems. It is essential that these systems be kept clean and leak–free, that filler caps and pressure relief mechanisms be correctly installed at all times and that coolant levels be maintained.

Always maintain engine coolant at the proper level. A low coolant level allows the water pump to mix air with the coolant. Air bubbles in the coolant can "insulate" the cylinder walls, preventing normal heat transfer. An abnormally low coolant level can cause the water pump to become "air–bound," a condition in which it works feverishly but pumps nothing. Without proper heat transfer, silicone elastomer head–to–block water hole seals can deteriorate and cylinder components can expand so that pistons rapidly cut through the lubricant on the liner walls. Scuffing and piston seizure may follow.

CAUTION: Use extreme care when removing a radiator pressure–control cap from an engine. The sudden release of pressure from a heated cooling system can result in a loss of coolant and possible personal injury (scalding) from the hot liquid.

An engine may contain the correct amount of properly inhibited coolant, but still fail to adequately cool the engine. In cases where this occurs, other causes of low coolant flow, either engine or cooling system related, should be investigated.

1. Always use a properly inhibited coolant.
2. Do not use soluble oil.
3. Maintain the prescribed inhibitor strength level by adding inhibitors as needed after testing the coolant.
4. Always follow the manufacturer's recommendations on inhibitor usage and handling.
5. If freeze protection is required, use a solution of water and antifreeze that meets the GM 6038M formulation or an equivalent antifreeze with a 0.15% maximum silicate content that meets GM 1899M performance specifications.
6. Reinhibit antifreeze with a non–chromate inhibitor system.
7. Do not use a chromate inhibitor with antifreeze.
8. Do not use methoxy propanol base antifreeze.

9. Do not mix ethylene glycol base antifreeze with methoxy propanol base antifreeze in the cooling system.

10. Antifreeze makeup solutions should be mixed at the same concentration as the original coolant.

11. Do not use sealer additives or antifreeze containing sealer additives.

12. Do not use methyl alcohol base antifreeze.

13. Use extreme care when removing the radiator pressure–control cap.

14. Do not add inhibitor supplements to *new* antifreeze solutions, except for the *initial fill* to provide optimum cavitation protection.

15. Use an antifreeze solution year–round for freeze and boil–over protection. Seasonal changing of coolant from an antifreeze solution to an inhibitor–water solution is *not recommended*.

16. A cooling system properly maintained and protected with supplemental corrosion inhibitors can be operated up to two years, 200,000 miles, or 6000 hours, whichever comes first. At this interval the antifreeze should be drained and the cooling system cleaned thoroughly.

SECTION 14

ENGINE TUNE-UP

CONTENTS

ENGINE TUNE-UP PROCEDURES

There is no scheduled interval for performing an engine tune-up. As long as the engine performance is satisfactory, no tune-up should be needed. Minor adjustments in the valve and injector operating mechanism, governor, etc. should only be required periodically to compensate for normal wear on parts.

To comply with emissions regulations for on-highway vehicle engines, injector timing, exhaust valve clearance, engine idle and no-load speeds, and throttle delay or fuel modulator settings must be checked and adjusted, if necessary, at 50,000 mile intervals (refer to Section 15.1).

The type of governor used depends upon the engine application. Since each governor has different characteristics, the tune-up procedure varies accordingly. The following types of governors are used:

1. Limiting speed mechanical.
2. Variable speed mechanical.
3. Hydraulic.

The mechanical 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. A single-weight variable speed governor name plate is stamped S.W.-V.S.

Normally, when performing a tune–up on an engine in service, it is only necessary to check the various adjustments for a possible change in the settings. However, if a cylinder head, governor or injectors have been replaced or overhauled, then certain tune–up adjustments are required. Accurate tune–up adjustments are very important if maximum performance and economy are to be obtained.

If a supplementary governing device, such as the throttle delay mechanism, is used, it must be disconnected prior to the tune–up. After the governor and injector rack adjustments are completed, the supplementary governing device must be reconnected and adjusted.

To tune–up an engine completely, perform all of the adjustments in the applicable tune–up sequence given below.

CAUTION: To prevent the possibility of personal injury, use turbocharger inlet shield J 26554–A anytime the turbocharger inlet is exposed.

Use new valve rocker cover gaskets after the tune–up is completed and reinstall the valve rocker covers.

Tune–Up Sequence For Mechanical Governor

CAUTION: Before starting an engine after an engine speed control adjustment or after removal of the engine governor cover, the technician must determine that the injector racks move to the no–fuel position when the governor stop lever is placed in the stop position. Engine overspeed will result if the injector racks cannot be positioned at no fuel with the governor stop lever. An overspeeding engine can result in engine damage which could cause personal injury.

1. Adjust the exhaust valve clearance, cold.
2. Time the fuel injectors.
3. Adjust the governor gap.
4. Position the injector rack control levers.
5. Adjust the maximum no–load speed.
6. Adjust the idle speed.
7. Adjust the Belleville spring for "TT" horsepower.
8. Adjust the buffer screw.
9. Adjust the throttle booster spring (variable speed governor only).
10. Adjust the supplementary governing device, if used.

Tune–up Sequence For Hydraulic Governor

1. Adjust the exhaust valve clearance.
2. Time the fuel injectors.
3. Position the injector rack control levers.
4. Adjust the governor linkage.
5. Adjust the load limit screw.
6. Compensation adjustment (PSG governors only).
7. Adjust the speed droop.
8. Adjust the maximum no–load speed.

EMISSIONS REGULATIONS FOR ON-HIGHWAY VEHICLE ENGINES

On–highway vehicle engines built by Detroit Diesel Allison are certified to be in compliance with Federal and California Emission Regulations established for each model year.

Engine certification is dependent on five physical characteristics:

1. Fuel injector type.
2. Maximum full–load engine speed.
3. Camshaft timing.
4. Fuel injector timing.
5. Throttle delay (orifice size).

The following Charts summarize all of the pertinent data concerning the specific engine configurations required for each model year.

When serviced, all on–highway vehicle engines should comply with the specifications for the specific model year in which the engine was built.

Trucks in a fleet containing engines of various model years can be tuned to the latest model year, provided the engines have been updated to meet the specifications for that particular year.

1974 CERTIFIED AUTOMOTIVE ENGINES

Engine	Injectors	*Maximum Full-Load Engine Speed	Camshaft Timing	Injector Timing	Injector Timing Gage	Throttle Delay	Yield Link
6V, 8V	9270	2100	Standard	1.460"	J 1853	No	No
6V, 8V	9275	2100	Standard	1.460"	J 1853	No	No
6V, 8V	9280	2100	Standard	1.460"	J 1853	No	No
6VT, 8VT	9280	2100	Standard	1.484"	J 1242	‡ Yes	Yes
6V, 8V	9285	2100	Standard	1.460"	J 1853	No	No
6VT, 8VT	9285	2100	Standard	1.484"	J 1242	‡ Yes	Yes
6VT, 8VT	9290	2100	Standard	1.484"	J 1242	‡ Yes	Yes

* Not to exceed fuel injector size and maximum operating speed that has been established for the specific application of the engine.

‡ .078" diameter fill hole, .016" diameter discharge orifice.

Use minimum idle speed of 500 rpm on all engines.

1975 CERTIFIED AUTOMOTIVE ENGINES

Engine	Injectors	*Maximum Full-Load Engine Speed	Camshaft Timing	Injector Timing	Injector Timing Gage	Throttle Delay	Yield Link
FEDERAL							
6V, 8V	9270	2100	Standard	1.460"	J 1853	No	No
6V, 8V	9275	2100	Standard	1.460"	J 1853	No	No
6V, 8V	9280	2100	Standard	1.460"	J 1853	No	No
6VT, 8VT	9280	2100	Standard	1.484"	J 1242	‡ Yes	Yes
6V, 8V	9285	2100	Standard	1.460"	J 1853	No	No
6VT, 8VT	9285	2100	Standard	1.484"	J 1242	‡ Yes	Yes
6VT, 8VT	9290	2100	Standard	1.484"	J 1242	‡ Yes	Yes
FEDERAL AND CALIFORNIA							
6VTA, 8VTA	9280	2100	Standard	1.484"	J 1242	§‡ Yes	Yes
6VTA, 8VTA	9285	2100	Standard	1.484"	J 1242	§‡ Yes	Yes
6VTA, 8VTA	9290	2100	Standard	1.484"	J 1242	§‡ Yes	Yes

* Not to exceed fuel injector size and maximum operating speed that has been established for the specific application of the engine.

‡ .078" diameter fill hole, .016" diameter discharge orifice.

§ Offset piston linkage.

Use minimum idle speed of 500 rpm on all engines, except coach engines where a minimum of 400 rpm is allowed.

1976 CERTIFIED AUTOMOTIVE ENGINES

Engine	CALIFORNIA				FEDERAL							
	6V-92TA Aftercooled		8V-92TA Aftercooled		6V-92	8V-92	6V-92T			8V-92T		
	TA	TTA	TA	TTA			T	OTM	TT	T	OTM	TT
Injectors	9A80 9A85 9A90	9A90	9280 9285 9290	9290	9270 9275 9280 9285	9270 9275 9280 9285	9280 9285 9290	9280 9285 9290	9290	9280 9285 9290	9280 9285 9290	9290
Approved Constant Horsepower for TTA Engines		270		365					240-270			365
*Maximum Full-Load Engine Speed	2100	▲ 1900 min. 1950 max.	2100	▲ 1900 min. 1950 max.	2100	2100	2100	2100	▲ 1900 min. 1950 max.	2100	2100	▲ 1900 min. 1950 max.
Camshaft Timing	Std.	Std.	Std.	Std.	Std.	Std.	Std.	Std.	Std.	Std.	Std.	Std.
Injector Timing	1.500"	1.500"	1.484"	1.484"	1.460"	1.460"	1.484"	1.484"	1.484"	1.484"	1.484"	1.484"
Throttle Delay Yield Link	‡ Req'd.	‡ Req'd.	‡ Req'd.	‡ Req'd.	Not Req'd.	Not Req'd.	‡ Req'd.	‡ Req'd.	‡ Req'd.	‡ Req'd.	‡ Req'd.	‡ Req'd.
Turbocharger A/R	TV 8102 1.08	TV 8102 1.08	TV 8101 1.60	TV 8101 1.60			T 18A40 1.14	TV 8102 1.2.3	TV 8102 1.23	T 18A40 1.50	TV 8101 1.84	TV 8101 1.84

* Use a minimum idle speed of 400 rpm on all coach engines with throttle delay, and a minimum idle speed of 500 rpm on all other automotive applications.

▲ TT (TTA) must have full load rpm within the range shown.

‡ .078" diameter fill hole, .016" diameter discharge orifice.

6V and 8V-92 engine cylinder liners have a 1.05" port height; 1.95:1 blower drive ratio (6V-92TA).

1977 CERTIFIED AUTOMOTIVE ENGINES

(Federal)

Engine	6V-92	8V-92	6V-92T			8V-92T			8V-92TA	
			T	OTM	TT	T	OTM	TT	T	TT
(a) Injectors	9270 9275 9280 9285	9270 9275 9280 9285	9280 9285 9290	9280 9285 9290	9290	9280 9285 9290	9280 9285 9290	9290 9A90	9290	9290
(a) Approved Minimum Constant Horsepower					Min. - Max. 240-270			365 (9290) 335 (9A90)		365
(a) Maximum Rated Speed	2100	2100	2100	2100	1950	2100	2100	2100 (9290)	2100	2100
(a) Minimum Rated Speed	2100 (9270) 1950 (9275) 1950 (9280) 2100 (9285)	2100 (9270) 1950 (9275) 1950 (9280) 2100 (9285)	2100 (9280) 1950 (9285) 1950 (9290)	2100 (9280) 1950 (9285) 1900 (9290)	1900	2100 (9280) 1950 (9285) 1950 (9290)	2100 (9280) 1950 (9285) 1900 (9290)	1800 (9A90)	1900	1900
Gear Train Timing	Std.	Std.	Std.	Std.	Std.	Std.	Std.	Std.	Std.	Std.
Injector Timing	1.460"	1.460"	1.484"	1.484"	1.484"	1.484"	1.484"	1.484"	1.484"	1.484"
Throttle Delay (Yield Link)	None	None	(f) % REQ.	(f) % REQ.	(f) % REQ.	(f) % REQ.	(f) % REQ.	(f) % REQ.	(f) % REQ.	(f) % REQ.
Setting			.636" (9290) .570" (9280 and 9285)		.636"	.636" (9290) .570" (9280 and 9285)		.636" (9290) .570" (9A90)	.636"	.636"
Liner Port Height	1.05"	1.05"	1.05"	1.05"	1.05"	1.05"	1.05"	1.05"	1.05"	1.05"
Compression Ratio	19:1	19:1	17:1	17:1	17:1	17:1	17:1	17:1	17:1	17:1
Blower Drive Ratio	2.6:1	2.6:1	2.05:1	2.05:1	2.05:1	2.05:1	2.05:1	2.05:1	2.05:1	2.05:1
Governor Type		Limiting Speed								
Thermostat		170-180° F (77-82° C) Nominal Opening Temperature								
Turbocharger A/R			T18A40 1.14	TV8102 1.23	TV8102 1.23	T18A90 1.50	TV8101 1.84	TV8101 1.84	TV8101 1.60	TV8101 1.60

(California)

Engine	6V-92		8V-92	
	TA	TTA	TT	TTA
(a) Injectors	9A80 9A85 9A90	9A90	9A80 9A85 9A90	9A90
(a) Approved Minimum Constant Horsepower		Min. - Max. 240-270		335
(a) Maximum Rated Speed	2100	1950	2100	2100
(a) Minimum Rated Speed	1950	1900	1950	1800
Gear Train Timing	Std.	Std.	Std.	Std.
Injector Timing	1.484"	1.484"	1.484"	1.484"
Throttle Delay (Yield Link)	(f) % REQ.	(f) % REQ.	(f) % REQ.	(f) % REQ.
Setting	.636" (9A90) .570" (9A80 and 9A85)	.636"	.636" (9A90) .570" (9A80 and 9A85)	.636
Liner Port Height	.950"	.950"	.950"	.950"
Compression Ratio	17:1	17:1	17:1	17:1
Blower Drive Ratio	2.05:1	2.05:1	2.05:1	2.05:1
Governor Type	Limiting Speed			
Thermostat	170-180° F (77-82° C) Nominal Opening Temperature			
Turbocharger A/R	TV8102 1.08	TV8102 1.08	TV8101 1.60	TV8101 1.60

(a) Not to exceed fuel injector size and maximum operating speed that has been established. No-load speed will vary with injector size and governor type

(f) Small fill hole (.078" Dia.), .016" discharge orifice.

% Offset piston linkage.

Use minimum idle speed of 500 rpm on all engines, except coach engines where a minimum of 400 rpm is allowed.

1978 CERTIFIED AUTOMOTIVE ENGINES

FEDERAL

ENGINE FAMILIES	6V-92	8V-92	6V-92T			8V-92T			8V-92TA	
			T	OTM	TT	T	OTM	TT	TA	TTA
INJECTORS (a)	9270 9275 9280 9285	9270 9275 9280 9285	9280 9285 9290(g)	9280 9285 9290(g)	9290(g)	9280 9285 9290(g)	9280 9285 9290(g)	9290(g) 9A90(g)	9290(g)	9290(g)
APPROVED CONSTANT HORSEPOWER FOR TT & TTA ENGINES					240-270			9290-365 9A90 335-365		365
MAXIMUM FULL LOAD SPEED (b)	2100	2100	2100	2100	2100	2100	2100	2100	2100	2100
MINIMUM FULL LOAD SPEED	9270-1950 9275-1950 9280-1950 9285-2100	9270-1950 9275-1950 9280-1950 9285-2100	1900	1900	1800	1900	1900	9290-1900 9A90-1800**	1900	1900
CAMSHAFT LOBE POSITION	STD.	STD.	STD.	STD.	STD.	STD.	STD.	STD.	STD.	STD.
INJECTOR TIMING	1.460	1.460	1.484	1.484	1.484	1.484	1.484	1.484	1.484	1.484
THROTTLE DELAY YIELD LINK	NOT REQ.	NOT REQ.	(f) REQ.	(f) REQ.	(f) REQ.	(f) REQ.	(f) REQ.	(f) REQ.	(f) REQ.	(f) REQ.
TURBOCHARGER A/R			*T18A40 1.14	TV8102 1.23	TV8102 1.23	*T18A90 1.50	TV8101 1.84	TV8101 1.84	TV8101 1.60	TV8101 1.60

**335 BHP 8V-92TT use 9A90 injectors only @ 1800 RPM.

CALIFORNIA

ENGINE FAMILIES	6V-92TAC		8V-92TAC	
	TAC	TTAC	TAC	TTAC
INJECTORS (a)	9A80 9A85 9A90(g)	9A90(g)	9A80 9A85 9A90(g)	9A90(g)
APPROVED CONSTANT HORSEPOWER FOR TTAC ENGINES		240-270		335-365
MAXIMUM (b) FULL LOAD SPEED	2100	2100	2100	2100
MINIMUM FULL LOAD SPEED	1950	1900	1950	1800
CAMSHAFT LOBE POSITION	RET.	RET.	RET	RET.
INJECTOR TIMING	1.484	1.484	1.484	1.484
THROTTLE DELAY YIELD LINK	(f) REQ.	(f) REQ.	(f) REQ.	(f) REQ.
TURBOCHARGER A/R	TV8102 1.08	TV8102 1.08	TV8101 1.60	TV8101 1.60

(a) See Engine Application Rating (Sales Tech Data Book I, Vol. 3) for specific application usage of injector size and full-load speed combination. No-load speed will vary with injector size and governor type.

(b) Use a minimum idle speed of 400 rpm on all coach engines with throttle delay and a minimum idle speed of 500 rpm on all other engines.

(f) Small fill hole (.078" dia.), .016" discharge orifice.

(g) .570" setting — gage J-25559.

1979 CERTIFIED AUTOMOTIVE ENGINES

FEDERAL ENGINES | CALIFORNIA ENGINES

FAMILIES	6V-92TA COACH	6V-92TA	6V-92TTA	8V-92TA	8V-92TTA	6V-92TAC COACH	6V-92TAC	6V-92TTAC	8V-92TAC	8V-92TTAC
Injectors	9B70 9B75 9B80	9B70, 9B75 9B80, 9B85 9B90	9B90	9A80 9A85 9A90	9A90	9B70 9B75 9B80	9B70, 9B75 9B80, 9B85 9B90	9B90	9A80 9A85 9A90	9A90
Maximum Full Load Speed	2100	2100	2100	2100	2100	2100	2100	2100	2100	2100
Minimum Full Load Speed	1800	1800	1800	1900	1800	1800	1800	1800	1900	1800
Minimum Idle Speed	500	500	500	500	500	500	500	500	500	500
Gear Train Timing	Std.	Std.	Std.	Std.	Std.	Std.	Std.	Std.	Std.	Std.
Injector Timing	1.470	1.470	1.470	1.480	1.480	1.490	1.490	1.490	1.500	1.500
Throttle Delay Setting	.636 ①	§ .504 9B90-.570	§ .570	§ .570 9A90-.636	.636 §	.636 ①	.570 § 9B90-.636	.636 §	.594 § 9A90-.660	.660 §
Liner Port Height	.95	.95	.95	.95	.95	.95	.95	.95	.95	.95
Liner Part Number	5107176	5107176	5107176	5107176	5107176	5107176	5107176	5107176	5107176	5107176
Turbocharger A/R	TV8102 1.23 A/R	TV8102 1.23 A/R	TV8102 1.23 A/R	TV8101 ▲ 1.60 A/R	TV8101 ▲ 1.60 A/R	TV8102 1.23 A/R	TV8102 1.23 A/R	TV8102 1.23 A/R	TV8101 ▲ 1.60 A/R	TV8101 ▲ 1.60 A/R
Turbocharger Part Number	5102353	5102353	5102353	‡ 5101513	‡ 5101513	5102353	5102353	5102353	‡ 5101513	‡ 5101513
Blower Drive Ratio	2.05:1	2.05:1	2.05:1	1.95:1	1.95:1	2.05:1	2.05:1	2.05:1	1.95:1	1.95:1
Blower Part Number	5101528	5101528	5101528	5101483	5101483	5101528	5101528	5101528	5101483	5101483
Compression Ratio	17:1	17:1	17:1	17:1	17:1	17:1	17:1	17:1	17:1	17:1
Exhaust Valve Material	Stellite Face Inconel X	Stellite Face Inconel X	Stellite Face Inconel X	Stellite Face Inconel X	Stellite Face Inconel X	Stellite Face Inconel X	Stellite Face Inconel X	Stellite Face Inconel X	Stellite Face Inconel X	Stellite Face Inconel X
Exhaust Valve Part Number	† 5100437	† 5100437	† 5100437	5100437	5100437	5100437	5100437	5100437	5100437	5100437
Certification Label Number	14B7-270	14B7-270	14B7-270	14B7-272	14B7-272	14B7-271	14B7-271	14B7-271	14B7-273	14B7-273

① Double fill hole (.250) .016 diameter discharge orifice.

† 6V-92TA - Carpenter valve. Available.

‡ Double 0-92 (5107590).

§ Small fill hole (.078 dia.) .016 diameter discharge orifice.

▲ Optional 5LM-864, 6.5 sq. in., 5107687.

PIN GAGE

J-25558 For .069" & .072"

TIMING GAGES

Series 53, 71 & 92

J-1853 For 1.460"
J-26888 For 1.466"
J-24236 For 1.470"
J-29065 For 1.480"
J-1242 For 1.484"
J-29066 For 1.490"
J-9595 For 1.496"
J-25454 For 1.500"
J-8909 For 1.508"
J-25502 For 1.520"

THROTTLE DELAY AND STARTING AID GAGES

J-24889 For .345"
J-28779 For .365"
J-24882 For .385"
J-9509-2 For .404"
J-23190 For .454"
J-29062 For .504"
J-25559 For .570"
J-26927 For .586" & .686"
J-25560 For .636"
J-29064 For .660"

1980 CERTIFIED AUTOMOTIVE ENGINES

	FEDERAL						CALIFORNIA					
ENGINE FAMILIES	**(b) 6V-92TA Coach**	**(b) (c) 6V-92TA Coach**	**6V-92TA**	**6V-92TTA**	**8V-92TA**	**8V-92TTA**	**(b) 6V-92TAC Coach**	**(b) (c) 6V-92TAC Coach**	**6V-92TAC**	**6V-92TTAC**	**8V-92TAC**	**8V-92TTAC**
Injectors (a)	9B70 9B75 9B80	7G65 7G70 7G75	9B90	9B90	9A90	9A90	9C70 9C75 9C80	7G65 7G70 7G75	9C90	9C90	9C90	9C90
Maximum Full Load Speed (a)	2100	2100	2100	2100	2100	2100	2100	2100	2100	2100	2100	2100
Minimum Full Load Speed	1800	1800	1800	1800	1800	1800	1900	1900	1900	1900	1900	1900
Minimum Idle Speed	500	500	500	500	500	500	500	500	700	700	700	700
Gear Train Timing	Std.	Std.	Std.	Std.	Std.	Std.	Std.	Std.	Std.	Std.	Std.	Std.
Injector Timing	1.470	1.470	1.470	1.470	1.480	1.480	1.480	1.460	1.480	1.480	1.480	1.480
Throttle Delay Setting	(e) .636	(e) .636	(d) .570	(d) .570	(d) .636	(d) .636	(e) .636	(e) .636	(d) .660	(d) .660	(d) .660	(d) .660
Turbocharger A/R	TV8102 1.23 A/R	TV7101 1.39 A/R	TV8102 1.23 A/R	TV8102 1.23 A/R	TV8101 1.60 A/R 5LM-864 6.5 Sq. In.	TV8101 1.60 A/R 5LM-864 6.5 Sq. In.	TV8102 1.08	TV7101 1.39 A/R	TV8102 1.08	TV8102 1.08	TV8101 1.39	TV8101 1.39

(a) Refer to Engine Application Rating (Sales Tech Data Book I, Vol. 3) for specific application usage of injector size and full load speed combination. No load speed will vary with injector size and governor.

(b) Use No. 1 Diesel Fuel.

(c) Engines built June, 1980 or later.

(d) Small fill hole (.078 dia.) .016 dia. discharge orifice.

(e) Double fill hole (.250 dia.) .016 dia. discharge orifice.

1980 CERTIFIED AUTOMOTIVE ENGINES

ENGINE	INJECTOR	RATED BHP	PEAK TORQUE (LB-FT)
6V-92TA (Coach #)	9B70 9B75 9B80	253 @ 2100 265 @ 2100 277 @ 2100	722 @ 1200 762 @ 1200 805 @ 1200
6V-92TA	9B90	335 @ 2100	957 @ 1300
6V-92TTA	9B90	250 @ 1800 270 @ 1950 270 @ 2100 307 @ 1900 335 @ 2100	957 @ 1300 957 @ 1300 957 @ 1300 957 @ 1300 957 @ 1300
6V-92TAC (California) (Coach)	9C70 9C75 9C80	204 @ 2100 224 @ 2100 248 @ 2100	622 @ 1300 683 @ 1300 743 @ 1300
6V-92TAC (California)	9C90	305 @ 2100	921 @ 1300
6V-92TTAC (California)	9C90	270 @ 1950 305 @ 2100	921 @ 1300 921 @ 1300
8V-92TA	9A90	435 @ 2100	1242 @ 1400
8V-92TTA	9A90	335 @ 1800 365 @ 1950 365 @ 2100 435 @ 2100	1242 @ 1400 1242 @ 1400 1242 @ 1400 1242 @ 1400
8V-92TAC (California)	9C90	405 @ 2100	1236 @ 1300
8V-92TTAC (California)	9C90	365 @ 1950 405 @ 2100	1236 @ 1300 1236 @ 1300

ALL ENGINE HORSEPOWER RATINGS ARE BASED ON SAE CONDITIONS
85°F (29.4°C) — AIR INLET TEMPERATURE
29.00 IN. HG (98.19 kPa) — BAROMETER (DRY)

No. 1 DIESEL FUEL

1981 CERTIFIED AUTOMOTIVE ENGINES

FEDERAL

ENGINE FAMILIES	6V-92TA Coach	6V-92TA	6V-92TTA	8V-92TA	8V-92TTA
Injectors (a)	7G65 7G70 7G75	9B90	9B90	9A90	9A90
Maximum Full Load Speed (a)	2100	2100	2100	2100	2100
Minimum Full Load Speed	1800	1800	1800	1900	1800
Minimum Idle Speed	500	500	500	500	500
Gear Train Timing	Std.	Std.	Std.	Std.	Std.
Injector Timing	1.470	1.470	1.470	1.480	1.480
Throttle Delay Setting	.504 (b) .636 (c)	(b) .570	(b) .570	(b) .636	(b) .636
Turbocharger A/R	TV-7101 1.39 A/R	TV-8102 1.23 A/R	TV-8102 1.23 A/R	TV-8101 1.60 A/R 5LM-864 6.5 Sq. In.	TV-8101 1.60 A/R 5LM-864 6.5 Sq. In.

CALIFORNIA

ENGINE FAMILIES	6V-92TAC Transit Coach	6V-92TAC All Others Coaches	6V-92TAC	6V-92TTAC	8V-92TAC	8V-92TTAC
Injectors (a)	9E65 9E70	7G65 7G70 7G75	9C90	9C90	9C90	9C90
Maximum Full Load Speed (a)	2100	2100	2100	2100	2100	2100
Minimum Full Load Speed	1900	1900	1900	1900	1900	1900
Minimum Idle Speed	500	700	700	700	700	700
Gear Train Timing	Std.	Std.*	Std.	Std.	Std.	Std.
Injector Timing	1.460	1.460	1.480	1.480	1.480	1.480
Throttle Delay Setting	(c) .636	(b) .636	(b) .660	(b) .660	(b) .660	(b) .660
Turbocharger A/R	TV-7101 1.23	TV-7101 1.39 A/R	TV-8102 1.08	TV-8102 1.08	TV-8101 1.39	TV-8101 1.39

(a) Refer to Engine Application Rating (Sales Tech Data Book I, Vol. 3) for specific application usage of injector size and full load speed combination. No load speed will vary with injector size and governor.

(b) Small fill hole (.078 dia.) .016 dia. discharge orifice.

(c) Double fill hole (.250 dia.) .016 dia. discharge orifice.

1981 CERTIFIED AUTOMOTIVE ENGINES

ENGINE	INJECTOR	RATED BHP	PEAK TORQUE (LB-FT)
6V-92TA (Coach)	7G65 7G70 7G75	253 @ 2100 277 @ 2100 294 @ 2100	766 @ 1200 816 @ 1300 873 @ 1300
6V-92TA	9B90	335 @ 2100	957 @ 1300
6V-92TTA	9B90	250 @ 1800 270 @ 1950 270 @ 2100 307 @ 1900 335 @ 2100	957 @ 1300 957 @ 1300 957 @ 1300 957 @ 1300 957 @ 1300
6V-92TAC (California) (Transit Coach)	9E65 9E70	240 @ 2100 260 @ 2100	798 @ 1000 846 @ 1000
6V-92TAC (California) (All Other Coaches)	7G65 7G70 7G75	230 @ 2100 253 @ 2100 271 @ 2100	744 @ 1200 800 @ 1300 856 @ 1300
6V-92TAC (California)	9C90	305 @ 2100	921 @ 1300
6V-92TTAC (California)	9C90	270 @ 1950 305 @ 2100	921 @ 1300 921 @ 1300
8V-92TA	9A90	435 @ 2100	1242 @ 1400
8V-92TTA	9A90	335 @ 1800 365 @ 1950 365 @ 2100 404 @ 1900 435 @ 2100	1242 @ 1400 1242 @ 1400 1242 @ 1400 1242 @ 1400 1242 @ 1400
8V-92TAC (California)	9C90	405 @ 2100	1236 @ 1300
8V-92TTAC (California)	9C90	365 @ 1950 405 @ 2100	1236 @ 1300 1236 @ 1300

ALL ENGINE HORSEPOWER RATINGS ARE BASED ON SAE CONDITIONS

85°F (29.4°C) — AIR INLET TEMPERATURE

29.00 IN. HG (98.19 kPa) — BAROMETER (DRY)

1982 CERTIFIED AUTOMOTIVE ENGINES

	FEDERAL					CALIFORNIA				
FAMILIES	6V-92TA Coach	6V-92TA	6V-92TTA	8V-92TA	8V-92TTA	6V-92TA Coach	6V-92TA	6V-92TTA	8V-92TA	8V-92TTA
INJECTORS	7G65 7G70 7G75	9B80 9B85 9B90	9B90	9A80 9A85 9A90 7G75 S	9A90	9E65 9E70 7G75 ⊗	9F90	9F90	7G75 Ⓢ • 9F80 9F85 9F90	9F90
MAX. FULL LOAD SPEED	2100	2100	2100	2100	2100	2100	2100	2100	2100	2100
MIN. FULL LOAD SPEED	1800	1800	1800	1800	1800	1900	1800	1800	1800	1800
MIN. IDLE SPEED	500/500 ##	500	500	500	500	⊗ ## 500/700	500	500	700	700
GEAR TR. TIMING	Std.	Std.	Std.	Std.	Std.	Std.	Std.	Std.	Std.	Std.
INJECTOR TIMING	1.470	1.470	1.470	1.466	1.466	1.460	1.520	1.520	1.520	1.520
THROTTLE DELAY SETTING ⊕	.636 .504##	%% 9B90-.570	.570%%	.570%% 9A90-.636	.636%%	X .636	9F80, 85-.570 9F90-.636	.636	9F90-.660 9F80, 85-.594	.660
LINER PORT HGHT.	.95	.95	.95	.95	.95	.95	.95	.95	.95	.95
LINER PART NO.	5107176	5107176	5107176	5107176	5107176	5107176	5107176	5107176	5107176	5107176
TURBO-CHARGER A/R	TV-7101 1.39 A/R	TV-7111 1.23 A/R	TV-7111 1.23 A/R	TV-8117 1.39 A/R	TV-8117 1.39 A/R	TV-7101 ⊗ 1.23	TV-7111 1.23 A/R	TV-7111 1.23 A/R	TV-8117 1.39 A/R	TV-8117 1.39 A/R
TURBO-CHARGER P/N	5103760	8923051	8923051	S 8923340	8923340	5101509	8923051	8923051	8923340	8923340
BLOWER DR. RATIO	2.05:1	1.95:1	1.95:1	1.95:1	1.95:1	2.05	1.95	1.95	2.00 S	2.00
BLOWER PART NO.	5101528 5104936 5103854	5101528 5104936 5103854	5101528 5104936 5103854	5101484 8920613 8923371	5101484 8920613 8923371	Ⓟ	®	®	8923474 8923476 8923475	8923474 8923476 8923475
COMP. RATIO	17:1	17:1	17:1	17:1	17:1	17:1	17:1	17:1	17:1	17:1
EXHAUST VALVE P/N	5106136	5106136	5106136	5106136	5106136	5106136	5106136	5106136	5106136	5106136
CERT. LABEL NO.	14B7-337	14B7-337	14B7-337	14B7-337	14B7-339					

S SILVER ENGINE - 7G75, 1800 RPM, TV-7111 TURBO, 8923648, 1.39 A/R (48-1), .465 THROTTLE DELAY, 1.470 INJ. TIMING, 700 RPM IDLE.

SINGLE FILL HOLE-UPRIGHT PARLOR COACH

%% SMALL FILL HOLE (.078 DIA.) .016 DIA. DISCHARGE ORIFICE

⊕ DOUBLE FILL HOLE (.250 DIA.) .016 DIA. DISCHARGE ORIFICE

Ⓟ 5101528, 5104936, 5103854

® 8923495, 8923497, 8923496

SINGLE FILL HOLE-UPRIGHT COACH

⊗ PARLOR COACH - 7G65, 70, 75 - TV-7101 A/R 1.39 (P/N 5103760) 700 RPM IDLE, .078 DIA. THROTTLE DELAY FILL HOLE

Ⓢ SILVER ENGINE - 7G75, 1800 RPM, TV-7111, 8923735, 1.39 A/R (52-3), THROTTLE DELAY .594, 1.508 INJECTOR TIMING, 1.95:1 BLOWER DRIVE RATIO, USES FEDERAL BLOWERS.

1982 CERTIFIED AUTOMOTIVE ENGINES

ENGINE	INJECTOR	RATED BHP	PEAK TORQUE (LB-FT)
6V-92TA (Coach)	7G65 7G70 7G75	253 @ 2100 277 @ 2100 294 @ 2100	766 @ 1200 816 @ 1300 873 @ 1300
6V-92TA/TTA	9B90	307 @ 1800 270 @ 1800 270 @ 2100 330 @ 2100	963 @ 1200 963 @ 1200 963 @ 1200 963 @ 1200
6V-92TAC (California) (Transit Coach)	9E65 9E70	240 @ 2100 260 @ 2100	798 @ 1000 846 @ 1000
6V-92TAC (California) (All Other Coaches)	7G65 7G70 7G75	232 @ 2100 253 @ 2100 271 @ 2100	744 @ 1200 800 @ 1300 856 @ 1300
6V-92TAC/TTAC (California)	9F90	304 @ 1800 270 @ 1800 270 @ 2100 325 @ 2100	958 @ 1200 958 @ 1200 958 @ 1200 958 @ 1200

ALL ENGINE HORSEPOWER RATINGS ARE BASED ON SAE CONDITIONS
85°F (29.4°C) — AIR INLET TEMPERATURE
29.00 IN. HG (98.19 kPa) — BAROMETER (DRY)

1982 CERTIFIED AUTOMOTIVE ENGINES

ENGINE	INJECTOR	RATED BHP	PEAK TORQUE (LB-FT)
8V-92TA (355)	7G75	355 @ 1800	1150 @ 1200
8V-92TA/TTA	9A90	365 @ 1950 365 @ 2100 445 @ 2100	1250 @ 1300 1250 @ 1300 1250 @ 1300
8V-92TAC (California 355)	7G75	355 @ 1800	1150 @ 1200
8V-92TAC/TTAC (California)	9F90	365 @ 1950 365 @ 2100 440 @ 2100	1250 @ 1300 1250 @ 1300 1250 @ 1300

Effective January 1, 1982, California allowed the use of Federal certified engines in *Public Transit Busses* and in *Authorized Emergency Vehicles* as defined in section 165 of the California Vehicle Code.

1983 CERTIFIED AUTOMOTIVE ENGINES

	FEDERAL					CALIFORNIA				
ENGINE FAMILIES	**6V-92TA Coach**	**6V-92TA/ TTA**	**8V-92TA Transit Coach**	**8V-92TA (355)**	**8V-92TA/ TTA**	**6V-92TAC Transit Coach**	**6V-92TAC All Other Coaches**	**6V-92TAC/ TTAC**	**8V-92TAC (355)**	**8V92TAC/ TTAC**
Injectors (a)	7G65 7G70 7G75	9B90	9E65 9E70	9E70	9A90	9E65 9E70	7G65 7G70 7G75	9F90	7G75	9F90
Maximum Full Load Speed (a)	2100	2100	2100	1800	2100	2100	2100	2100	1800	2100
Minimum Full Load Speed	1800	1800	1800	1800	1800	1900	1900	1800	1800	1800
Minimum Idle Speed	500	500	500	500	500	500	700	500	500	700
Gear Train Timing	Std.	Std.	Std.	Std.	Std.	Std.	Std.	Std.	Std.	Std.
Injector Timing	1.470	1.464	1.466	1.470	1.460	1.460	1.460	1.520	1.508	1.515
Throttle Delay Setting	.636 (h) .504 (f)	(f) (l)	(h) .636	DNA	(f) .594	(h) .636	(f) .636	(f) .636	DNA	(f) .660
Modulator Setting	DNA	.480	DNA	.345	.480	DNA	DNA	.480	.454	.490
Turbocharger A/R	TV7101 1.39 A/R	TV7301 1.08 A/R	TV7111 1.39 A/R	TV7301 1.23 A/R	TV8301 1.39 A/R	TV7101 1.23 A/R	TV7101 1.39 A/R	TV7111 1.23 A/R	TV7301 1.23 A/R	TV8301 1.39 A/R
Turbocharger Part No.	5103760	8924252 (m)(o) 8923051 (n)	89236498 (n)	8924682 (m)	8923340 (n) 8924254 (m)(o)	5101509	5103760	8924253 (m)(o) 8923051 (n)	8924682 (m)	8923340 (n) 8924254 (m)(o)
Blower Drive Ratio	2.05:1	1.95:1	1.95:1	1.95:1	1.95:1	2.05:1	2.05:1	1.95:1	1.95:1	1.95:1
Blower Part No.	5101528 (m)	5104936 (n) 8923953 (m) 8924627 (o)	5101484 (m)	8923954 (m)	8920613 (n) 8923954 (m) 8924629 (o)	5101528 (m)	5101528 (m)	8923495 (m) 8923496 (o) 8923497 (n)	8923954 (m) 8924629 (o)	8924047 (m) 8924630 (o) 8923475 (n)
Comparison Ratio	17:1	17:1	17:1	17:1	17:1	17:1	17:1	17:1	17:1	17:1
Exhaust Valve Part No.	5106136	5106136	5106136	5106136	5106136	5106136	5106136	5106136	5106136	5106136
Liner Part No.	5107176	5107176	5107176	5107176	5107176	5107176	5107176	5107176	5107176	5107176
Liner Port Height	.95	.95	.95	.95	.95	.95	.95	.95	.95	.95

DNA—Does not apply.

(a) Refer to Engine Application Rating (Sales Tech Data Book 1, Vol. 3) for specific application usage of injector size and full load speed combination. No load speed will vary with injector size and governor.

(f) Small fill hole (.078 dia.) .016 dia. discharge orifice.

(h) Double fill hole (.250 dia.) .016 dia. discharge orifice.

(l) 6V-92 TA with rated speed below 1900 RPM use throttle delay setting .636". For rated speed 1900 and above use .610".

(m) Front Blower - Mounted Turbo.

(n) Rear Blower - Mounted Turbo.

(o) Rear Bracket - Mounted Turbo.

1983 CERTIFIED AUTOMOTIVE ENGINES

ENGINE	INJECTOR	RATED BHP	PEAK TORQUE (LB-FT)
6V-92TA (Coach)	7G65 7G70 7G75	253 @ 2100 277 @ 2100 294 @ 2100	766 @ 1200 816 @ 1300 873 @ 1300
6V-92TA/TTA	9B90	307 @ 1800 270 @ 1800 270 @ 2100 330 @ 2100	963 @ 1200 963 @ 1200 963 @ 1200 963 @ 1200
6V-92TAC (California) (Transit Coach)	9E65 9E70	240 @ 2100 260 @ 2100	798 @ 1000 846 @ 1000
6V-92TAC (California) (All Other Coaches)	7G65 7G70 7G75	232 @ 2100 253 @ 2100 271 @ 2100	744 @ 1200 800 @ 1300 856 @ 1300
6V-92TAC/TTAC (California)	9F90	304 @ 1800 270 @ 1800 270 @ 2100 325 @ 2100	958 @ 1200 958 @ 1200 958 @ 1200 958 @ 1200

1983 CERTIFIED AUTOMOTIVE ENGINES

ENGINE	INJECTOR	RATED BHP	PEAK TORQUE (LB-FT)
8V-92TA (Transit Coach)	9E65 9E70	330 @ 2100 345 @ 2100	1043 @ 1200 1090 @ 1200
8V-92TA (355)	9E70	355 @ 1800	1150 @ 1200
8V-92TA/TTA	9A90	365 @ 1950 365 @ 2100 445 @ 2100	1250 @ 1300 1250 @ 1300 1250 @ 1300
8V-92TAC (California 355)	7G75	355 @ 1800	1150 @ 1200
8V-92TAC/TTAC (California)	9F90	365 @ 1950 365 @ 2100 440 @ 2100	1250 @ 1300 1250 @ 1300 1250 @ 1300

ALL ENGINE HORSEPOWER RATINGS ARE BASED ON SAE CONDITIONS

85°F (29.4°C) — AIR INLET TEMPERATURE

29.00 IN. HG (98.19 kPa) — BAROMETER (DRY)

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1984 CERTIFIED AUTOMOTIVE ENGINES

FEDERAL

ENGINE FAMILIES	6V-92TA Coach	6V-92TA (1600 RPM)	6V-92TA/TTA	8V-92TA Transit Coach	8V-92TA (355)	8V-92TA (1600 RPM)	8V-92TA/TTA
Injectors (a)	7G65 7G70 7G75	9E85	9B90	9E65 9E70	7G75	9E80	9A90
Maximum Full Load Speed (a)	2100	1600	2100	2100	1800	1600	2100
Minimum Full Load Speed	1800	1600	1750	2100	1800	1600	1800
Minimum Idle Speed	500	500	500	500	500	500	500
Gear Train Timing	Std.	Std.	Std.	Std.	Std.	Std.	Std.
Injector Timing	1.470	1.500	1.475	1.470	1.470	1.496	1.470
Throttle Delay Setting	636 (h) 504 (f)	DNA	(f) .636	(h) .636	DNA	DNA	(f) .594
Modulator Setting	DNA	.404	.465	DNA	.465	.404	.404
Turbocharger A/R	TV7101 1.39 A/R	TV7301 1.08 A/R	TV7301 1.08 A/R	TV7111 1.39 A/R	TV7301 1.23 A/R	TV7301 1.23 A/R	TV8301 1.39 A/R

6V Cam Assy. — LB 8926265 (Fed.)
6V Cam Assy. — RB 8926264 (Fed.)
8V Cam Assy. — LB 8926246 (Fed.)
8V Cam Assy. — RB 8926245 (Fed.)
6V Cam Assy. — LB 5108111 (Cal.)
6V Cam Assy. — RB 5108112 (Cal.)
8V Cam Assy. — LB 5108117 (Cal.)
8V Cam Assy. — RB 5108118 (Cal.)

ENGINE	INJECTOR	RATED BHP	PEAK TORQUE (LB-FT.)
6V-92TA (Coach)	7G65 7G70 7G75	253 @ 2100 277 @ 2100 294 @ 2100	766 @ 1200 816 @ 1300 873 @ 1300
6V-92TA (1600 RPM)	9E85	290 @ 1600	1015 @ 1000
6V-92TA/ TTA	9B90	307 @ 1800 270 @ 1800 270 @ 2100 330 @ 2100	963 @ 1200 963 @ 1200 963 @ 1200 963 @ 1200
6V-92TAC (California) (Transit Coach)	9E65 9E70	240 @ 2100 260 @ 2100	798 @ 1000 846 @ 1000
6V-92TAC (California) (All Other Coaches)	7G65 7G70 7G75	232 @ 2100 253 @ 2100 271 @ 2100	744 @ 1200 800 @ 1300 856 @ 1300
6V-92TAC/ TTAC (California)	9F90	304 @ 1800 270 @ 1800 270 @ 2100 325 @ 2100	958 @ 1200 958 @ 1200 958 @ 1200 958 @ 1200
8V-92TA (Transit Coach)	9E65 9E70	330 @ 2100 345 @ 2100	1043 @ 1200 1090 @ 1200
8V-92TA (1600 RPM)	9E80	350 @ 1600	1275 @ 1000
8V-92TA (355)	7G75	355 @ 1800	1150 @ 1200
8V-92TA/ TTA	9A90	365 @ 1950 365 @ 2100 400 @ 1800 445 @ 2100	1250 @ 1300 1250 @ 1300 1250 @ 1300 1250 @ 1300
8V-92TAC (California 355)	7G75	355 @ 1800	1150 @ 1200
8V-92TAC/ TTAC (California)	9F90	365 @ 1950 365 @ 2100 440 @ 2100	1250 @ 1300 1250 @ 1300 1250 @ 1300

ALL ENGINE HORSEPOWER RATINGS ARE BASED ON SAE J1349 CONDITIONS

CALIFORNIA

ENGINE FAMILIES	6V-92TAC TRANSIT COACH	6V-92TAC ALL OTHER COACHES	6V-92TAC/TTAC	8V-92TAC (355)	8V-92TAC/TTAC
Injectors (a)	9E65 9E70	7G65 7G70 7G75	9F90	7G75	9F90
Maximum Full Load Speed (a)	2100	2100	2100	1800	2100
Minimum Full Load Speed	1900	1900	1800	1800	1800
Minimum Idle Speed	500	700	500	500	700
Gear Train Timing	Std.	Std.	Std.	Std.	Std.
Injector Timing	1.460	1.460	1.520	1.508	1.520
Throttle Delay Setting	(h) .636	(f) .636	DNA	DNA	(f) .660
Modulator Setting	DNA	DNA	.490	.454	.490
Turbocharger A/R	TV-7101 1.23 A/R	TV-7101 1.39 A/R	TV-7301 1.23 A/R	TV-7301 1.23 A/R	TV-8301 1.39 A/R

DNA Does not apply.

(a) Refer to Engine Application Rating (Sales Tech Data Book 18SA315) for specific application usage of injector size and full load speed combination. No load speed will vary with injector size and governor.

(f) Small fill hole (.078 dia.) .016 dia. discharge orifice.

(h) Double fill hole (.250 dia.) .016 dia. discharge orifice.

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1985 CERTIFIED AUTOMOTIVE ENGINES

ENGINE	INJECTOR	RATED BHP	RPM	PEAK TORQUE (LB-FT)	RPM	MAX FL SPEED	MIN FL SPEED	MIN IDLE SPEED	INJECTOR TIMING	THROTTLE DELAY SETTING	FUEL MODULATOR SETTING	TURBO	A/R
6V-92T (AIR/AIR)	9K85	290	1600	1050	1000	1600	1600	500	1.475	DNA	.454	TA-7501	2.59
	9J85	300	1800	975	1200	1800	1750	500	1.464	DNA	.465	TA-7501	2.69
6V-92TA (1600 RPM)	9E85	290	1600	1015	1000	1600	1600	500	1.480	DNA	.385	TV-7511	1.08
6V-92TA	9B80	268	1800	862	1200	2100	1800	500	1.470	.570	DNA	TV-7111	1.23
	9B80	286	2100	862	1200	2100	1800	500	1.470	.570	DNA	TV-7111	1.23
	9B90	307	1800	963	1200	2100	1800	500	1.470	.570	DNA	TV-7111	1.23
	9B90	330	2100	963	1200	2100	1800	500	1.470	.570	DNA	TV-7111	1.23
	9G85	300	1800	975	1200	1800	1750	500	1.466	DNA	.465	TV-7511	1.08
	9G90	350	2100	1020	1200	2100	1900	500	1.466	.636	.480	TV-7511	1.08
6V-92TTA	9B90	270	1800	963	1200	2100	1800	500	1.470	.570	DNA	TV-7111	1.23
	9B90	270	2100	963	1200	2100	1800	500	1.470	.570	DNA	TV-7111	1.23
	9G85	270	1800	975	1200	1800	1750	500	1.466	DNA	.465	TV-7511	1.08
	9G85	270	2100	975	1200	2100	1750	500	1.466	DNA	.465	TV-7511	1.08
	9G90	300	2100	1020	1200	2100	1900	500	1.466	.636	.480	TV-7511	1.08
6V-92TAC (CAL)	9F85	294	1800	950	1200	2100	1800	500	1.520	.660	.490	TV-7511	1.23
	9F85	320	2100	950	1200	2100	1800	500	1.520	.660	.490	TV-7511	1.23
	9F90	300	1800	1000	1200	2100	1800	500	1.520	DNA	.490	TV-7511	1.23
	9F90	340	2100	1000	1200	2100	1800	500/700***	1.520	.660	.490	TV-7511	1.23
6V-92TTAC (CAL)	9F90	270	2100	1000	1200	2100	1800	500/700***	1.520	.660	.490	TV-7511	1.23
	9F90	300	2100	1000	1200	2100	1800	500/700***	1.520	.660	.490	TV-7511	1.23
6V-92TA (ALCC)	9H85	300	1800	975	1200	1800	1750	500	1.475	DNA	.454	TV-7511	1.08
6V-92TA (COACH)	9F70, 9T70 #1	245	2100	775	1200	2100	1800	500	1.460	.594	DNA	TV-7511	0.96
	9F70, 9T70 #2	253	2100	775	1200	2100	1800	500	1.460	.594	DNA	TV-7511	0.96
	9G75, 9S75 #1	260	2100	823	1200	2100	1800	500	1.460	.594	DNA	TV-7511	0.96
	9G75, 9S75 #2	277	2100	840	1200	2100	1800	500	1.460	.594	DNA	TV-7511	0.96
	9F80, 9S80 #1	280	2100	849	1200	2100	1800	500	1.460	.636	DNA	TV-7511	1.08
	9F80, 9S80 #2	294	2100	875	1200	2100	1800	500	1.460	.636	DNA	TV-7511	1.08
	9H85 #1	315	2100	976	1200	2100	1800	700	1.460	.636	.480	TV-7511	1.08
	9H85 #2	325	2100	1007	1200	2100	1800	700	1.460	.636	.480	TV-7511	1.08
6V-92TAC (COACH/CAL)	9E65, 9S65 #1	230	2100	793	1000	2100	1800	500	1.470	.636	DNA	TV-7511	1.08
	9E65, 9S65 #2	240	2100	825	1000	2100	1800	500	1.470	.636	DNA	TV-7511	1.08
	9E70, 9S70 #1	245	2100	835	1000	2100	1800	500	1.470	.636	DNA	TV-7511	1.08
	9E70, 9S70 #2	260	2100	872	1000	2100	1800	500	1.470	.636	DNA	TV-7511	1.08
	9F80, 9S80 #1	255	2100	846	1000	2100	1800	500	1.470	.636	DNA	TV-7511	1.08
	9F80, 9S80 #2	270	2100	882	1000	2100	1800	500	1.470	.636	DNA	TV-7511	1.08
	9F90 #1	310	2100	954	1200	2100	2100	500	1.470	.660	DNA	TV-7511	1.23
	9F90 #2	320	2100	989	1200	2100	2100	500	1.470	.660	DNA	TV-7511	1.23
6V-92TA (PARLOR) (COACH)	9F70 #2	253	2100	775	1200	2100	1800	500	1.460	.504	DNA	TV-7511	0.96
	9G75 #2	277	2100	840	1200	2100	1800	500	1.460	.504	DNA	TV-7511	0.96
	9F80 #2	300	2100	893	1200	2100	1800	500	1.460	.504	.454	TV-7511	0.96
	9H85 #2	330	2100	1007	1200	2100	1800	500	1.460	.636	.480	TV-7511	1.08
8V-92TA (1600 RPM)	9E80	350	1600	1250	1000	1600	1600	500	1.470	DNA	.385	TV-8512	1.23
8V-92TA	7G75	350	1800	1175	1200	1800	1800	500	1.460	DNA	.385	TV-8512	1.23
	9G85	400	1800	1250	1300	2100	1800	500	1.458	DNA	.404	TV-8511	1.39
	9G85	450	2100	1250	1300	2100	1800	500	1.458	.594	.404	TV-8511	1.39
	9G90	475	2100	1330	1300	2100	1900	500	1.458	.610	.454	TV-8511	1.39
8V-92TTA	9G85	365	1900	1250	1300	2100	1800	500	1.458	.594	.404	TV-8511	1.39
	9G90	400	2100	1330	1300	2100	1900	500	1.458	.610	.454	TV-8511	1.39
8V-92TAC (CAL)	7G75	350	1800	1175	1200	1800	1800	500	1.508	DNA	.454	TV-8512	1.23
	9F90	400	1800	1250	1300	2100	1800	700	1.520	DNA	.490	TV-8511	1.39
	9F90	450	2100	1250	1300	2100	1800	700	1.520	.660	.490	TV-8511	1.39
8V-92TTAC (CAL)	9F90	400	2100	1250	1300	2100	1800	700	1.520	.660	.490	TV-8511	1.39
8V-92TA (ALCC)	7G75	350	1800	1175	1200	1800	1800	500	1.470	DNA	.404	TV-8512	1.23
	9G85	400	1800	1250	1300	1800	1800	500	1.475	DNA	.454	TV-8511	1.39
8V-92TA (COACH)	9E65 #2	340	2100	1134	1000	2100	2100	500	1.470	.636	DNA	TV-8512	1.23
	9E70 #2	365	2100	1187	1000	2100	2100	500	1.470	.636	DNA	TV-8512	1.23
8V-92TA (PARLOR) (COACH)	9A80 #2	404	2100	1143	1300	2100	2100	500	1.458	.594	.404	TV-8511	1.39

TA Turbocharged/Jacket Water Aftercooled.
TTA Constant Horsepower/Turbocharged/Jacket Water Aftercooled.
All Engine Horsepower Ratings Are Based On SAE J 1349 Conditions.
*** Minimum Idle Speed: 500 W/Fuel Modulator, 700 W/Throttle Delay.

ALCC Advanced Liquid Charge Cooling.
DNA Does Not Apply.

#1 Diesel Fuel #1.
#2 Diesel Fuel #2.

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1986 CERTIFIED AUTOMOTIVE ENGINES

ENGINE	INJECTOR	RATED BHP	RPM	PEAK TORQUE (LB-FT)	RPM	MAX FL SPEED	MIN FL SPEED	MIN IDLE SPEED	INJECTOR TIMING	THROTTLE DELAY SETTING	FUEL MODULATOR SETTING	TURBO	A/R
6V-92T	9K85	290	1600	1050	1000	1600	1600	500	1.496	DNA	.454	TA-7501	2.59
(AIR/AIR)	9J85	300	1800	975	1200	1800	1750	500	1.464	DNA	.465	TA-7502	2.95
6V-92TA (1600 RPM)	9E85	290	1600	1015	1000	1600	1600	500	1.480	DNA	.385	TV-7511	1.08
6V-92TAC	9F85	306	2100	917	1200	2100	1950	700	1.520	.570	.454	TV-7111	1.23
(CAL) @	9F90	325	2100	958	1200	2100	1950	700	1.520	.636	.480	TV-7111	1.23
6V-92TA	9G85	300	1800	975	1200	1800	1800	500	1.466	DNA	.465	TV-7511	1.08
	9G90	350	2100	1020	1200	2100	2100	500	1.466	.636	.480	TV-7511	1.08
6V-92TTA	9G85	270	1800	975	1200	1800	1800	500	1.466	DNA	.465	TV-7511	1.08
	9G85	270	2100	975	1200	2100	2100	500	1.466	DNA	.465	TV-7511	1.08
	9G90	300	2100	1020	1200	2100	2100	500	1.466	.636	.480	TV-7511	1.08
6V-92TAC	9F85	320	2100	950	1200	2100	1950	500	1.520	.660	.490	TV-7511	1.23
(CAL)	9F90	300	1800	1000	1200	2100	1800	500	1.520	DNA	.490	TV-7511	1.23
	9F90	340	2100	1000	1200	2100	1800	500/700***	1.520	.660	.490	TV-7511	1.23
6V-92TTAC	9F90	270	2100	1000	1200	2100	1800	500/700***	1.520	.660	.490	TV-7511	1.23
(CAL)	9F90	300	2100	1000	1200	2100	1800	500/700***	1.520	.660	.490	TV-7511	1.23
	9F90	270	1800	1000	1200	1800	1800	500/700***	1.520	.660	.490	TV-7511	1.23
6V-92TA (ALCC)	9H85	300	1800	975	1200	1800	1800	500	1.475	DNA	.454	TV-7511	1.08
6V-92TA	9F70, 9T70 #1	245	2100	775	1200	2100	2100	500	1.460	.594	DNA	TV-7511	0.96
(COACH)	9F70, 9T70 #2	253	2100	775	1200	2100	2100	500	1.460	.594	DNA	TV-7511	0.96
	9G75, 9S75 #1	260	2100	823	1200	2100	2100	500	1.460	.594	DNA	TV-7511	0.96
	9G75, 9S75 #2	277	2100	840	1200	2100	2100	500	1.460	.594	DNA	TV-7511	0.96
	9F80, 9S80 #1	280	2100	849	1200	2100	2100	500	1.460	.636	DNA	TV-7511	1.08
	9F80, 9S80 #2	294	2100	875	1200	2100	2100	500	1.460	.636	DNA	TV-7511	1.08
	9H85 #1	315	2100	976	1200	2100	2100	700	1.460	.636	.480	TV-7511	1.08
	9H85 #2	325	2100	1007	1200	2100	2100	700	1.460	.636	.480	TV-7511	1.08
6V-92TAC	9E65, 9S65 #1	230	2100	793	1000	2100	2100	500	1.470	.636	DNA	TV-7511	1.08
(COACH/CAL)	9E65, 9S65 #2	240	2100	825	1000	2100	2100	500	1.470	.636	DNA	TV-7511	1.08
	9E70, 9S70 #1	245	2100	835	1000	2100	2100	500	1.470	.636	DNA	TV-7511	1.08
	9E70, 9S70 #2	260	2100	872	1000	2100	2100	500	1.470	.636	DNA	TV-7511	1.08
	9F80, 9S80 #1	255	2100	846	1000	2100	2100	500	1.470	.636	DNA	TV-7511	1.08
	9F80, 9S80 #2	270	2100	882	1000	2100	2100	500	1.470	.636	DNA	TV-7511	1.08
	9F90 #1	310	2100	954	1200	2100	2100	500	1.470	.660	DNA	TV-7511	1.23
	9F90 #2	320	2100	989	1200	2100	2100	500	1.470	.660	DNA	TV-7511	1.23
6V-92TA	9F70 #2	253	2100	775	1200	2100	2100	500	1.460	.504	DNA	TV-7511	0.96
(PARLOR)	9G75 #2	277	2100	840	1200	2100	2100	500	1.460	.504	DNA	TV-7511	0.96
(COACH)	9F80 #2	300	2100	893	1200	2100	2100	500	1.460	.504	.454	TV-7511	0.96
	9H85 #2	330	2100	1007	1200	2100	2100	500	1.460	.636	.480	TV-7511	1.08
8V-92TA (1600 RPM)	9E80	350	1600	1250	1000	1600	1600	500	1.470	DNA	.454	TV-8512	1.23
8V-92TA	7G75	350	1800	1175	1200	1800	1800	500	1.460	DNA	.385	TV-8512	1.23
	9G85	400	1800	1250	1300	2100	1800	500	1.458	DNA	.404	TV-8511	1.39
	9G85	450	2100	1250	1300	2100	1800	500	1.458	.594	.404	TV-8511	1.39
	9G90	475	2100	1330	1300	2100	2100	500	1.458	.610	.454	TV-8511	1.39
8V-92TTA	9G90	400	2100	1330	1300	2100	1900	500	1.458	.610	.454	TV-8511	1.39
8V-92TAC	7G75	350	1800	1175	1200	1800	1800	500	1.508	DNA	.454	TV-8512	1.23
(CAL)	9F90	400	1800	1250	1300	2100	1800	700	1.520	DNA	.490	TV-8511	1.39
	9F90	450	2100	1250	1300	2100	1800	700	1.520	.660	.490	TV-8511	1.39
8V-92TTAC (CAL)	9F90	400	2100	1250	1300	2100	1800	700	1.520	.660	.490	TV-8511	1.39
8V-92TA	7G75	350	1800	1175	1200	1800	1800	500	1.470	DNA	.454	TV-8512	1.23
(ALCC)	9G85	400	1800	1250	1300	1800	1800	500	1.475	DNA	.465	TV-8511	1.39
8V-92TA	9E65 #2	340	2100	1134	1000	2100	2100	500	1.470	.636	DNA	TV-8512	1.23
(COACH)	9E70 #2	365	2100	1187	1000	2100	2100	500	1.470	.636	DNA	TV-8512	1.23
8V-92TA (PARLOR) (COACH)	9A80 #2	404	2100	1143	1300	2100	2100	500	1.458	.594	.404	TV-8511	1.39

NOTES:

TA Turbocharged/Jacket Water Aftercooled.
TTA Constant Horsepower/Turbocharged/Jacket Water Aftercooled.
All Engine Horsepower Ratings Are Based On SAE J1349 Conditions.
Specifications Subject to Change Without Notice.

JWAC Jacket Water Aftercooled.
AIR/AIR Air-to-Air Charge Cooling.
ALCC Advanced Liquid Charge Cooling.

#1 Diesel Fuel #1.
#2 Diesel Fuel #2.
DNA Does Not Apply.
@ With Blower 8923497.

*** Minimum Idle Speed: 500 W/Fuel Modulator, 700 W/Throttle Delay.

1987 CERTIFIED AUTOMOTIVE ENGINES

ENGINE	INJECTOR	RATED BHP	RPM	PEAK TORQUE (LB-FT)	RPM	MAX FL SPEED	MIN FL SPEED	MIN IDLE SPEED	INJECTOR TIMING	THROTTLE DELAY SETTING	FUEL MODULATOR SETTING	TURBO	A/R
6V-92T	9K85	290	1600	1050	1200	1600	1600	500	1.496	DNA	.454	TA-7501	2.59
(AIR/AIR)	9J85	300	1800	975	1200	1800	1750	500	1.464	DNA	.465	TA-7502	2.95
6V-92T (DDEC) (AIR/AIR)	5234770	300	1800	1050	1200	1800	1800	500	1.460	DNA	DNA	TA-7502	2.95
6V-92T (A/A) DDEC-CAL	5234770	300	1800	1050	1200	1800	1800	500	1.460	DNA	DNA	TA-7502	2.95
6V-92TA (1600 RPM)	9E85	290	1600	1015	1000	1600	1600	500	1.480	DNA	.385	TV-7511	1.08
6V-92TA	9G85	300	1800	975	1200	1800	1800	500	1.466	DNA	.465	TV-7511	1.08
	9G90	350	2100	1020	1200	2100	1900	500	1.466	.636	.480	TV-7511	1.08
6V-92TA (JWAC) +	5234770	300	1800	975	1200	1800	1800	500	1.460	DNA	DNA	TV-7511	1.08
(DDEC) +	5234770	350	2100	1020	1200	2100	2100	500	1.460	DNA	DNA	TV-7511	1.08
6V-92TTA	9G85	270	1800	975	1200	1800	1800	500	1.466	DNA	.465	TV-7511	1.08
	9G85	270	2100	975	1200	2100	2100	500	1.466	DNA	.465	TV-7511	1.08
	9G90	300	2100	1020	1200	2100	2100	500	1.466.	.636	.480	TV-7511	1.08
6V-92TAC	9F85	320	2100	950	1200	2100	1950	500	1.520	.660	.490	TV-7511	1.23
(CAL)	9F90$	325	2100	958	1200	2100	1800	700	1.520	.636	.480	TV-7511	1.23
	9F90	300	1800	1000	1200	2100	1800	500	1.520	DNA	.490	TV-7511	1.23
	9F90	340	2100	1000	1200	2100	1800	500/700***	1.520	.660	.490	TV-7511	1.23
	9F80	300	2100	920	1200	2100	1800	500	1.520	.660	.490	TV-7511	1.08
6V-92TTAC	9F90	270	2100	1000	1200	2100	1800	500/700***	1.520	.660	.490	TV-7511	1.23
(CAL)	9F90	300	2100	1000	1200	2100	1800	500/700***	1.520	.660	.490	TV-7511	1.23
	9F90	270	1800	1000	1200	1800	1800	500/700***	1.520	.660	.490	TV-7511	1.23
6V-92TA	9H85	300	1800	975	1200	1800	1800	500	1.475	DNA	.454	TV-7511	1.08
(ALCC)	DDEC	300	1800	975	1200	1800	1800	500	1.460	DNA	.454	TV-7511	1.08
6V-92TA	9E60,#1	205	2100	672	1000	2100	2100	500	1.475	.636	DNA	TV-7503	1.08
	9E60,#2	220	2100	710	1000	2100	2100	500	1.475	.636	DNA	TV-7503	1.08
(COACH)	9F70,9T70#1	245	2100	775	1200	2100	2100	500	1.460	.594	DNA	TV-7511	0.96
	9F70,9T70#2	253	2100	775	1200	2100	2100	500	1.460	.594	DNA	TV-7511	0.96
	9G75,9S75#1	260	2100	823	1200	2100	2100	500	1.460	.594	DNA	TV-7511	0.96
	9G75,9S75#2	277	2100	840	1200	2100	2100	500	1.460	.594	DNA	TV-7511	0.96
	9F80,9S80#1	280	2100	849	1200	2100	2100	500	1.460	.636	DNA	TV-7511	1.08
	9F80,9S80#2	294	2100	875	1200	2100	2100	500	1.460	.636	DNA	TV-7511	1.08
	9H85#1	315	2100	976	1200	2100	2100	500	1.460	.636	.480	TV-7511	1.08
	9H85#2	325	2100	1007	1200	2100	2100	500	1.460	.636	.480	TV-7511	1.08
6V-92TA	5234850#1	245	2100	757	1200	2100	2100	500	1.460	DNA	DNA	TV-7511	0.96
(DDEC)	5234850#1	245	2100	823	1200	2100	2100	500	1.460	DNA	DNA	TV-7511	0.96
(COACH)	5234850#2	253	2100	780	1200	2100	2100	500	1.460	DNA	DNA	TV-7511	0.96
	5234850#2	253	2100	840	1200	2100	2100	500	1.460	DNA	DNA	TV-7511	0.96
	5234850#1	260	2100	823	1200	2100	2100	500	1.460	DNA	DNA	TV-7511	0.96
	5234850#2	277	2100	840	1200	2100	2100	500	1.460	DNA	DNA	TV-7511	0.96
6V-92TA (DDEC)	5234850	300	1950	1042	1300	1950	1950	600	1.460	DNA	DNA	TV-7511	0.96
(PARLOR)	5234850	287	1950	893	1200	1950	1950	600	1.460	DNA	DNA	TV-7511	0.96
(COACH)	5234850#2	300	2100	893	1200	2100	2100	600	1.460	DNA	DNA	TV-7511	0.96
	5234850#1	285	2100	870	1200	2100	2100	600	1.460	DNA	DNA	TV-7511	0.96
6V-92TAC (DDEC)	5234850#2	260	2100	867	1000	2100	2100	500	1.460	DNA	DNA	TV-7511	0.96
(COACH/CAL)	5234850#1	245	2100	815	1000	2100	2100	500	1.460	DNA	DNA	TV-7511	0.96
6V-92TAC	9E65#1	230	2100	793	1000	2100	2100	500	1.470	.636	DNA	TV-7511	1.08
(COACH/CAL)	9E65#2	240	2100	825	1000	2100	2100	500	1.470	.636	DNA	TV-7511	1.08
	9E70#1	245	2100	835	1000	2100	2100	500	1.470	.636	DNA	TV-7511	1.08
	9E70#2	260	2100	872	1000	2100	2100	500	1.470	.636	DNA	TV-7511	1.08
	9F80#1	255	2100	846	1000	2100	2100	500	1.470	.636	DNA	TV-7511	1.08
	9F80#2	270	2100	882	1000	2100	2100	500	1.470	.636	DNA	TV-7511	1.08
6V-92TAC	9F90#1	310	2100	954	1200	2100	2100	500	1.470	.660	DNA	TV-7511	1.23
(COACH/CAL)	9F90#2	320	2100	989	1200	2100	2100	500	1.470	.660	DNA	TV-7511	1.23
6V-92TA (PARLOR	9F80#2	300	2100	893	1200	2100	2100	500	1.460	.504	.454	TV-7511	0.96
COACH)	9H85#2	330	2100	1007	1200	2100	2100	500	1.460	.636	.454	TV-7511	1.08
8V-92TA (1600 RPM)	9E80	350	1600	1250	1000	1600	1600	500	1.470	DNA	.454	TV-8512	1.23
8V-92TA	7G75	350	1800	1175	1200	1800	1800	500	1.460	DNA	.385	TV-8512	1.23
	9G85	400	1800	1250	1300	2100	1800	500	1.458	DNA	.404	TV-8511	1.39
	9G85	450	2100	1250	1300	2100	1800	500	1.458	.594	.404	TV-8511	1.39
	9G90†	475	2100	1330	1300	2100	2100	500	1.475	.570	.404	TV-8511	1.39
8V-92TA	5234770	400	1800	1315	1300	1800	1800	500	1.460	DNA	DNA	TV-8511	1.23
(DDEC)	5234775†	475	2100	1425	1300	2100	2100	500	1.460	DNA	DNA	TV-8511	1.39
	+5234770	450	2100	1330	1300	2100	2100	500	1.460	DNA	DNA	TV-8511	1.39
	5234770	400	2100	1330	1300	2100	2100	500	1.460	DNA	DNA	TV-8511	1.23
8V92TAC DDEC-CAL	5234770	400	1800	1315	1300	1800	1800	500	1.460	DNA	DNA	TV-8511	1.39
8V-92TTA	9G90	400	2100	1330	1300	2100	2100	500	1.458	.570	.404	TV-8511	1.39
8V-92TAC	7G75	350	1800	1175	1200	1800	1800	500	1.508	DNA	.454	TV-8512	1.23
(CAL)	9F90	400	1800	1250	1300	1800	1800	700	1.520	.660	.490	TV-8511	1.39
	9F90	450	2100	1250	1300	2100	1800	700	1.520	.660	.490	TV-8511	1.39
8V-92TTAC (CAL)	9F90	400	2100	1250	1300	2100	700	1800	1.520	.660	.490	TV-8511	1.39
8V-92TA	7G75	350	1800	1175	1200	1800	1800	500	1.470	DNA	.454	TV-8512	1.23
(ALCC)	9G85	400	1800	1250	1300	1800	1800	500	1.475	DNA	.465	TV-8511	1.39
8V-92TA	9E65#2	340	2100	1134	1000	2100	2100	500	1.470	.636	DNA	TV-8512	1.23
(PARLOR	9E70#2	365	2100	1187	1000	2100	2100	500	1.470	.636	DNA	TV-8512	1.23
COACH)	9A80#2	404	2100	1143	1300	2100	2100	500	1.458	.594	.404	TV-8511	1.39
8V-92TA (DDEC) (PARLOR COACH)	5234770#2	400	2100	1150	1300	2100	2100	500	1.460	DNA	DNA	TV-8511	1.23

NOTES: ***Minimum Idle Speed: 500 w/Fuel Modulator, 700 w/Throttle Delay.
$ Non Bypass Blower
† Full-Sized Blower

+Pending 4-87
#1 Diesel Fuel #1
#2 Diesel Fuel #2

DNA — Does Not Apply
AIR/AIR — Air to Air Charge Cooling
ALCC — Advanced Liquid Charge Cooling
TA — Turbocharged/Jacket Water Aftercooled.

TTA — Constant Horsepower/Turbocharged/Jacket Water Aftercooled.
All Engine Horsepower Ratings are Based on SAE J1349 Conditions.
Specifications Subject to Change without Notice.

Truck Models

ENGINE	CERTI-FICATION	INJECTOR	RATED BHP	RPM	PEAK TORQUE (LB-FT)	RPM	MAX FL SPEED	MIN FL SPEED	MIN IDLE SPEED	INJECTOR TIMING	FUEL MODULATOR SETTING	TURBO	A/R
6V-92T (A/A DDEC)	F	5234915	300	1800	1050	1200	DNA	DNA	500	1.520	DNA	TA-7503	2.95 Sq. In.
6V-92TAC (DDEC)	C	5234915	300	2100	975	1200	DNA	DNA	500	1.520	DNA	TV-7512	1.08
6V-92TA (DDEC)	F	5234775	350	2100	1020	1200	DNA	DNA	500	1.520	DNA	TV-7512	1.23
	F	5234915	300	1800	975	1200	DNA	DNA	500	1.520	DNA	TV-7512	1.08
6V-92TA (MUI)	F	9G90	350	2100	995	1200	DNA	DNA	500	1.480	.454	TV-7512	1.23
8V-92TA (DDEC)	F	5234775	475	2100	1425	1200	DNA	DNA	600	1.520	DNA	TV-8513	1.39
	F	5234775	475	2100	1350	1200	DNA	DNA	600	1.520	DNA	TV-8513	1.39
	F	5234915	400	1800	1315	1200	DNA	DNA	600	1.520	DNA	TV-8513	1.23
8V-92TA (MUI)	F	9G85	445	2100	1330	1200	DNA	DNA	500	1.480	.404	TV-8513	1.39
8V92TAC (DDEC)	C	5234775	450	2100	1425	1200	DNA	DNA	600	1.520	DNA	TV-8513	1.39
	C	5234915	400	1800	1315	1200	DNA	DNA	600	1.520	DNA	TV-8513	1.23

Coach Models

ENGINE	CERTI-FICATION	INJECTOR	RATED BHP	RPM	PEAK TORQUE (LB-FT)	RPM	MAX FL SPEED	MIN FL SPEED	MIN IDLE SPEED	INJECTOR TIMING	FUEL MODULATOR SETTING	TURBO	A/R
6V-92TA (DDEC)	F	5234775#2◇	330	2100	1020	1200	DNA	DNA	600	1.520	DNA	TV-7512	1.23
	F	5234915#2◇	300	1950	1050	1200	DNA	DNA	600	1.520	DNA	TV-7512	1.08
	F	5234915#1◇	285	2100	800	1200	DNA	DNA	600	1.520	DNA	TV-7512	1.08
	F	5234915#2◇	300	2100	880	1200	DNA	DNA	600	1.520	DNA	TV-7512	1.08
	F	5234915#1◇	276	1950	800	1200	DNA	DNA	600	1.520	DNA	TV-7512	1.08
	F	5234915#2◇	289	1950	890	1200	DNA	DNA	600	1.520	DNA	TV-7512	1.08
	F	5234915#1■	260	2100	800	1200	DNA	DNA	600	1.520	DNA	TV-7512	0.96
	F	5234915#2■	277	2100	880	1200	DNA	DNA	600	1.520	DNA	TV-7512	0.96
	F	5234915#1■	245	2100	705	1200	DNA	DNA	600	1.520	DNA	TV-7512	0.96
	F	5234915#2■	253	2100	775	1200	DNA	DNA	600	1.520	DNA	TV-7512	0.96
6V-92TA (MUI)	F	9G85◇	330	2100	990	1200	DNA	DNA	500	1.475	.404	TV-7512	1.23
	F†	9F80◇	300	2100	890	1200	DNA	DNA	500	1.466	.365	TV-7512	1.08
	F†	9G75#2■	277	2100	880	1000	DNA	DNA	500	1.475	.594*	TV-7511	0.96
	F†	9F70#2■	253	2100	825	1000	DNA	DNA	500	1.475	.594*	TV-7511	0.96
	F†	9G75#1■	267	2100	867	1000	DNA	DNA	500	1.475	.594*	TV-7511	0.96
	F†	9F70#1■	245	2100	814	1000	DNA	DNA	500	1.475	.594*	TV-7511	0.96
6V-92TAC (DDEC)	C	5234915#2◇	300	2100	975	1200	DNA	DNA	500	1.520	DNA	TV-7512	1.08
	C	5234915#2◇	300	2100	820	1200	DNA	DNA	500	1.520	DNA	TV-7512	1.08
	C	5234915#1■	260	2100	815	1000	DNA	DNA	600	1.520	DNA	TV-7512	1.08
	C	5234915#2■	277	2100	880	1200	DNA	DNA	600	1.520	DNA	TV-7512	1.08
	C	5234915#1■	245	2100	730	1000	DNA	DNA	600	1.520	DNA	TV-7512	0.96
	C	5234915#2■	253	2100	775	1200	DNA	DNA	600	1.520	DNA	TV-7512	0.96
8V-92TA (DDEC)	F	5234775◇	475	2100	1350	1200	DNA	DNA	600	1.520	DNA	TV-8513	1.39
	F	5234915◇	400	2100	1150	1200	DNA	DNA	600	1.520	DNA	TV-8513	1.23
8V-92TAC (MUI)	F	9F80◇	400	2100	1235	1200	DNA	DNA	500	1.470	.404	TV-8513	1.23
8V-92TAC (DDEC)	C	5234775◇	450	2100	1425	1200	DNA	DNA	600	1.520	DNA	TV-8513	1.39
	C	5234915◇	400	2100	1150	1200	DNA	DNA	600	1.520	DNA	TV-8513	1.23

DNA = Does Not Apply ◇ = Parlor ■ = Transit #1-Diesel Fuel #1 #2 = Diesel Fuel #2
* Throttle Delay
† Data Also Applies to 9S80, 9S75 and 9T70 Injectors

EXHAUST VALVE CLEARANCE ADJUSTMENT

The correct exhaust valve clearance at normal engine operating temperature is important for smooth, efficient operation of the engine.

Insufficient valve clearance can result in loss of compression, misfiring cylinders and, eventually, burned valve seats and valve seat inserts. Excessive valve clearance will result in noisy operation, increased valve face wear and valve lock damage.

Whenever the cylinder head is overhauled, the exhaust valves are reconditioned or replaced, or the valve operating mechanism is replaced or disturbed in any way, the valve clearance must be adjusted to the cold setting to allow for normal expansion of the engine parts during the engine warm–up period. This will ensure a valve setting that is close enough to the specified clearance to prevent damage to the valves when the engine is started.

The exhaust valve bridges must be adjusted and the adjustment screws locked securely at the time the cylinder head is installed on the engine. The necessary adjustment procedure is outlined in Section 1.2.2.

The exhaust valve bridge balance should be checked when a general valve adjustment is performed. After the bridges are balanced, adjust the valve clearance at the *push rod only.*

Do not disturb the exhaust valve bridge adjusting screw.

All of the exhaust valves may be adjusted in firing order sequence during one full revolution of the crankshaft. Refer to the *General Specifications* at the front of the manual for the engine firing order.

Valve Clearance Adjustment (Cold Engine)

1. If not done previously, clean the loose dirt from the exterior of the engine and remove the valve rocker covers. Discard the gaskets. Then, cover any drain cavities in the cylinder head to prevent foreign material from entering.
2. Place the governor speed control lever in the *idle speed* position. If a stop lever is provided, secure it in the *stop* position.
3. Rotate the crankshaft, with engine barring tool J 22582 or with the starting motor, until the injector follower is fully depressed on the particular cylinder to be adjusted. If a wrench or barring tool is used on the crankshaft bolt at the front of the engine, do not turn the crankshaft in a left–hand direction of rotation because the bolt may be loosened.

CAUTION: To reduce the risk of personal injury when barring over or "bumping" the starter while performing an engine tune–up, personnel should keep their hands and clothing away from the engine as there is a remote possibility the engine could start.

4. Loosen the exhaust valve rocker arm push rod locknut.
5. Place a .016" feeler gage (J 9708–01) between the valve bridge and the valve rocker arm pallet (Fig. 1). Adjust the push rod to obtain a smooth "pull" on the feeler gage.

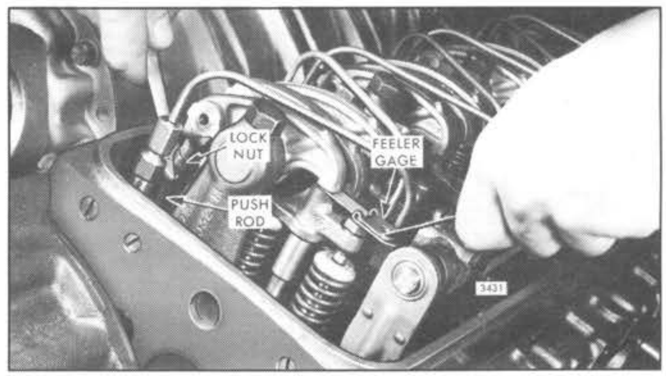


Fig. 1 – Adjusting Valve Clearance

6. Remove the feeler gage. Hold the push rod with a 5/16" wrench and tighten the locknut with a 1/2" wrench.
7. Recheck the clearance. At this time, if the adjustment is correct, the .015" gage will pass freely between the valve bridge and the rocker arm pallet, but the .017" gage will not pass through. Readjust the push rod, if necessary.
8. Adjust and check the remaining exhaust valves in the same manner as above.

Valve Clearance Adjustment (Hot Engine)

It is *not* necessary to make a final hot engine exhaust valve clearance adjustment after a cold engine adjustment has been performed. However, if a hot engine adjustment is desired, use the following procedure.

Maintaining normal engine operating temperature is particularly important when making the hot engine exhaust valve clearance adjustment. If the engine is allowed to cool off before setting any of the valves, the clearance, when running at full load, may become insufficient.

NOTICE: Since these adjustments are normally made while the engine is stopped, it may be necessary to run the engine between adjustments to maintain normal operating temperature.

1. With the engine at normal operating temperature (refer to Section 13.2), set the exhaust valve clearance with feeler gage J 9708–01. At this time, if the valve clearance is correct, the .013" gage will pass freely between the valve bridge and the valve rocker arm pallet, but the .015" feeler gage will not pass through. Readjust the push rod, if necessary.
2. After the exhaust valve clearance has been adjusted, check the fuel injector timing (Section 14.2).

Check Exhaust Valve Clearance Adjustment

1. With the engine at 100°F (38°C) or less, check the valve clearance.
2. If a .016" feeler gage ± .004" will pass between the valve bridge and the valve rocker arm pallet, the valve clearance is satisfactory. If necessary, adjust the push rod.

FUEL INJECTOR TIMING

To time an injector properly, the injector follower must be adjusted to a definite height in relation to the injector body.

All of the injectors can be timed in firing order sequence during one full revolution of the crankshaft. Refer to *General Specifications* in the *General Information* Section at the front of the manual for the engine firing order.

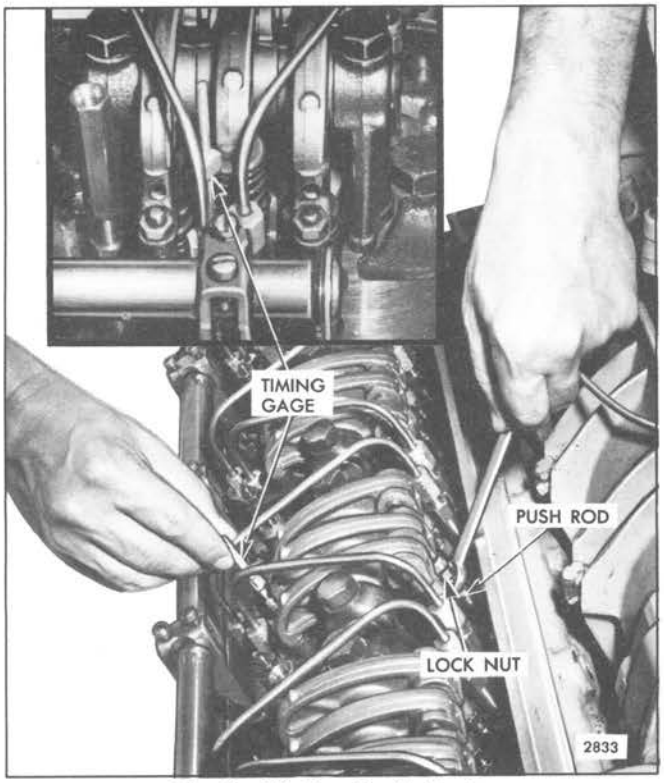


Fig. 1 – Timing Fuel Injector

Time Fuel Injector

After the exhaust valve clearance has been adjusted (Section 14.1), time the fuel injectors as follows:

1. Place the governor speed control lever in the *idle speed* position. If a stop lever is provided, secure it in the *stop* position.
2. Rotate the crankshaft, with the starting motor or with engine barring tool J 22582, until the exhaust valves are fully depressed on the particular cylinder to be timed. If a wrench is used on the crankshaft bolt at the front of the engine, do not turn the crankshaft in a left-hand direction of rotation because the bolt could be loosened.

CAUTION: To reduce the risk of personal injury when barring over or "bumping" the starter while performing an engine tune-up, personnel should keep their hands and clothing away from the engine as there is a remote possibility the engine could start.

3. Place the small end of the injector timing gage (refer to Table 1 or Section 14 for the correct timing gage) in the hole provided in the top of the injector body with the flat of the gage toward the injector follower (Fig. 1).

• Injector	Timing Dimension	Timing Gage	Camshaft Timing
9270	1.460"	J 1853	Standard
9275*	1.460"	J 1853	Standard
9280*	1.460"	J 1853	Standard
9285*	1.460"	J 1853	Standard
9290*	1.460"	J 1853	Standard
9295#	1.484"	J 1242	Standard
9200†	1.484"	J 1242	Standard
9215	1.484"	J 1242	Standard
M15@	1.460"	J 1853	Standard
M15**	1.470"	J 24236	Standard

* Turbocharged engines use 1.484" timing (gage J1242).
† 16V 92T (1800 rpm generator set – 860 bhp).
# Generator set only.
• For automotive applications, refer to Section 14.
@ Marine pleasurecraft and all purpose industrial (non-FP). Exceptions: Models 8063-7400, 8083-7400 use 1.470".
** All purpose industrial (FP).

TABLE 1 – INJECTOR TIMING

4. Loosen the injector rocker arm push rod locknut.
5. Turn the push rod and adjust the injector rocker arm until the extended part of the gage will just pass over the top of the injector follower.
6. Hold the push rod and tighten the locknut. Check the adjustment and, if necessary, readjust the push rod.
7. Time the remaining injectors in the same manner as outlined above.
8. If no further engine tune-up is required, reinstall the valve rocker covers, using new gaskets.

LIMITING SPEED MECHANICAL GOVERNOR

INJECTOR RACK CONTROL ADJUSTMENT

6V AND 8V ENGINES

Two types of limiting speed mechanical governors are used. The difference between each type of governor is in the high–speed spring retainer and spring housing assembly. Certain engines use the standard limiting speed governor while some engine applications use the dual range limiting speed governor. The only variation in the tune–up procedure between each type of governor is in the setting of the maximum no–load speed.

After adjusting the exhaust valves and timing the fuel injectors, adjust the governor and position the injector rack control levers.

Before proceeding with the governor and injector rack adjustments, disconnect any supplementary governing device. After the adjustments are completed, reconnect and adjust the supplementary. governing device as outlined in Section 14.14.

Back out the external starting aid screw.

On "TT" engines, back out the Belleville spring retainer nut until there is approximately .060" clearance between the washers and the retainer nut (Fig. 1).

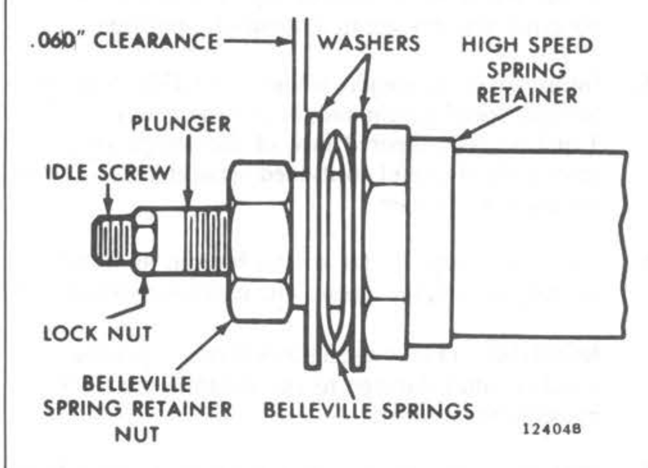


Fig. 1 – Belleville Washer Location

ADJUST GOVERNOR GAP

A properly adjusted governor gap will accomplish the following:

- Provide sufficient weight travel in the idle range to prevent stalling during deceleration. A tight gap reduces weight travel in the idle range.
- Provide enough weight travel in the high speed control range to prevent engine overspeed with light loads at full throttle. A loose gap reduces weight travel in the high speed range.
- Prevent the force generated by the low speed weights (double weight governors) from compressing the high speed spring. If the gap is too tight, the force of the heavy idle weights operating on the high speed spring will cause the high speed spring to compress at too low a speed, resulting in low power.

DOUBLE WEIGHT GOVERNOR

The gap on double weight limiting speed governors may be set using the "static" or the "engine–on" method. The "static" or *weight pry* method allows the technician to set the gap accurately in the most efficient, cost effective manner. For this reason DDC recommends using this method whenever possible.

Static Method

The following procedure is accomplished with the engine *stopped* using governor weight wedge tool J 35516.

CAUTION: To avoid personal injury and prevent possible engine damage, the following precautions should be observed:

•Make sure the turbocharger compressor inlet guard or compressor air inlet shield J 26554–A is installed any time the engine is running and the turbocharger air inlet piping is removed. The use of these guards does not preclude any other safety practices contained in this service manual.

•After replacing the governor cover and before starting the engine, make sure the injector racks move to the "no fuel" position when the governor stop lever is in the "stop" position.

Verification of the governor gap setting should not be considered necessary until "Vehicle Low Power/Performance at Low Mileage" (section 15.2) has been used to troubleshoot an engine performance concern.

Checking the Gap

1. In a vehicle, set the engine idle speed at 600 RPM and stop the engine.

   NOTICE: This static governor gap setting is established at the factory based upon a 600 RPM engine idle. Therefore, when *verifying* a factory tune–up the governor idle speed should be set at 600 RPM.

   CAUTION: Disconnect the grounded battery cable(s) to prevent accidental engine cranking and possible personal injury while the gap is being checked or set.

2. Clean and remove the governor cover. Discard the gasket.

3. With the engine stopped, manually bar the engine over *in the direction of normal engine rotation* until the governor weights are in a horizontal position.

   On "TT" governors, the Belleville spring retainer nut must be backed out until there is approximately .060" clearance between the washers and the retainer nut before checking or resetting the governor gap.

4. Insert governor weight wedge J35516 between the low–speed weight and the governor riser (see Figs. 2, 3 and 4). The tapered face of the wedge should be against the riser and positioned between the flanges on the ends of the riser.

5. Push the wedge as far to the bottom as it will go, forcing the weights against the maximum travel stop.

   NOTICE: Do not use a screwdriver to pry the weights, since damage to the weights, riser or housing could result.

6. While holding the wedge in the bottom position, use a feeler gauge to measure the gap between the low speed spring cap and the high speed spring plunger (see Figs. 5 and 6). The gap should measure .003" – .019". Reset the gap to .008" if the measured gap is out of limits (see "GOVERNOR GAP ADJUSTMENT PROCEDURE" below).

7. Remove the wedge and replace the governor cover, using a new gasket.

8. Reset Belleville springs (see Section 14.3.5 of the Service Manual).

GOVERNOR GAP ADJUSTMENT PROCEDURE

These procedures permit adjusting the gap while the governor is installed on an engine or removed and on a bench.

Before adjusting the gap on "TT" governors, the Belleville spring retainer nut must be backed out until there is approximately .060" clearance between the washers and the retainer nut (see Fig. 5).

A. Setting The Gap — Governor On The Engine

1. Disconnect any supplementary governor devices.

2. Set the engine idle speed at 600 RPM and stop the engine.

   CAUTION: Disconnect the grounded battery cable(s) to prevent accidental engine cranking and possible personal injury while the gap is being checked or set.

3. Clean and remove the governor cover. Discard the gasket.

4. With the engine stopped, manually bar the engine over *in the direction of normal engine rotation* until the governor weights are in a horizontal position.

5. Insert governor weight wedge Tool J35516 between the low–speed weight and the governor riser (see Figs. 3 and 4). The tapered face of the wedge should be against the riser and positioned between the flanges on the ends of the riser.

6. Push the wedge as far to the bottom as it will go, forcing the weights against the maximum travel stop.

   NOTICE: Do not use a screwdriver to pry the weights, since damage to the weights, riser or housing could result.

7. With the wedge in the bottom position, use a feeler gauge to set the gap between the low speed spring cap and the high speed spring plunger at .008". Then tighten the governor gap adjusting screw lock nut (see Figs. 5 and 6).

8. Push down on the governor weight wedge tool to be sure it did not move while the gap was being set. Recheck the gap while holding the tool in this position. If the gap is incorrect, reset to .008", repeating the steps outlined above.

9. Remove the wedge.

The buffer, idle speed, no–load speed and starting aid screws, the injector racks and supplemental governor devices require adjustment whenever the governor gap is changed.

10. Reset Belleville springs (see Section 14.3.5 of the Engine Service Manual).

B. Setting The Gap — Governor On A Bench

NOTICE: When setting the governor gap on a bench, the governor *must* be mounted on a blower to support and protect the governor weight carrier shaft.

1. Position the idle screw. On all non–"TT" governors with a normal 1.00" long idle adjustment screw, the screw should be set so that it extends .325". On all "TT" governors with a normal 1.00" long idle adjustment screw, the screw should be set to extend .400". This dimension is measured from the face of the idle speed adjusting screw lock nut to the end of the idle speed adjusting screw with a tolerance of ± .015" (see Fig. 5). For governors with a variable high–speed option, which use a 1.75" long idle adjustment screw, the screw should be set to extend 1.075" on all non–"TT" governors or 1.150" on all "TT" governors. These idle screw projections result in a nominal 600 RPM idle speed.

2. Rotate the governor weights until they are in a horizontal position.

3. Insert governor weight wedge Tool J35516 between the low–speed weight and the governor riser (see Figs. 3 and 4). The tapered face of the wedge should be against the riser and positioned between the flanges on the ends of the riser. To prevent the weights from rotating when the governor weight wedge tool is inserted, a clean, soft rag should be wedged between the blower housing and the blower rotors.

4. Push the wedge as far to the bottom as it will go, forcing the weights against the maximum travel stop.

NOTICE: Do not use a screwdriver to pry the weights, since damage to the weights, riser or housing could result.

5. Check to make sure that the governor high–speed spring plunger is seated. Turn in the high–speed retainer as required to seat the plunger.

6. With the wedge in the bottom position, use a feeler gauge between the low speed spring cap and the high speed spring plunger to set the gap at .008". Then tighten the governor gap adjusting screw lock nut (see Figs. 5 and 6).

7. Push down on the governor weight wedge tool to be sure it did not move while the gap was being set. Recheck the gap while holding the tool in this position. If the gap is incorrect, reset to .008", repeating the steps outlined above.

8. Remove the wedge and reinstall the cover using a new gasket.

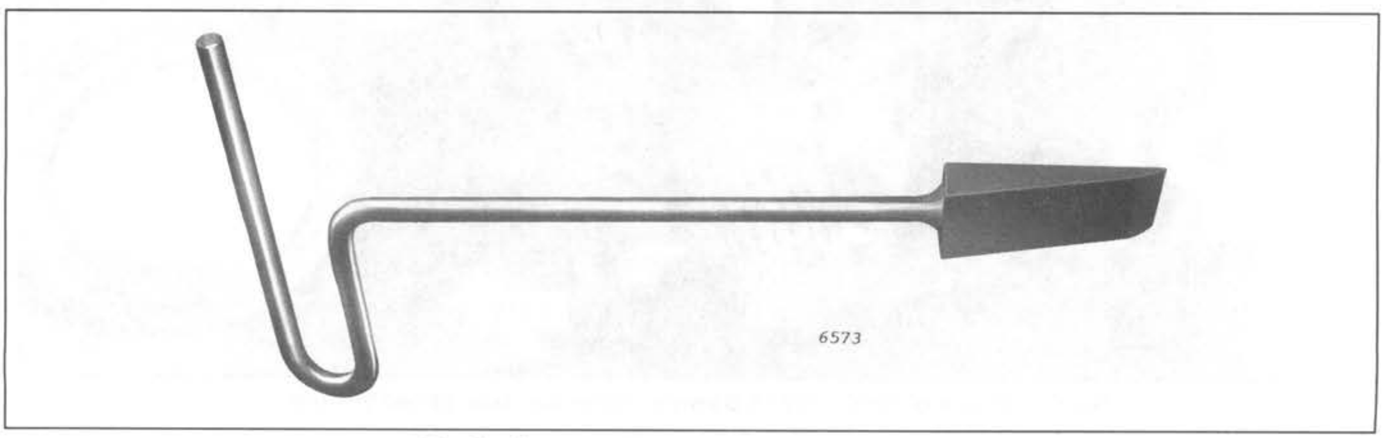


Fig. 2 – Governor Weight Wedge Tool J35516

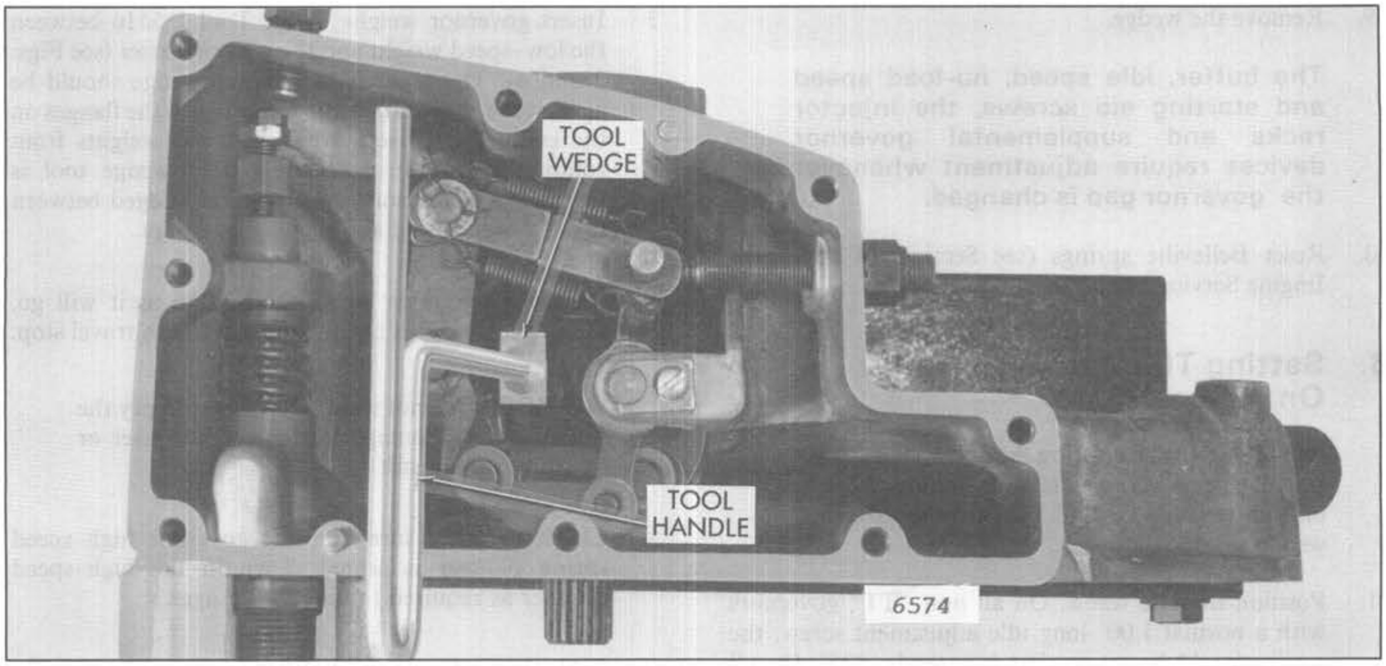


Fig. 3 – Tool J35516 Inserted Between Low Speed Weight and Riser

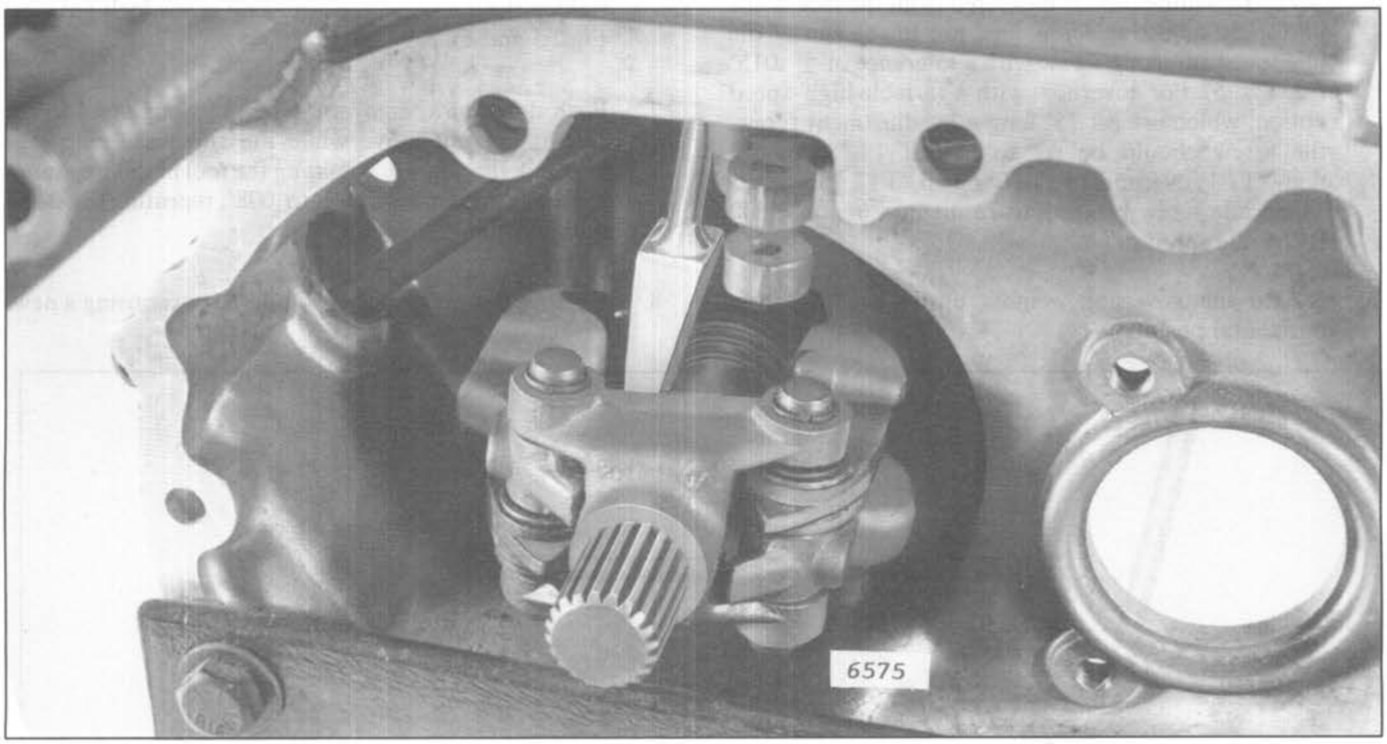


Fig. 4 – Wedge of Tool J35516 Between Riser and Low Speed Weight

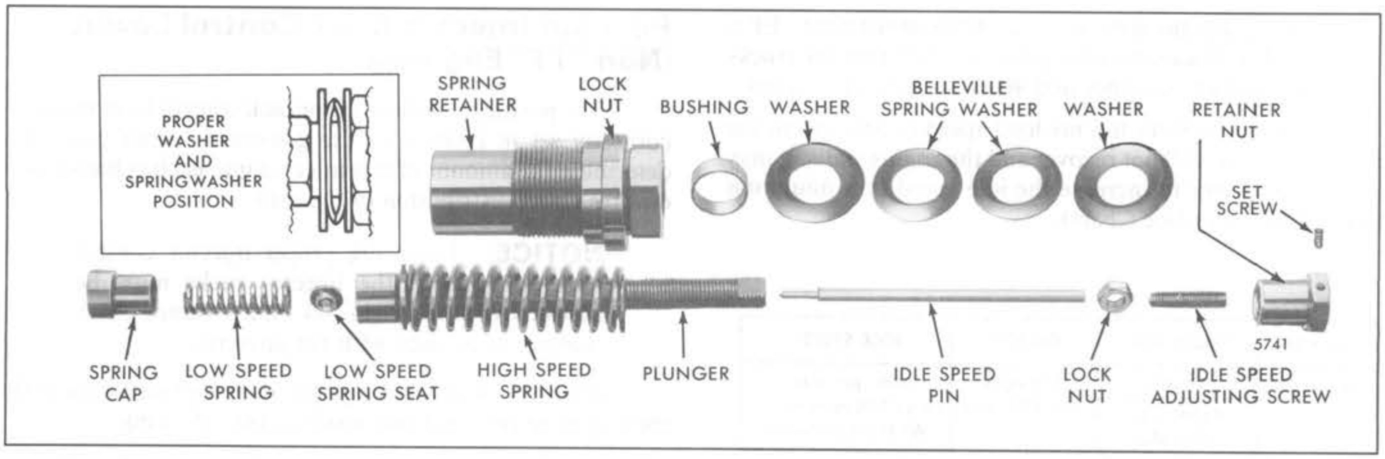


Fig. 5 – High and Low-Speed Springs and Plunger Details Including Belleville Washers (TTA-Fuel Squeezer Engines)

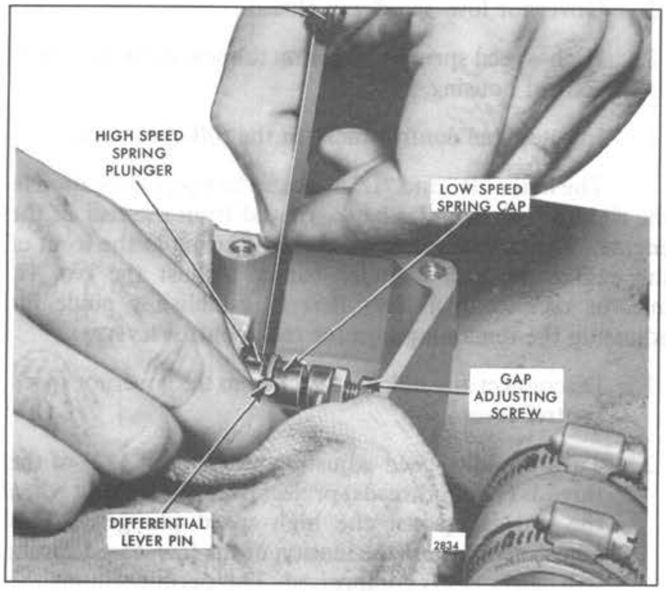


Fig. 6 – Adjusting Governor Gap

ADJUST GOVERNOR GAP

ENGINE ON METHOD

Double Weight Governor

With the engine stopped and at normal operating temperature, adjust the governor gap as follows:

CAUTION: If the gap adjustment is to be made with the engine in the vehicle, it is suggested that the fan assembly be removed due to the closeness of the fan blades to the engine governor.

1. Remove the high-speed spring retainer cover.
2. Back out the buffer screw until it extends approximately 5/8" from the locknut (Fig. 17).
3. Start the engine and loosen the idle speed adjusting screw locknut. Then, adjust the idle screw to obtain the desired engine idle speed (Fig. 16). Hold the screw and tighten the locknut to hold the adjustment. For "TT" engines, set the idle speed to 500 rpm. EPA certified minimum idle speeds are 500 rpm for trucks and highway coaches and 400 rpm for city coaches.
4. Stop the engine. Clean and remove the governor cover and lever assembly and the valve rocker covers. Discard the gaskets.
5. Start and run the engine between 1100 and 1300 rpm by manual operation of the differential lever. Do not overspeed the engine.
6. Check the gap between the low-speed spring cap and the high-speed spring plunger with a feeler gage (Fig. 6). The gap should be .002"-.004". If the gap setting is incorrect, reset the gap adjusting screw.
7. Recheck the gap with the engine operating between 1100 and 1300 rpm and readjust, if necessary.
8. Stop the engine and, using a new gasket, install the governor cover and lever assembly. Tighten the screws.

Single Weight Governor

With the engine stopped and at normal operating temperature, adjust the governor gap as follows:

NOTICE: If the gap adjustment is to be made with the engine in the vehicle, it is suggested that the fan assembly be removed due to the closeness of the fan blades to the engine governor.

1. Remove the high-speed spring retainer cover.
2. Back out the buffer screw until it extends approximately 5/8" from the locknut (Fig. 17).
3. Start the engine and loosen the idle speed adjusting screw locknut. Then, adjust the idle screw to obtain the desired engine idle speed (Fig. 16). Hold the screw

and tighten the locknut to hold the adjustment. EPA certified minimum idle speeds are 500 rpm for trucks and highway coaches and 400 rpm for city coaches.

If, in going from top no-load speed to idle speed, the engine governor will not recover and the engine stalls, it may become necessary to increase the idle speed to a minimum speed of 600 rpm (see Chart).

ENGINE	INJECTOR	DROOP	IDLE SPEED
6 and 8V Turbo	90 mm Regardless of Prefix	175 rpm (was 125 rpm)	600 rpm min. (was 500 rpm min.) All Injector Sizes

4. Stop the engine. Clean and remove the governor cover and lever assembly and the valve rocker cover. Discard the gaskets.
5. Remove the fuel rod from the differential lever and the injector control tube lever.
6. Check the gap between the low–speed spring cap and the high–speed spring plunger with gage J 23478 (.200") – (Fig. 7). Be sure the external starting aid screw (if used) is backed out far enough to make it ineffective when making this adjustment.
7. If required, loosen the locknut and turn the gap adjusting screw until a slight drag is felt on the gage.
8. Hold the adjusting screw and tighten the locknut.
9. Recheck the gap and readjust, if necessary.
10. Install the fuel rod between the govenor and injector control tube lever.
11. Use a new gasket and install the governor cover and lever assembly.

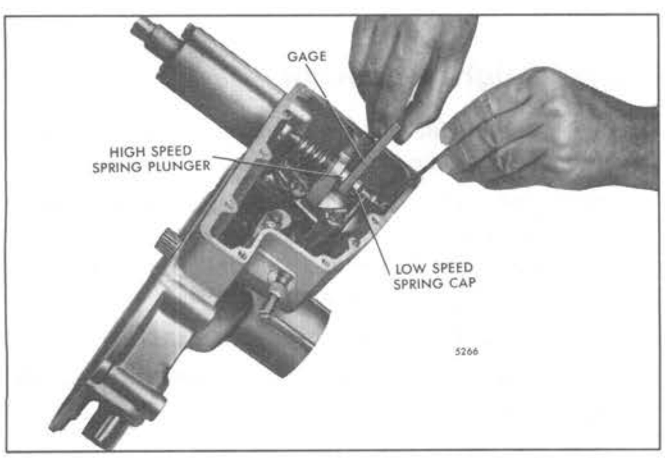


Fig. 7 – Adjusting Governor Gap (Single Weight Governor) with Feeler Gage J 23478

Position Injector Rack Control Levers (Non "TT" Engines)

The positions of the injector rack control lever must be correctly set in relation to the governor. Their positions determine the amount of fuel injected into each cylinder and ensures equal distribution of the load.

NOTICE: To ensure proper injector control rack adjustment, the injector racks must be adjusted with the yield link and governor cover that are to be used with the governor.

Properly positioned injector rack control levers with the engine at full load will result in the following:

1. Speed control lever at the *maximum speed* position.
2. Governor low–speed gap closed.
3. High–speed spring plunger on the seat in the governor control housing.
4. Injector fuel control racks in the *full–fuel* position.

The letter "R" and "L" indicate the injector location in the right or left cylinder bank, viewed from the rear of the engine. The cylinders are numbered starting at the front of the engine on each cylinder bank. Adjust the No. 1L injector rack control lever first to establish a guide for adjusting the remaining injector rack control levers.

1. Disconnect any linkage attached to the governor speed control lever.
2. Turn the idle speed adjusting screw until 1/2" of the threads (12–14 threads) project from the locknut when the nut is against the high–speed plunger. This adjustment lowers the tension of the low–speed spring so it can be easily compressed. This permits closing the low–speed gap without bending the fuel rods or causing the *yield mechanism springs to yield or stretch*. A false fuel rack setting may result if the idle speed adjusting screw is not backed out as noted above.

Injector racks must be adjusted so the effort to move the throttle from the *idle speed* position to the *maximum speed* position is uniform. A sudden increase in effort can result from:

a. Injector racks adjusted too tight causing the yield link to separate.
b. Binding of the fuel rods.
c. Failure to back out idle screw.

3. Back out the buffer screw approximately 5/8", if it has not already been done.
4. Remove the clevis pin from the fuel rod and the right cylinder bank injector control tube lever.

5. Loosen all of the inner and outer injector rack control lever adjusting screws or adjusting screws and locknuts. Be sure all of the injector rack control levers are free on the injector control tubes.

6. Move the speed control lever to the *maximum speed* position and hold it in that position with light finger pressure (Fig. 8 or 9).

Two Screw Assembly

Turn the inner adjusting screw of the No. 1L injector rack control lever down until a slight movement in the control tube lever is observed or a step–up in effort to turn the screwdriver is noted (Fig. 8). This will place the No. 1L injector rack in the *full–fuel* position. Turn down the outer adjusting screw until it bottoms lightly on the injector control tube. Then, alternately tighten both the inner and outer adjusting screws.

One Screw and Locknut Assembly

Tighten the adjusting screw of the No. 1L injector rack control lever until the injector rack clevis is observed to roll up or an increase in effort to turn the screwdriver is noted (Fig. 9). Tighten the screw approximately 1/8 of a turn more and lock securely with the adjusting screw locknut. This will place the No. 1L injector rack in the *full–fuel* position.

NOTICE: Overtightening of the injector rack control lever adjusting screws during installation or adjustment can result in damage to the injector control tube. The recommended torque of the adjusting screws is 24–36 **lb–in** (3–4 N•m).

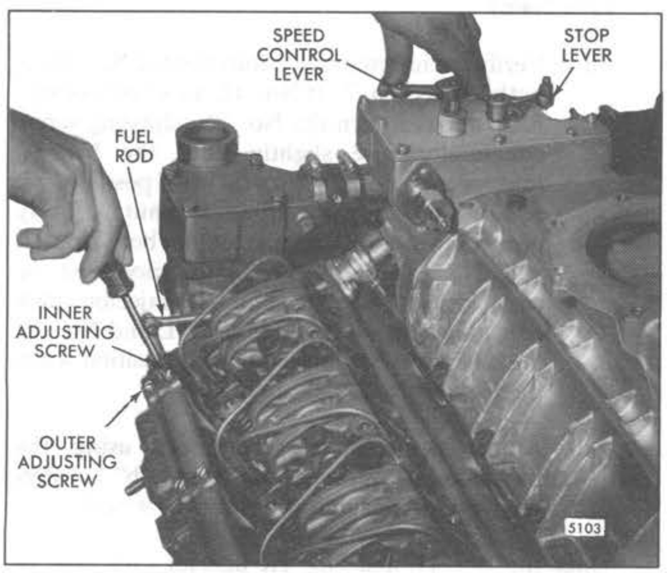


Fig. 8 – Positioning No. 1 Injector Rack Control Lever (Two Screw Assembly)

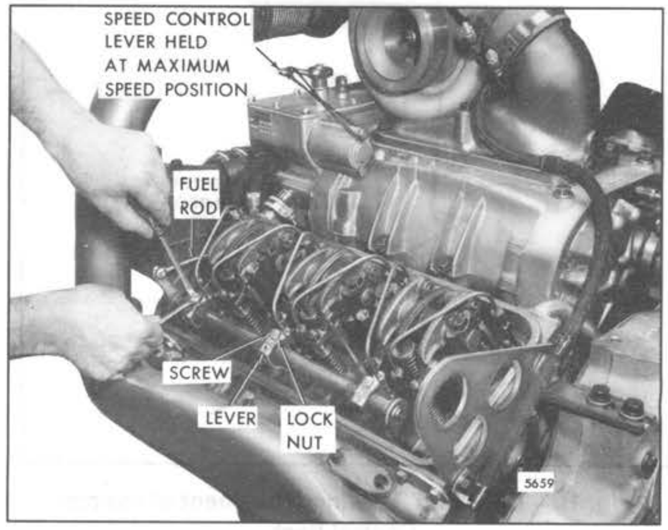


Fig. 9 – Position No. 1 Injector Rack Control Lever (One Screw and Locknut Assembly)

The above step should result in placing the governor linkage and control tube assembly in the same position that they will attain while the engine is running at full load.

7. To be sure of the proper rack adjustment, hold the speed control lever in the *maximum speed* position and press down on the injector rack with a screwdriver or finger tip and note the "rotating" movement of the injector control rack (Fig. 10). Hold the speed control lever in the *maximum speed* position and, using a screwdriver, press downward on the injector control rack. The rack should tilt downward, and when the pressure of the screwdriver is released, the control rack should "spring" back upward (Fig. 11).

If the rack does not return to its *original* position, it is too loose. To correct this condition with the *Two Screw Assembly*, back off the outer adjusting screw slightly and tighten the inner adjusting screw slightly. To correct this condition with the *One Screw and Locknut Assembly*, loosen the locknut and turn the adjusting screw clockwise a slight amount and retighten the locknut.

The setting is too tight if, when moving the speed control lever from the *no–speed* to the *maximum speed* position, the injector rack becomes tight before the speed control lever reaches the end of its travel (as determined by the stop under the governor cover). This will result in a step–up in effort required to move the speed control lever to the end of its travel. To correct this condition with the *Two Screw Assembly*, back off the inner adjusting screw slightly and tighten the outer adjusting screw slightly. To correct this condition with the *One Screw and Locknut Assembly*, loosen the locknut and turn the adjusting screw counterclockwise a slight amount and retighten the locknut.

8. Remove the clevis pin from the fuel rod and the left bank injector control tube lever.

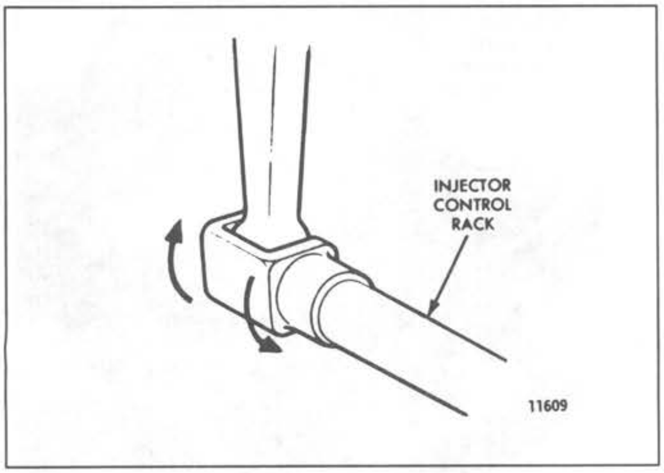


Fig. 10 – Checking Rotating Movement of Injector Control Rack

9. Insert the clevis pin in the fuel rod and the right cylinder bank injector control tube lever and position the No. 1R injector rack control lever as previously outlined in Step 6 and 7 for the No. 1L injector rack control lever.

10. Insert the clevis pin in the fuel rod and the left bank injector control tube lever. Repeat the check on the No. 1L and No. 1R injector rack control levers as outlined in Step 7. Check for and eliminate any deflection which occurs at the bend in the fuel rod where it enters the cylinder head.

11. To adjust the remaining injector rack control levers, remove the clevis pins from the fuel rods and the injector control tube levers, hold the injector control racks in the *full–fuel* position by means of the lever on the end of the control tube and proceed as follows:

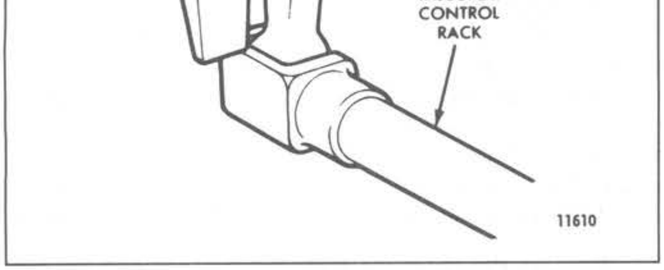


Fig. 11 – Checking Injector Control Rack "Spring"

Two Screw Assembly.

a. Turn down the inner adjusting screw of the injector rack control lever until the screw bottoms (injector control rack in the *full–fuel* position).

b. Turn down the outer adjusting screw of the injector rack control lever until it bottoms on the injector control tube.

c. While still holding the control tube lever in the *full–fuel* position, adjust the inner and outer adjusting screws to obtain the same condition as outlined in Step 7. Tighten the screws.

NOTICE: Overtightening of the injector rack control tube lever adjusting screws during installation or adjustment can result in damage to the injector control tube. The recommended torque of the adjusting screws is 24–36 **lb–in** (3–4 N•m).

One Screw and Locknut Assembly.

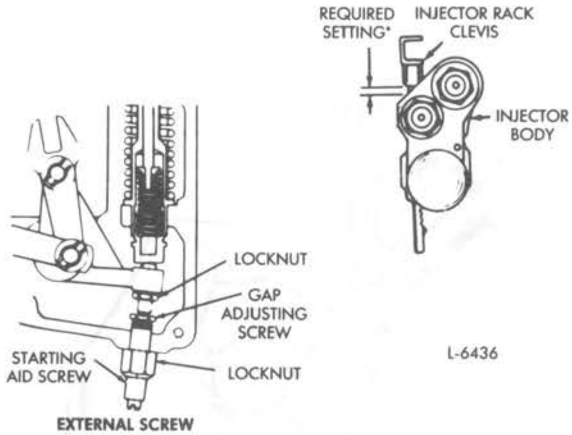
a. Tighten the adjusting screw of the No. 2L injector rack control lever until the injector rack clevis is observed to roll up or an increase in effort to turn the screwdriver is noted. Securely lock the adjusting screw locknut.

NOTICE: Overtightening of the injector rack control tube lever adjusting screws during installation or adjustment can result in damage to the injector control tube. The recommended torque of the adjusting screws is 24–36 **lb–in** (3–4 N•m).

b. Verify the injector rack adjustment of No. 1L as outlined in Step 7. If No. 1L does not "spring" back upward, turn the No. 2L adjusting screw counterclockwise slightly until the No. 1L injector rack returns to its *full–fuel* position and secure the adjusting screw locknut. Verify proper injector rack adjustment for both No. 1L and No. 2L injectors. Turn clockwise or counterclockwise the No. 2L injector rack adjusting screw until both No. 1L and No. 2L injector racks are in the *full–fuel* position when the locknut is securely tightened.

c. Adjust the remaining injectors using the proceedures outlined in Step "b" always verifying proper injector rack adjustment.

Once the No. 1L and No. 1R injector rack control levers are adjusted, do not try to alter their settings. All adjustments are made on the remaining control racks.



INJECTOR	GAGE SETTING*	TOOL NUMBER
9200	.454"	J23190
9215	.454"	J23190
9225	.454"	J23190
9280	.385"	J24882
9285	.385"	J24882
9290	.454"	J23190
9295	.454"	J23190
9A80	.385"	J24882
9A85	.385"	J24882
9A90	.454"	J23190
9B70	.385"	J24882
9B75	.385"	J24882
9B80	.385"	J24882
9B85	.385"	J24882
9B90	.454"	J23190
9C70	.385"	J24882
9C75	.385"	J24882
9C80	.385"	J24882
9C90	.454"	J23190
9E65	.385"	J24882
9E70	.385"	J24882
9E80	.385"	J24882
9E85	.385"	J24882

INJECTOR	GAGE SETTING*	TOOL NUMBER
9F70	.454"	J23190
9F80	.454"	J23190
9F85	.454"	J23190
9F90	.454"	J23190
7G65	.385"	J24882
7G70	.385"	J24882
7G75	.385"	J24882
9G75	.454"	J23190
9G85	.454"	J23190
9G90	.454"	J23190
9H85	.404"	J9509C
9J85	.454"	J23190
9K85	.404"	J9509C
9S65	.454"	J23190
9S70	.454"	J23190
9S75	.454"	J23190
9S80	.454"	J23190
9T70	.454"	J23190

Fig. 12 – Starting Aid Screw Adjustment

12. When all of the injector rack control levers are adjusted, recheck their settings. With the control tube lever in the *full–fuel* position, check each control rack as in Step 7. All of the control racks must have the same "spring" condition with the control tube lever in the *full–fuel* position.

13. Insert the clevis pin in the fuel rod and the injector control tube levers.

14. Turn the idle speed adjusting screw in until it projects 3/16" from the locknut, to permit starting the engine.

15. On current turbocharged engines, adjust the external starting aid screw as follows:

    a. With the engine *stopped,* place the governor stop lever in the *run* position and the speed control lever in the *idle speed* position.

    b. Adjust the starting aid screw to obtain the required setting between the shoulder on the injector rack clevis and the injector body (Fig. 12). Select the proper gage and measure the setting at No. 2R cylinder. When the starting aid screw is properly adjusted, the gage should have a small clearance of 1/64" in the space along the injector rack shaft between the rack clevis and the injector body.

    c. After completing the adjustment, hold the starting aid screw and tighten the locknut.

    d. Check the injector rack clevis–to–body clearance after performing the following:

        1. Position the stop lever in the *run* position.

        2. Move the speed control lever from the *idle speed* position to the *maximum speed* position.

        3. Return the speed control lever to the *idle speed* position.

Movement of the governor speed control lever is to take–up the clearance in the governor linkage. The injector rack clevis–to–body clearance can be increased by turning the starting aid screw farther in against the gap adjusting screw, or reduced by backing it out. The starting aid screw will be ineffective if the speed control lever is advanced toward wide open throttle during start–up.

CAUTION: Before starting an engine after an engine speed control adjustment or after removal of the engine governor cover and lever assembly, the technician must determine that the injector racks move to the *no–fuel* position when the governor stop lever is placed in the *stop* position. Engine overspeed will result if the injector racks cannot be positioned at no fuel with the governor stop lever. An overspeeding engine can result in engine damage which could cause personal injury.

16. Use new gaskets and reinstall the valve rocker covers.

Postion Injector Rack Control Levers ("TT" Engines)

To ensure proper injector control rack adjustment, the injector racks must be adjusted with the yield link and governor cover that are to be used with the governor.

The position of the injector rack control levers must be correctly set in relation to the governor. Their positions determine the amount of fuel injected into each cylinder and ensure equal distribution of the load. Properly positioned injector rack control levers with the engine at full load will result in the following:

1. Speed control lever at the *maximum speed* position.
2. Governor low–speed gap closed.
3. High–speed spring plunger on the seat in the governor control housing.
4. Injector fuel control racks in the *full–fuel* position.
5. The effort to move the throttle from the *idle speed* position to the *maximum speed* position is uniform. A sudden increase in effort usually near the *full–fuel* position can result from:
   a. Injector racks adjusted too tight causing the yield link to separate.
   b. Binding of the fuel rods on the cylinder head.
   c. Failure to back out idle screw.

The letters "R" and "L" indicate the right or left cylinder bank as viewed from the rear of the engine. The cylinder positions are established starting at the front of the engine on each cylinder bank. For example, the first cylinder from the front of the engine on the left bank is considered No. 1L, the second is No. 2L, and so forth.

1. Disconnect any linkage attached to the governor speed control lever.
2. Turn the idle speed adjusting screw until there is no tension in the idle spring. A false fuel rack setting may result if the idle speed adjusting screw is not backed out as noted above or removed.

Injector racks must be adjusted so the effort to move the throttle from the *idle speed* position to the *maximum speedposition* is uniform. A sudden increase in effort usually near the *full–fuel* position can result from:

   a. Injector racks adjusted too tight causing the yield link to separate.
   b. Binding of the fuel rods on the cylinder head.
   c. Failure to back out the idle screw.

3. Remove the clevis pin from the fuel rod at the right bank injector control tube lever.
4. Loosen all of the injector rack control lever adjusting screws and locknuts on both cylinder heads enough to determine the freeness of the control lever and injector rack. Be sure all of the injector rack control levers are free on the injector control tubes.

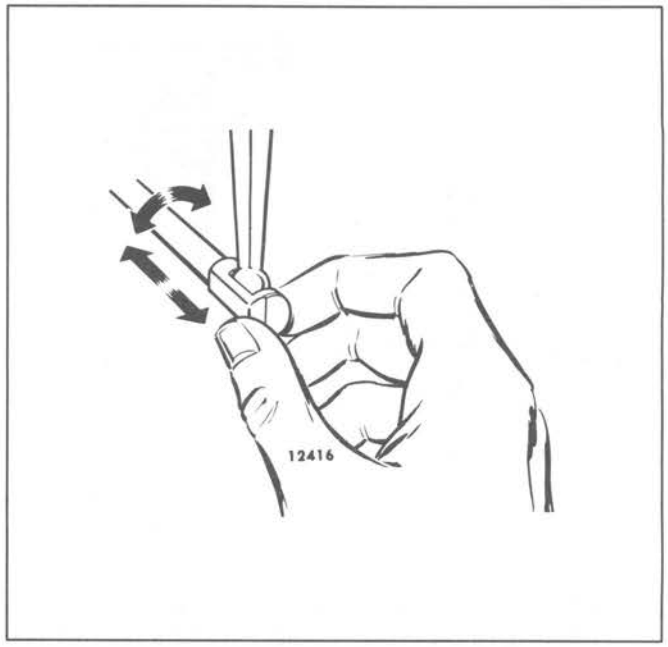


Fig. 13 – Checking Rotating Movement of Injector Control Rack

5. Move the speed control lever to the *maximum speed* position with light finger pressure. Turn down the adjusting screw of the No. 1L injector rack control tube lever until the injector rack clevis is bottomed against the injector body. The injector rack should be easily rotated but not moved in and out (Fig. 13). This will place the No. 1L injector rack in the *full–fuel* position.

The preceding steps should result in placing the governor linkage and control tube assembly in the same position they will attain while the engine is operating at full load.

6. To verify proper injector rack adjustment, hold the speed control lever in the *maximum speed* position using a screwdriver or finger tip and note that the injector rack clevis rotates freely but the rack will not move inboard or outboard. If the rack and lever moves inboard or outboard, it is too loose. The injector rack is too tight if the rack clevis springs back after being depressed with a screwcriver. Again, verify the injector rack adjustment.
7. Remove the clevis pin from the fuel rod at the left bank injector control tube lever.
8. Insert the clevis pin in the fuel rod at the right cylinder bank injector control tube lever and position the No. 1L injector rack control lever as previously outlined in Procedures 5 and 6 for the No. 1L injector rack control lever. Insert the clevis pin in the fuel rod at the left bank injector control tube lever.

9. Verify that the adjustment for the No. 1L and No. 1R injector racks are equal. Move the speed control lever to the *maximum speed* position. Rotate the clevis pins at the injector control tube levers and note a *slight* drag or resistance. With the fingertips the pin should move freely back and forth with no fuel rod deflection. This slight drag should be equal for both pins. If the drag is not equal turn either the No. 1R or No. 1L rack adjusting screw until both 1L and 1R pins are the same. Move the speed control lever back to the *idle* position and then back to the *full–fuel* position and note that the fuel rods do not deflect. If they do deflect the rack adjustment for either bank is too tight and *must* be readjusted as outlined previously.

Once the No. 1L and No. 1R injector rack control levers are adjusted, do not try to alter their settings. All adjustments are made on the remaining control racks.

10. To adjust the remaining injector rack control levers, remove the clevis pins from the fuel rod at the injector control tube levers. Hold the left bank injector control racks in the *full–fuel* position by means of the lever on the end of the control tube and proceed as follows:

    a. Tighten the adjusting screw of the No. 2L injector rack control lever until the injector rack clevis is observed to roll up or an increase in effort to turn the screwdriver is noted. Now you can have "kick–up" which you should not have had before. Securely lock the adjusting screw locknut.

    b. Verify the injector rack adjustment on No. 1L. If No. 1L does not "spring" back upward, turn the No. 2L adjusting screw counterclockwise slightly until the No. 1L injector rack returns to its *full–fuel* position and secure the adjusting screw locknut. Verify proper injector rack adjustment for both No. 1L and No. 2L injectors. Turn clockwise or counterclockwise the No. 2L injector rack adjusting screw until both No. 1L and No. 2L injector racks are in the *full–fuel* position when the locknut is securely tightened.

    c. Adjust the remaining injectors using the procedures outlined in Step "B", always verifying proper injector rack adjustment.

11. When all of the injector rack control levers are adjusted, recheck their settings. With the control tube level in the *full–fuel* position, check each injector control rack as outlined in Step 10. All of the injector control racks must have the same spring condition with the control tube levers in the *full–fuel* position as described in Item 10 (a and b).

12. Insert the clevis pins in the fuel rods at the injector control tube lever and secure with a cotter pin. Recheck the rack settings as described in Item 5.

13. Turn the idle speed adjusting screw in until it projects approximately 3/16" from the locknut to permit starting of the engine.

CAUTION: Before starting an engine after an engine speed control adjustment or after removal of the engine governor cover and lever assembly, the technician must determine that the injector racks move to the *no–fuel* position when the governor stop lever is placed in the *stop* position. Engine overspeed will result if the injector racks cannot be positioned at no fuel with the governor stop lever. An overspeeding engine can result in engine damage which could cause personal injury.

14. Use new gaskets and reinstall the valve rocker covers.

Adjust Maximum No–Load Engine Speed

All governors are properly adjusted before leaving the factory. However, if the governor has been reconditioned or replaced, and to ensure the engine speed will not exceed the recommended no–load speed as given on the engine option plate, set t

STANDARD GOVERNOR

After positioning the injector rack control levers, set the maximum no–load engine speed:

Be sure the buffer screw projects approximately 5/8" from the locknut to prevent interference while adjusting the maximum no–load speed.

1. Loosen the spring retainer locknut (Fig. 14) and back off the high–speed spring retainer approximately five turns.

2. With the engine running at operating temperature and no load on the engine, place the speed control lever in the *maximum speed* position. Turn the high–speed spring retainer until the engine is operating at the recommended no–load speed.

3. Hold the high–speed spring retainer and tighten the locknut, using spanner wrench J 5345–5.

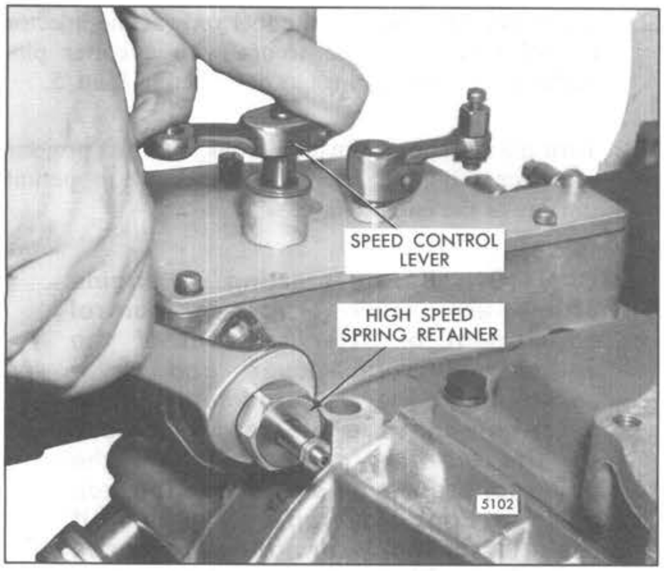


Fig. 14 – Adjusting Maximum No–Load Speed

DUAL RANGE GOVERNOR

After positioning the injector control levers, set the maximum engine speeds.

Be sure the buffer screw (or fast idle air cylinder) projects 5/8" from the locknut to prevent interference while adjusting the maximum no–load speeds.

With the spring housing assembly mounted on the governor, the piston and sleeve assembled with four .100" shims and ten .010" shims and the low maximum speed screw extending from the spring housing approximately 1–1/4", proceed as follows:

NOTICE: Do not apply air or oil pressure to the governor until performing Step 1f.

1. Set the high maximum no–load engine speed:

   a. Start and warm–up the engine. Then, position the speed control lever in the *maximum speed* position.

   b. Turn the low maximum speed adjustment screw in until the high maximum speed desired is obtained.

   c. Stop the engine and remove the spring housing assembly.

   d. Note the distance ("X" distance Fig. 15) the piston is from the bottom of the spring housing when it is against the low maximum speed screw, then remove the sleeve from the piston. When checking this distance, the piston should be held tight against the adjustment screw of the cover that is held in position, with its gasket, against the end of the spring housing.

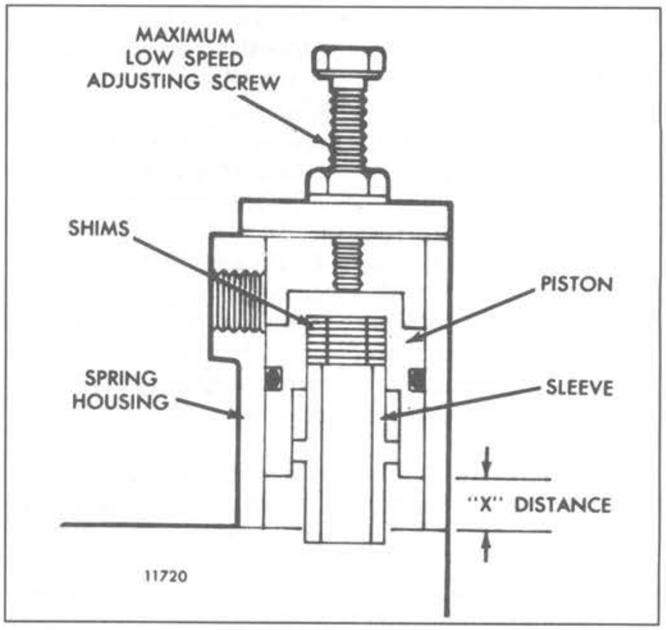


Fig. 15 – Dual Range Governor (Top View)

NOTICE: Do not permit the seal ring on the piston to slide past the air inlet port, since the seal ring will be damaged.

   e. Remove a quantity of shims, from the shims within the piston, equal to the distance noted in Step d.

   f. Start the engine and position the speed control lever in the *maximum speed* position and apply air or oil pressure to the governor and note the engine speed.

   g. Remove the air or oil pressure from the governor and stop the engine. Then, install or remove shims as required to obtain the correct high maximum no–load speed. Removing shims will decrease the engine speed and adding shims will increase the engine speed. Each .010" shim removed or added will decrease or increase the engine speed approximately 10 rpm.

2. Set the low maximum no–load engine speed:

   a. Adjust the low maximum speed adjusting screw, with the speed control lever held in the *maximum speed* position, until the desired low maximum speed is obtained. Turn the screw in to increase or out to decrease the engine speed.

   b. Recheck the engine speed and readjust, if necessary.

3. Check both the hgh maximum and low maximum engine speeds. Make any adjustment that is necessary as outlined in Steps 1 and 2.

Adjust Idle Speed

With the maximum no–load speed properly adjusted, adjust the idle speed as follows:

1. With the engine running, at normal operating temperature and with the buffer screw backed out to avoid contact with the differential lever, turn the idle speed adjusting screw until the engine operates at approximately 15 rpm below the recommended idle speed (Fig. 16).

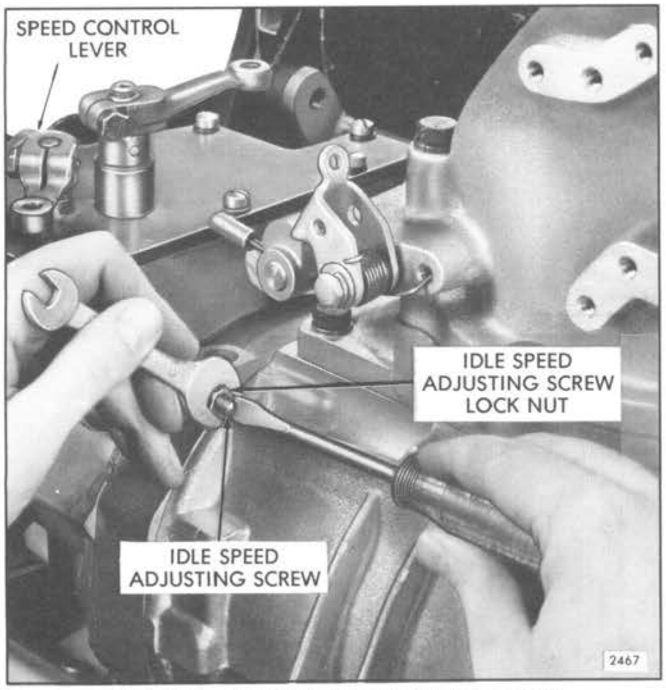


Fig. 16 – Adjusting Engine Idle Speed

NOTICE: It may be necessary to use the buffer screw to eliminate engine roll. Back out the buffer screw, after the idle speed is established, to the previous setting (5/8").

2. Hold the idle screw and tighten the locknut.
3. Install the high–speed spring retainer cover and tighten the two bolts.
4. For "TT" engines, refer to Section 14.3.5 for the adjustment of the Belleville spring.

Adjust Buffer Screw

If the engine is running satisfactorily and has no roll, do not set the buffer screw.

With the idle speed properly set, adjust the buffer screw as follows:

1. With the engine running at normal operating temperature, turn the buffer screw in so it contacts the differential lever as lightly as possible and still eliminates engine roll (Fig. 17). Do not increase the engine idle speed more than 15 rpm with the buffer screw.

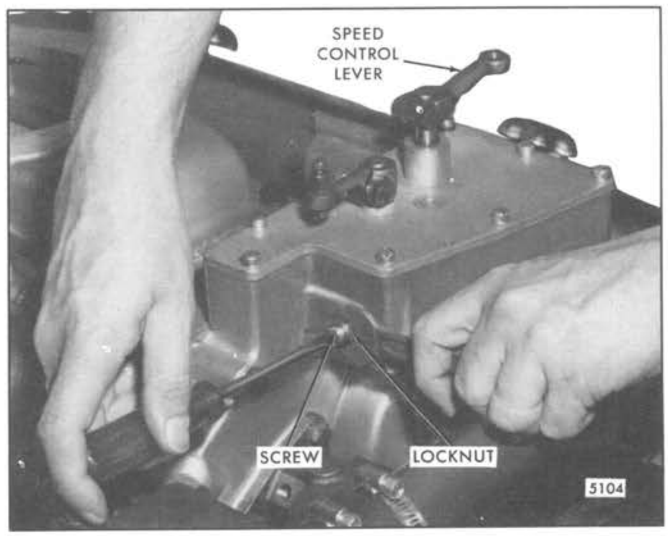


Fig. 17 – Adjusting Buffer Screw

2. Recheck the maximum no–load speed. If it has increased more than 25 rpm, back off the buffer screw until the increase is less than 25 rpm.
3. Hold the buffer screw and tighten the locknut.
4. Shutdown the engine.

LIMITING SPEED MECHANICAL GOVERNOR AND INJECTOR RACK CONTROL ADJUSTMENT

12V–92 AND 16V–92 ENGINES

The governor (Fig. 1) on the 12V and 16V engine is mounted on and driven from the front end of the rear blower.

NOTICE: Before proceeding with the governor and injector rack adjustments, disconnect any supplementary governing device. After the adjustments are completed, reconnect and adjust the supplementary governing device, as outlined in Section 14.14.

Back out the external starting aid screw. After adjusting the exhaust valves and timing the fuel injectors, adjust the governor and position the injector rack control levers.

If the engine or governor has been overhauled, or the injector control linkage has been disturbed, the control link levers in the governor housing and auxiliary control link housing must be aligned before proceeding with the engine tune-up. Refer to Fig. 2 and position the control link levers, as follows:

1. Disconnect the linkage to the governor speed control lever and stop levers.
2. Remove the covers from the governor housing and auxiliary control link housing.
3. Disconnect the adjustable link from the lever in the auxiliary control link housing.
4. Remove the connecting pin from the auxiliary governor control link lever.

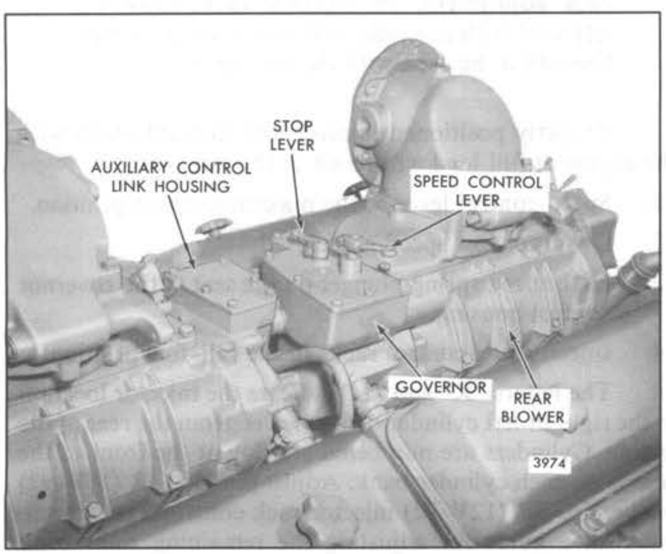


Fig. 1 – Governor Mounting

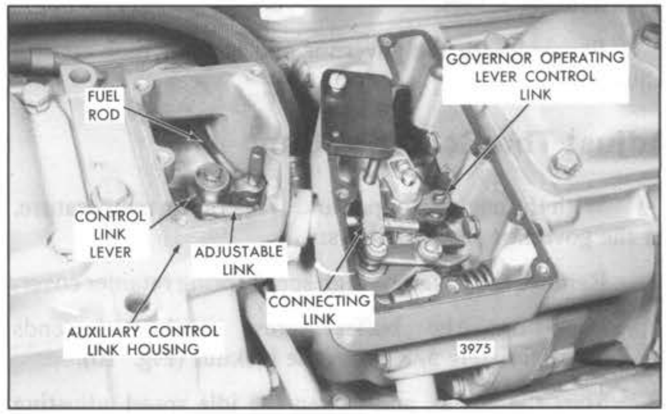


Fig. 2 – Positioning Control Link Levers with Tools J 21779 and J 21780

5. Install gage J 21779 so it extends through the lever and fuel rod and into the gage hole in the bottom of the housing. With the gage in place, the auxiliary control link lever will be in the *mid-travel* position.
6. Remove the connecting pin from the control link lever in the governor housing and install gage J 21780. Install the gage so the pin extends through the connecting link, control lever and fuel rod and the governor housing dowel pin extends into the small hole in the gage. Then install a governor cover bolt (Fig. 2). With gage J 21780 in place, the governor control link lever will be in the mid-travel position and parallel to the auxiliary control link lever.

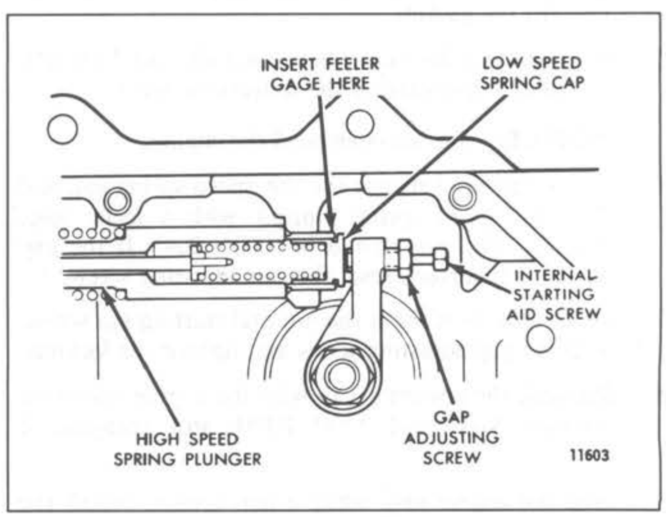


Fig. 3 – Governor Gap Adjustment

7. Adjust the length of the adjustable connecting link to retain the lever positions obtained in Steps 5 and 6 and install the link.
8. Remove gages J 21779 and J 21780 and reinstall the control link lever connecting pins.
9. Install the governor housing and auxiliary control link housing covers.

Proceed with the governor and injector rack control adjustment.

Adjust The Governor Gap

With the engine stopped and at operating temperature, set the governor gap as follows:

1. Remove the governor high speed spring retainer cover.
2. Back out the buffer screw until it extends approximately 5/8" from the locknut (Fig. 10).
3. Start the engine and loosen the idle speed adjusting screw locknut. Then adjust the idle screw to obtain the desired idle speed (Fig. 9). The recommended idle speed is 400–450 rpm, but may vary with special engine applications.

Hold the screw and tighten the locknut to hold the adjustment.

NOTICE: Governors used in turbocharged engines include a starting aid screw threaded into the governor housing (current engines) or the governor gap adjusting screw (early engines). A locknut is not required on early engines as both the gap adjusting screw and the starting aid screw incorporate a nylon patch in lieu of locknuts.

4. Stop the engine. Clean and remove the governor cover and lever assembly and the valve rocker covers. Discard the gaskets.
5. Start and run the engine between 1100 and 1300 rpm by manual operation of the differential lever.

NOTICE: Do not overspeed the engine.

6. Check the gap between the low speed spring cap and the high speed spring plunger with a feeler gage (Fig. 3). The gap should be .002"–.004". If the gap setting is incorrect, reset the gap adjusting screw.
7. On governors without the internal starting aid screw, hold the gap adjusting screw and tighten the locknut.
8. Recheck the governor gap with the engine operating between 1100 and 1300 RPM and readjust, if necessary.
9. Stop the engine and, using a new gasket, install the governor cover and lever assembly.

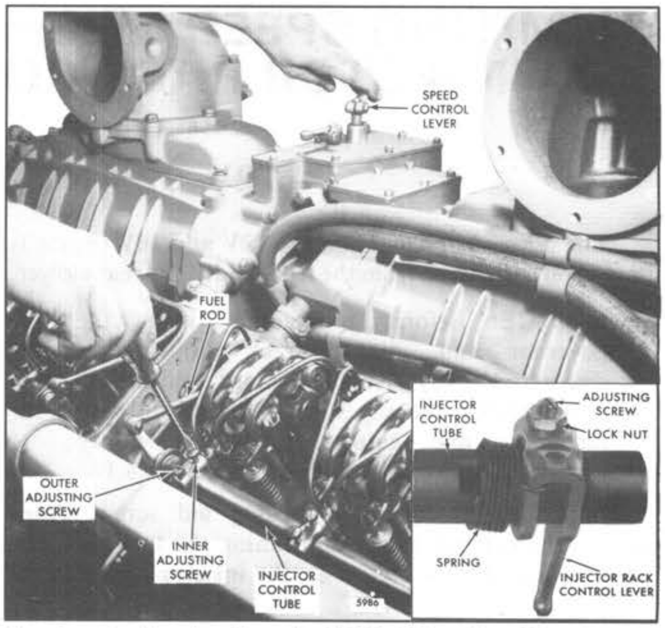


Fig. 4 – Positioning No. 4R (16V–92) or No. 3R (12V–92) Injector Rack Control Lever

NOTICE: Do not install the governor cover and lever assembly at this time on early engines that include the internal starting aid screw.

Position Injector Rack Control Levers

The position of the injector racks must be correctly set in relation to the governor. Their position determines the amount of fuel injected into each cylinder and ensures equal distribution of the load.

NOTICE: To ensure proper injector control rack adjustment, the injector racks must be adjusted with the yield link and governor cover that are to be used with the governor.

Properly positioned injector rack control levers with the engine at full load will result in the following:

1. Speed control lever at the maximum speed position.
2. Governor low speed gap closed.
3. High speed spring plunger on the seat in the governor control housing.
4. Injector fuel control racks in the full–fuel position.

The letters "R" and "L" indicate the injector location in the right or left cylinder bank, viewed from the rear of the engine. Cylinders are numbered starting at the front of the engine on each cylinder bank. Adjust the No. 4R (16V–92) or the No. 3R (12V–92) injector rack control lever first to establish a guide for adjusting the remaining right bank injector rack control levers.

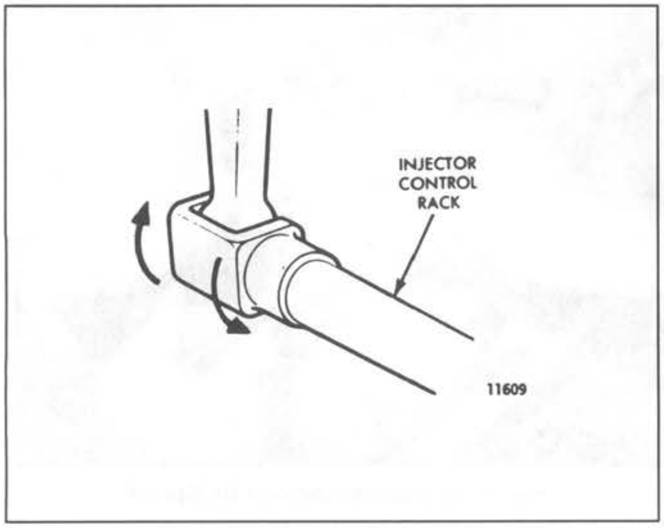


Fig. 5 – Checking Rotating Movement of Injector Control Rack

1. Adjust the idle speed adjusting screw until 1/2" of the threads (12–14 threads) project from the locknut when the nut is against the high–speed plunger.

   NOTICE: A false full–fuel rack setting may result if the idle speed adjusting screw is not backed out as noted above.

   Injector racks must be adjusted so the effort to move the throttle from the idle speed position to the maximum speed position is uniform. A sudden increase in effort can result from:

   a. Injector racks adjusted too tight causing the yield link to separate.
   b. Binding of the fuel rods.
   c. Failure to back out the idle screw.

2. Back out the buffer screw approximately 5/8" if it has not already been done.
3. Loosen all of the inner and outer injector rack control lever adjusting screws or adjusting screws and locknuts on both cylinder banks. Be sure all of the levers are free on the injector control tubes.

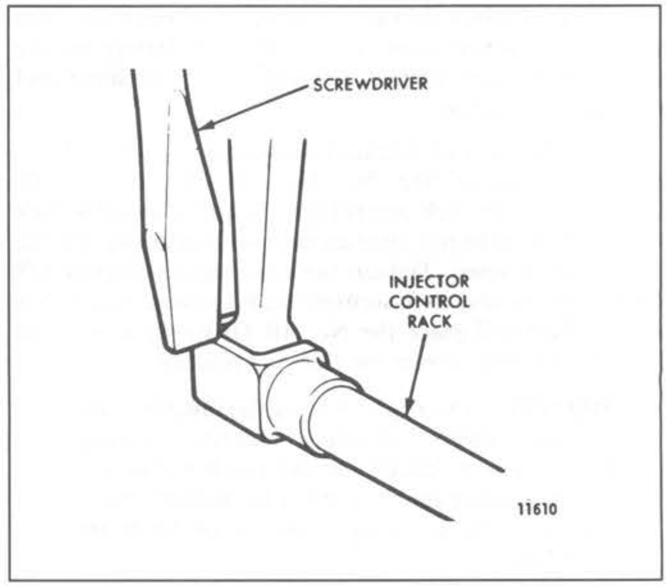
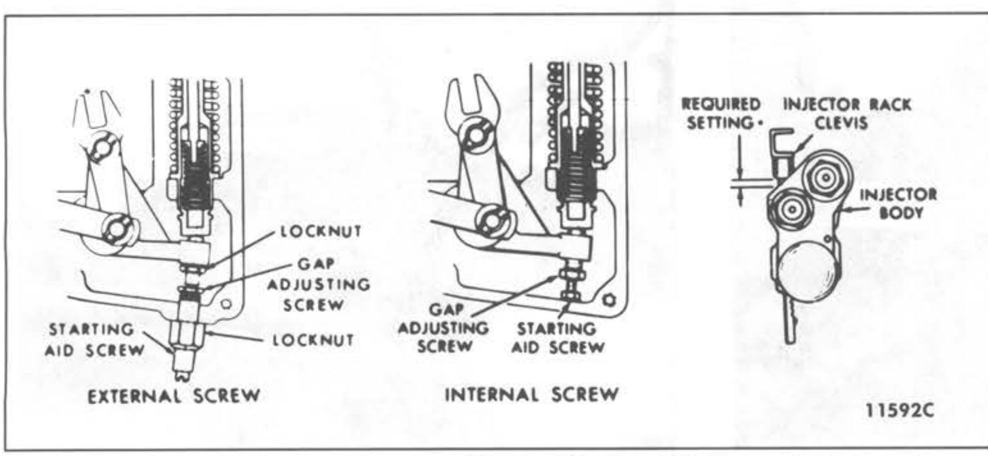


Fig. 6 – Checking Injector Control Rack "Spring"

4. Check for any bind in the governor to control tube linkage by moving the linkage through its full range of travel.
5. Remove the clevis pins which attach the right rear bank and both left bank fuel rods to the injector control tube levers.
6. Move the speed control lever to the maximum speed position.
7. Hold the speed control lever with light finger pressure (Fig. 4) and proceed as follows:

   Two Screw Assmebly — Adjust the No. 4R (16V–92) or No. 3R (12V–92) injector rack by turning the inner adjusting screw down until a slight movement of the control tube is observed or a step–up in effort to turn the screwdriver is noted.



INJECTOR	GAGE SETTING*	TOOL NUMBER
9200	.454"	J 23190
9215	.454"	J 23190
9225	.454"	J 23190
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9A80	.385"	J 24882
9A85	.385"	J 24882
9A90	.454"	J 23190
9B70	.385"	J 24882
9B75	.385"	J 24882
9B80	.385"	J 24882
9B85	.385"	J 24882
9B90	.454"	J 23190
9C70	.385"	J 24882
9C75	.385"	J 24882
9C80	.385"	J 24882
9C90	.454"	J 23190
9E65	.385"	J 24882
9E70	.385"	J 24882
9F90	.454"	J 23190
7G65	.385"	J 24882
7G70	.385"	J 24882
7G75	.385"	J 24882

Fig. 7 – Starting Aid Screw Adjustment

This will place the rack in the full–fuel position. Turn the outer adjusting screw until it bottoms lightly on the control tube. Then alternately tighten both the inner and outer adjusting screws.

One Screw and Locknut Assembly — Tighten the adjusting screw of the No. 4R (16V–92) or No. 3R (12V–92) injector rack control lever until the injector rack clevis is observed to roll up or an increase in effort to turn the screwdriver is noted. Tighten the screw approximately 1/8 of a turn more and lock securely with the adjusting screw locknut. This will place the No. 4R (16V–92) or No. 3R (12V–92) injector rack in the *full–fuel* position.

> **NOTICE:** Overtightening of the injector rack control lever adjusting screws during installation or adjustment can result in damage to the injector control tube. The recommended torque of the adjusting screws is 24–36 **lb–in** (3–4 N•m).

The above step should result in placing the governor linkage and control tube assembly in the same position that they will attain while the engine is running at full load.

8. To be sure of the proper rack adjustment, hold the speed control lever in the *maximum speed* position and press down on the injector rack with a screwdriver or finger tip and note the "rotating" movement of the injector control rack (Fig. 5). Hold the speed control lever in the *maximum speed* position and, using a screwdriver, press downward on the injector control rack. The rack should tilt downward (Fig. 6) and, when the pressure of the screwdriver is released, the control rack should " spring" back upward.

If the rack does not return to its original position, it is too loose. To correct this condition with the *Two Screw Assembly, back off the outer adjusting screw slightly and tighten the inner adjusting screw slightly. To correct this condition with the One Screw and Locknut Assembly,*

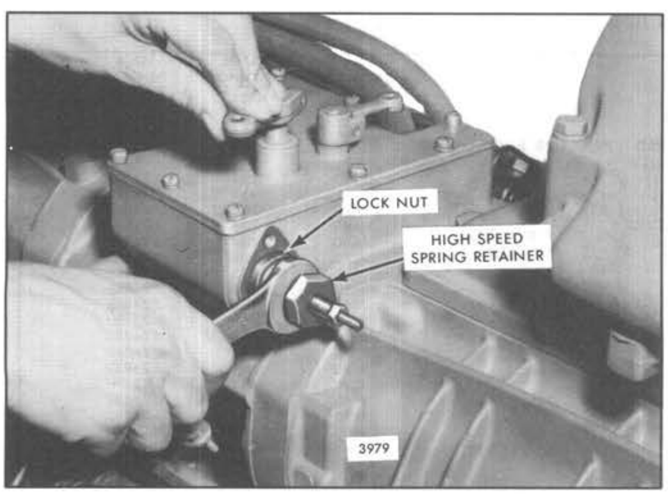


Fig. 8 – Adjusting Maximum No–Load Speed

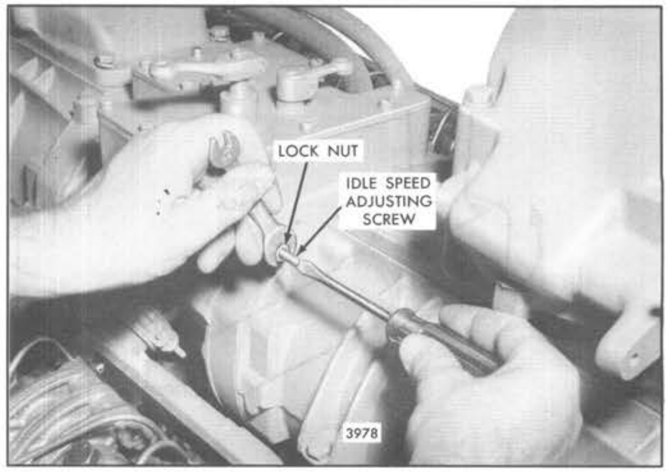


Fig. 9 – Adjusting Engine Idle Speed

loosen the locknut and turn the adjusting screw clockwise a slight amount and retighten the locknut.

The setting is too tight if, when moving the speed control lever from the *no–speed* to the *maximum speed* position, the injector rack becomes tight before the speed control lever reaches the end of its travel (as determined by the stop under the governor cover). This will result in a step–up in effort required to move the speed control lever to the end of its travel. To correct this condition with the *Two Screw Assembly,* back off the inner adjusting screw slightly and tighten the outer adjusting screw slightly. To correct this condition with the *One Screw and Locknut Assembly,* loosen the locknut and turn the adjusting screw counterclockwise a slight amount and retighten the locknut.

9. Remove the fuel rod–to–control tube lever clevis pin from the right front bank fuel rod and install it on the right right rear bank fuel rod and adjust the No. 5R (16V–92) or No. 4R (12V–92) injector rack, as outlined in Steps 6, 7, and 8.

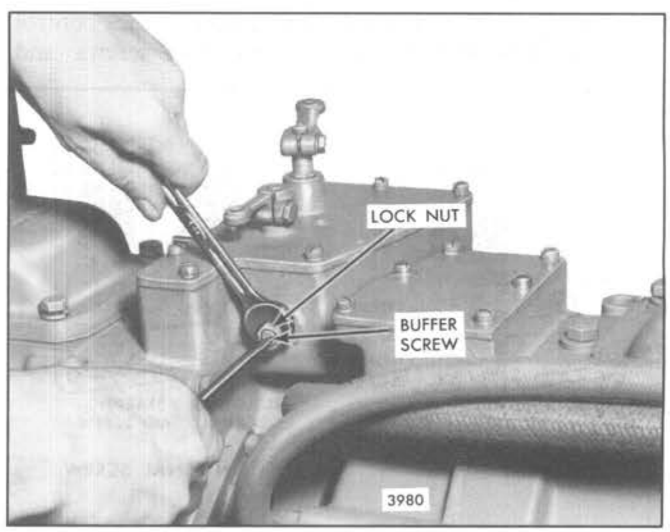


Fig. 10 – Adjusting Buffer Screw

10. Repeat Step 9 for adjustment of the No. 4L and No. 5L (16V–92) or No. 3L and No. 4L (12V–92) injector racks. When the settings are correct, the No. 4R, 5R, 4L and 5L (16V–92) or No. 3R, 4R, 3L and 4L (12V–92) injector racks will be snug on the ball end of the control levers when the injectors are in the full–fuel position.

11. With the fuel rod disconnected from the injector control tube lever, adjust the remaining injector rack control levers on the right front bank. Hold the No. 4R (16V–92) or No. 3R (12V–92) injector rack in the full–fuel position by means of the control tube lever and proceed as follows:

    Two Screw Assembly:

    a. Turn the inner adjusting screw of the No. 3R (16V–92) or No. 2R (12V–92) injector rack control lever until the injector rack has moved into the full–fuel position. Turn the outer adjusting screw down until it bottoms lightly on the injector control tube. Then alternately tighten both the inner and outer adjusting screws.

    NOTICE: Overtightening of the injector rack control tube lever adjusting screws during installation or adjustment can result in damage to the injector control tube. The recommended torque of the adjusting screws is 24–36 **lb–in** (3–4 N•m).

    b. Recheck the No. 4R (16V–92) or No. 3R (12V–92) injector rack to be sure it has remained snug on the ball end of the injector rack control lever. If the rack of the No. 4R (16V–92) or No. 3R (12V–92) injector has become loose, back off the inner adjusting screw slightly on the No. 3R (16V–92) or No. 2R (12V–92) injector rack control lever and tighten the outer adjusting screw.

    One Screw and Locknut Assembly:

    a. Tighten the adjusting screw of the No. 3R (16V–92) or No. 2R (12V–92) injector rack control lever until the injector rack clevis is observed to roll up or an increase in effort to turn the screwdriver is noted. Securely lock the adjusting screw locknut.

    NOTICE: Overtightening of the injector rack control tube lever adjusting screws during installation or adjustment can result in damage to the injector control tube. The recommended torque of the adjusting screws is 24–36 **lb–in** (3–4 N•m).

    b. Verify the injector rack adjustment of No. 4R (16V–92) or No. 3R (12V–92), as outlined in Step 8. If No. 4R (16V–92) or No. 3R (12V–92) does not "spring" back upward, turn the No. 3R counterclockwise slightly until the No. 4R (16V–92) or No. 3R (12V–92) injector rack returns to its full–fuel position and secure the adjusting screw locknut. Verify proper injector rack adjustment for both No. 4R and No. 3R (16V–92) or No. 3R and No. 2R (12V–92) injectors. Turn clockwise or counterclockwise the No. 3R (16V–92) or No. 2R (12V–92) injector rack adjusting screw until both No. 4R and No. 3R (16V–92) or No. 3R and No. 2R (12V–92) injector racks are in the full–fuel position when the locknut is securely tightened.

When the settings are correct, both injector racks must respond in the same manner on the ball ends of the control levers when the injector control tube lever is held in the full–fuel position.

12. Position the remaining injector rack control levers on the right front cylinder bank, as outlined in Step 11.

13. Adjust the remaining injector rack control levers on the right rear, left front and left rear cylinder banks in the same manner as outlined in Steps 11 and 12.

14. Install the four fuel rod–to–control tube lever clevis pins and check the adjustment of the injector rack control levers.

15. Turn the idle speed adjusting screw in until it projects 3/16" from the locknut, to permit starting the engine.

16. On *current turbocharged engines,* adjust the external starting aid screw, as follows:

    a. With the engine* stopped place the governor stop lever in the run* position and the speed control lever in the idle speed position.

    b. Adjust the starting aid screw to obtain the required setting between the shoulder on the injector rack clevis and the injector body (Fig. 7). Select the proper gage and measure the setting at any convenient cylinder. When the starting aid screw is properly adjusted, the gage should have a small clearance of 1/64" in the space along the injector rack shaft between the rack clevis and the injector body.

    c. After completing the adjustment, hold the starting aid screw and tighten the locknut.

    d. Check the injector rack clevis–to–body clearance after performing the following:

        1. Position the stop lever in the run position.
        2. Move the speed control lever from the idle speed position to the maximum speed position.

3. Return the speed control lever to the idle speed position.

Movement of the speed control lever is to take–up the clearance in the governor linkage. The injector rack clevis–to–body clearance can be increased by turning the starting aid screw farther in against the gap adjusting screw, or reduced by backing it out.

NOTICE: The starting aid screw will be ineffective if the speed control lever is advanced toward wide open throttle during start–up.

CAUTION: An overspeeding engine can result in engine damage which could cause personal injury.

17. Use new gaskets and reinstall the valve rocker covers.

Adjust Idle Speed

1. With the engine running, at normal operating temperature and with the buffer screw backed out to avoid contact with the differential lever, turn the idle speed adjusting screw (Fig. 9) until the engine is operating approximately 15 rpm below the recommended idle speed. The recommended idle speed is 400–450 rpm but may vary with certain engine applications.

   NOTICE: It may be necessary to use the buffer screw to eliminate engine roll. Back out the buffer screw, after the idle speed is established, to the previous setting (5/8").

2. Hold the idle screw and tighten the locknut.
3. Install the high speed spring retainer cover.

*Adjust Maximum No–Load Engine Speed

All governors are properly adjusted before leaving the factory. However, if the governor has been reconditioned or replaced and to ensure the engine speed will not exceed the recommended no–load speed as given on the option plate, set the maximum no–load speed as follows:

NOTICE: Be sure the buffer screw projects 5/8" to prevent interference while adjusting the maximum no–load speed.

1. Loosen the spring retainer locknut and back off the high–speed spring retainer approximately five turns (Fig. 8).
2. With the engine running at operating temperature and no load on the engine, place the speed control lever in the *maximum speed* position. Turn the high speed spring retainer until the engine is operating at the recommended no–load speed.
3. Hold the high speed spring retainer and tighten the locknut using spanner wrench J 5345–5.

Adjust Buffer Screw

With the idle speed properly set, adjust the buffer screw, as follows:

1. With the engine running at normal operating temperature, turn the buffer screw in so it contacts the differential lever as lightly as possible and still eliminates engine roll (Fig. 10).

   NOTICE: Do not increase the engine idle speed more than 15 rpm with the buffer screw.

2. Recheck the maximum no–load speed. If it has increased more than 25 rpm, back off the buffer screw until the increase is less than 25 rpm.
3. Hold the buffer screw and tighten the locknut.

STATIC DOUBLE WEIGHT LIMITING SPEED GOVERNOR GAP CHECKING AND SETTING PROCEDURE

The following is accomplished with the engine *stopped.*

A new governor weight wedge tool (J35516 – Fig. 11) and the accompanying procedure can be used *only* on double weight limiting speed governors.

CAUTION: To avoid personal injury and prevent possible engine damage, the following precautions should be observed:

Make sure the compressor inlet guard or compressor air inlet shield J 26554 is installed any time the engine is running and the turbocharger compressor air inlet piping is removed. The use of these guards does not preclude any other safety practices contained in the Service Manual.

After replacing the governor cover and before starting the engine, make sure that the injector racks move to the "no fuel" position when the governor stop lever is in the "stop" position.

Verification of the governor gap setting should not be considered necessary until "Vehicle Low Power/ Performance at Low Mileage" (Section 15.2) has been used to troubleshoot the engine performance concern.

Governor Gap Checking Procedure

1. In a vehicle, set the engine idle speed at 600 RPM and stop the engine.

   NOTICE: The static governor gap setting is established at the factory based upon a 600 RPM engine idle. Therefore, when *verifying* a factory tune–up the governor idle speed should be set at 600 RPM.

   CAUTION: Disconnect the grounded battery cable (s) to prevent accidental engine cranking and possible personal injury while the gap is being checked or set.

2. Clean and remove the governor cover. Discard the gasket.
3. With the engine stopped, manually bar the engine over *in the direction of normal engine rotation* until the governor weights are in a horizontal position.

   On "TT" governors, the Belleville spring retainer nut must be backed out until there is approximately .060" clearance between the washers and the retainer nut before checking or resetting the governor gap.

4. Insert governor weight wedge J35516 between the low–speed weight and the governor riser (see Figs. 12 and 13). The tapered face of the wedge should be against the riser and positioned between the flanges on the ends of the riser.
5. Push the wedge as far to the bottom as it will go, forcing the weights against the maximum travel stop.

   NOTICE: Do not use a screwdriver to pry the weights, since damage to the weights, riser, or housing could result.

6. While holding the wedge in the bottom position, use a feeler gauge to measure the gap between the low speed spring cap and the high speed spring plunger (see Figs. 14 and 15). The gap should measure .003" – .019". Reset the gap to .008" if the measured gap is out of limits (see "GOVERNOR GAP ADJUSTMENT PROCEDURE" below).
7. Remove the wedge and replace the governor cover, using a new gasket.
8. Reset Belleville springs (see Section 14.3.5 of the Service Manual).

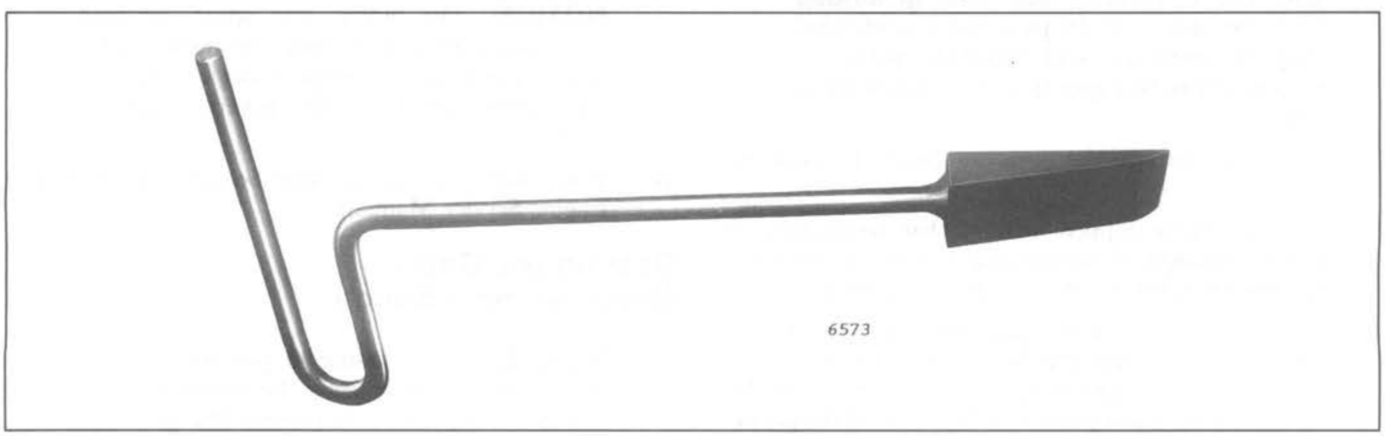


Fig. 11 – Governor Weight Wedge Tool J35516

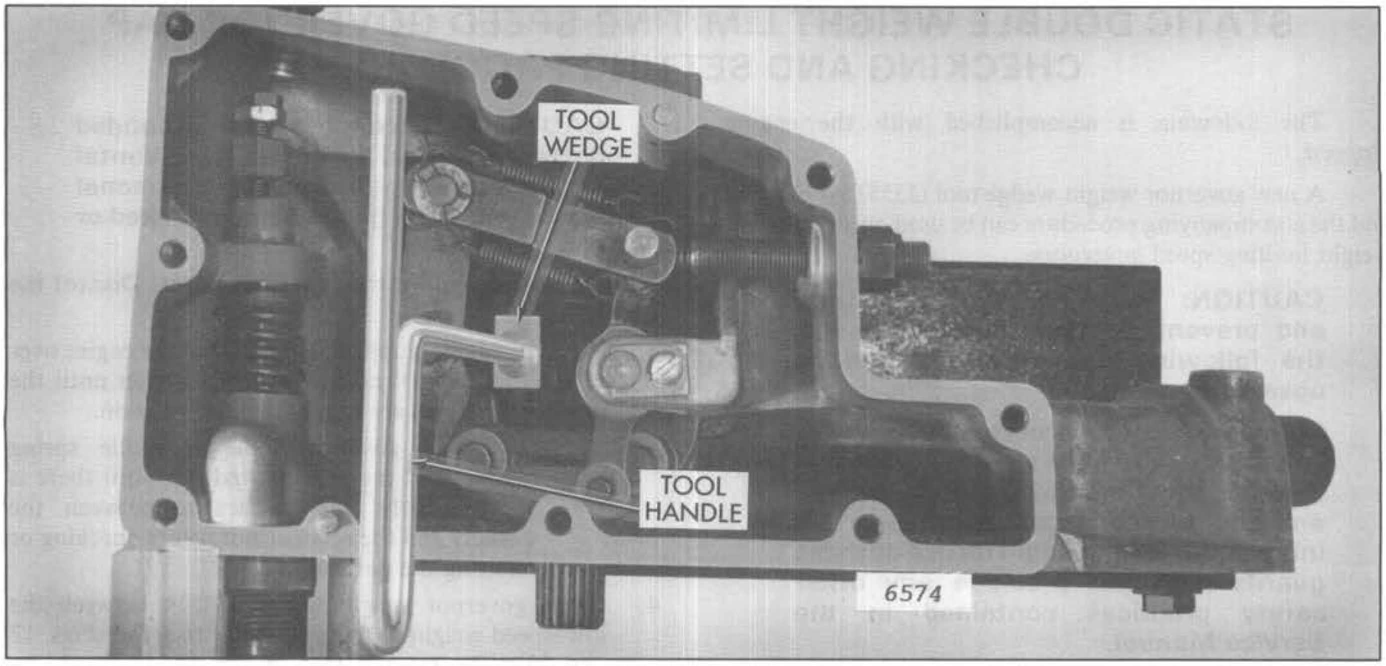


Fig. 12 – Tool J35516 Inserted Between Low Speed Weight and Riser

Governor Gap Adjustment Procedure

These procedures permit adjusting the gap while the governor is installed on an engine or removed and on a bench.

Before adjusting the gap on "TT" governors, the Belleville spring retainer nut must be backed out until there is approximately .060" clearance between the washers and the retainer nut (see Fig. 14).

Setting the Gap – Governor on the Engine

1. Disconnect any supplementary governor devices.
2. Set the engine idle speed at 600 RPM and stop the engine.

   CAUTION: Disconnect the grounded battery cable (s) to prevent accidental engine cranking and possible personal injury while the gap is being checked or set.

3. Clean and remove the governor cover. Discard the gasket.
4. With the engine stopped, manually bar the engine over *in the direction of normal engine rotation* until the governor weights are in a horizontal position.
5. Insert governor weight wedge Tool J35516 between the low–speed weight and the governor riser (see Figs. 12 and 13). The tapered face of the wedge should be against the riser and positioned between the flanges on the ends of the riser.
6. Push the wedge as far to the bottom as it will go, forcing the weights against the maximum travel stop.

   NOTICE: Do not use a screwdriver to pry the weights, since damage to the weights, riser, or housing could result.

7. Use a feeler gauge to set the gap between the low speed spring cap and the high speed spring plunger at .008". Then tighten the governor gap adjusting screw lock nut (see Figs. 14 and 15).
8. Push down on the governor weight wedge tool to be sure it did not move while the gap was being set. Recheck the gap while holding the tool in this position. If the gap is incorrect, reset to .008", repeating the steps outlined above.
9. Remove the wedge.

   NOTICE: The buffer, idle speed, no–load speed and starting aid screws, the injector racks, and supplemental governor devices require adjustment whenever the governor gap is changed.

10. Reset Belleville springs (see Section 14.3.5 of the Engine Service Manual).

Setting the Gap – Governor on a Bench

NOTICE: When setting the governor gap on a bench, the governor *must* be mounted on a blower to support and protect the governor weight carrier shaft.

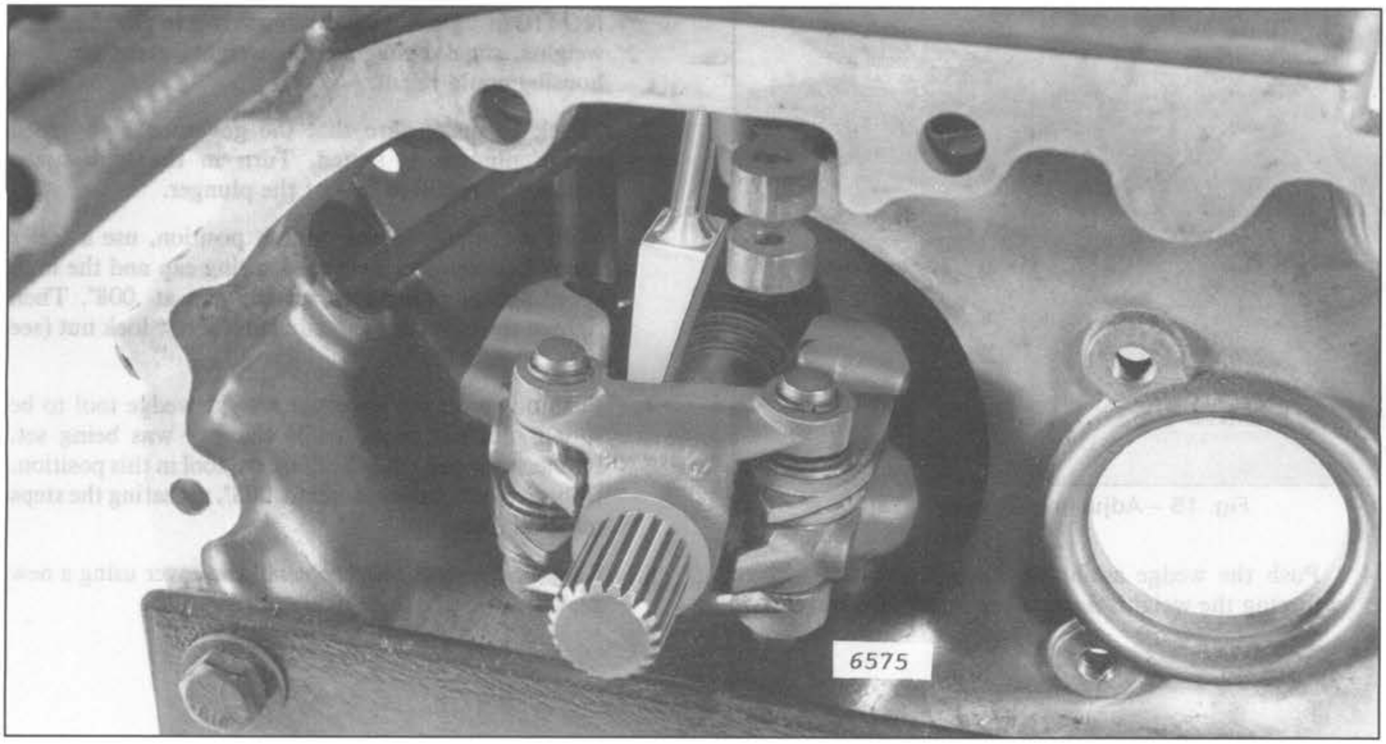


Fig. 13 – Wedge of Tool J35516 Between Riser and Low Speed Weight (Detail)

1. Position the idle screw. On all Non–"TT" governors with a normal 1.00" long idle adjustment screw, the screw should be set so that it extends .325". On all "TT" governors with a normal 1.00" long idle adjustment screw, the screw should be set to extend .400". This dimension is measured from the face of the idle speed adjusting screw lock nut to the end of the idle speed adjusting screw with a tolerance of ± .015" (see Fig. 14). For governors with a variable high–speed option, which use a 1.75" long idle adjustment screw, the screw should be set to extend 1.075" on all non–"TT" governors or 1.150" on all "TT" governors. These idle screw projections result in a nominal 600 RPM idle speed.

2. Rotate the governor weights until they are in a horizontal position.

3. Insert governor weight wedge Tool J35516 between the low–speed weight and the governor riser (see Figs. 12 and 13). The tapered face of the wedge should be against the riser and positioned between the flanges on the ends of the riser. To prevent the weights from rotating when the governor weight wedge tool is inserted, a clean, soft rag should be wedged between the blower housing and the blower rotors.

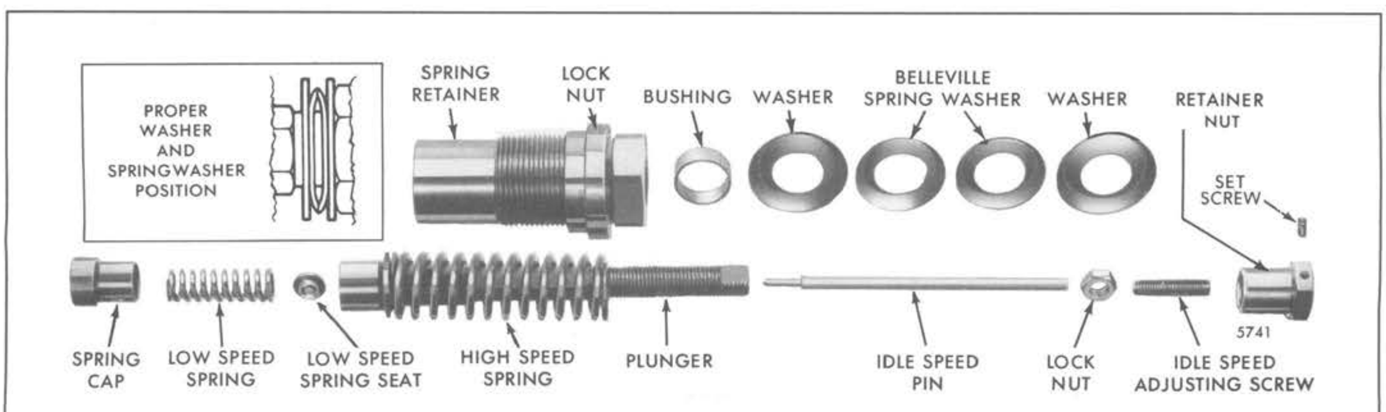


Fig. 14 – High and Low–Speed Springs and Plunger Details Including Belleville Washers (TTA Engines)

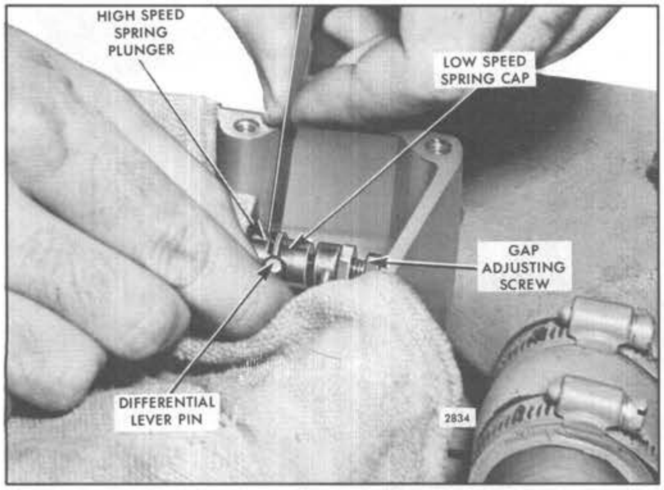


Fig. 15 – Adjusting Governor Gap

4. Push the wedge as far to the bottom as it will go, forcing the weights against the maximum travel stop.

NOTICE: Do not use a screwdriver to pry the weights, since damage to the weights, riser, or housing could result.

5. Check to make sure that the governor high–speed spring plunger is seated. Turn in the high–speed retainer as required to seat the plunger.

6. With the wedge in the bottom position, use a feeler gauge between the low speed spring cap and the high speed spring plunger to set the gap at .008". Then tighten the governor gap adjusting screw lock nut (see Figs. 14 and 15).

7. Push down on the governor weight wedge tool to be sure it did not move while the gap was being set. Recheck the gap while holding the tool in this position. If the gap is incorrect, reset to .008", repeating the steps outlined above.

8. Remove the wedge and reinstall the cover using a new gasket.

LIMITING SPEED MECHANICAL GOVERNOR

ADJUSTMENT – (VARIABLE LOW–SPEED)

The variable low–speed limiting speed mechanical governor is used on turbocharged highway vehicle engines where the same engine powers both the vehicle and the auxiliary equipment for unloading bulk products (such as cement, grain or liquids) and a high idle speed range is desired during auxiliary operation.

The governor is a single–weight type and provides an idle speed range of 500 to 1800 rpm.

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. 2), 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.

CAUTION: Failure to return the device to normal idle speed could result in loss of control of the engine at idle and personal injury could result.

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.

After adjusting the exhaust valves and timing the injectors, adjust the governor and position the injector rack control levers.

Adjust Governor Gap

With the engine at operating temperature, adjust the governor gap as follows:

1. Stop the engine. Back out the buffer screw until it extends approximately 5/8" from the locknut.
2. Remove the governor cover and lever assembly.
3. Check the gap (.200") between the low–speed spring cap and the high–speed spring plunger with gage J 23478 (Fig. 3). A .200" stack–up of feeler gages can be used to check the gap if the gage is not available. Be sure the external starting aid screw is backed out far enough to make it ineffective when making this adjustment.
4. If required, loosen the locknut and turn the gap adjusting screw until a slight drag is felt on the gage.
5. Hold the adjusting screw and tighten the locknut.
6. Recheck the gap and readjust, if necessary.
7. Affix a new gasket to the top of the governor housing. Place the governor cover assembly on the governor housing with the pin in the stop control shaft assembly in the slot of the diffrential lever and the dowel pins in the housing in the dowel pin holes in the cover.

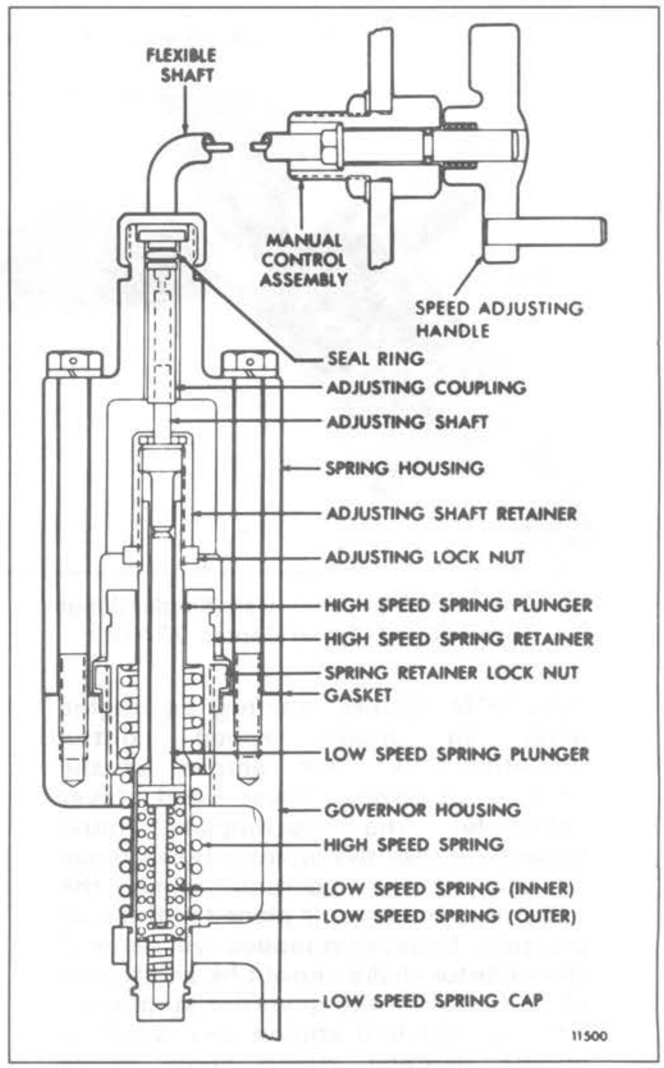


Fig. 1 – Cable Operated Governor Spring Housing and Components

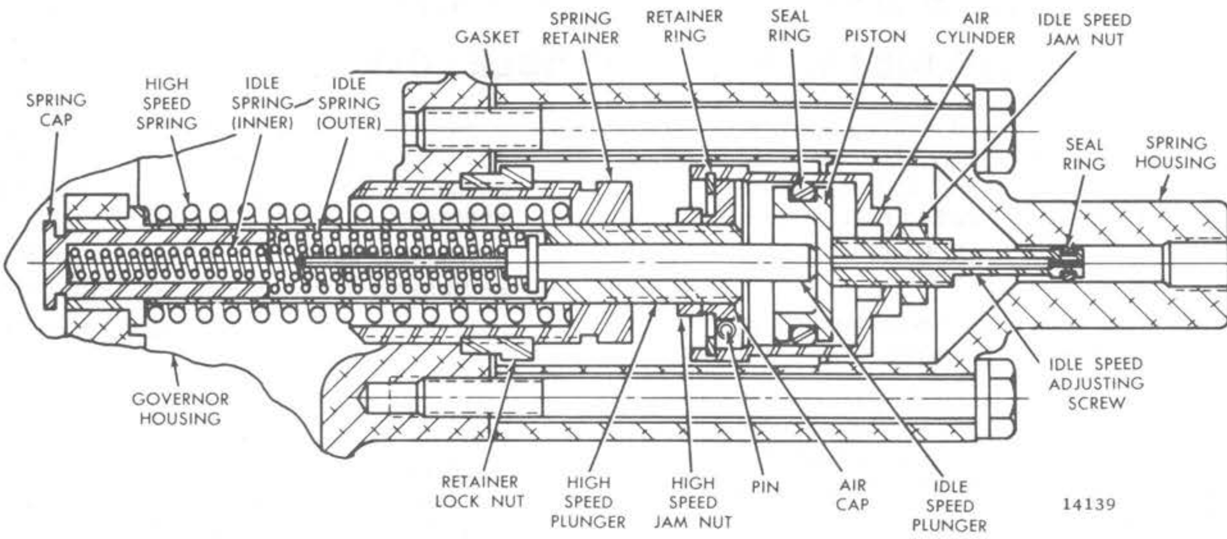


Fig. 2 – Air Operated Governor Spring Housing and Components

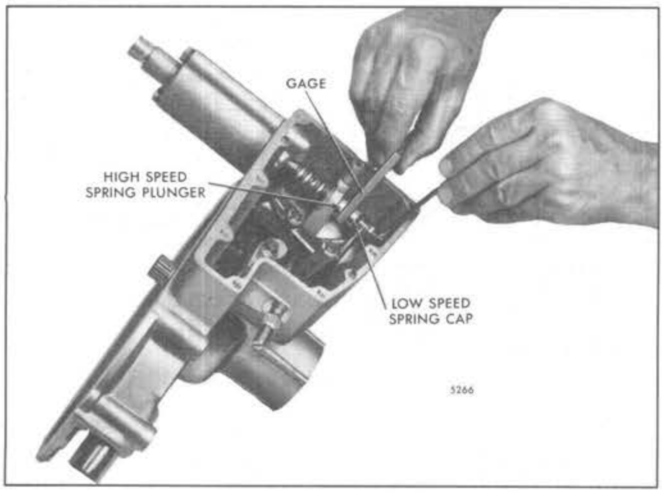


Fig. 3 – Adjusting Governor Gap (Single–Weight Governor) with Feeler Gage J 23478

CAUTION: Before starting an engine after an engine speed control adjustment or after removal of the engine governor cover and lever assembly, the technician must determine that the injector racks move to the *no–fuel* position when the governor stop lever is placed in the *stop* position. Engine overspeed will result if the injector racks cannot be positioned at no fuel with the governor stop lever. An overspeeding engine can result in engine damage which could cause personal injury.

Position Injector Rack Control Levers

If the governor gap was adjusted, position the injector rack control levers as outlined in Section 14.3.

Check Spring Housing Gasket

Remove the spring housing from the governor housing. Check the gasket for tears, breaks, etc. If the gasket requires replacement, remove the spring pack from the governor housing, replace the gasket and reinstall the spring pack.

NOTICE: When removing the spring pack, care should be taken so that the low–speed spring cap does not fall off the spring pack into the governor.

Adjust Maximum No–Load Engine Speed

Adjust the maximum no–load engine speed as outlined for the limiting speed mechanical governor in Section 14.3.

Adjust Idle Speed

CABLE OPERATED GOVERNOR

a. Back out the variable low–speed adjusting shaft until the shoulder on the shaft contacts the shaft retainer (Fig. 1).

b. Hold the locknut and loosen the low–speed adjusting shaft retainer. Start the engine.

c. Adjust the retainer and shaft assembly to obtain the desired idle speed (500 rpm minimum). Then, hold the retainer and tighten the locknut to retain the adjustment. It may be necessary to use the buffer screw to eliminate engine roll.

d. Place the spring housing over the spring pack. Install the variable low–speed adjuster coupling. Center the coupling before securing the spring housing to the governor. Tighten the attaching bolts. Install the flexible shaft and manual control assembly.

Verify operation of the installation by using the speed adjusting handle to check idle speed settings.

AIR OPERATED GOVERNOR

■Maximum Idle Speed

a. Remove the air cylinder assembly from the high–speed plunger. Loosen the idle speed jam nut. Turn the idle speed, adjusting screw clockwise into the air cylinder, until the piston contacts the air cap and the air cap contacts the retainer ring (Fig. 3). Rotate the air cylinder on the high–speed plunger 2–3 turns.

b. Start the engine. With the speed control lever in the *idle* position, turn the air cylinder clockwise to raise the idle speed and counterclockwise to lower the idle speed. Initial observed idle speed will be between the minimum and maximum idle speeds.

c. Lock the air cylinder to the high–speed plunger with the jam nut in the position which provides the desired maximum idle speed.

■Minimum Idle Speed

Make this adjustment after the maximum idle speed adjustment is completed.

a. Run the engine with the speed control lever in the *idle speed* position.

b. Turn the idle speed adjusting screw counterclockwise to lower the idle speed. Over 1/8" travel of the screw is required to reach minimum idle speed. Tighten the jam nut when at the desired minimum idle speed (see RPM minimum). It may be necessary to use the buffer screw to eliminate engine roll.

c. Install the spring housing over the spring pack. Tighten the attaching bolts. Connect the air supply to the spring housing. Verify operation of installation by applying and varying air pressure to check the idle speed settings.

If speeds of less than 1800 rpm are always required, the speed can be set and achieved with unregulated air. Additional lower speeds can be achieved with regulated air pressure.

Adjust Buffer Screw

Adjust the buffer screw as outlined in Section 14.3, if not already done during the tune–up.

LIMITING SPEED MECHANICAL GOVERNOR ADJUSTMENT

FAST IDLE CYLINDER

The 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 cylinder, if used, is also mounted on the governor cover.

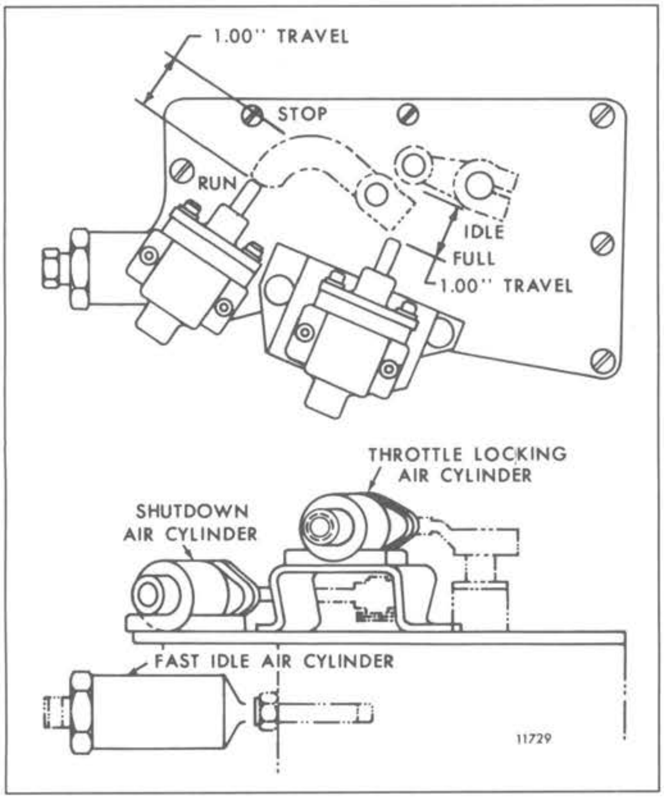


Fig. 1 – Governor with Fast Idle Cylinder

The fast idle air cylinder and the throttle locking air cylinder are actuated at the same time by air from a common air line. The engine shutdown air cylinder is connected to a separate air line.

The air supply for the fast idle air cylinder is usually controlled by an air valve actuated by an electric solenoid. The fast idle system should be installed so that it will function only when the parking brake system is in operation to make it tamper–proof.

The vehicle accelerator–to–governor throttle linkage is connected to a yield link so the operator cannot overcome the force of the air cylinder holding the speed control lever in the *idle* position while the engine is operating at the single fixed high idle speed.

Operation

During highway operation, the governor functions as a limiting speed governor.

For operation of auxiliary equipment, the vehicle is stopped and the parking brake set. Then, with the engine running, the low speed switch is placed in the *on* position. When the fast idle air cylinder is actuated, the force of the dual idle spring (Fig. 2) is added to the force of the governor low–speed spring, thus increasing the engine idle speed.

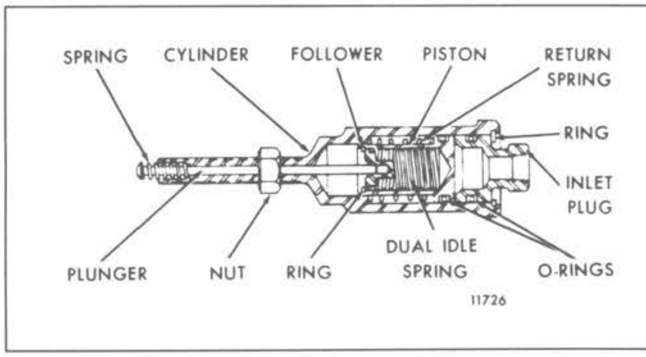


Fig. 2 – Fast Idle Air Cylinder

The governor now functions as a constant speed governor at the high idle speed setting, maintaining a near constant engine speed regardless of the load within the capacity of the engine. The fast idle system provides a single fixed high idle speed that is not adjustable, except by disassembling the fast idle air cylinder and changing the dual idle spring. As with all mechanical governors, when load is applied, the engine speed will be determined by the governor droop.

Adjust Governor

Adjust the governor as outlined in Section 14.3. However, before adjusting the governor gap, back out the de–energized fast idle air cylinder until it will not interfere with the governor adjustments. After the normal idle speed setting is made, adjust the de–energized fast idle air cylinder as follows:

1. Turn in the fast idle cylinder assembly until an increase of idle speed is noted. The increase in idle speed should not exceed 15 rpm. Tighten the fast idle jam nut.

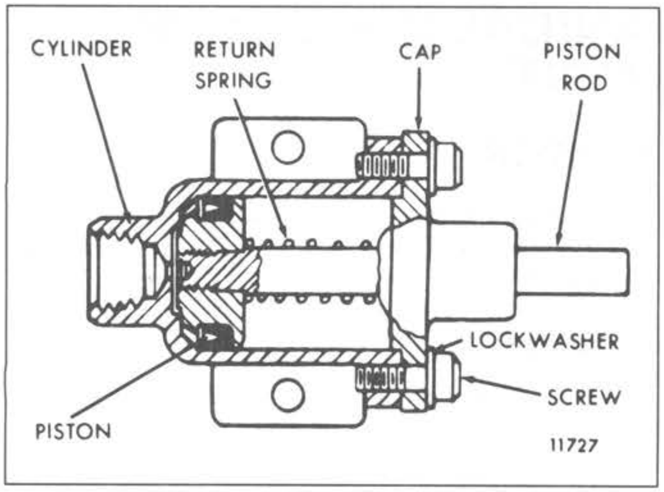


Fig. 3 – Throttle Locking Air Cylinder

2. Lock the governor throttle in the *idle* position and apply full shop air pressure to the fast idle air cylinder. The engine idle speed must increase from 325 to 500 rpm ± 50 rpm, depending on the original idle speed setting and fast idle spring used.

The throttle locking air cylinder is adjusted on its mounting bracket so it will lock the throttle in the *idle* position when it is activated, but will not limit the throttle movement when not activated (Fig. 3).

GOVERNOR SETTINGS FOR "TT" ENGINES

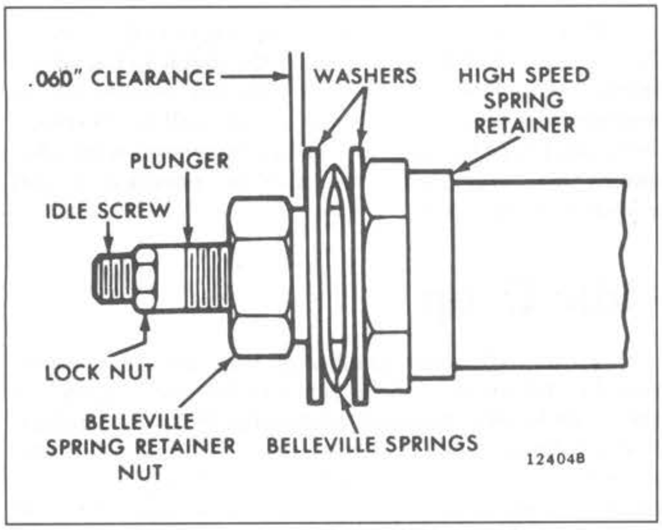


Fig. 1 – Belleville Washer Location

The operating characteristics of a "TT" engine are – it's ability to maintain reasonably constant horsepower over a wide speed range and its 6% torque rise per one hundred rpm. These characteristics are achieved by the action of two Belleville springs (washers) in a limiting speed governor.

NOTICE: The horsepower for "TT" engines indicate a flat horsepower performance curve. However, during dynamometer testing an engine may exhibit horsepower readings slightly above or below the flat curve. A 5% horsepower variation from the flat published curve is acceptable.

The spring force provided by the Belleville springs works with the governor weights to pull the injector racks out of fuel as the engine speed is increased. Conversely, as the engine speed is reduced by increased load, the high–speed spring overcomes the force of the Belleville springs and moves the injector racks to an increased fuel position. The racks move progressively into more fuel to maintain the constant horsepower until the racks are in full fuel at a speed near 1500 rpm.

Tune–up the "TT" engine the same as a standard engine tune–up as outlined in Section 14.3.

After completing the standard engine tune–up of setting injector timing, valve clearance, governor gap, injector racks and engine speeds, adjust the Belleville spring (washer) "TT" (tailor torqued) device.

Remove the piston from the throttle delay or apply shop air pressure to the fuel modulators to make sure they are inoperative during the tune–up process.

NOTICE: Use spanner wrench J 5345–5 to loosen or tighten the spring retainer locknut during the no–load speed adjustment. Always use the yield link in the governor when performing the engine tune–up.

Adjustment of the Belleville springs for the TT horsepower can be accomplished by two methods, depending on the equipment available at the service outlet. These methods are:

1. Idle Drop – without a dynamometer
2. Power Reduction Factor – using an engine, chassis or output shaft dynamometer

For satisfactory results, both methods require an engine in good condition and properly tuned.

NOTICE: Do not attempt a Belleville spring (washer) adjustment, an idle drop setting, or a power reduction setting until an engine tune–up has been properly performed.

HORSEPOWER RATING AND COOLING SYSTEM CAPACITY

On–highway truck manufacturers provide cooling systems compatible with the horsepower ratings of the engines ordered by their customers. Vehicles are normally equipped with a base cooling system when the low horsepower version of an engine is specified. A higher engine horsepower rating increases the heat rejection rate for the engine and, in practically all instances, will require an upgraded cooling system. When vehicles are ordered with higher engine horsepower ratings, upgraded cooling systems are automatically provided by the truck manufacturers.

The horsepower ratings of most Detroit Diesel vehicle engines can be easily upgraded after the engine is put in service. However, *increasing the horsepower output without also modifying the cooling system will, in practically all instances, lead to engine overheating when the engine is used in certain service applications and geographic areas of operation. Damage resulting from engine modifications contrary to manufacturer's recommendations will not be covered under warranty.*

NOTICE: Installation and use of any fuel injectors other than those which have been certified for each engine may constitute *tampering* and be in violation of Federal and/or State laws.

If increased horsepower is essential to vehicle operation, the truck dealer/distributor or local Detroit Diesel distributor should be contacted to determine whether the cooling system can handle additional heat load or to specify the parts necessary to uprate the cooling system.

A truck buyer who knows that a higher horsepower rating will be required during the life of his vehicle should order the vehicle with cooling system components for the higher horsepower engine *or* order the vehicle with the higher horsepower rating.

If the higher horsepower rating is specified, a Detroit Diesel dealer/distributor can derate the engine to the output desired. This procedure ensures adequate cooling for all horsepower levels at which the engine will be operated. Compatibility of the cooling system components with other options and accessories will also be provided if this procedure is followed.

METHOD 1 – Idle Drop

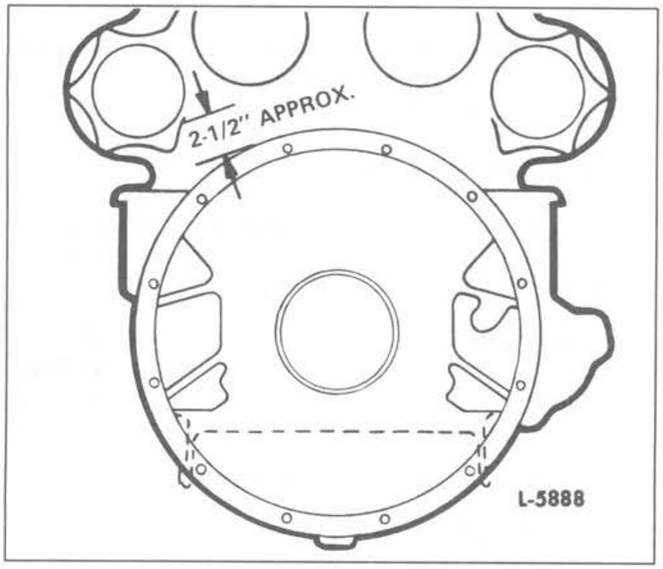


Fig. 2 – Identification of Engine Flywheel

The idle drop method is an effective, accurate means of setting "TT" horsepower.

The idle drop method requires a specific reduction in engine speed to position the Belleville springs and the governor low and high–speed springs. The positioning of these governor components results in obtaining the desired "TT" horsepower.

When performing an idle drop horsepower adjustment on a "TT" engine having a 102 or 118 tooth flywheel, an accurate tachometer is mandatory (Digital Tachometer J 26791 recommended). Each one (1) rpm error in setting the idle drop results in a two or three horsepower error.

The tachometer is installed in the flywheel housing drain plug hole and operates by counting the flywheel teeth, using a magnetic probe to pick–up impulses off the flywheel ring gear. The electronic module displays the engine speed digitally to one decimal place within one rpm accuracy. These capabilities make it ideal for setting horsepower on the "TT" engines using the idle drop method.

To determine the number of teeth on the flywheel, when identification of the engine flywheel part number or type is not known, measure the distance from the camshaft flywheel housing cover lower bolt head and the outer circumference of the flywheel housing bell (Fig. 2). If this distance is approximately 1–1/4", it is a 118 tooth flywheel. For the 102 tooth flywheel, the distance will be approximately 2–1/2".

When the number of teeth on the flywheel is known, set the switch on the tachometer to the proper position. Proceed as follows:

1. Perform the standard engine tune–up. Set the no–load speed as required by the engine type, injector size and governor (see Charts).
2. Disconnect the accelerator linkage from the governor speed control lever if it has not already been done.
3. Run the engine until a stabilized engine coolant temperature is obtained.
4. Refer to 1978 Chart and, using engine type, injector size and governor, select the initial and specified idle drop numbers for the rated "TT" horsepower and rated engine speed at which the engine is to operate.

Each idle drop Chart (1979 on) includes the following information:

Maximum Full Load RPMs

Governor Part Numbers

Belleville Washer Part Numbers

Injector Size

Initial Idle Drop Starting RPM

The above should be considered to insure the correct chart is being used. To maintain certification as required by law, the engine horsepower cannot be adjusted beyond the limits outlined on each chart.

5. Set the initial idle speed (using the idle adjusting screw) to that determined in Step "4" above.

6. With the governor speed control lever in the idle position, turn the Belleville spring retainer nut (Fig. 1) clockwise on the plunger until the specified idle drop speed is achieved. Secure the retainer nut with the locking screw. When the specified idle speed is achieved, the engine is power controlled to the "TT" horsepower rating.

NOTICE: Idle speeds must be exact and steady. If they are not, check for bind or rubbing in the fuel control system: governor, fuel rods, injector control tubes and injector control racks.

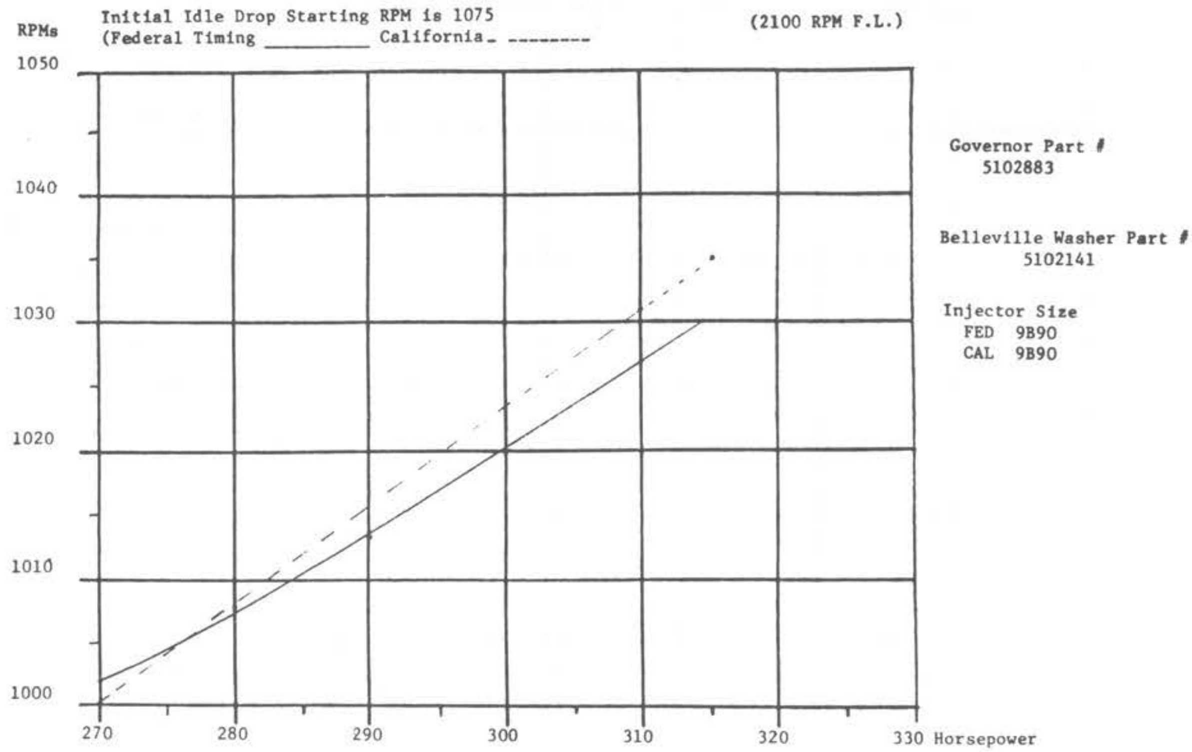
7. Lower the idle speed to the desired operating idle speed, using the idle adjusting screw.
8. Adjust the buffer screw and the starting aid screw.

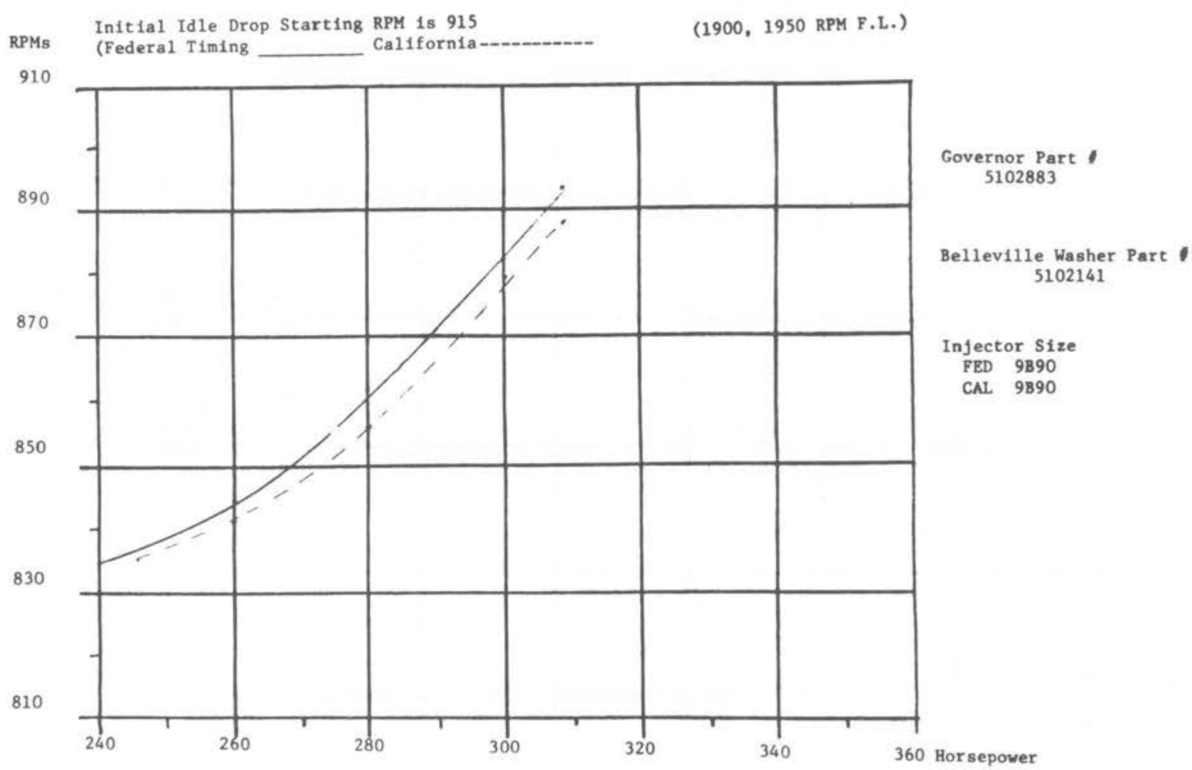
ENGINE TYPE	INJECTOR SIZE	THROTTLE DELAY SETTING	RATED HORSEPOWER @ RATED SPEED	INITIAL IDLE	IDLE DROP SETTING
6V-92TT*	9290	.570	270 @ 1800 260 @ 1800 250 @ 1800 240 @ 1800	880 880 880 880	810 804 798 792
6V-92TT*	9290	.570	270 @ 1850 260 @ 1850 250 @ 1850 240 @ 1850	880 880 880 880	808 802 796 790
6V-92TT	9290	.636	270 @ 1900 260 @ 1900 250 @ 1900 240 @ 1900	915 915 915 915	850 845 840 835
6V-92TT	9290	.636	270 @ 1950 260 @ 1950 250 @ 1950 240 @ 1950	915 915 915 915	848 843 838 833
6V-92TT*	9290	.636	270 @ 1900 260 @ 1900 250 @ 1900 240 @ 1900	950 950 950 950	877 873 869 865
6V-92TT*	9290	.636	270 @ 1950 260 @ 1950 250 @ 1950 240 @ 1950	950 950 950 950	875 871 867 863
6V-92TT	9290	.636	290 @ 1900	915	860
6V-92TT	9290	.636	290 @ 1950	915	858
6V-92TT*	9290	.636	270 @ 1950 260 @ 1950 250 @ 1950 240 @ 1950	950 950 950 950	875 871 867 863
6V-92TT	9290	.636	270 @ 2100	1075	995
6V-92TTA*	9A90	.636	270 @ 1900	975	900
6V-92TTA*	9A90	.636	270 @ 1950	975	899
6V-92TTA	9A90	.636	270 @ 1900 260 @ 1900 250 @ 1900 240 @ 1900	915 915 915 915	838 832 825 819
6V-92TTA	9A90	.636	270 @ 1950 260 @ 1950 250 @ 1950 240 @ 1950	915 915 915 915	837 831 824 818
6V-92TTA	9A90	.636	270 @ 2100	1075	995
8V-92TT*	9A90	.570	335 @ 1800	830	765
8V-92TT*	9A90	.570	335 @ 1850	830	763
8V-92TT	9290	.636	365 @ 1900	915	850
8V-92TT	9290	.636	365 @ 1950	915	848
8V-92TT*	9A90	.570	365 @ 1900 335 @ 1900	950 950	880 870
8V-92TT*	9A90	.570	365 @ 1950 335 @ 1950	950 950	878 868
8V-92TT	9290	.636	365 @ 2100	1075	1005
8V-92TTA*	9A90	.636	335 @ 1800	880	795
8V-92TTA*	9A90	.636	335 @ 1850	880	793
8V-92TTA*	9A90	.636	365 @ 1900 335 @ 1900	950 950	877 865
8V-92TTA*	9A90	.636	365 @ 1950 335 @ 1950	950 950	875 863
8V-92TTA	9A90	.636	365 @ 1900 335 @ 1900	950 950	867 845
8V-92TTA	9A90	.636	365 @ 1950 335 @ 1950	950 950	865 843
8V-92TTA	9A90	.636	365 @ 2100	1075	1000

*Uses Belleville Spring (Orange Dye)

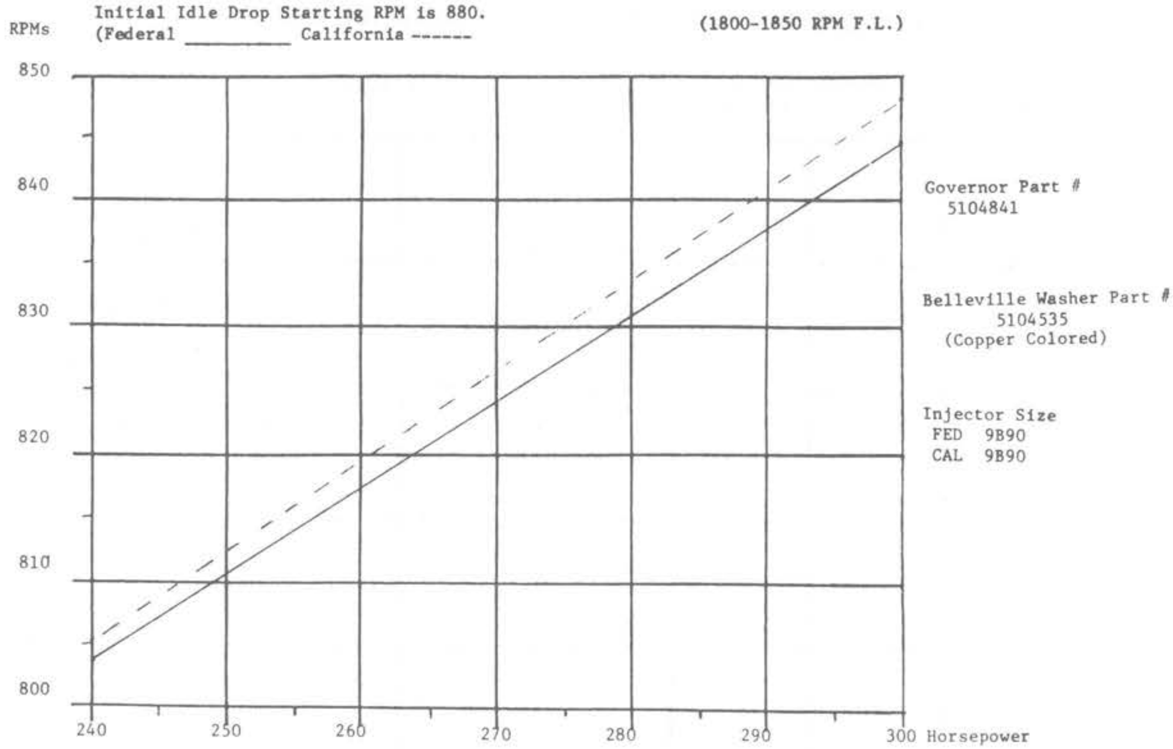
1978 Fed. & Calif.

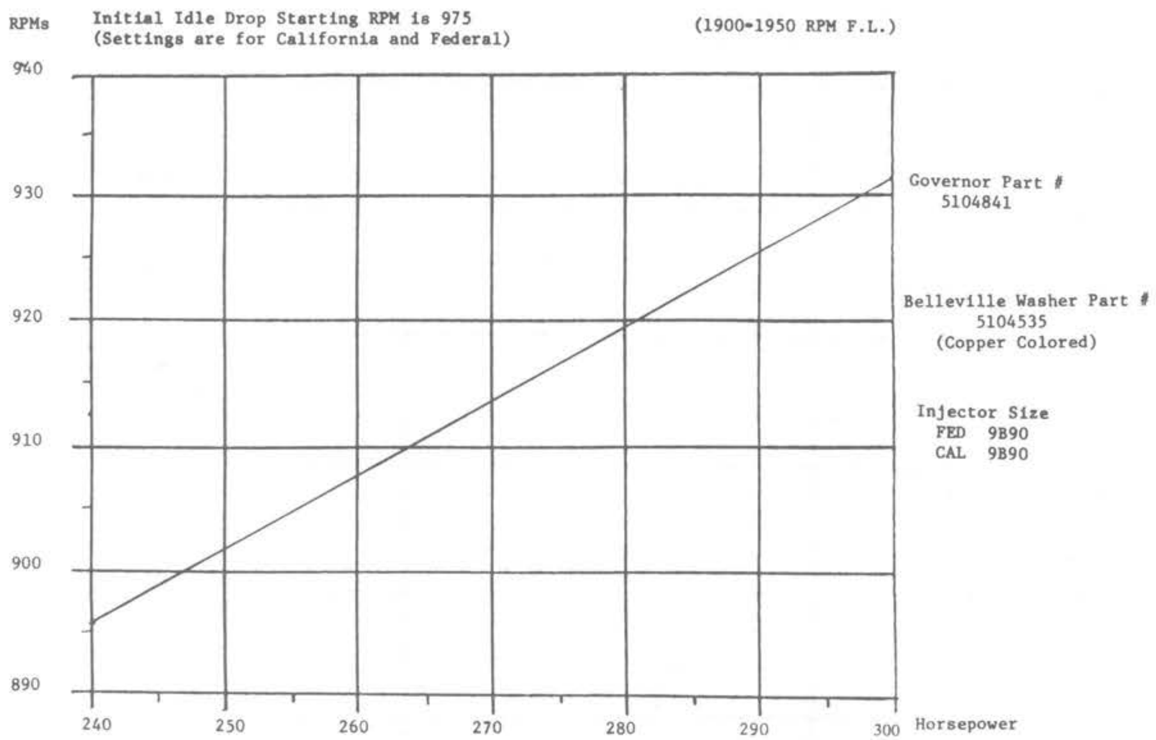
6V-92TTA IDLE DROP SETTINGS FOR AUTOMOTIVE ENGINES





1979 Fed. & Calif., 1980–1981 Fed. – Only

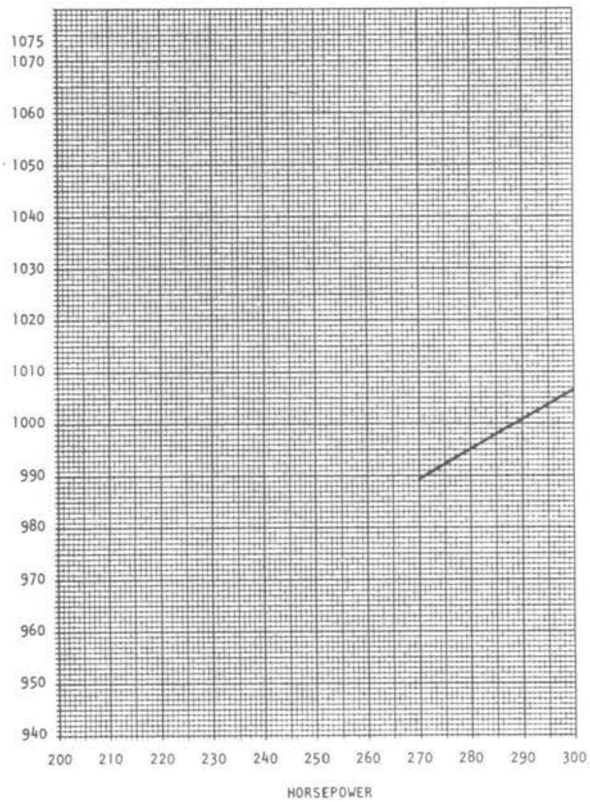




1979 Fed. & Calif., 1980–1981 Fed. – Only

5102883 GOVERNOR
1075 RPM INITIAL IDLE

6V-92 FEDERAL ENGINE
2100 RPM FULL LOAD

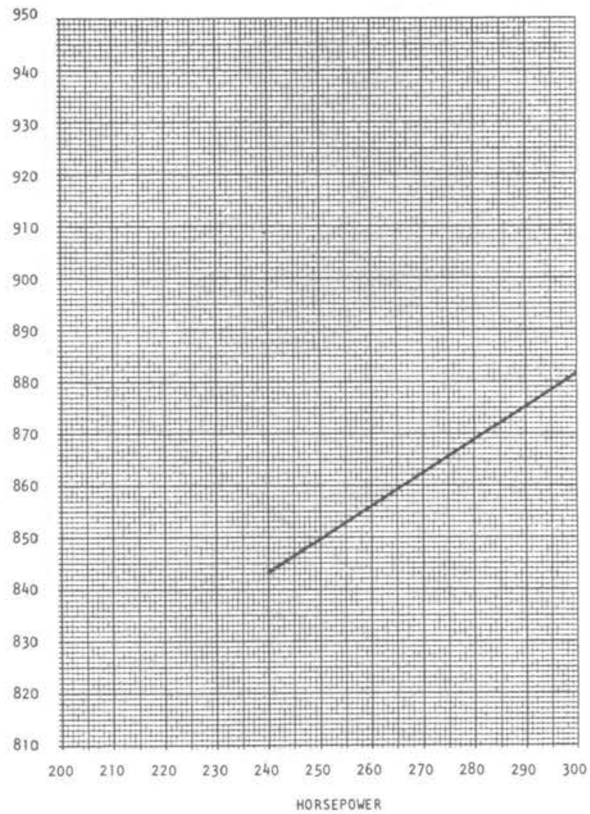


TYPICAL "TAILORED TORQUE" SETTINGS:
DROP TO 989 RPM YIELDS 270 HP
DROP TO 1006 RPM YIELDS 300 HP

IDLE
DROP
RPM

5102883 GOVERNOR
950 RPM INITIAL IDLE

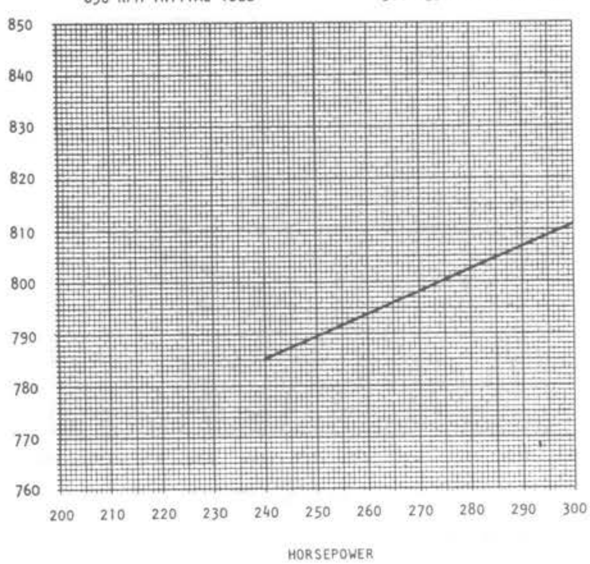
6V-92 FEDERAL ENGINE
1900-1950 RPM FULL LOAD



TYPICAL "TAILORED TORQUE" SETTINGS:
DROP TO 844 RPM YIELDS 240 HP
DROP TO 863 RPM YIELDS 270 HP

8922147 GOVERNOR
850 RPM INITIAL IDLE

6V-92 FEDERAL ENGINES
1900-1950 RPM FULL LOAD

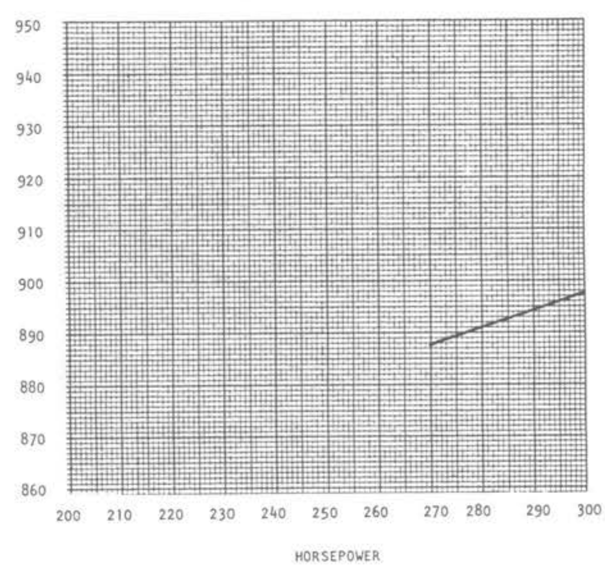


TYPICAL "TAILORED TORQUE" SETTINGS:
DROP TO 785 RPM YIELDS 240 HP
DROP TO 798 RPM YIELDS 270 HP

IDLE
DROP
RPM

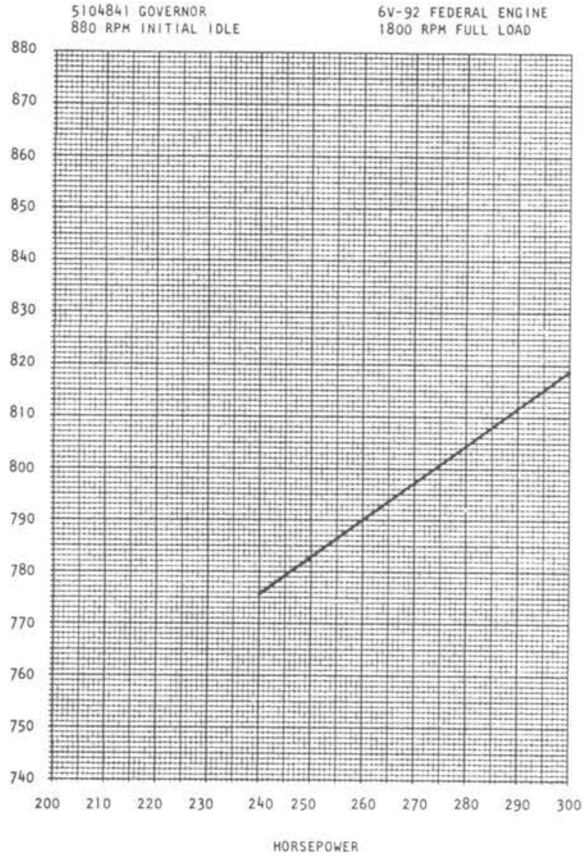
8922147 GOVERNOR
950 RPM INITIAL IDLE

6V-92 FEDERAL ENGINE
2100 RPM FULL LOAD



TYPICAL "TAILORED TORQUE" SETTINGS:
DROP TO 888 RPM YIELDS 270 HP
DROP TO 897 RPM YIELDS 300 HP

1982 Fed. – Silver Engines Only

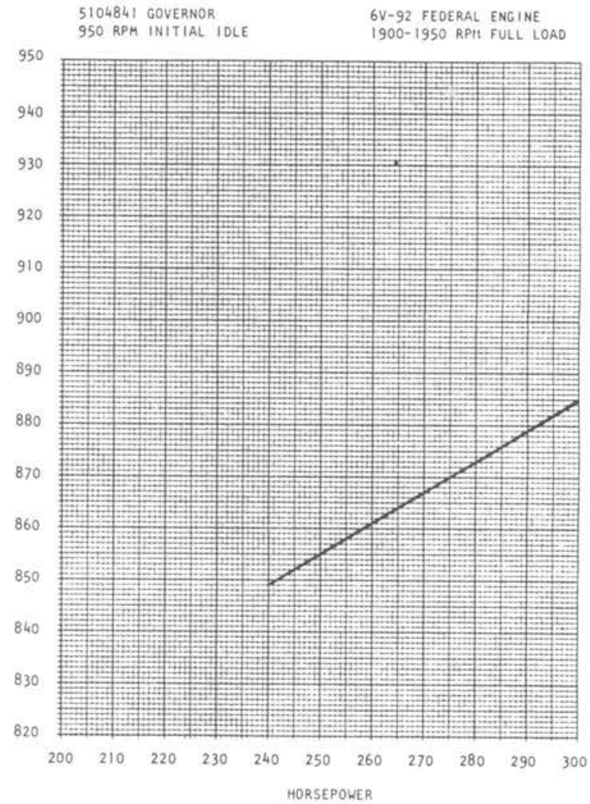


TYPICAL "TAILORED TORQUE" SETTINGS:

DROP TO 775 RPM YIELDS 240 HP

DROP TO 797 RPM YIELDS 270 HP

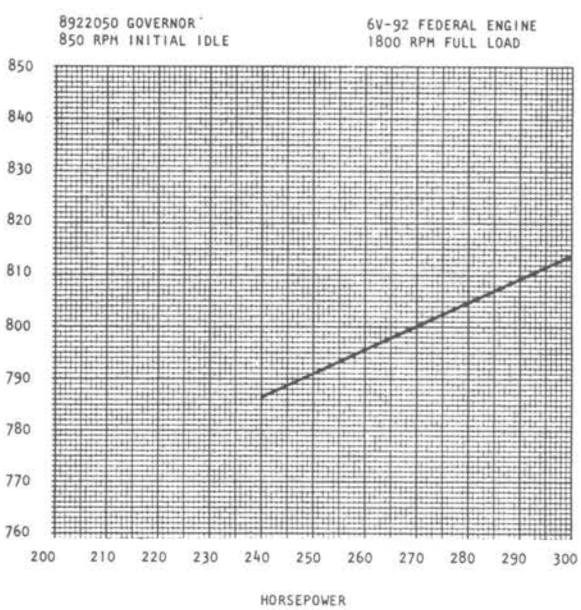
IDLE
DROP
RPM



TYPICAL "TAILORED TORQUE" SETTINGS:

DROP TO 849 RPM YIELDS 240 HP

DROP TO 867 RPM YIELDS 270 HP

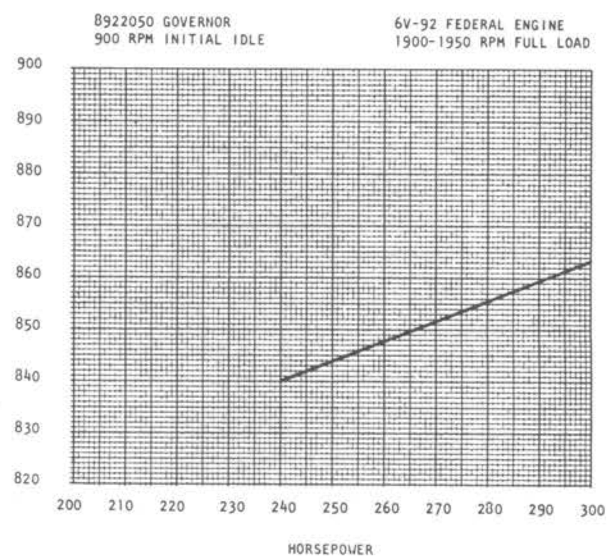


TYPICAL "TAILORED TORQUE" SETTINGS:

DROP TO 787 RPM YIELDS 240 HP

DROP TO 800 RPM YIELDS 270 HP

IDLE
DROP
RPM



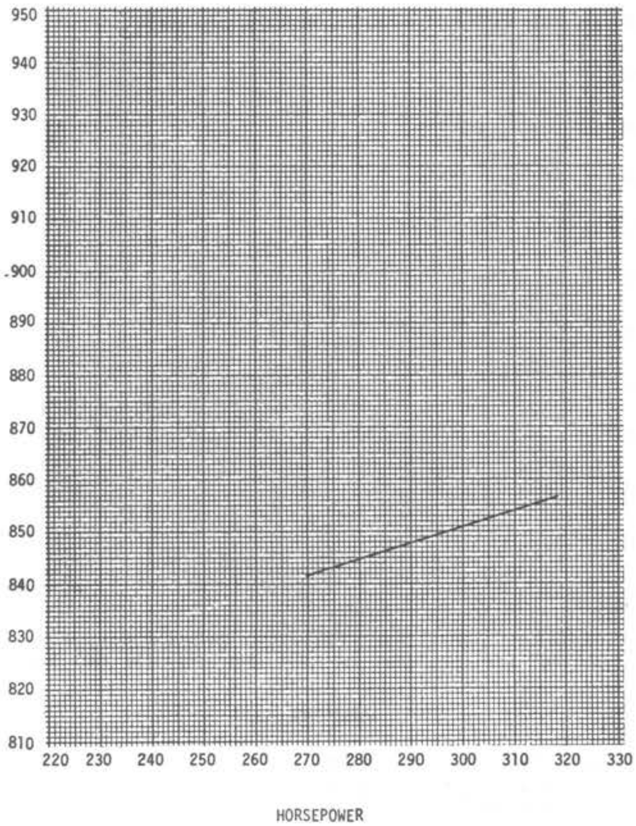
TYPICAL "TAILORED TORQUE" SETTINGS:

DROP TO 840 RPM YIELDS 240 HP

DROP TO 852 RPM YIELDS 270 HP

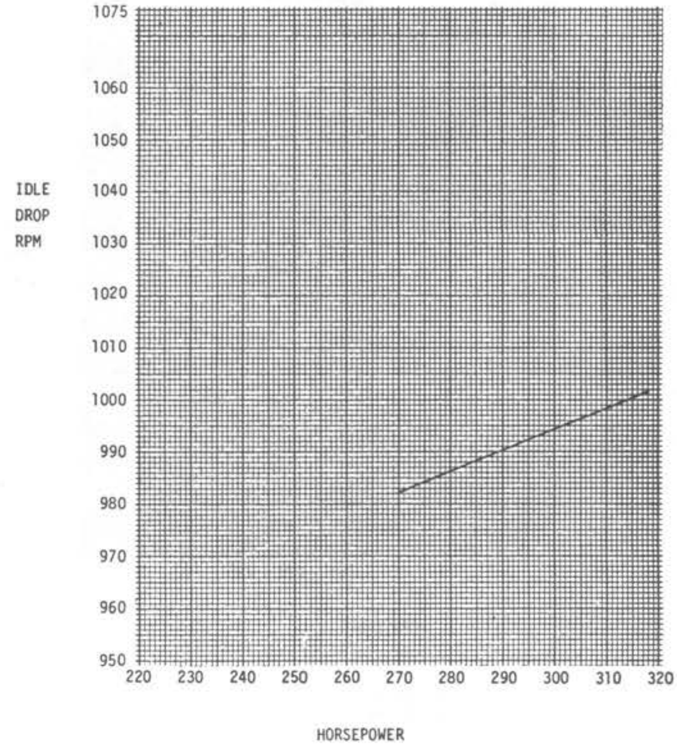
1982 Fed. – Silver Engines Only

8924430 Governor 6V-92 Federal Engine
950 RPM Initial Idle 2100 RPM Full Load



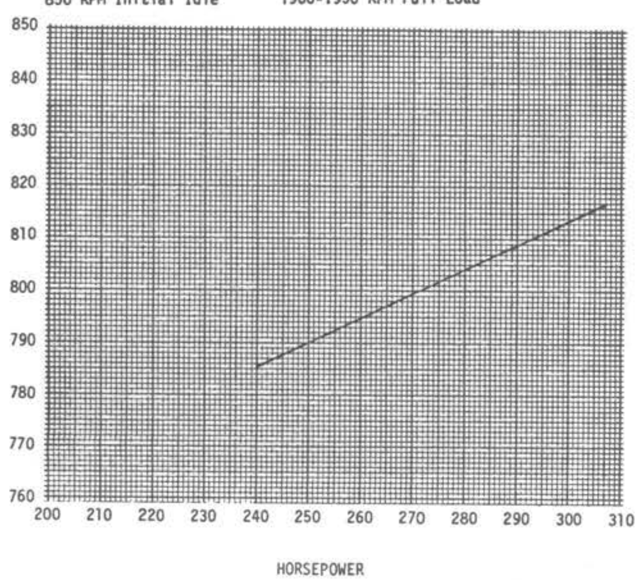
Typical "Tailored Torque" Setting:
Drop to 842 RPM Yields 270 HP

8924428 Governor 6V-92 Federal Engine
1075 RPM Initial Idle 2100 RPM Full Load



Typical "Tailored Torque" Setting:
Drop to 983 RPM Yields 270 HP

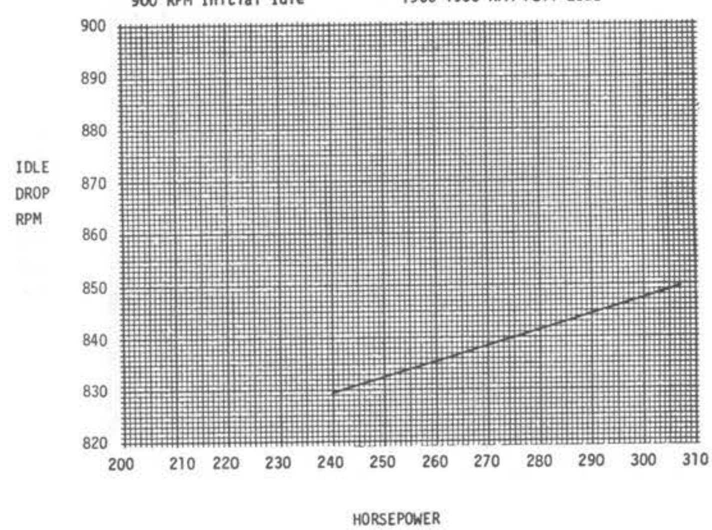
8924430 Governor 6V-92 Federal Engine
850 RPM Initial Idle 1900-1950 RPM Full Load



Typical "Tailored Torque" Settings:

Drop to 786 RPM Yields 240 HP
Drop to 800 RPM Yields 270 HP

8924431 Governor 6V-92 Federal Engine
900 RPM Initial Idle 1900-1950 RPM Full Load



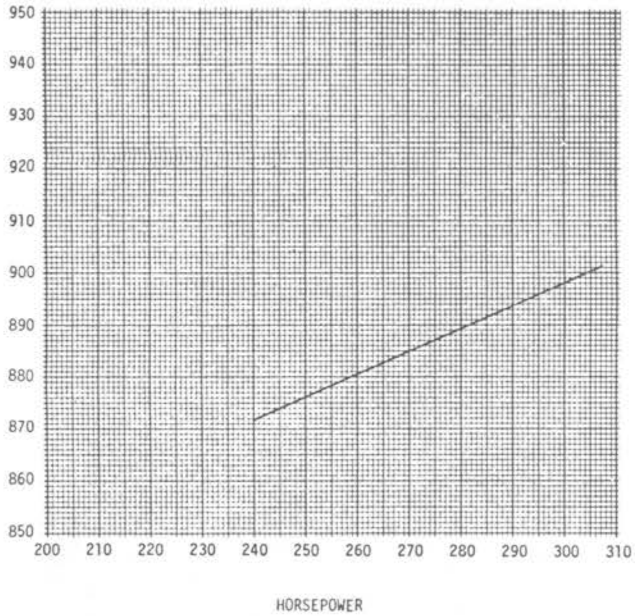
Typical "Tailored Torque" Settings:

Drop to 830 RPM Yields 240 HP
Drop to 839 RPM Yields 270 HP

1983 Federal

8924429 Governor
950 RPM Initial Idle

6V-92 Federal Engine
1900-1950 RPM Full Load

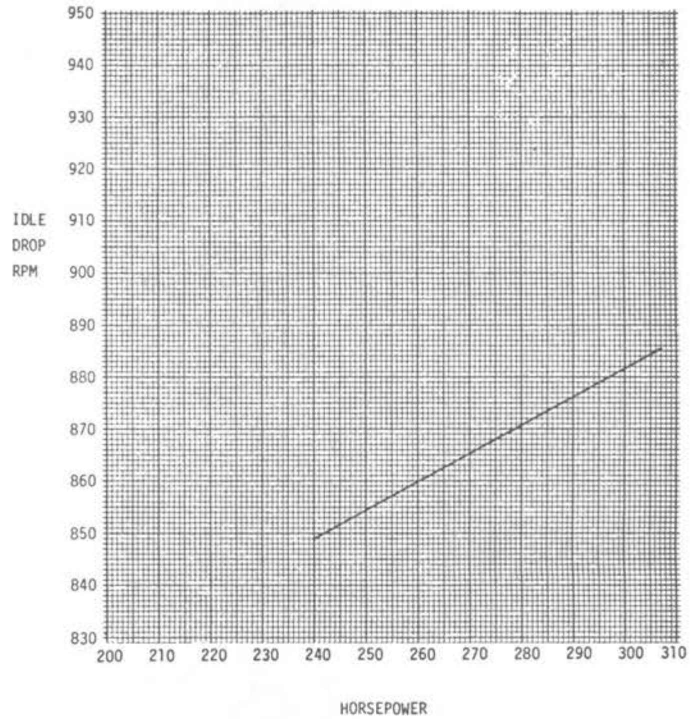


Typical "Tailored Torque" Settings:

Drop to 872 RPM Yields 240 HP
Drop to 885 RPM Yields 270 HP

8924428 Governor
950 RPM Initial Idle

6V-92 Federal Engine
1900-1950 RPM Full Load

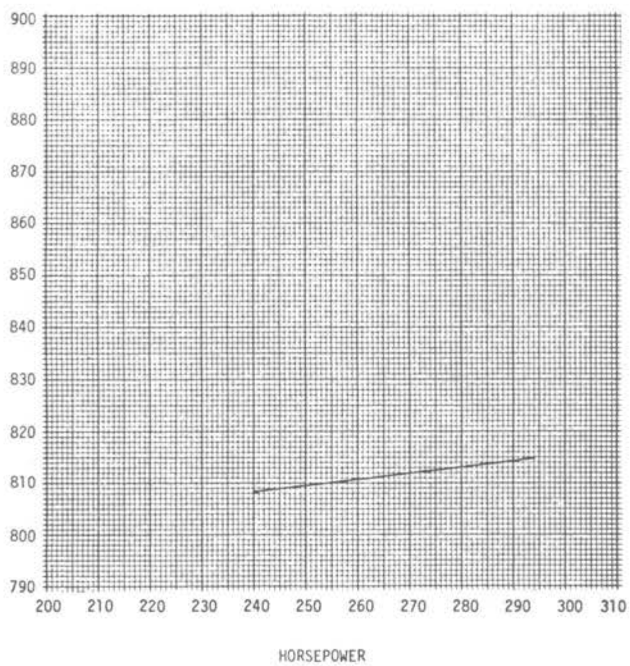


Typical "Tailored Torque" Settings:

Drop to 849 RPM Yields 240 HP
Drop to 866 RPM Yields 270 HP

8924429 Governor
900 RPM Initial Idle

6V-92 Federal Engine
1800 RPM Full Load

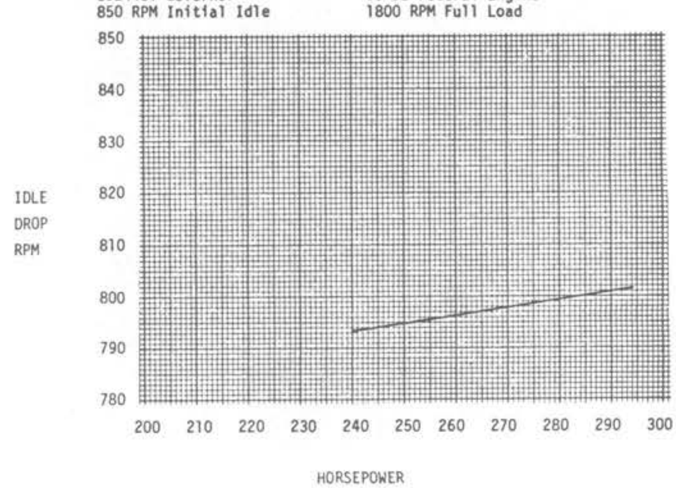


Typical "Tailored Torque" Settings:

Drop to 809 RPM Yields 240 HP
Drop to 812 RPM Yields 270 HP

8924431 Governor
850 RPM Initial Idle

6V-92 Federal Engine
1800 RPM Full Load

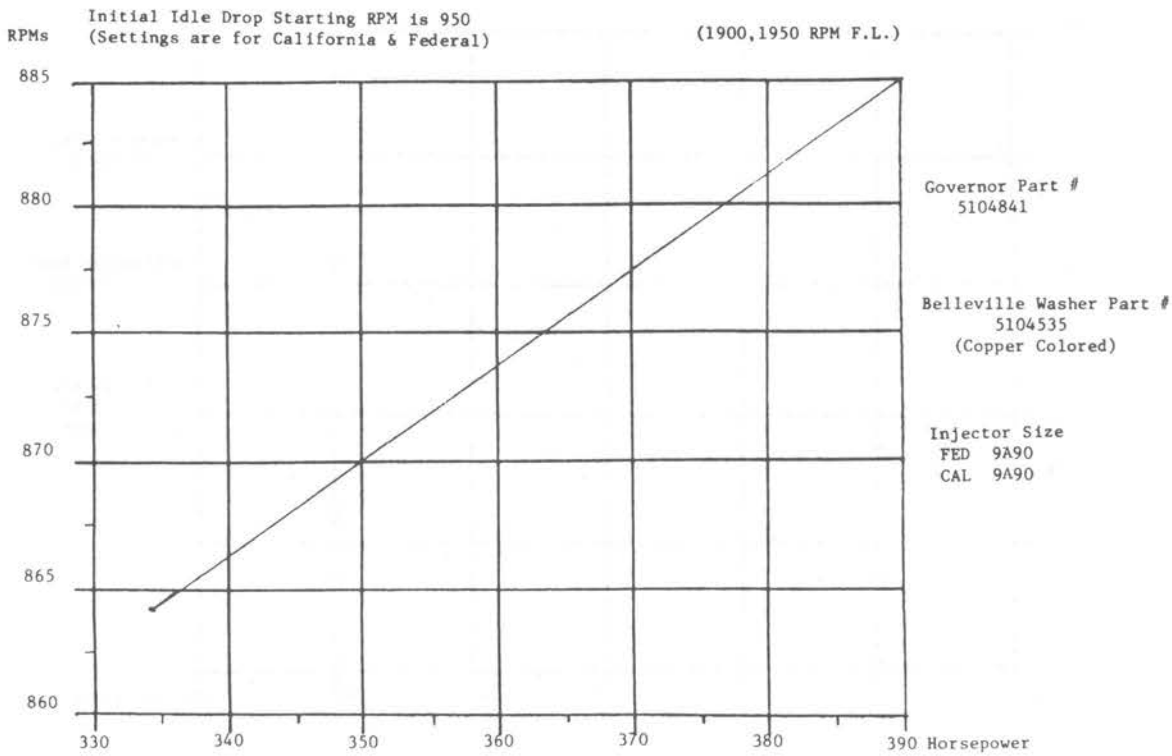


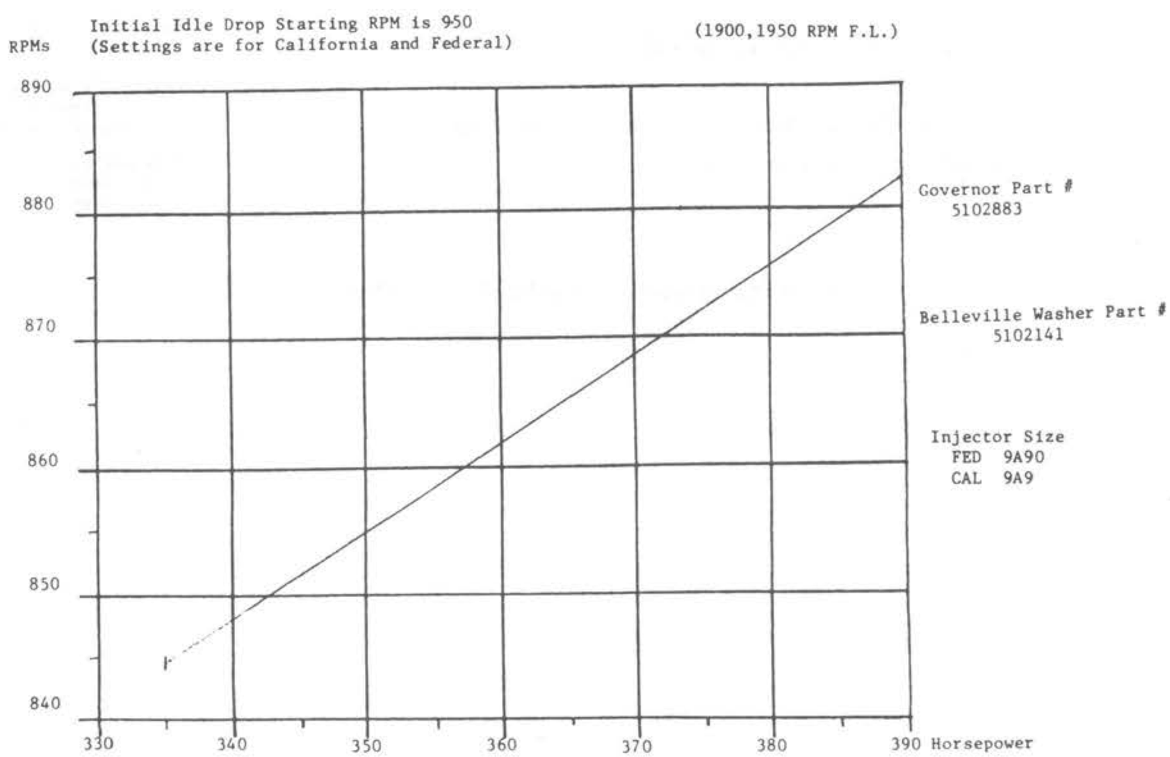
Typical "Tailored Torque" Settings:

Drop to 794 RPM Yields 240 HP
Drop to 798 RPM Yields 270 HP

1983 Federal (Cont.)

8V-92TTA IDLE DROP SETTINGS FOR AUTOMOTIVE ENGINES

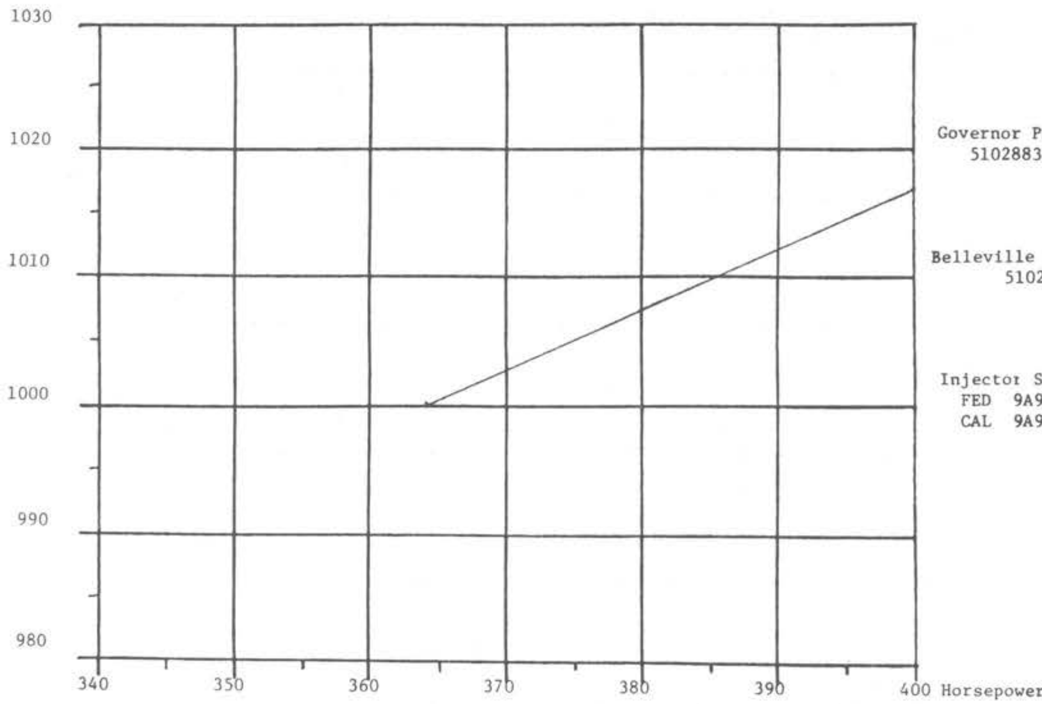




1979 Fed. & Calif., 1980–1981 Fed. – Only

Initial Idle Drop Starting RPM is 1075
(Settings are for California and Federal)

(2100 RPM F.L.)



Governor Part #
5102883

Belleville Washer Part #
5102141

Injector Size
FED 9A90
CAL 9A90

8V92TTA IDLE DROP SETTINGS FOR 1979 (1800 RPM F.L.) ENGINES

Initial Idle Drop Starting RPM is 880
(Settings are for California and Federal)

THE SETTING FOR THIS ENGINE IS 335 HORSEPOWER ONLY. THIS IS ACQUIRED BY IDLE DROPPING TO 795 R.P.M.'S.

Governor Part #
5104841

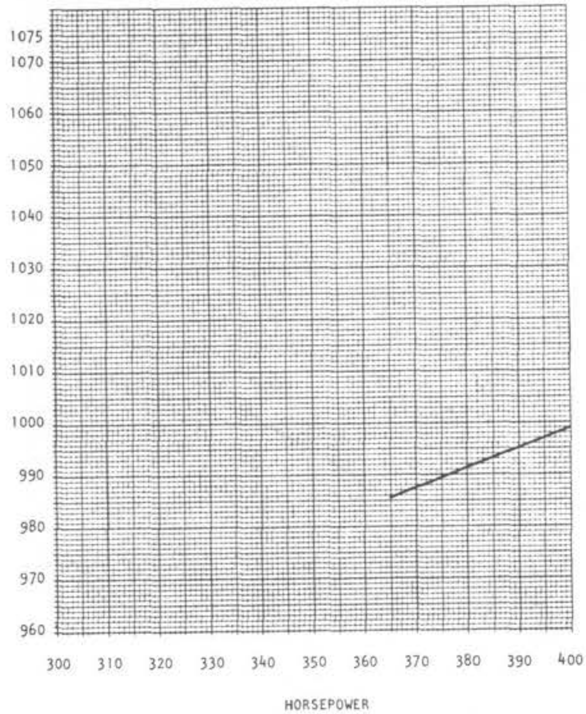
Belleville Washer Part #
5104535
(Copper Colored)

Injector Size
FED 9A90
CAL 9A90

1979 Fed. & Calif., 1980–1981 Fed. – Only

5102883 GOVERNOR
1075 RPM INITIAL IDLE

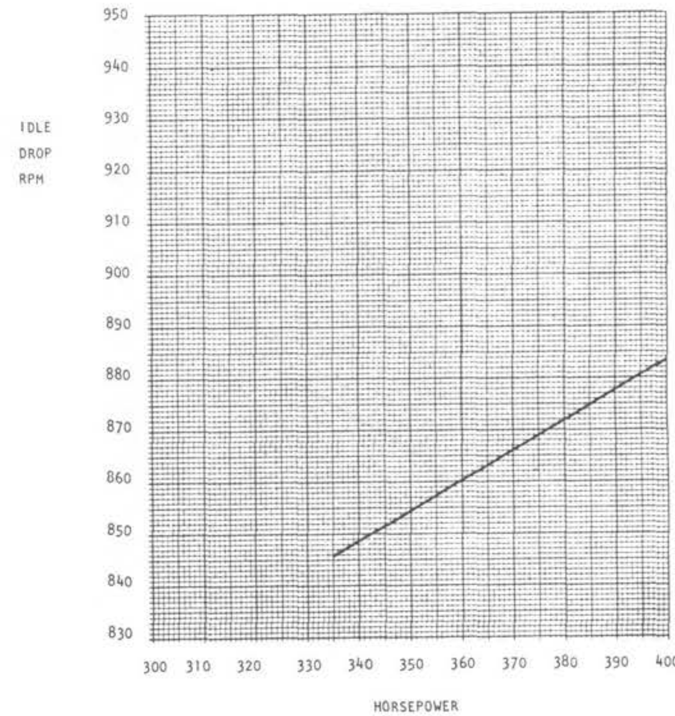
8V-92 FEDERAL ENGINE
2100 RPM FULL LOAD



TYPICAL "TAILORED TORQUE" SETTINGS:
DROP TO 986 RPM YIELDS 365 HP
DROP TO 999 RPM YIELDS 400 HP

5102883 GOVERNOR
950 RPM INITIAL IDLE

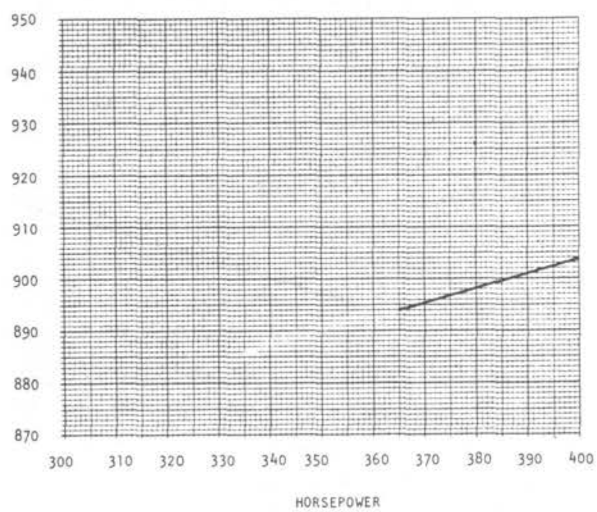
8V-92 FEDERAL ENGINE
1900-1950 RPM FULL LOAD



TYPICAL "TAILORED TORQUE" SETTINGS:
DROP TO 846 RPM YIELDS 335 HP
DROP TO 863 RPM YIELDS 365 HP

8922147 GOVERNOR
950 RPM INITIAL IDLE

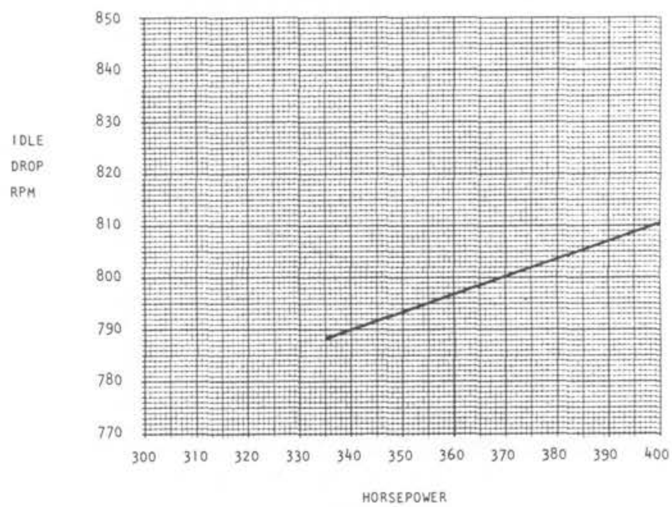
8V-92 FEDERAL ENGINE
2100 RPM FULL LOAD



TYPICAL "TAILORED TORQUE" SETTINGS:
DROP TO 894 RPM YIELDS 365 HP
DROP TO 904 RPM YIELDS 400 HP

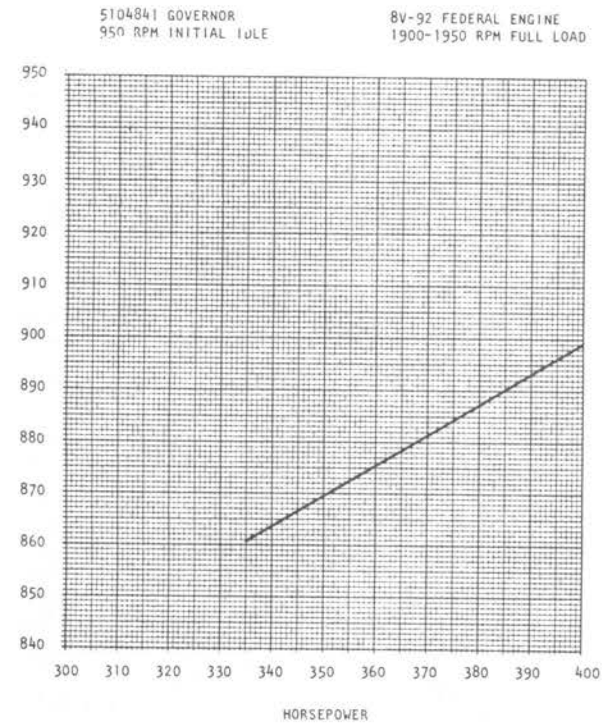
8922147 GOVERNOR
850 RPM INITIAL IDLE

8V-92 FEDERAL ENGINE
1900-1950 RPM FULL LOAD

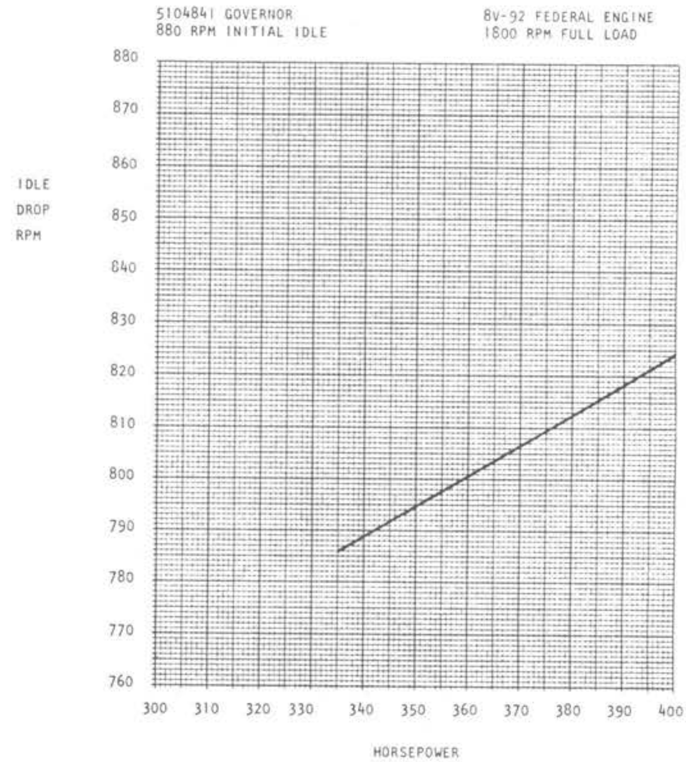


TYPICAL "TAILORED TORQUE" SETTINGS:
DROP TO 788 RPM YIELDS 335 HP
DROP TO 799 RPM YIELDS 365 HP

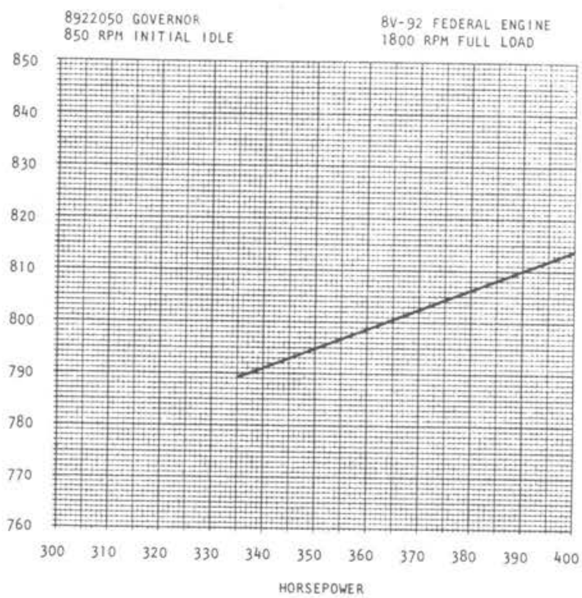
1982 Fed. – Silver Engines Only



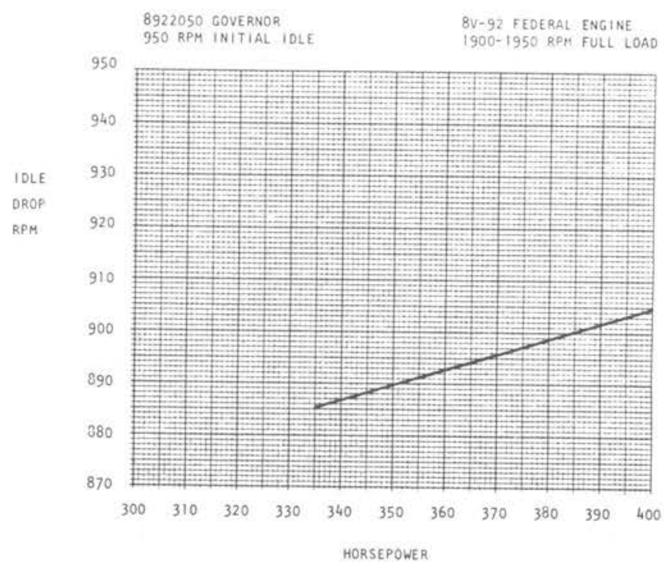
TYPICAL "TAILORED TORQUE" SETTINGS:
DROP TO 861 RPM YIELDS 335 HP
DROP TO 878 RPM YIELDS 365 HP



TYPICAL "TAILORED TORQUE" SETTINGS:
DROP TO 786 RPM YIELDS 335 HP
DROP TO 803 RPM YIELDS 365 HP



TYPICAL "TAILORED TORQUE" SETTINGS:
DROP TO 789 RPM YIELDS 335 HP
DROP TO 800 RPM YIELDS 365 HP

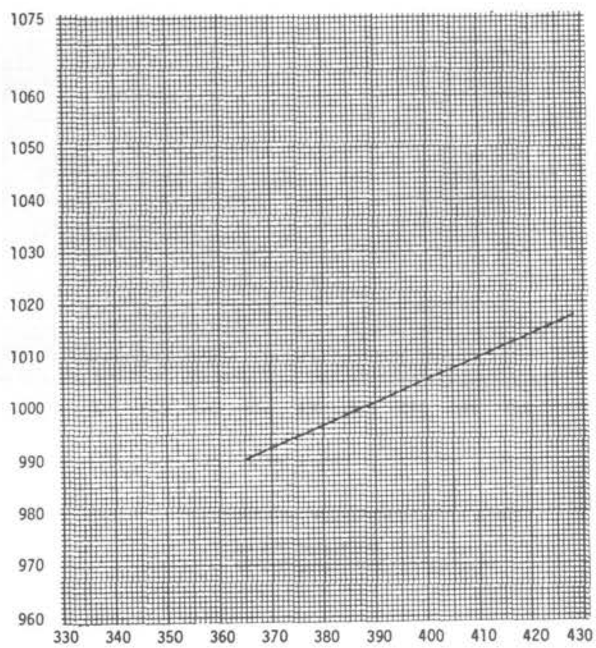


TYPICAL "TAILORED TORQUE" SETTINGS:
DROP TO 885 RPM YIELDS 335 HP
DROP TO 894 RPM YIELDS 365 HP

1982 Fed. – Silver Engines Only

8924428 Governor
1075 RPM Initial Idle

8V-92 Federal Engine
2100 RPM Full Load

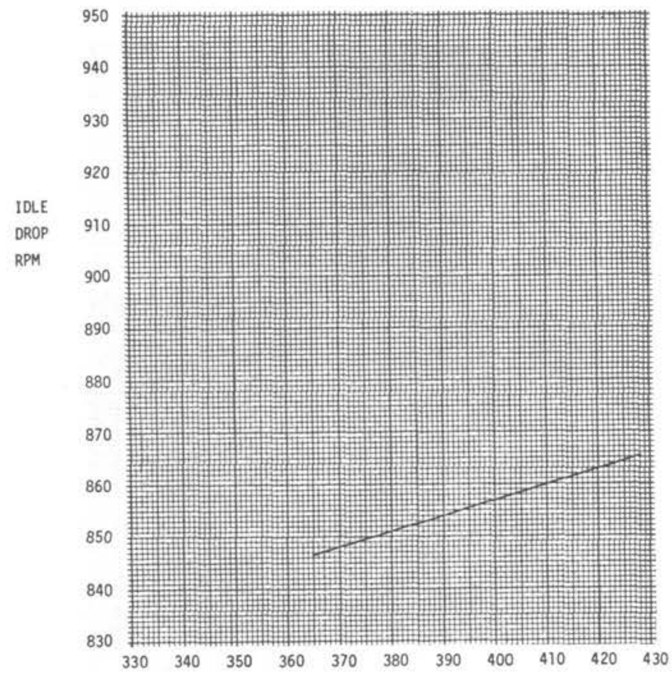


Typical "Tailored Torque" Setting:

Drop to 990 RPM Yields 365 HP

8924430 Governor
950 RPM Initial Idle

8V-92 Federal Engine
2100 RPM Full Load

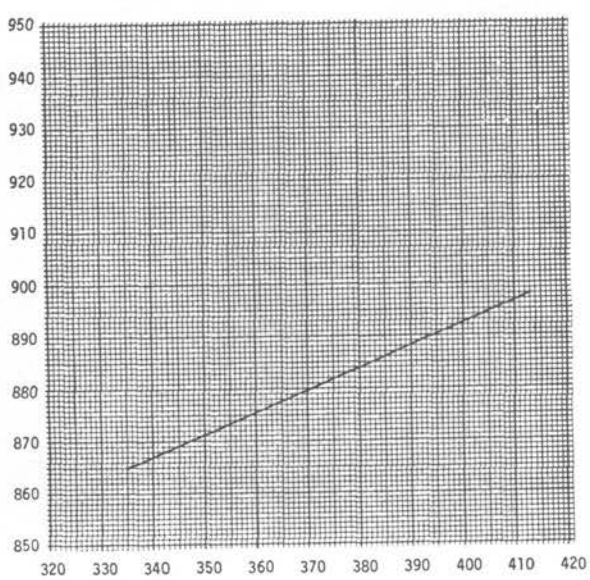


Typical "Tailored Torque" Setting:

Drop to 847 RPM Yields 365 HP

8924429 Governor
950 RPM Initial Idle

8V-92 Federal Engine
1900-1950 RPM Full Load

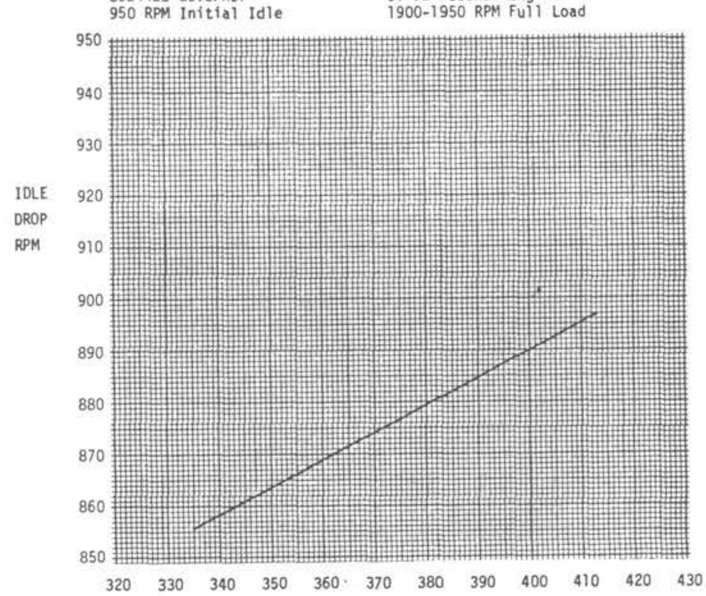


Typical "Tailored Torque" Settings:

Drop to 865 RPM Yields 335 HP
Drop to 878 RPM Yields 365 HP

8924428 Governor
950 RPM Initial Idle

8V-92 Federal Engine
1900-1950 RPM Full Load



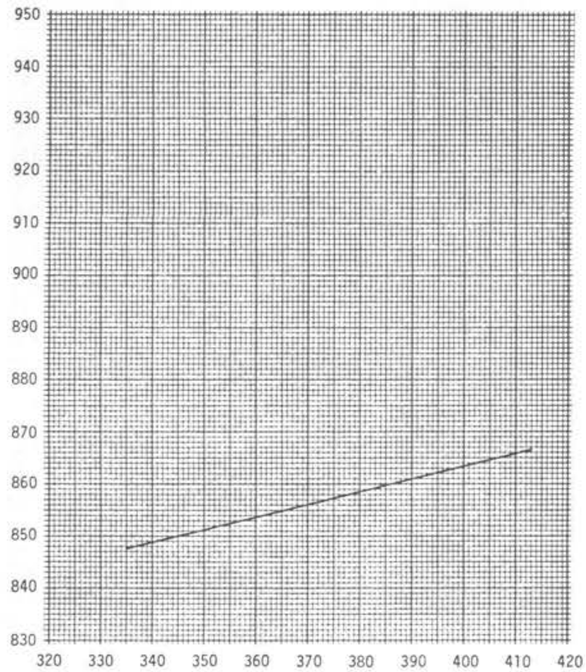
Typical "Tailored Torque" Settings:

Drop to 856 RPM Yields 335 HP
Drop to 872 RPM Yields 365 HP

1983 Federal

8924431 Governor
950 RPM Initial Idle

8V-92 Federal Engines
1900-1950 RPM Full Load

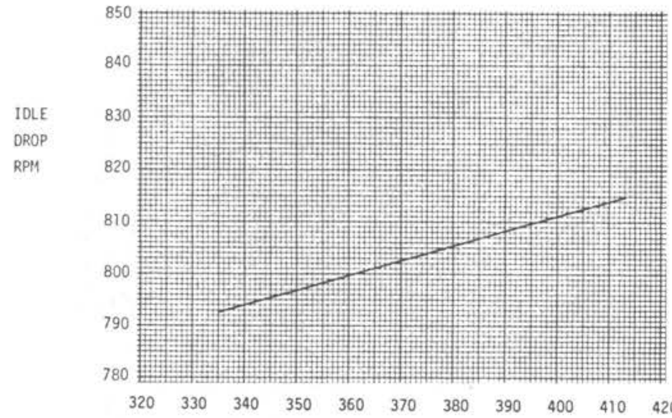


Typical "Tailored Torque" Settings:

Drop to 848 RPM Yields 335 HP
Drop to 855 RPM Yields 365 HP

8924430 Governor
850 RPM Initial Idle

8V-92 Federal Engine
1900-1950 RPM Full Load

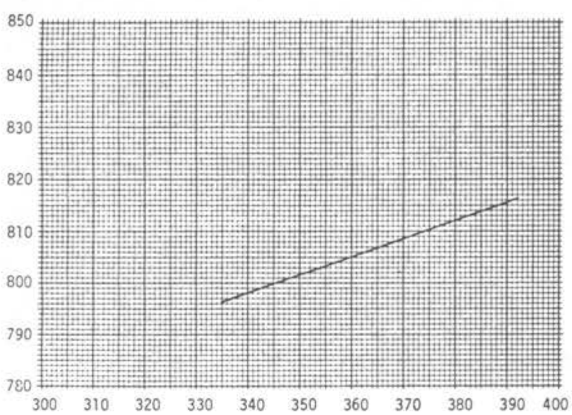


Typical "Tailored Torque" Settings:

Drop to 793 RPM Yields 335 HP
Drop to 802 RPM Yields 365 HP

8924431 Governor
850 RPM Initial Idle

8V-92 Federal Engine
1800 RPM Full Load

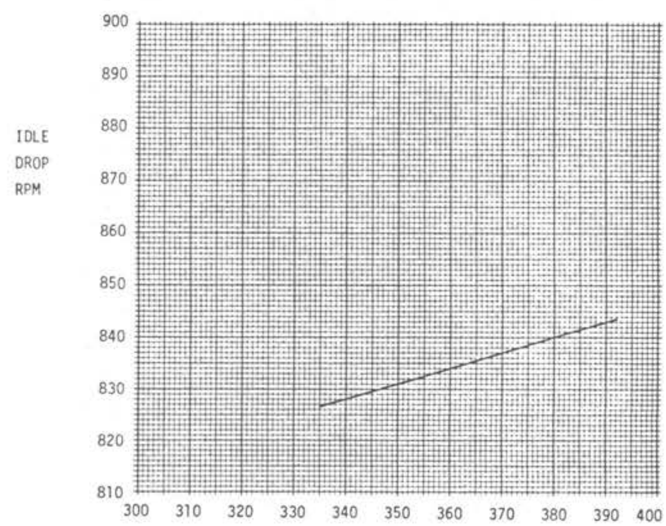


Typical "Tailored Torque" Settings:

Drop to 797 RPM Yields 335 HP
Drop to 807 RPM Yields 365 HP

8924429 Governor
900 RPM Initial Idle

8V-92 Federal Engine
1800 RPM Full Load



Typical "Tailored Torque" Settings:

Drop to 826 RPM Yields 335 HP
Drop to 835 RPM Yields 365 HP

1983 Federal (Cont.)

METHOD 2 - Power Reduction Factor

This method consists of setting "TT" engine horsepower to a specific percentage below full throttle horsepower as observed on an engine, chassis or output shaft dynamometer.

This method will provide the desired horsepower, within a reasonable tolerance, even with normal variations of test conditions. Some of these variations would be:

Dynamometer Calibration

Driveline Efficiency

Fuel Grade and Temperature

Air Density

Tire Slippage

Proceed as follows:

1. Perform the standard engine tune up.

NOTICE: The throttle delay piston must be removed and the Belleville spring retainer nut must be backed out until there is approximately .060" clearance between the washers and retainer nut (Fig. 1) prior to operating the engine on the dynamometer.

ENGINE TYPE	MAXIMUM RATED B.H.P.	RATED "TT" HORSEPOWER	RATED ENGINE SPEED	NO-LOAD SPEED	POWER REDUCTION FACTOR
6V-92TT – 9290 Injectors Federal Certified Throttle delay setting .636 *Throttle delay setting .570	335 @ 2100 RPM 2275 RPM Maximum No-Load Speed	270*	1800	1950	.91
		270*	1850	2000	.89
		270	1900	2050	.88
		270	1950	2100	.86
		270	2100	2250	.82
		260*	1800	1950	.88
		260*	1850	2000	.86
		260	1900	2050	.84
		260	1950	2100	.83
		250*	1800	1950	.84
		250*	1850	2000	.83
		250	1900	2050	.81
		250	1950	2100	.80
		240*	1800	1950	.81
		240*	1850	2000	.79
		240	1900	2050	.78
		240	1950	2100	.77
6V-92TT – 9290 Injectors Federal Certified Throttle delay setting .636	335 @ 2100 RPM 2275 RPM Maximum No-Load Speed	290	1900	2050	.94
		290	1950	2100	.93
6V-92TTA – 9A90 Injectors California Approved Federal Certified Throttle delay setting .636	318 @ 2100 RPM 2275 RPM Maximum No-Load Speed	270	1900	2050	.91
		270	1950	2100	.89
		270	2100	2250	.86
		260	1900	2050	.87
		260	1950	2100	.86
		250	1900	2050	.84
		250	1950	2100	.83
		240	1900	2050	.81
		240	1950	2100	.79
8V-92TT – 9290 Injectors Federal Certified Throttle delay setting .636	430 @ 2100 RPM 2275 RPM Maximum No-Load	365	1900	2050	.92
		365	1950	2100	.91
		365	2100	2250	.87
8V-92TT – 9A90 Injectors Federal Certified Throttle delay setting .570	430 @ 2100 RPM 2275 RPM Maximum No-Load	335	1800	1950	.87
		335	1850	2000	.86
		335	1900	2050	.85
		335	1950	2100	.83
8V-92TTA – 9A90 Injectors California Approved Federal Certified Throttle delay setting .636	424 @ 2100 RPM 2275 RPM Maximum No-Load	365	1900	2050	.92
		365	1950	2100	.91
		365	2100	2250	.87
		335	1800	1950	.88
		335	1850	2000	.86
		335	1900	2050	.84
		335	1950	2100	.83
8V-92TTA – 9290 Injectors Federal Certified Throttle delay setting .636	440 @ 2100 RPM 2275 RPM Maximum No-Load	365	1900	2050	.90
		365	1950	2100	.89
		365	2100	2250	.85

Selected Engine Ratings – 1978 Fed. & Calif.

Engine Type	Max. Rated BHP	Rated TT H.P.	Rated Engine Speed	No-Load Speed	Power Reduction Factor
6V-92TTA	335 @ 2100 RPM	290	2100	2250	.89
Federal and	2275 RPM Maximum	280	2100	2250	.86
California	No Load Speed	270	2100	2250	.82
Engines		290	1950	2100	.93
	INJ. TIM. T/D	280	1950	2100	.90
	9B90 1.470 .570	270	1950	2100	.86
		260	1950	2100	.83
		250	1950	2100	.80
		240	1950	2100	.77
		290	1900	2050	.94
		280	1900	2050	.91
		270	1900	2050	.88
		260	1900	2050	.84
		250	1900	2050	.81
		240	1900	2050	.78
		290*	1850	2000	.96
		280*	1850	2000	.93
		270*	1850	2000	.89
		260*	1850	2000	.86
		250*	1850	2000	.83
*Uses Belleville Spring (Copper Flashed) P/N 5104535		240*	1850	2000	.79
		307*	1800	1950	N/A
		290*	1800	1950	.98
		280*	1800	1950	.95
		270*	1800	1950	.91
		260*	1800	1950	.88
		250*	1800	1950	.84
		240*	1800	1950	.81
8V-92TTA	Fed. - 435 @ 2100 RPM INJ. TIM. T/D	365	1900	2050	.92
Federal and	2275 RPM Maximum No Load 9A90 1.480 .636	365	1950	2100	.91
California		365	2100	2250	.87
Engines		335	1800	1950	.88
	Cal. - 430 @ 2100 RPM INJ. TIM. T/D	335	1850	2000	.86
	2275 RPM Maximum No Load 9A90 1.500 .660	335	1900	2050	.84
		335	1950	2100	.83

Selected Engine Ratings - 1979 Fed. & Calif., 1980-1981 Fed. - only

2. Set the no–load speed as required (see Charts).

3. Run the engine until the engine coolant temperature is above 170°F (77°C).

4. Using an engine, chassis or output shaft dynamometer, measure and record full throttle horsepower at 100 rpm below rated engine speed with the Belleville springs loose (Fig. 1).

NOTICE: Satisfactory power adjustment can be obtained only if the full throttle horsepower and adjusted horsepower (Step 4) are obtained with the engine cooling in the same mode, i.e., operating or not operating.

5. Select the power reduction factor in Table 2 or 3 for the proper engine type, desired rated horsepower and rated engine speed.

6. Multiply the horsepower recorded in Step 4 by the factor selected in Step 5. Record this value.

7. Adjust the Belleville spring retainer nut clockwise so that the observed horsepower is reduced to that recorded in Step 6 at 100 rpm below rated engine speed, with the governor speed control lever in the maximum speed position and the fan in the same mode as in Step 4. Verify that the engine is obtaining adjusted "TT" horsepower, within 5%, at rated engine speed. If the adjusted "TT" horsepower cannot be obtained at rated engine speed, governor droop interference may be the cause. If necessary, to eliminate droop interference, readjust the engine no–load speed from 150 to 175 rpm above rated engine speed and repeat the power reduction factor method.

8. Check the idle speed and, if necessary, reset to the specified idle speed.

9. Adjust the buffer screw and starting aid screw.

Engine Type	Max. Rated BHP	Rated TT H.P.	Rated Engine Speed	No-Load Speed	Power Reduction Factor
6V-92TTA	305 @ 2100 RPM	270	2100	2250	.88
	2275 RPM Maximum	270	1950	2100	.91
California	No Load Speed	260	1950	2100	.87
Engines		250	1950	2100	.84
	INJ. TIM. T/D	240	1950	2100	.81
	9C90 1.480 .660	270	1900	2050	.92
		260	1900	2050	.89
		250	1900	2050	.85
		240	1900	2050	.82
		270*	1850	2000	.93
		260*	1850	2000	.90
		250*	1850	2000	.86
*Uses Belleville Spring (Copper Flashed) P/N 5104535		240*	1850	2000	.83
		270*	1800	1950	.95
		260*	1800	1950	.91
		250*	1800	1950	.88
		240*	1800	1950	.84
8V-92TTA	Cal. - 405 @ 2100 RPM	365	1900	2050	.93
	2275 RPM Maximum No Load	365	1950	2100	.92
California		365	2100	2250	.90
Engines		335	1800	1950	.88
	INJ. TIM. T/D	335	1850	2000	.87
	9C90 1.480 .660	335	1900	2050	[illegible]5
		335	1950	2100	.84

Selected Engine Ratings – 1980–1981 Calif. – Only

Engine Type	Max. Rated H.P.	Rated TT H.P.	Rated Eng. Speed	No-Load Speed	Power Reduction Factor
6V-92TTA	330 @ 2100 RPM	270	2100	2250	.83
Federal	2275 RPM Max. No-Load Speed	270	1950	2100	.86
		240	1950	2100	.76
	INJ. TIM. T/D	270	1900	2050	.88
	9B90 1.470 .570	240	1900	2050	.78
		307*	1800	1950	N/A
		270*	1800	1950	.91
		240*	1800	1950	.81
8V-92TTA	445 @ 2100 RPM	365	2100	2250	.84
Federal	2275 RPM Max. No-Load Speed	365	1950	2100	.87
		335	1950	2100	.80
	INJ. TIM. T/D	365	1900	2050	.89
	9A90 1.466 .636	335	1900	2050	.82
		411*	1800	1950	N/A
		365*	1800	1950	.92
		335*	1800	1950	.85
6V-92TTA	325 @ 2100 RPM	270	2100	2250	.85
California	2275 RPM Max. No-Load Speed	270	1950	2100	.87
		240	1950	2100	.77
	INJ. TIM. T/D	270	1900	2050	.89
	9F90 1.520 .636	240	1900	2050	.79
		304*	1800	1950	N/A
		270*	1800	1950	.92
		240*	1800	1950	.82
8V-92TTA	440 @ 2100 RPM	365	2100	2250	.85
California	2275 RPM Max. No-Load Speed	365	1950	2100	.89
		335	1950	2100	.81
	INJ. TIM. T/D	365	1900	2050	.91
	9F90 1.520 .660	335	1900	2050	.83
		403*	1800	1950	N/A
		365*	1800	1950	.94
		335*	1800	1950	.87

*Uses Belleville spring (copper flashed) P/N 5104535.
N/A – Not Applicable.

Selected Engine Ratings – 1982 Fed. & Calif.

Engine Type and Max. Rated BHP		Rated TT H.P.	Rated Engine Speed(rpm)	No-Load Speed (rpm)	Power Reduction Factor
6V-92TTA Federal 330 @ 2100 RPM Ⓑ 2275 RPM Max. No-Load Speed	Injector 9B90 Timing 1.464 Throttle Delay .636 Ⓐ .610 Ⓑ Modulator Setting .480	270 Ⓑ	2100	2225	.83
		270 Ⓑ	1950	2075	.86
		240 Ⓑ	1950	2075	.76
		270 Ⓑ	1900	2025	.88
		240 Ⓑ	1900	2025	.78
		307 Ⓐ *	1800	1925	N/A
		270 Ⓐ *	1800	1925	.91
		240 Ⓐ *	1800	1925	.81
8V-92 TTA Federal 445 @ 2100 RPM 2275 RPM Max. No-Load Speed	Injector 9A90 Timing 1.460 Throttle Delay .594 Modulator Setting .480	365	2100	2225	.84
		365	1950	2075	.87
		335	1950	2075	.80
		365	1900	2025	.89
		335	1900	2025	.82
		411*	1800	1925	N/A
		365*	1800	1925	.92
		335*	1800	1925	.85
6V-92 TTA California 325 @ 2100 RPM 2275 RPM Max. No-Load Speed	Injector 9F90 Timing 1.520 Throttle Delay .636 Modulator Setting .480	270	2100	2225	.85
		270	1950	2075	.87
		240	1950	2075	.77
		270	1900	2025	.89
		240	1900	2025	.79
		304*	1800	1925	N/A
		270*	1800	1925	.92
		240*	1800	1925	.82
8V-92 TTA California 440 @ 2100 RPM 2275 RPM Max. No-Load Speed	Injector 9F90 Timing 1.515 Throttle Delay .660 Modulator Setting .490	365	2100	2225	.85
		365	1950	2075	.89
		335	1950	2075	.81
		365	1900	2025	.91
		335	1900	2025	.83
		403*	1800	1925	N/A
		365*	1800	1925	.94
		335*	1800	1925	.87

** = Uses Belleville Spring (Washer) 5104535 (Copper Flashed).*
N/A = Not Applicable

Selected Engine Ratings – 1983 Fed. & Calif.

Engine Type and Max. Rated BHP		Rated TT H.P.	Rated Engine Speed (rpm)	No-Load Speed (rpm)	Power Reduction Factor
6V-92TA 330 @ 2100 RPM	Injector 9B90 Timing 1.475 Throttle Delay .636 Modulator Setting .465	270 270	1800 2100	1950 2250	.91 .83
6V-92TAC 325 @ 2100 RPM	Injector 9F90 Timing 1.520 Throttle Delay DNA Modulator Setting .490	270 270	1800 2100	1950 2250	.92 .84
8V-92TA 445 @ 2100 RPM	Injector 9A90 Timing 1.470 Throttle Delay .594 Modulator Setting .404	365 365	1950 2100	2100 2250	.87 .84
8V-92TAC 440 @ 2100 RPM	Injector 9F90 Timing 1.520 Throttle Delay .660 Modulator Setting .490	365 365	1950 2100	2100 2250	.89 .85

Selected Engine Ratings – 1984 Fed. & Calif.

Engine Type and Max. Rated BHP		Rated TT H.P.	Rated Engine Speed (rpm)	No-Load Speed (rpm)	Power Reduction Factor
6V-92TA 300 @ 1800 RPM	Injector 9G85 Timing 1.466 Throttle Delay DNA Modulator Setting .465	270 270	1800 2100	1925 2250	.91 .83

Selected Engine Ratings – 1985 Fed. Only

Engine Type and Max. Rated BHP		Rated TT H.P.	Rated Engine Speed (rpm)	No-Load Speed (rpm)	Power Reduction Factor
6V-92TA 350 @ 2100 RPM	Injector 9G90 Timing 1.466 Throttle Delay .636 Modulator Setting .480	300	2100	2250	.88
6V-92TA 300 @ 2100 RPM	Injector 9G90 Timing 1.470 Throttle Delay .570 Modulator Setting DNA	270 270	1800 2100	1950 2250	.93 .86
6V-92TAC 340 @ 2100 RPM	Injector 9F90 Timing 1.520 Throttle Delay .660 Modulator Setting .490	300 270	2100 2100	2250 2250	.90 .81
8V-92TA 475 @ 2100 RPM	Injector 9G90 Timing 1.458 Throttle Delay .610 Modulator Setting .454	400 400	2100 1800	2250 1950	.87 .87
8V-92TAC 450 @ 2100 RPM	Injector 9F90 Timing 1.520 Throttle Delay .660 Modulator Setting .490	400	2100	2250	.91

Selected Engine Ratings – 1985, 1986 Fed. & Calif.

Engine Type and Max. Rated BHP		Rated TT H.P.	Rated Engine Speed (rpm)	No-Load Speed (rpm)	Power Reduction Factor
8V-92TA 475 @ 2100 RPM	Injector 9G90 Timing 1.475 Throttle Delay .570 Modulator Setting .404	400	2100	2250	.97

Selected Engine Ratings – 1986 Fed. Only

Engine Type and Max. Rated BHP		Rated TT H.P.	Rated Engine Speed (rpm)	No-Load Speed (rpm)	Power Reduction Factor
6V-92TA 300 @ 1800 RPM	Injector 9G85 Timing 1.466 Throttle Delay DNA Modulator Setting .465	270 270	1800 2100	1925 2250	.91 .83
6V-92TA 350 @ 2100 RPM	Injector 9G90 Timing 1.466 Throttle Delay .636 Modulator Setting .480	300	2100	2250	.87
6V-92TAC 340 @ 2100 RPM	Injector 9F90 Timing 1.520 Throttle Delay .660 Modulator Setting .490	270 300 270	1800 2100 2100	1950 2250 2250	.90 .81 .90
8V-92TA 475 @ 2100 RPM	Injector 9G90 Timing 1.475 Throttle Delay .570 Modulator Setting .404	400	2100	2250	.97
8V-92TAC 450 @ 2100 RPM	Injector 9F90 Timing 1.520 Throttle Delay .660 Modulator Setting .490	400	2100	2250	.90

Selected Engine Ratings – 1987 Fed. & Calif.

FLEXISPEC ENGINE GOVERNOR ADJUSTMENTS "TT" ENGINE

When it is desirable to adjust a "TT" 6V or 8V–92 engine to obtain non–TT maximum rated horsepower, proceed as follows:

1. Adjust the engine governor to obtain a no–load speed 175 rpm above the desired rated speed. Refer to Section 14.3 for the no–load engine speed adjustment.
2. Position the Belleville spring retainer to provide approximately .060" clearance between the Belleville washers and the retainer when the engine is not running (Fig. 1).

VARIABLE SPEED MECHANICAL GOVERNOR

INJECTOR RACK CONTROL ADJUSTMENT (6V-92 AND 8V-92)

The single-weight variable speed governor is mounted at the front of the engine and is driven by a blower rotor.

After adjusting the exhaust valves and timing the fuel injectors, adjust the variable speed mechanical governor and position the injector rack control levers.

Before proceeding with the governor and injector rack adjustments, disconnect any supplementary governing device. After the adjustments are completed, reconnect and adjust the supplementary governing device.

Adjust Governor Gap

With the engine stopped and at normal operating temperature, adjust the governor gap as follows:

1. Disconnect any linkage attached to the governor levers.
2. Back out the buffer screw until it extends approximately 5/8" from the locknut.
3. Clean and remove the governor cover and valve rocker covers. Discard the gaskets.
4. Place the speed control lever in the *maximum speed* position.
5. Insert a .006" feeler gage between the spring plunger and the plunger guide (Fig. 1). If required, loosen the locknut and turn the adjusting screw until a slight drag is noted on the feeler gage.

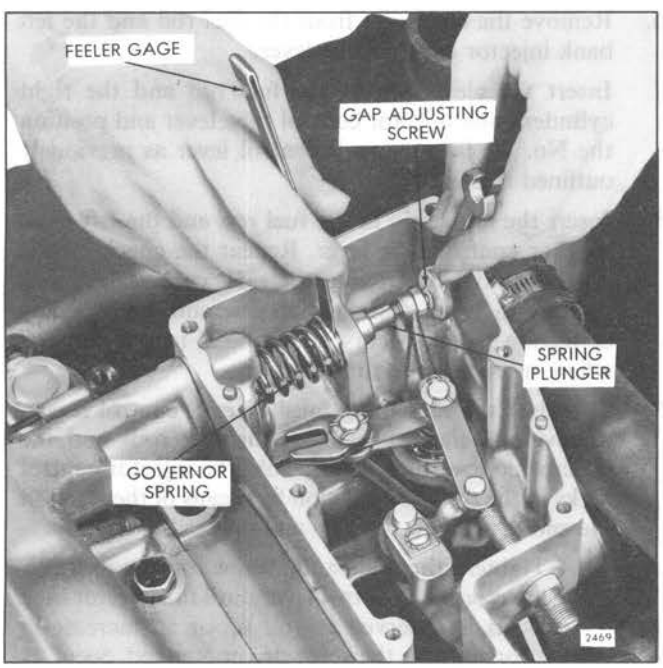


Fig. 1 – Adjusting Governor Gap

6. Hold the adjusting screw and tighten the locknut. Check the gap again and, if necessary, readjust.
7. Affix a new gasket on the top of the governor housing. Place the governor cover assembly on the governor housing with the pin in the throttle control shaft assembly in the slot of the differential lever and the dowel pins in the housing in the dowel pin holes in the cover. Tighten the screws.

Position Injector Rack Control Levers

The position of the injector rack control levers must be correctly set in relation to the governor. Their position determines the amount of fuel injected into each cylinder and ensures equal distribution of the load.

The engines use spring-loaded injector control tube assemblies which have a yield spring at each injector rack control lever with one screw and locknut to keep each injector rack properly positioned.

Properly positioned injector rack control levers, with the engine at full load, will result in the following:

1. Speed control lever at the *maximum speed* position.
2. Stop lever in the *run* position.
3. High-speed spring plunger within .005" to .007" of its seat in the governor control housing.
4. Injector fuel control racks in the *full-fuel* position.

The letters "R" and "L" indicate the injector location in the right or left cylinder bank, viewed from the rear of the engine. The cylinders are numbered starting at the front of the engine on each cylinder bank, Adjust the No. 1L injector rack control lever first to establish a guide for adjusting the remaining control levers.

1. Remove the clevis pin from the fuel rod and the right cylinder bank injector control tube lever.
2. Loosen all of the adjusting screws and locknuts on both injector control tubes. Be sure all of the injector rack control levers are free on the injector control tubes.
3. Move the speed control lever to the *maximum speed* position.
4. Move the stop lever to the *run* position and hold it in that position with light finger pressure. Tighten the adjusting screw of the No. 1L injector rack control lever until the injector rack clevis is observed to roll up or an increase in effort to turn the screwdriver is noted (Fig. 2). Tighten the screw approximately 1/8 of a turn more and lock securely with the adjusting screw locknut. This will place the No. 1L injector rack in the *full-fuel* position.

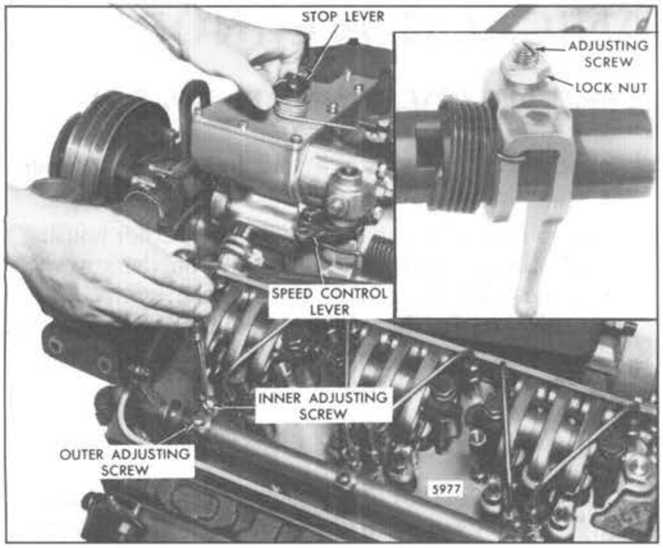


Fig. 2 – Positioning No. 1 Injector Rack Control Lever

NOTICE: Overtightening of the injector rack control lever adjusting screws during installation or adjustment can result in damage to the injector control tube. The recommended torque of the adjusting screws is 24–36 **lb–in** (3–4 N•m).

The above step should result in placing the governor linkage and control tube assembly in the same position that they will attain while the engine is running at full load.

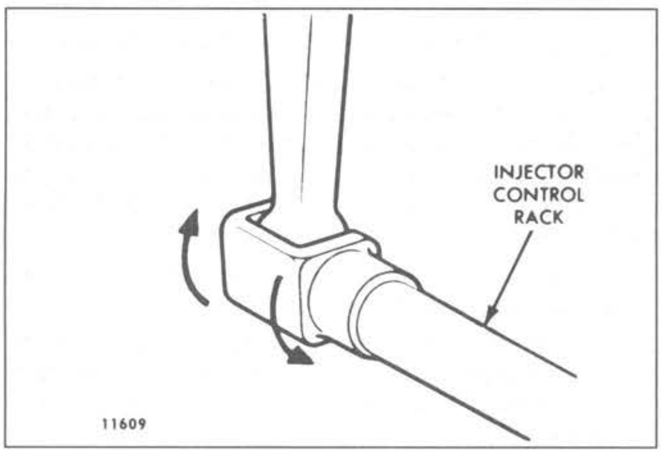


Fig. 3 – Checking Rotating Movement of Injector Control Rack

5. To be sure of the proper rack adjustment, hold the stop lever in the *run* position and press down on the injector rack with a screwdriver or finger tip and note the "rotating" movement of the injector control rack when the stop lever is in the *run* position (Fig. 3). Hold the stop lever in the *run* position and, using a screwdriver, press downward on the injector control rack. The rack should tilt downward and, when the pressure of the screwdriver is released, the control rack should "spring" back upward (Fig. 4).

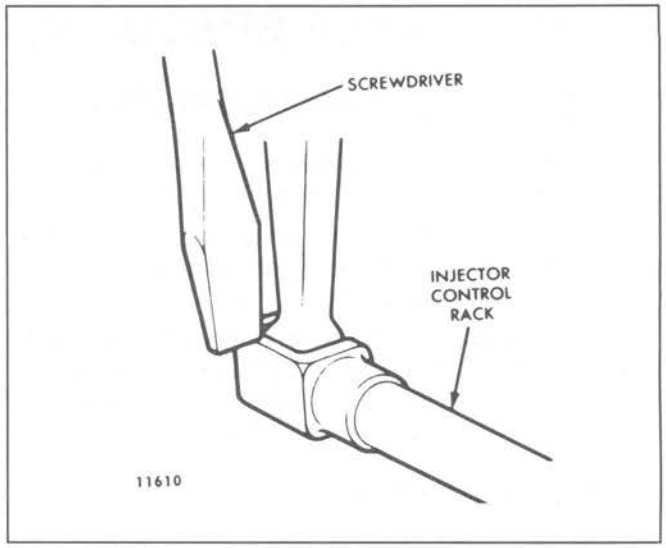


Fig. 4 – Checking Injector Control Rack "Spring"

If the rack does not return to its *original* position, it is too loose. To correct this condition, loosen the locknut and turn the adjusting screw clockwise a slight amount and retighten the locknut.

The setting is too tight if, when moving the stop lever from the stop to the *run* position, the injector rack becomes tight before the stop lever reaches the end of its travel. This will result in a step–up in effort required to move the stop lever to the end of its travel. To correct this condition, loosen the locknut and turn the adjusting screw counterclockwise a slight amount and retighten the locknut.

6. Remove the clevis pin from the fuel rod and the left bank injector control tube lever.
7. Insert the clevis pin in the fuel rod and the right cylinder bank injector control tube lever and position the No. 1R injector rack control lever as previously outlined in Step 4.
8. Insert the clevis pin in the fuel rod and the left bank injector control tube lever. Repeat the check on the No. 1L and No. 1R injector rack control levers as outlined in Step 5. Carefully observe and eliminate any deflection which occurs at the bend in the fuel rod where it enters the cylinder head.
9. To adjust the remaining injector rack control levers, remove the clevis pins from the fuel rods and the injector control tube levers, hold the injector control racks in the *full–fuel* position by means of the lever on the end of the control tube and proceed as follows:
   a. Tighten the adjusting screw of the No. 2L injector rack control lever until the injector rack clevis is observed to roll up or an increase in effort to turn the screwdriver is noted. Securely lock the adjusting screw locknut.

NOTICE: Overtightening of the injector rack control tube lever adjusting screws during installation or adjustment can result in damage to the injector control tube. The recommended torque of the adjusting screws is 24–36 **lb–in** (3–4 N•m).

b. Verify the injector rack adjustment of No. 1L as outlined in Step 5. No. 1L does not "spring" back upward, turn the No. 2L adjusting screw counterclockwise slightly until the No. 1L injector rack returns to its *full–fuel* position and secure the adjusting screw locknut. Verify proper injector rack adjustment for both No. 1L and No. 2L injectors. Turn clockwise or counterclockwise the No. 2L injector rack adjusting screw until both No. 1L and No. 2L injector racks are in the *full–fuel* position when the locknut is securely tightened.

c. Adjust the remaining injectors using the procedures outlined in Step "B" always verifying proper injector rack adjustment.

Once the No. 1L and No. 1R injector rack control levers are adjusted, do not try to alter their settings. All adjustments are made on the remaining control racks.

10. When all of the injector rack control levers are adjusted, recheck their settings. With the control tube lever in the *full–fuel* position, check each control rack as in Step 5. All of the control racks must have the same "spring" condition with the control tube lever in the *full–fuel* position.

11. Insert the clevis pins in the fuel rods and the injector control tube levers.

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 return to the *no–fuel* position when the governor stop lever is placed in the *stop* position. Engine overspeed will result if the injector racks cannot be positioned at no fuel with the governor stop lever. An overspeeding engine can result in engine damage which could cause personal injury.

12. Use new gaskets and reinstall the valve rocker covers.

Adjust Maximum No–Load Speed

All governors are properly adjusted before leaving the factory. However, if the governor has been reconditioned or replaced, and to ensure the engine speed will not exceed the recommended no–load speed as given on the engine option plate, set the maximum no–load speed as outlined below.

Start the engine and, after it reaches normal operating temperature, determine the maximum no–load speed of the engine with an accurate hand tachometer. Then, stop the engine and make the following adjustments, if required:

1. Disconnect the booster spring and the governor stop lever spring.
2. Remove the variable speed spring housing and the spring retainer located inside the housing from the governor housing.
3. Refer to Table 1 and determine the stop or shims required for the desired full–load speed. The speed will increase approximately 1 rpm for each .001" in shims added.

Full Load Speed*	Stops	Shims
1200 - 1750	2	Up to .325"
1750 - 2100	1	in Shims
2100 - 2300	0	Maximum

*No-Load Speed is 150-200 rpm above the Full-Load Speed, depending on engine application.

Table 1

4. Install the variable speed spring retainer and housing and tighten the two bolts.
5. Connect the booster spring. Start the engine and recheck the maximum no–load speed.
6. If required, add or remove shims to obtain the necessary operating speed. If the maximum no–load speed is raised or lowered more than 50 rpm by the installation or removal of shims, recheck the governor gap. If readjustment of the governor gap is required, the position of the injector racks must be rechecked.

Governor stops are used to limit the compression of the governor spring, which determines the maximum speed of the engine.

Adjust Idle Speed

With the maximum no–load speed properly adjusted, adjust the idle speed as follows:

1. Place the speed control lever in the *idle* position and the stop lever in the *run* position.
2. With the engine running at normal operating temperature, back out the buffer screw to avoid contact with the differential lever.
3. Loosen the locknut and turn the idle speed adjusting screw until the engine is operating at approximately 15 rpm below the recommended idle speed (Fig. 5). The recommended idle speed is 500 rpm, but may vary with special engine applications.
4. Hold the idle speed adjusting screw and tighten the locknut.

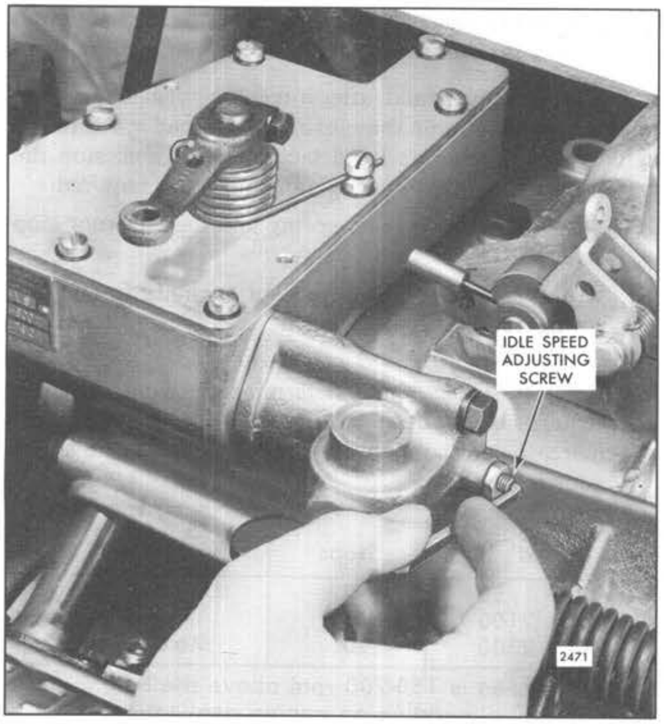


Fig. 5 – Adjusting Idle Speed

Adjust Buffer Screw

1. With the engine running at normal operating temperature, turn the buffer screw IN so that it contacts the differential lever as lightly as possible and still eliminates engine roll (Fig. 6). Do not raise the engine idle speed more than 15 rpm with the buffer screw.
2. Hold the buffer screw and tighten the locknut.

Adjust Booster Spring

With the idle speed adjusted, adjust the booster spring as follows:

1. Move the speed control lever to the *idle* speed position.
2. Refer to Fig. 7 and loosen the booster spring retaining nut on the speed control lever. Loosen the locknuts on the eyebolt at the opposite end of the booster spring.
3. With the speed control lever in the *idle* position, move the bolt in the slot of the speed control lever until the center of the bolt is on or slightly over center (toward the *idle speed* position) of an imaginary line through the bolt, lever shaft and eyebolt. Hold the bolt from turning and tighten the locknut.
4. Start the engine and move the speed control lever to the *maximum speed* position and release it. The speed control lever should return to the *idle speed* position, If it does not, reduce the booster spring tension. If it does, continue to increase the spring tension until the point is reached that it will not return to idle. Then, reduce the spring tension until it does return to idle and tighten the locknut on the eyebolt. This setting will result in the minimum force required to operate the speed control lever.
5. Connect the linkage to the governor levers.

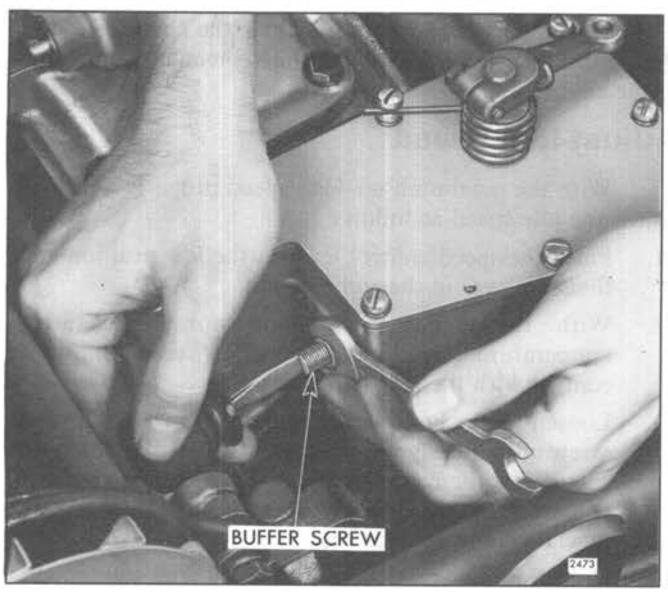


Fig. 6 – Adjusting Buffer Screw

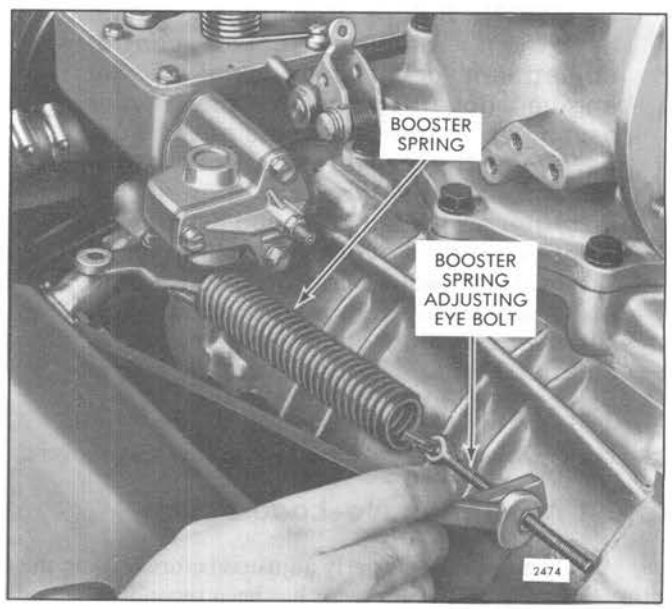


Fig. 7 – Adjusting Booster Spring

VARIABLE SPEED MECHANICAL GOVERNOR AND INJECTOR RACK CONTROL ADJUSTMENT (12V-92 and 16V-92)

The governor on the 12V and 16V engines is mounted on and driven from the front end of the rear blower (Fig. 1).

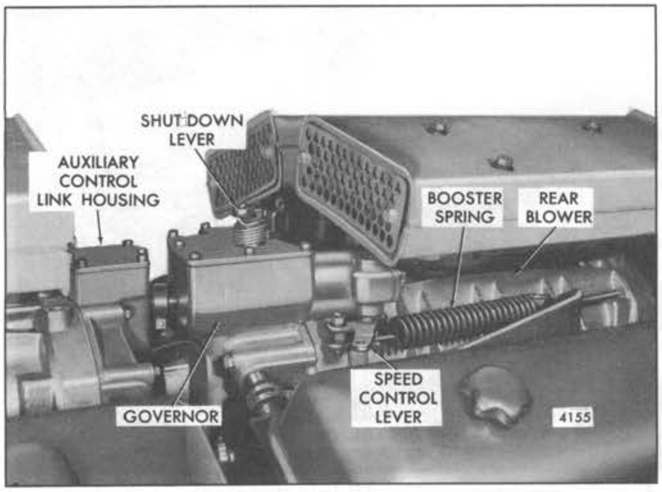


Fig. 1 – Governor Mounting

After adjusting the exhaust valves and timing the fuel injectors, adjust the governor and injector rack control levers.

If the engine or governor has been overhauled, or the injector control linkage has been disturbed, the control link levers in the governor housing and auxiliary control link housing must be aligned before proceeding with the engine tune-up. Refer to Fig. 2 and position the control link levers as follows:

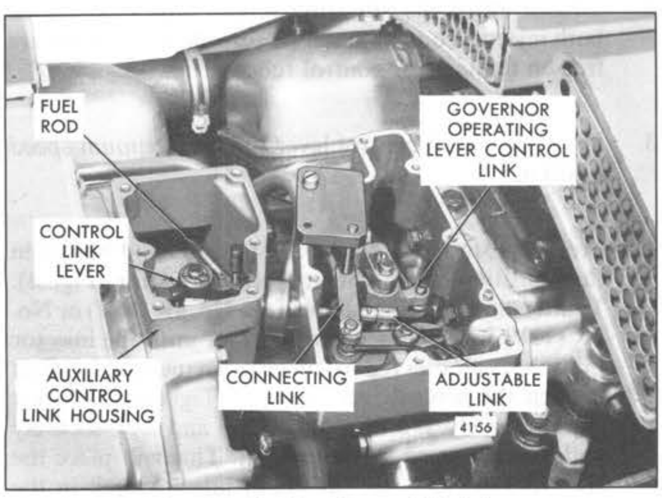


Fig. 2 – Positioning Control Link Levers

1. Disconnect the linkage to the governor speed control and stop levers.
2. Remove the covers from the governor housing and auxiliary control link housing.
3. Disconnect the adjustable link from the lever in the auxiliary control link housing.
4. Remove the connecting pin from the auxiliary governor control link lever.
5. Install gage J 21779 so it extends through the lever and fuel rod and into the gage hole in the bottom of the housing. With the gage in place, the auxiliary control link lever will be in the *mid-travel* position.
6. Remove the connecting pin from the control link lever in the governor housing and install gage J 21780. Install the gage so the pin extends through the connecting link, control lever, and fuel rod; and the governor housing dowel pin extends into the small hole in the gage. Then install a governor cover bolt to lock the gage in place (Fig. 2). With gage J 21780 in place, the governor control link lever will be in the *mid-travel* position and parallel to the auxiliary control link lever.
7. Adjust the length of the adjustable connecting link to retain the lever positions obtained in Steps 5 and 6 and install the link.
8. Remove gages J 21779 and J 21780 and reinstall the control link lever connecting pins.
9. Install the governor housing and auxiliary control link housing covers.

   Proceed with the governor and injector rack control adjustment.

Adjust Governor Gap

With engine stopped and at normal operating temperature, adjust the governor gap as follows:

1. Clean and remove the governor cover and the valve rocker covers. Discard the gaskets.
2. Back out the buffer screw until it extends approximately 5/8" from the locknut.
3. Place the speed control lever in the *maximum speed* position.

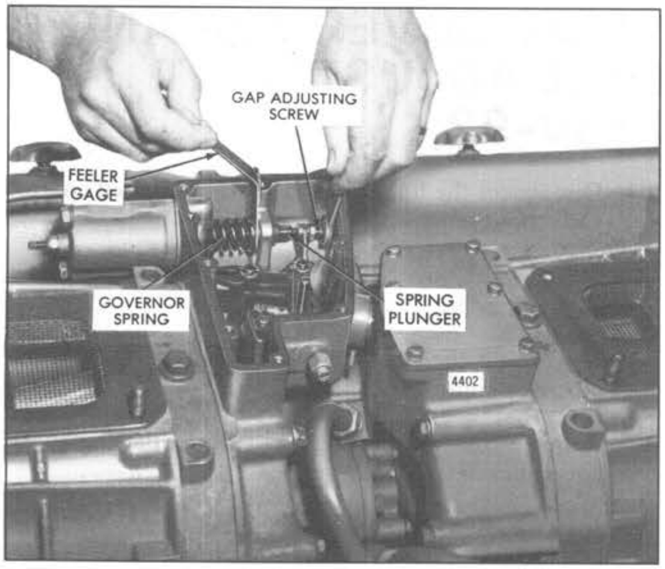


Fig. 3 – Adjusting Governor Gap

4. Insert a .006" feeler gage between the spring plunger and the plunger guide (Fig. 3). If required, loosen the locknut and turn the adjusting screw until a slight drag is noted on the feeler gage.

5. Hold the adjusting screw and tighten the locknut. Check the gap and readjust if necessary.

6. Affix a new gasket to the top of the governor housing. Place the governor cover assembly on the governor housing with the pin in the throttle control shaft assembly in the slot of the differential lever and the dowel pins in the cover. Tighten the screws.

Position Injector Rack Control Levers

The position of the injector rack control levers must be correctly set in relation to the governor. Their position determines the amount of fuel injected into each cylinder and ensures equal distribution of the load.

The engines use spring–loaded injector control tube assemblies which have a yield spring at each injector rack control lever with one screw and locknut to keep each injector rack properly positioned.

Properly positioned injector rack control levers with the engine at full load will result in the following:

1. Speed control lever at the *maximum speed* position.
2. Stop lever in the *run* position.
3. High–speed spring plunger within .005" to .007" of its seat in the governor control housing.
4. Injector fuel control racks in the *full–fuel* position.

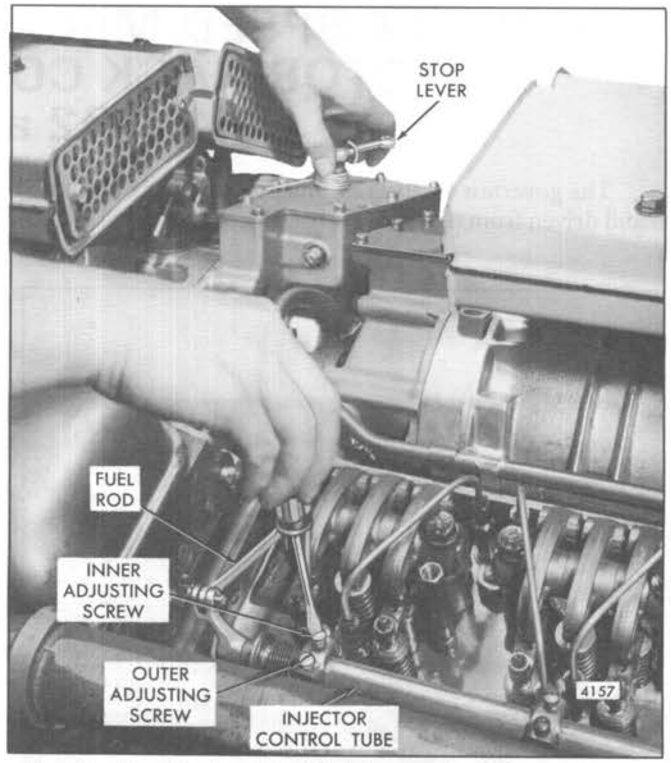


Fig. 4 – Positioning No. 4R Injector Rack Control Lever

The letters "R" and "L" indicate the injector location on the right or left cylinder bank, viewed from the rear of the engine. Cylinders are numbered starting at the front of the engine on each cylinder bank. Adjust the No. 4R injector rack control lever first to establish a guide for adjusting the remaining right bank injector rack control levers.

1. Remove the clevis pins which attach the right rear bank and both left–bank fuel rods to the injector control tube levers.

2. Loosen all of the adjusting screws and locknuts on both injector control tubes. Be sure all of the levers are free on the injector control tubes.

3. Move the speed control lever to the *maximum speed* position.

4. Move the stop lever to the *run* position and hold it in that position with a light finger pressure (Fig. 4). Tighten the adjusting screw of the No. 4R (16V) or No. 3R (12V) injector rack control lever until the injector rack clevis is observed to roll up or an increase in effort to turn the screwdriver is noted. Tighten the screw approximately 1/8 of a turn more and lock securely with the adjusting screw locknut. This will place the No. 4R (16V) or No. 3R (12V) injector rack in the *full–fuel* position.

NOTICE: Overtightening of the injector rack control lever adjusting screws during installation or adjustment can result in damage to the injector control tube. The recommended torque of the adjusting screws is 24–36 **lb.-in** (3–4 N.m).

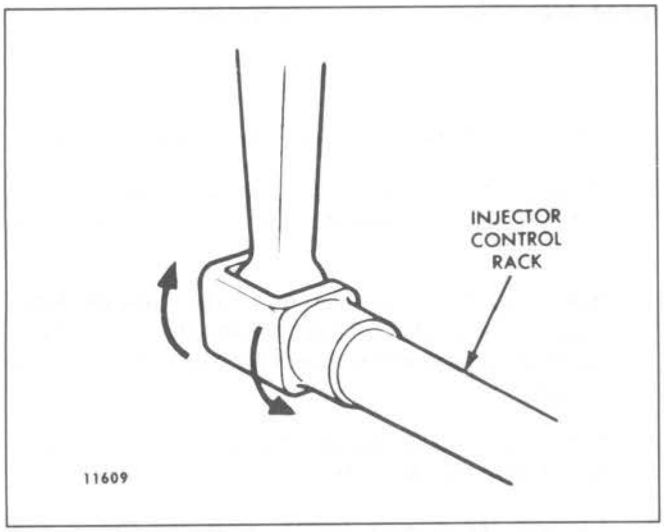


Fig. 5 – Checking Rotating Movement of Injector Control Rack

The above step should result in placing the governor linkage and control tube assembly in the same position that they will attain while the engine is running at full load.

5. To be sure of the proper rack adjustment, hold the stop lever in the *run* position and press down on the injector rack with a screwdriver or finger tip and note the "rotating" movement of the injector control rack when the stop lever is in the *run* position (Fig. 5). Hold the stop lever in the *run* position and, using a screwdriver, press downward on the injector control rack. The rack should tilt downward (Fig. 6) and, when the pressure of the screwdriver is released, the control rack should "spring" back upward.

   If the rack does not return to its *original* position, it is too loose. To correct this condition, loosen the locknut and turn the adjusting screw clockwise a slight amount and retighten the locknut.

   The setting is too tight if, when moving the stop lever from the stop to the *run* position, the injector rack becomes tight before the stop lever reaches the end of its travel. This will result in a step-up in effort required to move the stop lever to the end of its travel. To correct this condition, loosen the locknut and turn the adjusting screw counterclockwise a slight amount and retighten the locknut.

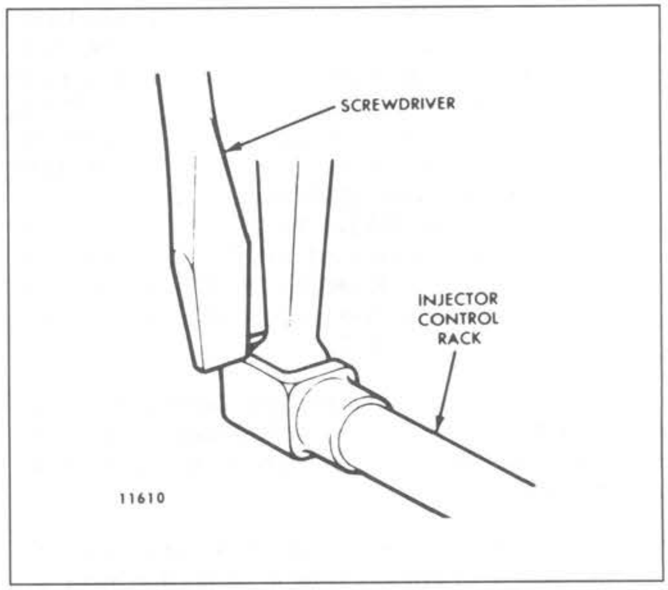


Fig. 6 – Checking Injector Control Rack "Spring"

6. Remove the fuel rod–to–control tube lever clevis pin from the right front bank fuel rod and install it on the right rear bank fuel rod and adjust the No. 5R (16V) or No. 4R (12V) injector rack as outlined in Steps 4 and 5.

7. Repeat Step 6 for adjustment of the No. 4L and 5L (16V) or No. 3L and 4L (12V) injector racks. When the settings are correct, the No. 4R, 5R, 4L and 5L (16V) or No. 3R, 4R, 3L and 4L (12V) injector racks will be snug on the ball end of the control levers when the injectors are in the *full–fuel* position.

8. With the fuel rod disconnected from the injector control tube lever, adjust the remaining injector rack control levers on the right front bank. Hold the No. 4R (16V) or No. 3R (12V) injector rack in the *full–fuel* position by means of the control tube lever and proceed as follows:

   a. Tighten the adjusting screw of the No. 3R (16V) or No. 2R (12V) injector rack control lever until the injector rack clevis is observed to roll up or an increase in effort to turn the screwdriver is noted. Securely lock the adjusting screw locknut.

   NOTICE: Overtightening of the injector rack control lever adjusting screws during installation or adjustment can result in damage to the injector control tube. The recommended torque of the adjusting screws is 24–36 **lb.-in** (3–4 N.m).

   b. Verify the injector rack adjustment of No. 4R (16V–92) or No. 3R (12V) as outlined in Step 5. If No. 4R (16V) or No. 3R (12V) does not "spring" back upward, turn the No. 3R (16V) or

No. 2R (12V) adjusting screw counterclockwise slightly until the No. 4R (16V) or No. 3R (12V) injector rack returns to its *full–fuel* position and secure the adjusting screw locknut. Verify proper injector rack adjustment for both No. 4R and No. 3R (16V) or No. 3R and No. 2R (12V) injectors. Turn clockwise or counterclockwise the No. 3R (16V) or No. 2R (12V) injector rack adjusting screw until both No. 4R and No. 3R (16V) or No. 3R and No. 2R (12V) injector racks are in the *full–fuel* position when the locknut is securely tightened.

When the settings are correct, both injector racks must respond in the same manner on the ball ends of the control levers when the injector control tube lever is held in the *full–fuel* position.

9. Position the remaining injector rack control levers on the right front cylinder bank as outlined in Steps 8.

10. Adjust the remaining injector rack control levers on the right rear, left front and left rear cylinder banks in the same manner as outlined in Steps 8 and 9.

11. Install the four fuel rod–to–control tube lever clevis pins and check the adjustment of the injector rack control levers.

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 return to the no–fuel position when the governor stop lever is placed in the *stop* position. Engine overspeed will result if the injector racks cannot be positioned at no fuel with the governor stop lever. An overspeeding engine can result in engine damage which could cause personal injury.

12. Use new gaskets and reinstall the valve rocker covers.

Adjust Maximum No–Load Speed

All governors are properly adjusted before leaving the factory. However, if the governor has been reconditioned or replaced, and to ensure the engine speed will not exceed the recommended no–load speed as given on the engine option plate, set the maximum no–load speed as outlined below.

Start the engine and, after it reaches normal operating temperature, determine the maximum no–load speed of the engine with an accurate hand tachometer. Then, stop the engine and make the following adjustments, if required:

Full Load Speed*	Stops	Shims
1200 - 1750 1750 - 2100 2100 - 2300	2 1 0	Up to .325" in Shims Maximum

*No-Load Speed is 150-225 rpm above Full-Load Speed depending on engine application.

TABLE 1

1. Disconnect the booster spring and governor stop lever.

2. Remove the variable speed spring housing and the variable speed spring plunger from the governor housing.

3. Refer to Table 1 and determine the stops or shims required for the desired full–load speed. The speed will increase approximatley 1 rpm for each .001" in shims added.

4. Install the variable speed spring plunger and housing and tighten the two bolts.

5. Connect the booster spring. Start the engine and recheck the maximum no–load speed.

6. If required, add or remove shims to obtain the desired full–load speed. If the maximum no–load speed is raised or lowered more than 50 rpm by the installation or removal of shims, recheck the governor gap. If readjustment of the governor gap is required, the position of the injector racks must be rechecked.

Governor stops are used to limit the compression of the governor spring, which determines the maximum speed of the engine.

Adjust Idle Speed

With the maximum no–load speed properly adjusted, adjust the idle speed as follows:

1. Place the speed control lever in the *idle* position and the stop lever in the *run* position.

2. With the engine running at normal operating temperature, back out the buffer screw to avoid contact with the differential lever.

3. Loosen the locknut and turn the idle speed adjusting screw until the engine is operating at approximately 15 rpm below the recommended idle speed (Fig. 7). The recommended idle speed is 550 RPM, but may vary with special engine applications.

4. Hold the idle speed adjusting screw from turning and tighten the locknut.

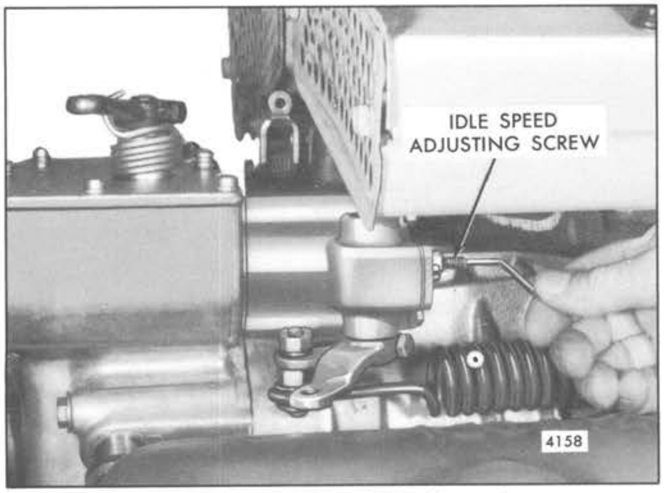


Fig. 7 – Adjusting Idle Speed

Adjust Buffer Screw

1. With the engine running at normal operating temperature, turn the buffer screw IN so it contacts the differential lever as lightly as possible and still eliminates engine roll (Fig. 8). Do not raise the idle speed more than 15 RPM with the buffer screw.

2. Hold the buffer screw from turning and tighten the locknut.

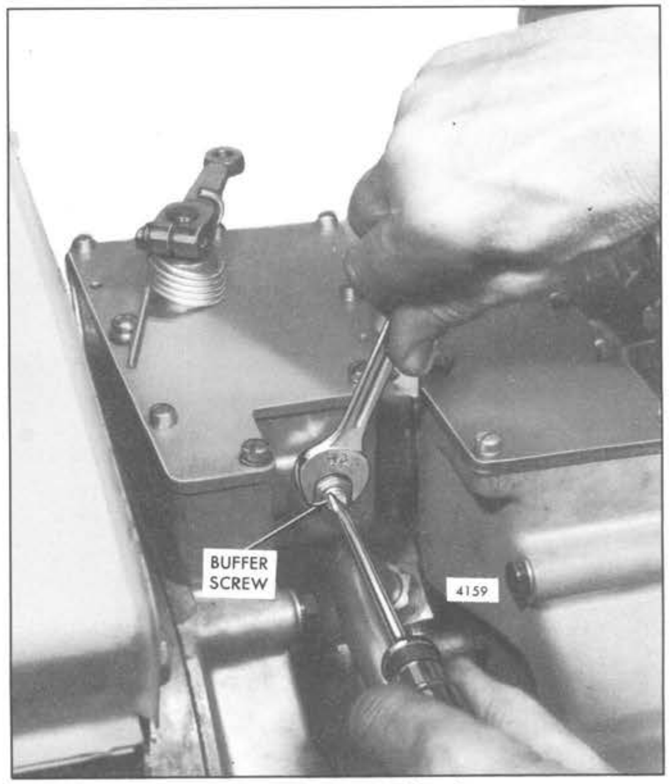


Fig. 8 – Adjusting Buffer Screw

Adjust Booster Spring

With the idle speed adjusted, adjust the booster spring as follows:

1. Move the speed control lever to the *idle speed* position.

2. Refer to Fig. 9 and loosen the nut on the booster spring retaining bolt on the governor speed control lever. Loosen the locknuts on the eyebolt at the opposite end of the spring.

3. Move the bolt in the slot of the speed control lever until the center of the bolt is on or slightly over center (toward the *idle speed* position) of an imaginary line through the bolt, lever shaft and eyebolt. Hold the bolt from turning and tighten the locknut.

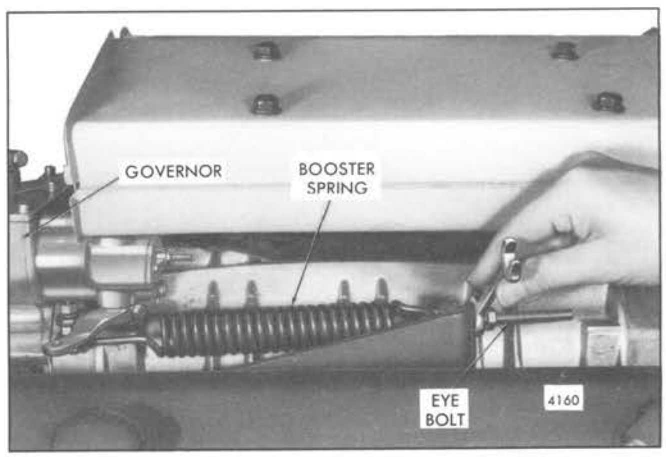


Fig. 9 – Adjusting Booster Spring

4. Start the engine and move the speed control lever to the *maximum speed* position and release it. The speed control lever should return to the *idle speed* position. If it does not, reduce the spring tension. If the lever does return to the *idle* position, increase the tension of the spring until the lever will not return to idle. Then, reduce the spring tension until the lever will return to idle and tighten the locknut on the eyebolt. This setting will result in a minimum force required to operate the speed control lever.

5. Connect the linkage to the governor levers.

SG VARIABLE SPEED HYDRAULIC GOVERNOR

INJECTOR RACK CONTROL ADJUSTMENT (6V–92 AND 8V–92)

After adjusting the exhaust valves and timing the fuel injectors, adjust the governor linkage and position the injector rack control levers (Fig. 1).

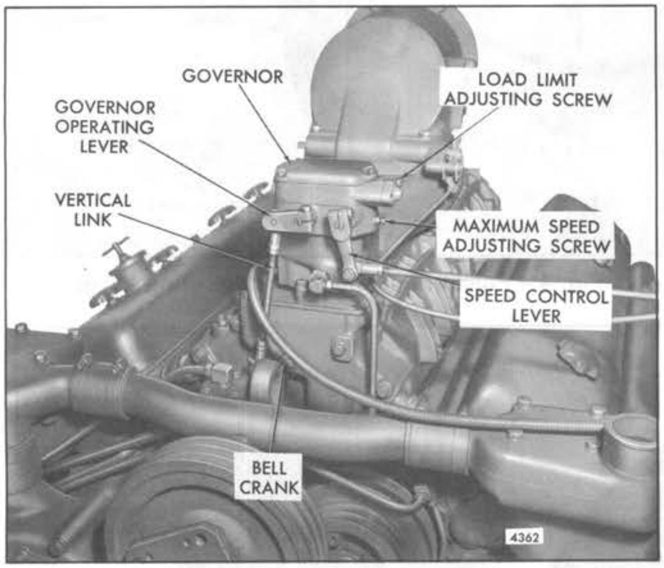


Fig. 1 – Hydraulic Governor Mounted on Engine

Position Injector Rack Control Levers and Adjust Governor Linkage

The position of the injector racks must be correctly set in relation to the governor. Their positions determine the amount of fuel injected into each cylinder and ensures equal distribution of the load.

1. Clean and remove the valve rocker cover from each cylinder head. Discard the gaskets.
2. Loosen all the adjusting screws and locknuts. Be sure all control levers are free on the control tubes.
3. Disconnect the vertical link assembly from the governor operating lever and the bell crank.
4. Loosen the bolt and slide the governor operating lever from the serrated shaft.
5. Place the bolt (removed from the lower end of the vertical link) through the bell crank and into the recessed hole in the drive housing (Fig. 2).
6. Adjust the No. 1R injector rack by tightening the adjusting screw until the injector rack clevis is observed to roll up or an increase in effort to turn the screwdriver is noted (Fig. 2). Tighten the screw approximately 1/8 of a turn more and lock securely with the adjusting screw locknut. This will place the No. 1R injector rack in the *full–fuel* position.

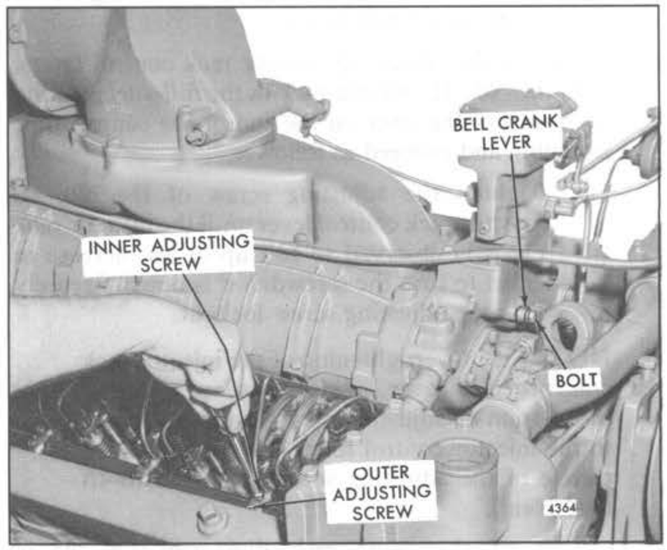


Fig. 2 – Positioning No. 1R Injector Rack Control Lever

NOTICE: Care should be taken to avoid setting the racks too tight causing the fuel rod to bend.

7. To be sure the rack control lever is properly adjusted, press down on the injector rack with a screwdriver or finger tip (Fig. 3). A light pressure should cause the rack to rotate. The rack is sufficiently tight if the rack returns or "springs" back to its *original* position when the pressure is removed. The rack is too tight if a heavy pressure is required to rotate the rack.

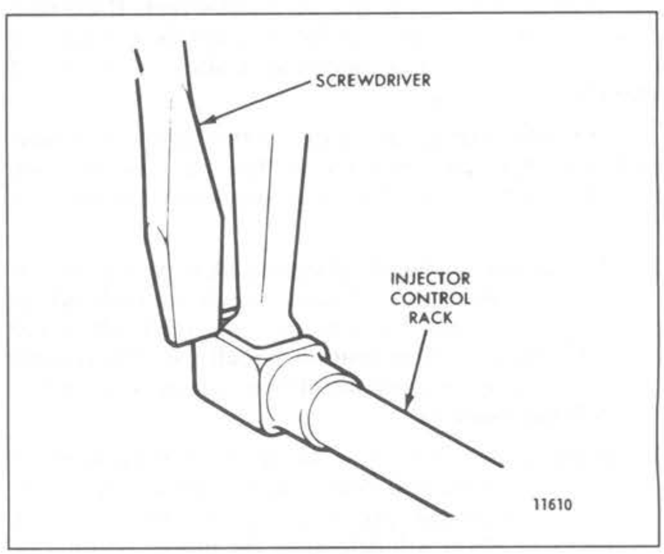


Fig. 3 – Checking Injector Rack "Spring"

8. Adjust the No. 1L injector rack control lever as outlined in Steps 6 and 7.

9. Check the adjustment on the No. 1R and 1L injector rack control lever. If the setting is correct, the injector racks will be in the *full–fuel* position and snug on the ball end of the control levers.

10. To adjust the remaining injector rack control levers, hold the No. 1L injector rack in the *full–fuel* position by means of the lever on the end of the control tube assembly and proceed as follows:

   a. Tighten the adjusting screw of the No. 2L injector rack control lever until the injector rack clevis is observed to roll up or an increase in effort to turn the screwdriver is noted. Securely lock the adjusting screw locknut.

   NOTICE: Overtightening of the injector rack control tube lever adjusting screws during installation or adjustment can result in damage to the injector control tube. The recommended torque of the adjusting screws is 24–36 **lb–in** (3–4 N•m).

   b. Verify the injector rack adjustment of No. 1L as outlined in Step 7. If No. 1L does not "spring" back upward, turn the No. 2L adjusting screw counterclockwise slightly until the No. 1L injector rack returns to its *full–fuel* position and secure the adjusting screw locknut. Verify proper injector rack adjustment for both No. 1L and No. 2L injectors. Turn clockwise or counterclockwise the No. 2L injector rack adjusting screw until both No. 1L and No. 2L injector racks are in the *full–fuel* position when the locknut is securely tightened.

Recheck the No. 1L injector rack to be sure that it has remained snug on the ball end of the injector rack control lever while positioning the No. 2L injector rack. If the rack of No. 1L injector has become loose, loosen the locknut and turn the adjusting screw clockwise a slight amount and retighten the lcoknut.

When the settings are correct, both injector racks must respond in the same manner on the ball end of their respective rack control levers as previously outlined in Step 7.

11. Position the remaining injector rack control levers on the left and right cylinder heads as outlined in Step 10b. When the settings are correct, all of the injector racks will be snug on the ball end of the control levers when the injector control tube lever is held in the *full–fuel* position.

12. Replace the governor operating lever on the serrated shaft so that the bolt hole is lined up within the proper lines on the linkage gage (Fig. 4). The type of governor (SGX or PSG) will determine the proper position of the lever.

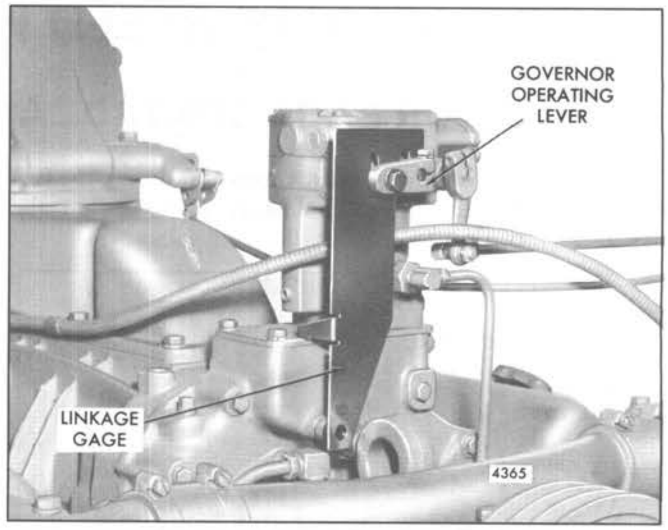


Fig. 4 – Positioning Governor Operating Lever

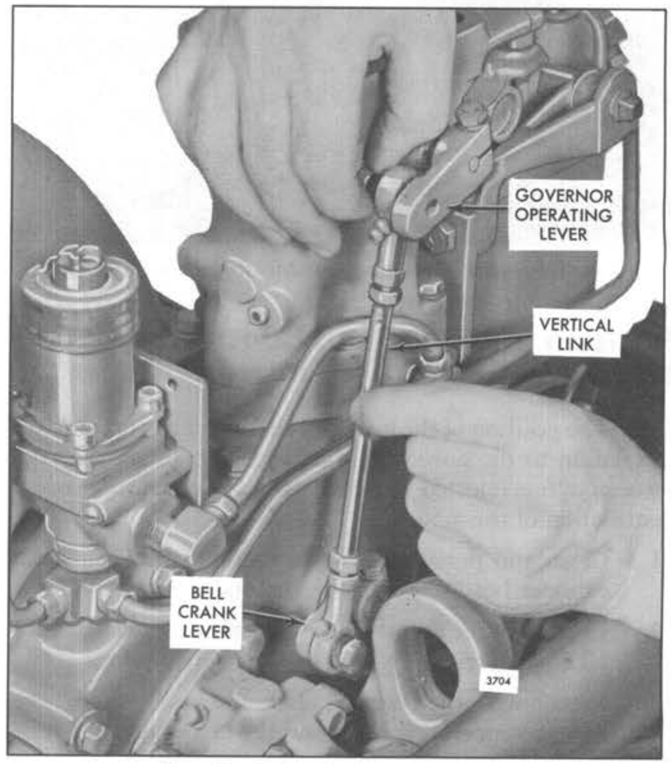


Fig. 5 – Adjusting Vertical Link

13. Remove the gage.

14. Move the bell crank lever to the *no–fuel* position.

15. Adjust the length of the vertical link so that the bolt holes of the levers and the centers of the rod end bearings are lined up (Fig. 5).

16. Replace the two bolts in the levers and tighten the bolts.

17. Remove the governor cover.

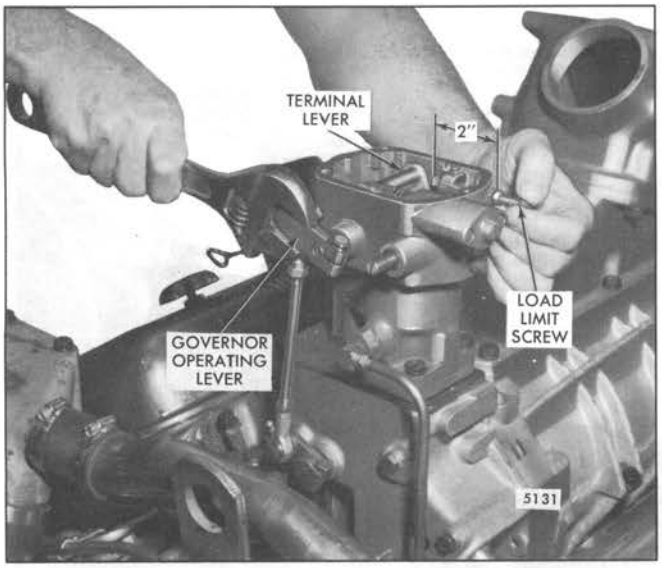


Fig. 6 – Adjusting Load Limit Screw

18. With the load limit screw backed all the way out, retain the governor operating lever in the *full–fuel* position. The governor terminal lever should touch the boss in the governor housing (Fig. 6). Adjust the vertical link so that all of the injector racks are in the *full–fuel* position, then tighten the rod end lock nuts securely.

19. Use a new gasket and reinstall a valve rocker cover on each cylinder head.

Adjust Load Limit

The load limit is set at the factory and further adjustment should be unnecessary. However, if the governor has had major repairs or the injector rack control levers have been repositioned, the load limit screw should be readjusted. With the injector rack control levers properly adjusted, the load limit may be set as follows:

1. Loosen the load limit screw locknut and adjust the load limit screw to obtain a distance of approximately 2" from the outside face of the boss on the governor subcap to the end of the screw. Then, place and retain the governor operating lever in the *full–fuel* position (Fig. 6). Do not overstress the linkage.

2. Turn the load limit adjusting screw until a .020" space exists between the fuel rod collar and the terminal lever. If the adjustment cannot be made with a feeler gage, turn the load limit adjusting screw (with the locknut tight enough to eliminate slack in the threads) inward until the injector racks just loosen on the ball end of the control levers.

3. Release the governor operating lever and hold the adjusting screw while tightening the locknut. Then, install the governor cover and tighten the screws.

Compensation Needle Valve Adjustment (PSG Governor)

Start the engine and, after the engine reaches normal operating temperature, adjust the governor compensation needle valve (without load on the engine) as follows:

1. Open the compensation needle valve (Fig. 10) two or three turns and allow the engine to "hunt" or "surge" for about one–half (1/2) minute to bleed any air which may be trapped in the governor oil passages.

2. Gradually close the valve until the "hunting" just stops. Check the amount of valve opening by closing the valve completely and noting the number of turns required to close it. Open the valve to the previously determined position at which the "hunting" stopped. Test the action of the governor by manually disturbing the engine speed. The engine should return promptly to the original steady speed with only a small overshoot. The correct valve setting will be between 1/8 and 1/2 turn open. Closing the valve farther than necessary will make the governor slow in returning the engine to normal speed after a load change.

Adjust Governor Speed Droop

INTERNAL DROOP ADJUSTMENT

The purpose of adjusting the speed droop is to establish a definite engine speed at no load with a given speed at rated full load.

The governor speed droop is set at the factory and further adjustment should be unnecessary. However, if the governor has been overhauled, the speed droop must be readjusted.

The best method of determining the engine speed is by using an accurate hand tachometer.

If a full rated load can be established on the unit, and the fuel rods, injector rack control levers and the load limit have been adjusted, set the speed droop as follows:

1. Start the engine and run it at approximately one–half the rated no–load speed until the lubricating oil temperature stabilizes. When the engine lubricating oil is cold, the governor regulation may be erratic. Regulation will become increasingly stable as the temperature of the oil increases.

2. Stop the engine and remove the governor cover.

3. Loosen the lock nut and back off the maximum speed adjusting screw approximately 5/8".

4. Loosen the screw and move the bracket so that the screw is midway between the ends of the slot in the bracket. Tighten the screw (Fig. 7).

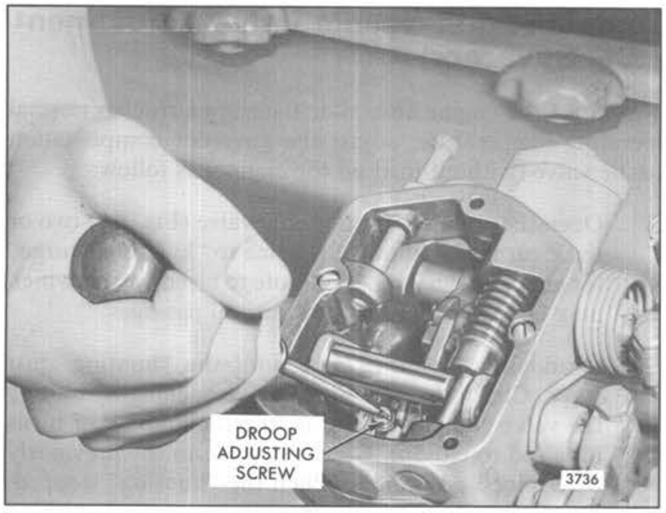


Fig. 7 – Adjusting Speed Droop

5. With the throttle in the *run* position, adjust the engine speed until the engine is operating at 3 to 5% above the recommended full–load speed.
6. Apply the full rated load on the engine and readjust the engine speed to the correct full–load speed.
7. Remove the rated load and note the engine speed after the speed stabilizes under no load. If the speed droop is correct, the engine speed will be approximately 3 to 5% higher than the full–load speed.

If the speed droop is too high, stop the engine, loosen the droop adjusting screw and move the adjusting bracket *in* toward the center of the governor. Tighten the screw. To increase the speed droop, move the bracket *out*, away from the center of the governor.

The speed droop in governors which control engines driving generators in parallel must be identical, otherwise the electrical load will not be equally divided.

Adjust the speed droop bracket in each governor to obtain the desired variation between engine no–load and full–load speeds. The recommended speed droop for generator sets operating in parallel is 50 rpm (2–1/2 cycles) for units operating at 1,000 and 1,200 rpm, and 75 rpm (2–1/2 cycles) for units operating at 1,500 and 1,800 rpm (Table 1). However, this speed droop recommendation may be varied to suit the individual application. Install the governor cover.

Full Load	No Load
50 cycles, 1000 rpm	52.5 cycles, 1050 rpm
60 cycles, 1200 rpm	62.5 cycles, 1250 rpm
50 cycles, 1500 rpm	52.5 cycles, 1575 rpm
60 cycles, 1800 rpm	62.5 cycles, 1875 rpm

TABLE 1

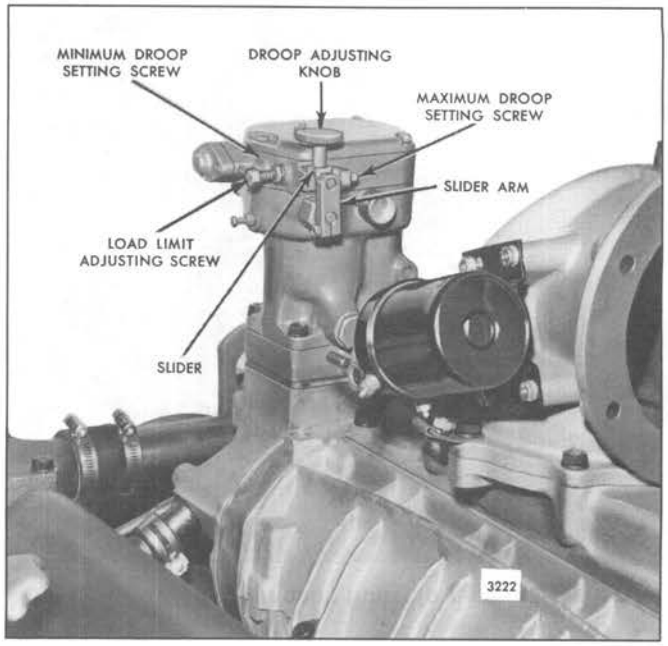


Fig. 8 – External Droop Control on PSG Isochronous Governor

EXTERNAL DROOP CONTROL

Some PSG type governors are equipped with an external adjustable droop control (Fig. 8). This permits the speed droop to be adjusted without removing the governor cover. With this feature, a unit can be paralleled with another unit that is operating at constant frequency (zero droop). The incoming unit must have its droop bracket set in the *maximum* position while it is being paralleled and while operating in parallel. When it is desired to stop the unit operating at constant frequency, shift the load to the incoming unit and move the governor droop bracket to zero droop. Then adjust the outgoing unit to maximum droop, remove it from the line and stop the engine. The incoming unit will now be carrying the load and operating at constant frequency (zero droop).

Adjust the governor speed droop as follows:

1. Start the engine and run it at approximately one–half of the rated full–load speed until the lubricating oil temperature stabilizes.
2. Remove the load from the engine.
3. Back off the compensation needle valve to release any air that may be trapped in the system. Turn the needle valve in slowly to reduce governor "hunting". The correct needle valve setting will be between 1/8 and 1/2 turn open.
4. Back out the minimum and maximum droop setting screws.
5. Loosen the droop adjusting knob and move the slide all the way in toward the center of the governor. Then tighten the knob.

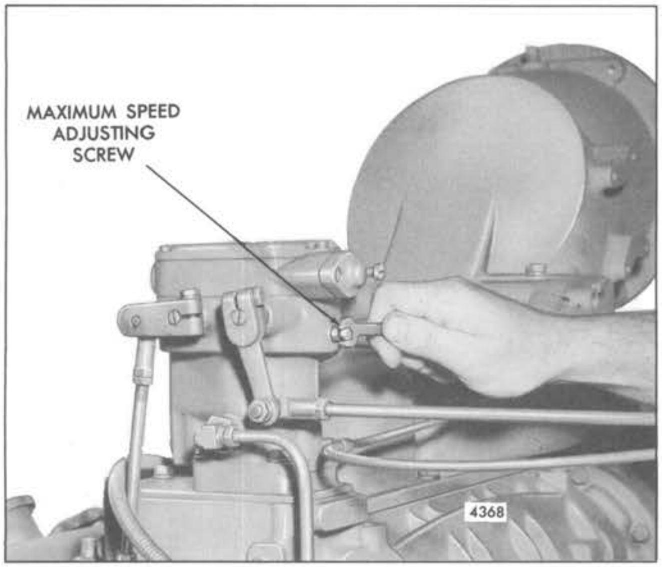


Fig. 9 – Adjusting Maximum No–Load Engine Speed

6. Loosen the locknut on the maximum speed adjusting screw and turn the screw out until 5/8" of the threads are exposed (Fig. 9).

7. With the engine operating at the recommended full–load speed, apply the full rated load and recheck the engine speed. If required, readjust the engine to full–load speed.

8. Remove the load and note the engine speed. If the zero droop setting is correct, the engine speed will remain constant. If the engine speed is higher, loosen the droop adjusting knob and set the slider to a *reduced droop* position.

9. When the desired minimum droop setting is reached, loosen the locknut and turn the minimum droop setting screw inward until it contacts the droop linkage within the governor. This will be felt by a step up of resistance while turning the adjusting screw. Lock the adjusting screw in this position.

10. Loosen the droop adjusting knob and slide the droop bracket in a direction to increase the droop. Perform Steps 7 and 8 to check the droop until the desired maximum speed droop is attained.

11. When the desired maximum droop setting is reached, loosen the locknut and turn the maximum droop setting screw inward until it contacts the droop slider arm. Lock the adjusting screw in this position.

12. Recheck the minimum and maximum droop setting as outlined in Steps 7 and 8 and adjust the adjustment screws, if necessary, until the correct settings are obtained.

Adjust Maximum No–Load Speed

With the speed droop properly adjusted, set the maximum no–load speed as follows:

1. With the engine operating at no load, adjust the speed until the engine is operating at approximately 8% higher than the rated full–load speed.

2. Turn the maximum speed adjusting screw (Fig. 9) in until the screw contacts the throttle linkage internally, limiting the maximum speed of the engine at 8% above the rated full load speed.

3. Hold the screw and tighten the lock nut.

Governors With Synchronizing Motor

Some hydraulic governors are equipped with a reversible electric synchronizing motor mounted on the governor cover (Fig. 10).

The adjustments on a governor equipped with a synchronizing motor are the same as on a governor without the motor. However, the governor cover and motor assembly must be removed when setting the engine speed droop (except on a governor equipped with an external droop adjustment). The cover and motor must be reinstalled to check the speed droop.

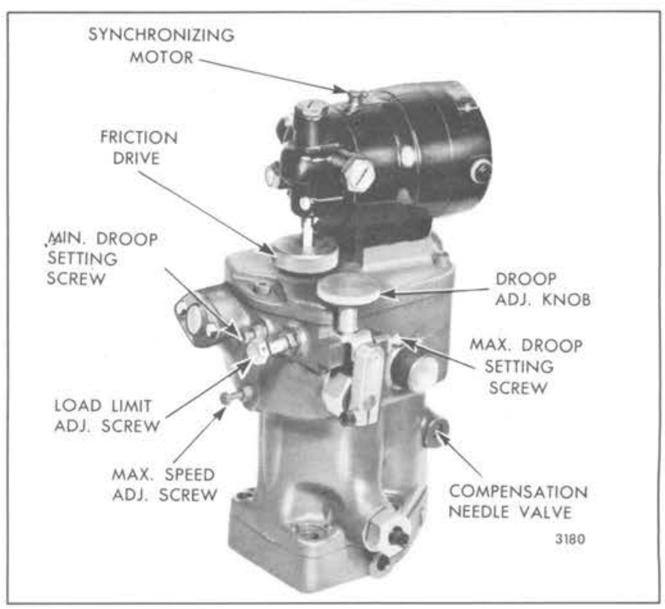


Fig. 10 – Typical Synchronizing Motor Mounting

SG VARIABLE SPEED HYDRAULIC GOVERNOR

INJECTOR RACK CONTROL ADJUSTMENT (12V AND16V)

The governor on the 12V and 16V engine is mounted on and driven from the front end of the rear blower (Fig. 1). The governor–to–injector control tube linkage is shown in Fig. 2.

After adjusting the exhaust valves and timing the fuel injectors, adjust the governor linkage and position the injector rack control levers.

Position Injector Rack Control Levers and Adjust Governor Linkage

The position of the injector racks must be correctly set in relation to the governor. Their positions determine the amount of fuel injected into each cylinder and ensures equal distribution of the load

1. Clean and remove the valve rocker cover from each cylinder head. Discard the gaskets.
2. Loosen all the adjusting screws and locknuts. Be sure all control levers are free on the control tubes.
3. Disconnect the vertical link assembly from the governor operating lever and the bell crank (Fig. 2).
4. Loosen the bolt and slide the governor operating lever from the serrated shaft.
5. Place the bolt (removed from the lower end of the vertical link) through the bell crank and into the recessed hole in the governor drive housing (Fig. 3).

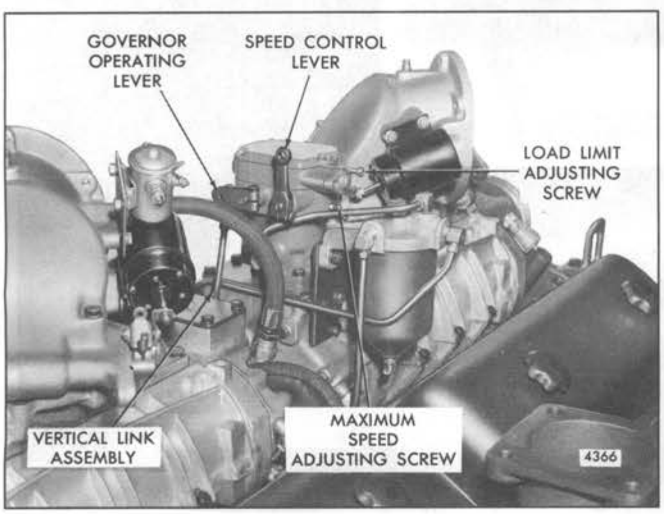


Fig. 1 – Hydraulic Governor Mounting

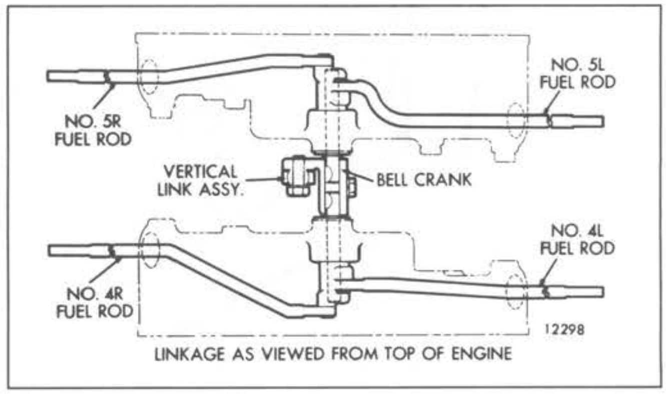


Fig. 2 – Governor to Injector Rack Control Linkage

6. Adjust the No. 4R (16V) or No. 3R (12V) injector rack by tightening the adjusting screw until the injector rack clevis is observed to roll up or an increase in effort to turn the screwdriver is noted (Fig. 5). Tighten the screw approximately 1/8 of a turn more and lock securely with the adjusting screw locknut. This will place the No. 4R (16V) or No. 3R (12V) injector rack in the *full–fuel* position.

NOTICE: Care should be taken to avoid setting the racks too tight causing the fuel rod to bend.

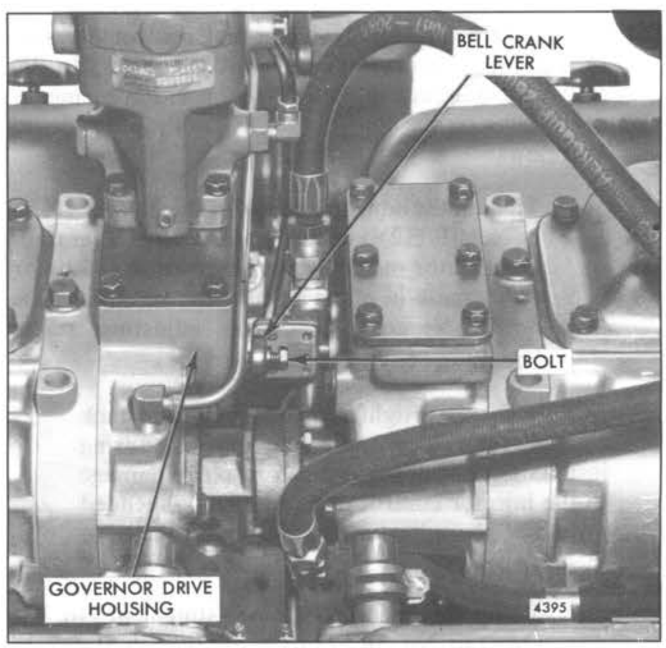


Fig. 3 – Positioning Bolt through Bell Crank Lever

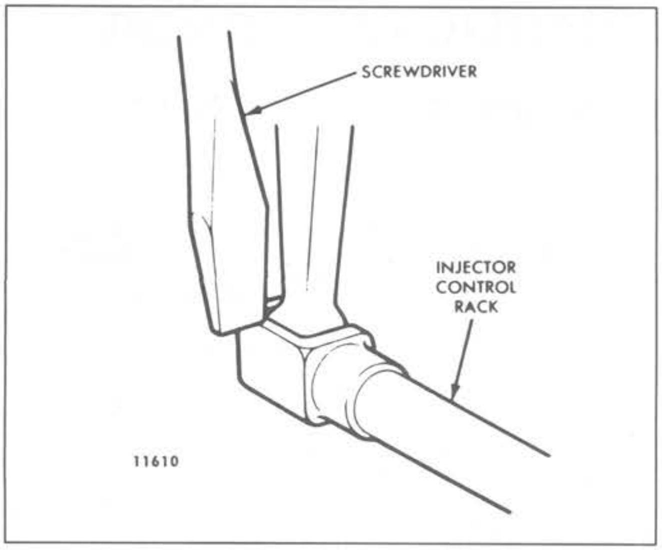


Fig. 4 – Checking Injector Rack "Spring"

7. To be sure the rack control lever is properly adjusted, press down on the injector rack with a screw driver or finger tip (Fig. 4). A light pressure should cause the rack to rotate. The rack is sufficiently tight if the rack returns ("springs" back) to its *original* position when the pressure is removed. The rack is too tight if a heavy pressure is required to rotate the rack.

8. Adjust the No. 5R, 4L and 5L (16V) or No. 4R, 3L and 4L (12V) injector rack control levers as outlined in Steps 6 and 7. when the settings are correct, all four of the injector racks will be snug on the ball end of the control levers when the injectors are in the *full–fuel* position.

9. To adjust the remaining injector rack control levers on the right front bank, hold the No. 4R (16V) or No. 2R (12V) injector rack in the *full–fuel* position by means of the lever on the control tube assembly and proceed as follows:

   a. Tighten the adjusting screw of the No. 3R (16V) or No. 2R (12V) injector rack control lever until the injector rack clevis is observed to roll up or an increase in effort to turn the screwdriver is noted. Securely lock the adjusting screw locknut.

NOTICE: Overtightening of the injector rack control tube lever adjusting screws during installation or adjustment can result in damage to the injector control tube. The recommended torque of the adjusting screws is 24–36 **lb–in** (3–4 N•m).

   b. Verify the injector rack adjustment of No. 4R (16V) or No. 3R (12V) as outlined in Step 7. If No. 4R (16V) or No. 3R (12V) does not "spring" back upward, turn the No. 3R (16V) or No. 2R (12V) adjusting screw counterclockwise slightly until the No. 4R (16V) or No. 3R (12V) injector rack returns to its *full–fuel* position and secure the adjusting screw locknut. Verify proper injector rack adjustment for both No. 4R and No. 3R (16V) or No. 3R and No. 2R (12V) injectors. Turn clockwise or counterclockwise the No. 3R (16V) or No. 2R (12V) injector rack adjusting screw until both No. 4R and No. 3R (16V) or No. 3R and No. 2R (12V) injector racks are in the *full–fuel* position when the locknut is securely tightened.

Recheck the No. 4R (16V) or No. 3R (12V) injector rack to be sure that it has remained snug on the ball end of the injector rack control lever. If the rack of No. 4R (16V) or No. 3R (12V) injector has become loose, lossen the locknut and turn the adjusting screw clockwise a slight amount and retighten the locknut.

When the settings are correct, both injector racks must respond in the same manner on the ball ends of their respective rack control levers as previously outlined in Step 7.

10. Position the remaining injector rack control levers on the right front cylinder head as outlined in Step 9b. When the settings are correct, all of the injector racks will be snug on the ball end of the control levers when the injector control tube lever is held in the *full–fuel* position.

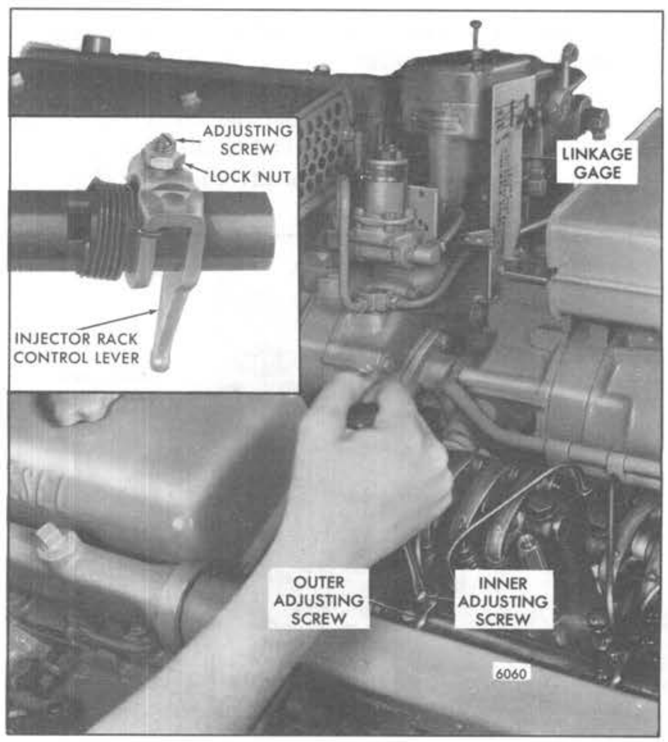


Fig. 5 – Positioning No. 4R Injector Rack Control Lever

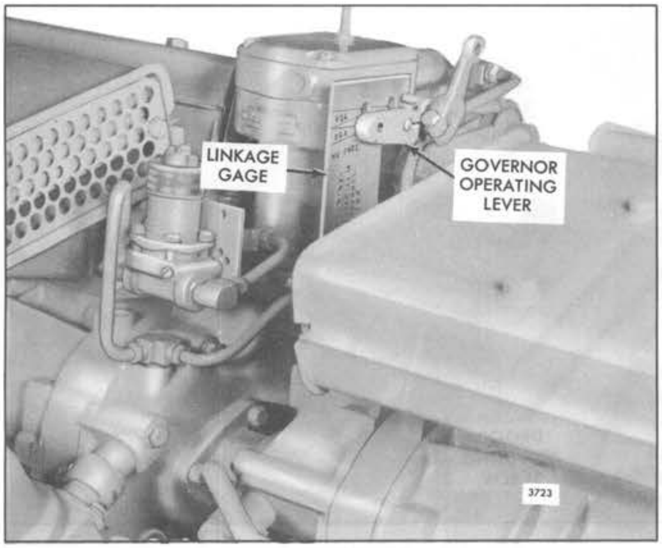


Fig. 6 – Positioning Governor Operating Lever

11. Adjust the remaining injector rack control levers on the right rear, left front and left rear cylinder heads in the same manner as outlined in Steps 9 and 10.

12. Replace the governor operating lever on the serrated shaft so that the bolt hole is lined up within the proper lines on the gage. The type of governor (SGX or PSG) will determine the proper position of the lever (Fig. 6).

13. Remove the gage.

14. Move the bell crank lever to the *no–fuel* position.

15. Adjust the length of the vertical link so that the bolt holes of the levers and the centers of the rod end bearings are lined up (Fig. 7).

16. Replace the two bolts in the levers and tighten the bolts.

17. Remove the governor cover.

18. With the load limit screw backed all the way out, retain the governor operating lever in the *full–fuel* position. The governor terminal lever should touch the boss on the governor housing. Adjust the vertical link so that all the injector racks are in the *full–fuel* position, then tighten the rod end locknuts securely.

19. Use a new gasket and install the valve rocker cover on each cylinder head.

Adjust Load Limit

The load limit is set at the factory and further adjustment should be unnecessary. However, if the governor has had major repairs or the injector rack control levers have been repositioned, the load limit screw should be readjusted.

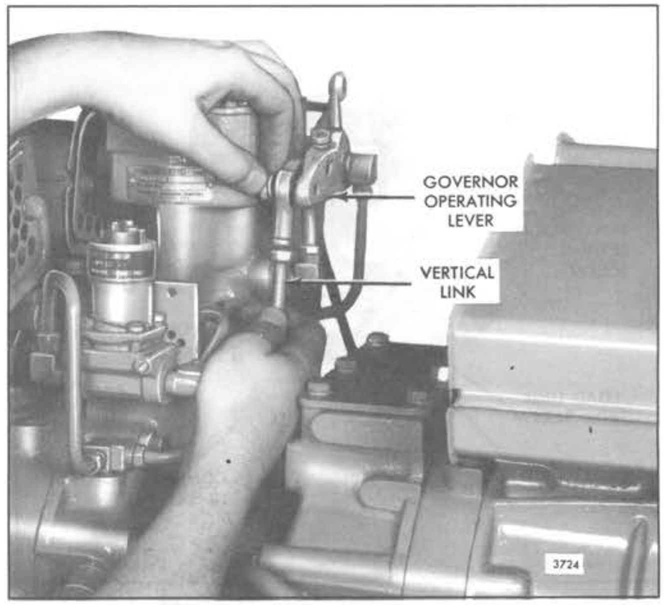


Fig. 7 – Adjusting Vertical Link

With the injector rack control levers properly adjusted, set the load limit as follows:

1. With the governor cover off and the load limit screw locknut loosened, place and retain the governor operating lever in the *full–fuel* position (Fig. 8). Do not overstress the linkage.

2. Turn the load limit adjusting screw in until the injector racks just loosen on the ball end of the control levers.

3. Release the governor operating lever and hold the adjusting screw while tightening the locknut. Install the governor cover and tighten the screws.

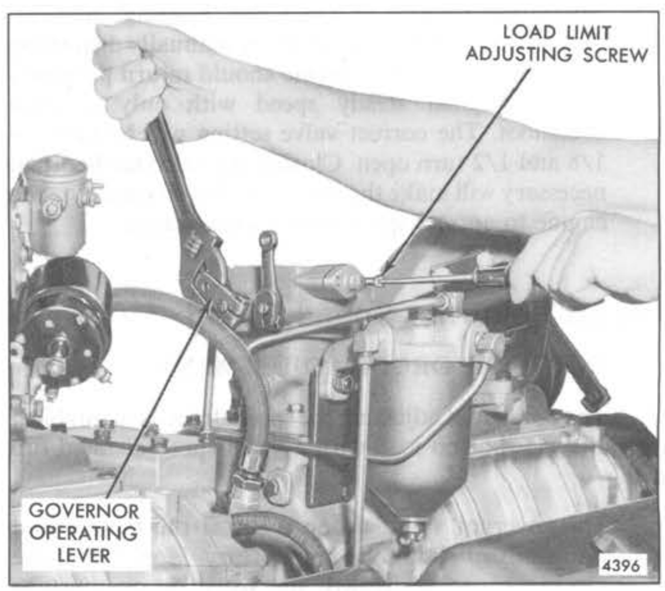


Fig. 8 – Adjusting Load Limit Screw

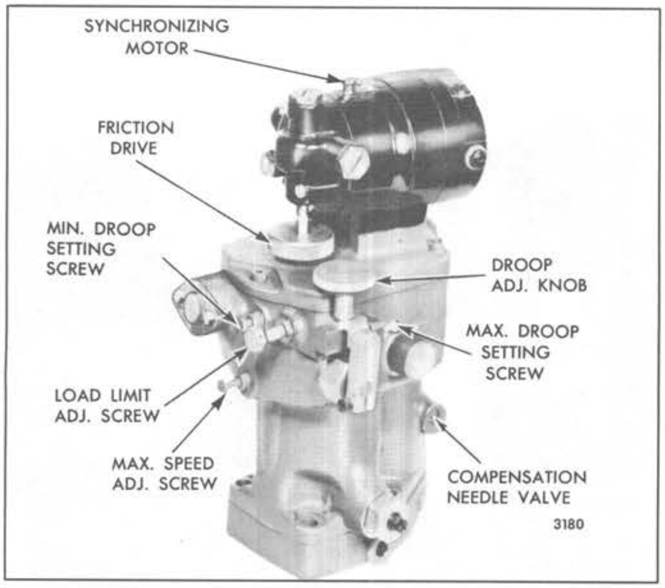


Fig. 9 – Typical Synchronizing Motor Mounting

Compensation Needle Valve Adjustment (PSG Governor)

Start the engine and, after the engine reaches normal operating temperature, adjust the governor compensation needle valve, without load on the engine, as follows:

1. Open the valve (Fig. 9) two or three turns and allow the engine to "hunt" or "surge" for about one–half minute to bleed any air which may be trapped in the governor oil passages.
2. Gradually close the valve until the "hunting" just stops. Check the amount of valve opening by closing the valve completely and noting the number of turns required to close it. Open the valve to the previously determined position at which the "hunting" stopped. Test the action of the governor by manually disturbing the engine speed. The engine should return promptly to the original steady speed with only a small overshoot. The correct valve setting will be between 1/8 and 1/2 turn open. Closing the valve farther than necessary will make the governor slow in returning the engine to normal speed after a load change.

Adjust Governor Speed Droop

INTERNAL DROOP ADJUSTMENT

The purpose of adjusting the speed droop is to establish a definite speed at no load with a given speed at rated full load.

The governor speed droop is set at the factory and further adjustment should be unnecessary. However, if the governor has been overhauled, the speed droop must be readjusted.

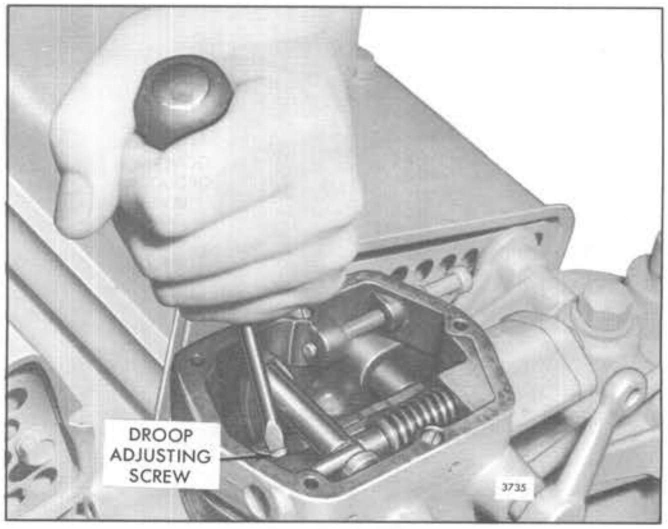


Fig. 10 – Adjusting Speed Droop

The best method of determining the engine speed is by using an accurate hand tachometer.

If a full rated load can be established on the unit, and the fuel rods, injector rack control levers and the load limit have been adjusted, set the speed droop as follows:

1. Start the engine and run it at approximately one–half the rated no–load speed until the lubricating oil temperature stabilizes. When the engine lubricating oil is cold, the governor regulation may be erratic. Regulation will become increasingly stable as the temperature of the oil increases.
2. Stop the engine and remove the governor cover.
3. Loosen the lock nut and back off the maximum speed adjusting screw approximately 5/8".
4. Loosen the droop adjusting screw (Fig. 10). Move the droop bracket so that the screw is midway between the ends of the slot in the bracket. Tighten the screw.
5. With the throttle in the *run* position, adjust the engine speed until the engine is operating at 3 to 5% above the recommended full–load speed.
6. Apply the full rated load on the engine and readjust the engine speed to the correct full–load speed.

Full Load	No Load
50 cycles, 1000 rpm	52.5 cycles, 1050 rpm
60 cycles, 1200 rpm	62.5 cycles, 1250 rpm
50 cycles, 1500 rpm	52.5 cycles, 1575 rpm
60 cycles, 1800 rpm	62.5 cycles, 1875 rpm

TABLE 2

7. Remove the rated load and note the engine speed after the speed stabilizes under no load. If the speed droop is correct, the engine speed will be approximately 3 to 5% higher than the full–load speed.

If the speed droop is too high, stop the engine, loosen the droop adjusting screw and move the adjusting bracket IN toward the center of the governor. Tighten the screw. To increase the speed droop, move the bracket OUT, away from the center of the governor.

The speed droop in governors which control engines driving generators in parallel must be identical, otherwise the electrical load will not be equally divided.

Adjust the speed droop bracket in each governor to obtain the desired variation between engine no–load and full–load speeds. The recommended speed droop for generator sets operating in parallel is 50 rpm (2–1/2 cycles) for units operating at 1,000 and 1,200 rpm, and 75 rpm (2–1/2 cycles) for units operating at 1,500 and 1,800 rpm (Table 2). However, this speed droop recommendation may be varied to suit the individual application.

EXTERNAL DROOP CONTROL

Some PSG type governors are equipped with an external adjustable droop control (Fig. 9). This permits the speed droop to be adjusted without removing the governor cover. With this feature, a unit can be paralleled with another unit that is operating at constant frequency (zero droop). The incoming unit must have its droop bracket set in the *maximum* position while it is being paralleled and while operating in parallel. When it is desired to stop the unit operating at constant frequency, shift the load to the incoming unit and move the governor droop bracket to zero droop. Then adjust the outgoing unit to maximum droop, remove it from the line and stop the engine. The incoming unit will now be carrying the load and operating at constant frequency (zero droop).

Adjust the governor speed droop as follows:

1. Start the engine and run it at approximately one–half of the rated full–load speed until the lubricating oil temperature stabilizes.
2. Remove the load from the engine.
3. Back off the compensation needle valve to release any air that may be trapped in the system. Turn the needle valve in slowly to reduce governor "hunting". The correct needle valve setting will be between 1/8 and 1/2 turn open.
4. Back out the minimum and maximum droop setting screws.
5. Loosen the droop adjusting knob and move the slider all the way in toward the center of the governor (Fig. 8). Then, tighten the knob.
6. Loosen the locknut on the maximum speed adjusting screw and turn the screw out until 5/8" of the threads are exposed.
7. With the engine operating at the recommended full–load speed, apply the full rated load and recheck the engine speed. If required, readjust the engine to full–load speed.
8. Remove the load and note the engine speed. If the zero droop setting is correct, the engine speed will remain constant. If the engine speed is higher, loosen the droop adjusting knob and set the slider to a *reduced droop* position.
9. When the desired minimum droop setting is reached, loosen the locknut and turn the minimum droop setting screw in until it contacts the droop linkage within the governor. This will be felt by a step up or resistance while turning the adjusting screw. Lock the adjusting screw in this position.
10. Loosen the droop adjusting knob and slide the droop bracket in a direction to increase the droop. Perform Steps 7 and 8 to check the droop until the desired maximum speed droop is attained.
11. When the desired maximum droop setting is reached, loosen the locknut and turn the maximum droop setting screw inward until it contacts the droop slider arm. Lock the adjusting screw in this position.
12. Recheck the minimum and maximum droop setting as outlined in Steps 7 and 8 and adjust the adjustment screws, if necessary, until the correct settings are obtained.

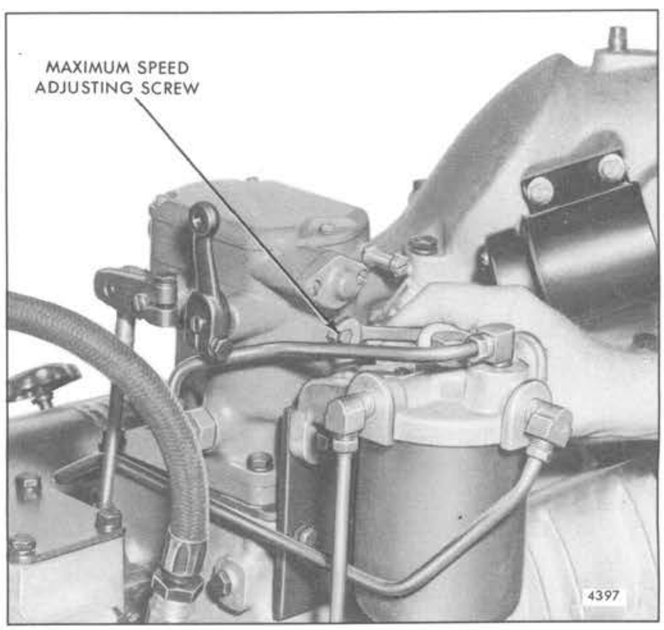


Fig. 11 – Adjusting Maximum No–Load Engine Speed

Adjust Maximum No–Load Speed

With the speed droop properly adjusted, set the maximum no–load speed as follows:

1. With the engine operating at no–load, adjust the speed until the engine is operating at approximately 8% higher than the rated full–load speed.
2. Turn the maximum speed adjusting screw (Fig. 11) in until the screw contacts the throttle linkage internally, limiting the maximum speed of the engine at 8% above the rated full load speed.
3. Hold the screw and tighten the lock nut.

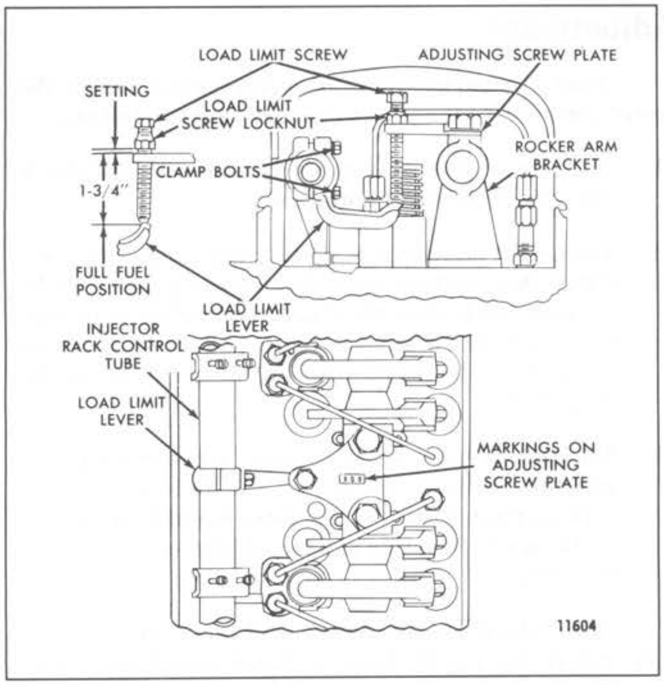
Governors With Synchronizing Motor

Some hydraulic governors are equipped with a reversible electric synchronizing motor mounted on the governor cover (Fig. 9).

The adjustments on a governor equipped with a synchronizing motor are the same as on a governor without the motor. However, the governor cover and motor assembly must be removed when setting the engine speed droop (except on a governor equipped with the external droop adjustment). The cover and motor must be reinstalled to check the speed droop.

SUPPLEMENTARY GOVERNING DEVICE ADJUSTMENT

ENGINE LOAD LIMIT DEVICE



1 – Engine Load Limit Device

Engines with mechanical governors may be equipped with a load limit device to reduce the maximum horsepower (Fig. 1).

This device consists of a load limit screw threaded into a plate mounted between two adjacent rocker arm shaft brackets and a load limit lever clamped to the injector control tube.

The load limit device is located between the No. 1 and No. 2 cylinders on *each* cylinder bank of a 6V engine and between the No. 2 and No. 3 cylinders on *each* cylinder bank of an 8V engine. On the 12V and 16V engines, four load limit devices are used (one on each cylinder head). The load limit device is located between the No. 1 and No. 2 cylinders and between the No. 4 and No. 5 cylinders (12V engines) or between the No. 2 and No. 3 cylinders and between the No. 6 and No. 7 cylinders (16V engines) on each cylinder bank.

When properly adjusted for the maximum horsepower desired, this device limits the travel of the injector control racks and thereby the fuel output of the injectors.

Adjustment

After the engine tune–up is completed, make sure the load limit devices are properly installed as shown in Fig. 1. Make sure the counterbores in the adjusting screw plates are up. The rocker arm shaft bracket bolts which fasten the adjusting screw plate to the brackets are tightened to 75–85 lb–ft (102–115 N•m) torque. All other rocker arm shaft bracket bolts are tightened to 90–100 lb–ft (122–136 N•m) torque. Then adjust the load limit device, on each cylinder head, as follows:

1. Loosen the load limit screw locknut and remove the screw.
2. Loosen the load limit lever clamp bolts so the lever is free to turn on the injector rack control tube.
3. With the screw out of the plate, lock the load limit screw locknut so the bottom of the nut is 1 3/4" from the bottom of the load limit screw for the initial setting (Fig. 1).
4. Thread the load limit screw into the adjusting screw plate until the lock nut *bottoms* against the top of the plate.
5. Hold the injector rack control tube in the full–fuel position and place the load limit lever against the bottom of the load limit screw. Then tighten the load limit lever clamp bolts.
6. Check to ensure that the injector racks will just go into the full–fuel position — readjust the load limit lever, if necessary.
7. Hold the load limit screw to keep it from turning, then *set* the locknut until the distance between the bottom of the locknut and the top of the adjusting screw plate corresponds to the dimension (or number of turns) stamped on the plate.

   NOTICE: If the plate is not stamped, adjust the load limit screw while operating the engine on a dynamometer test stand and note the number of turns required to obtain the desired horsepower. Then stamp the plate accordingly.

8. Thread the load limit screw into the plate until the locknut *bottoms* against the top of the plate. Be sure the nut turns with the screw.
9. Hold the load limit screw to keep it from turning, then tighten the locknut to secure the setting.

POWER CONTROL DEVICE

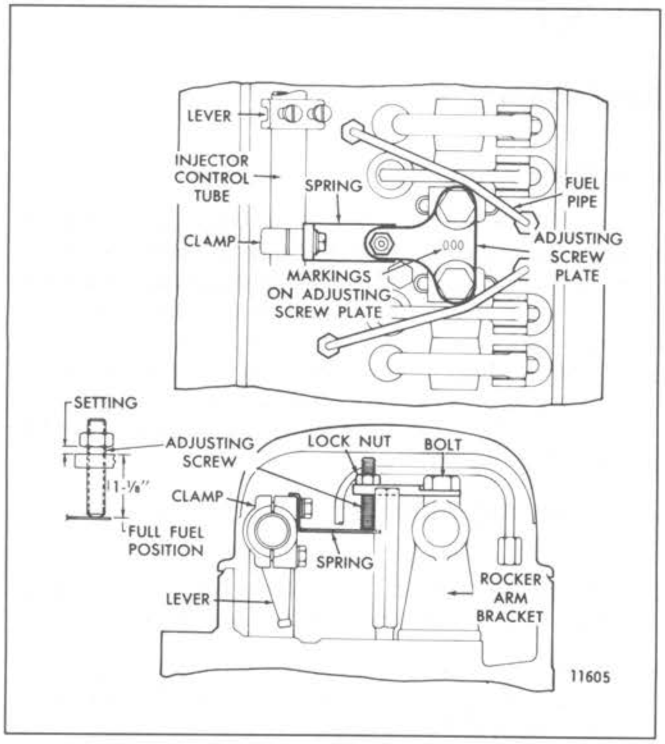


Fig. 2 – Power Control Device

The power control (torque limiting) device (Fig. 2) is used on some vehicle engines to limit the maximum horsepower output at the wheels without diminishing the performance at lower speeds where full power may be required. It limits the horsepower at, or just below, the normal full-load governed speed. These limiting characteristics are proportionately lessened as the engine speed is reduced and the horsepower required is reduced.

This device, one on each cylinder bank, consists of an adjusting screw threaded into a plate mounted between two adjacent rocker arm shaft brackets and a spring attached to a clamp on the injector control tube.

NOTICE: The rocker arm shaft bolts that retain the adjusting screw plates are tightened to 75–85 lb-ft (102–115 N•m) torque; all other rocker arm shaft bracket bolts are tightened to 90–100 lb-ft (122–136 N•m) torque.

The power control device is located between the No. 1 and No. 2 cylinders on *each* cylinder bank of a 6V engine, between the No. 2 and No. 3 cylinders on *each* cylinder bank of an 8V engine.

Adjustment

After the engine tune-up is completed, adjust the power control device on both cylinder banks as follows:

1. Place the vehicle on a chassis dynamometer and check the maximum wheel horsepower.
2. Loosen the power control spring attaching bolts. Then adjust both springs until they project parallel to the cylinder heads when the injector control racks are held in the full-fuel position. Tighten the spring attaching bolts to 7–9 lb-ft (10–12 N•m) torque to retain the adjustment.
3. Set each power control device, while holding the injector control racks in the full-fuel position, by turning the adjusting screw down (clockwise) until it just touches the spring and the locknut is tight against the plate.

Then release the injector control racks. Wipe the oil from each spring and the bottom of each adjusting screw so the point of contact can be seen readily.

NOTICE: Steps 2 and 3 must be completed on both cylinder banks before proceeding with Step 4.

4. Start the engine. Then, with the engine running at full governed speed, check the horsepower. If necessary, readjust the screws to obtain the specified horsepower. Turn the screws down to decrease the horsepower; turn the screws up to increase the horsepower. When the desired wheel horsepower is obtained, hold the screws from turning and tighten the locknuts.

NOTICE: If a dynamometer is not available, back up the locknuts the distance stamped on the plates. Then turn the screws and locknuts down together until the locknuts *bottom* on the plates. Hold the screws from turning and tighten the locknuts.

THROTTLE DELAY MECHANISM

The throttle delay mechanism is used in turbocharged engines to retard full-fuel injection when the engine is accelerated. This reduces exhaust smoke and also helps to improve fuel economy.

The throttle delay mechanism is installed between the No. 1 and No. 2 cylinders on the right bank cylinder head (Fig. 3).

It consists of a special rocker arm shaft bracket (which incorporates the throttle delay cylinder), a piston, throttle delay lever, connecting link, orifice plug, ball check valve and U-bolt.

A throttle delay bracket with two 1/4" fill holes and a 30-40" water restriction check valve is used in some 6V-92TA Coach engines. All tilt Coach engine models and some upright models use this throttle delay.

A yield link replaces the standard operating lever connecting link in the governor.

Operation

Oil is supplied to a reservoir above the throttle delay cylinder through an oil supply fitting in the drilled oil passage in the rocker arm shaft bracket (Fig. 3). As the injector racks are moved toward the no-fuel position, free movement of the throttle delay piston is assured by air drawn into the cylinder through the ball check valve. Further movement of the piston uncovers an opening which permits oil from the reservoir to enter the cylinder and displace the air. When the engine is accelerated, movement of the injector racks toward the full-fuel position is momentarily retarded while the piston expels the oil from the cylinder through an orifice. To permit full accelerator travel, regardless of the retarded injector rack position, a spring loaded yield link replaces the standard operating lever connecting link in the governor.

Inspection

The current throttle delay bracket has a closer tolerance on the piston and cylinder bore. The current piston link pin hole is offset below the piston centerline and has a larger pin boss diameter. The current piston link has two tabs to ensure that the piston is installed with the piston pin hole offset down. The current piston and link must be used together to ensure correct positioning of the piston. The current check valve has a nylon check ball in place of the former brass ball. When inspecting the throttle delay hydraulic cylinder, it is important that the check valve be inspected for wear.

To inspect the check valve, fill the throttle delay cylinder with diesel fuel oil and watch for check valve leakage while moving the engine throttle from the idle position to the *full-fuel* position. If more than a drop of leakage occurs, replace the check valve.

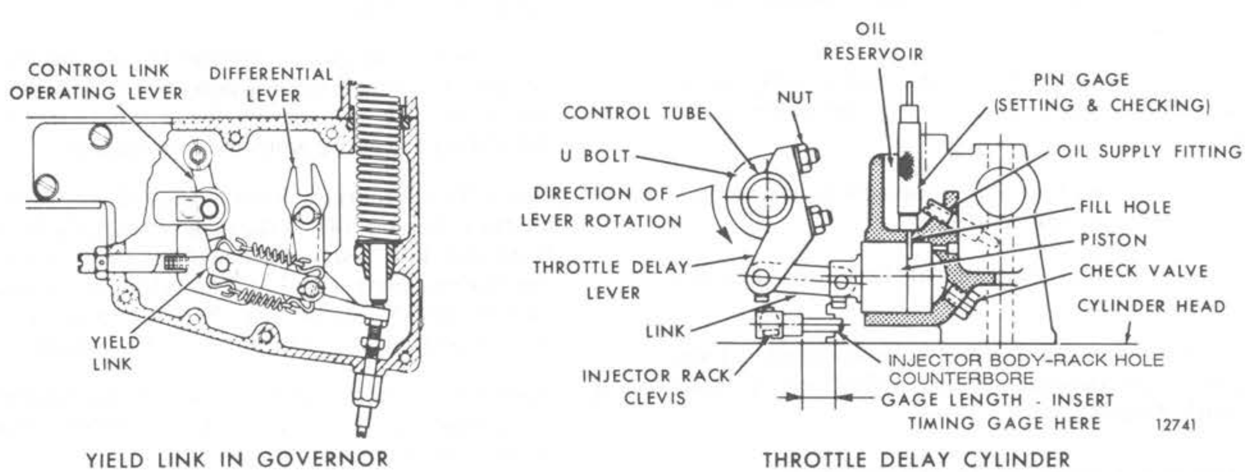


Fig. 3 – Throttle Delay Cylinder and Yield Link

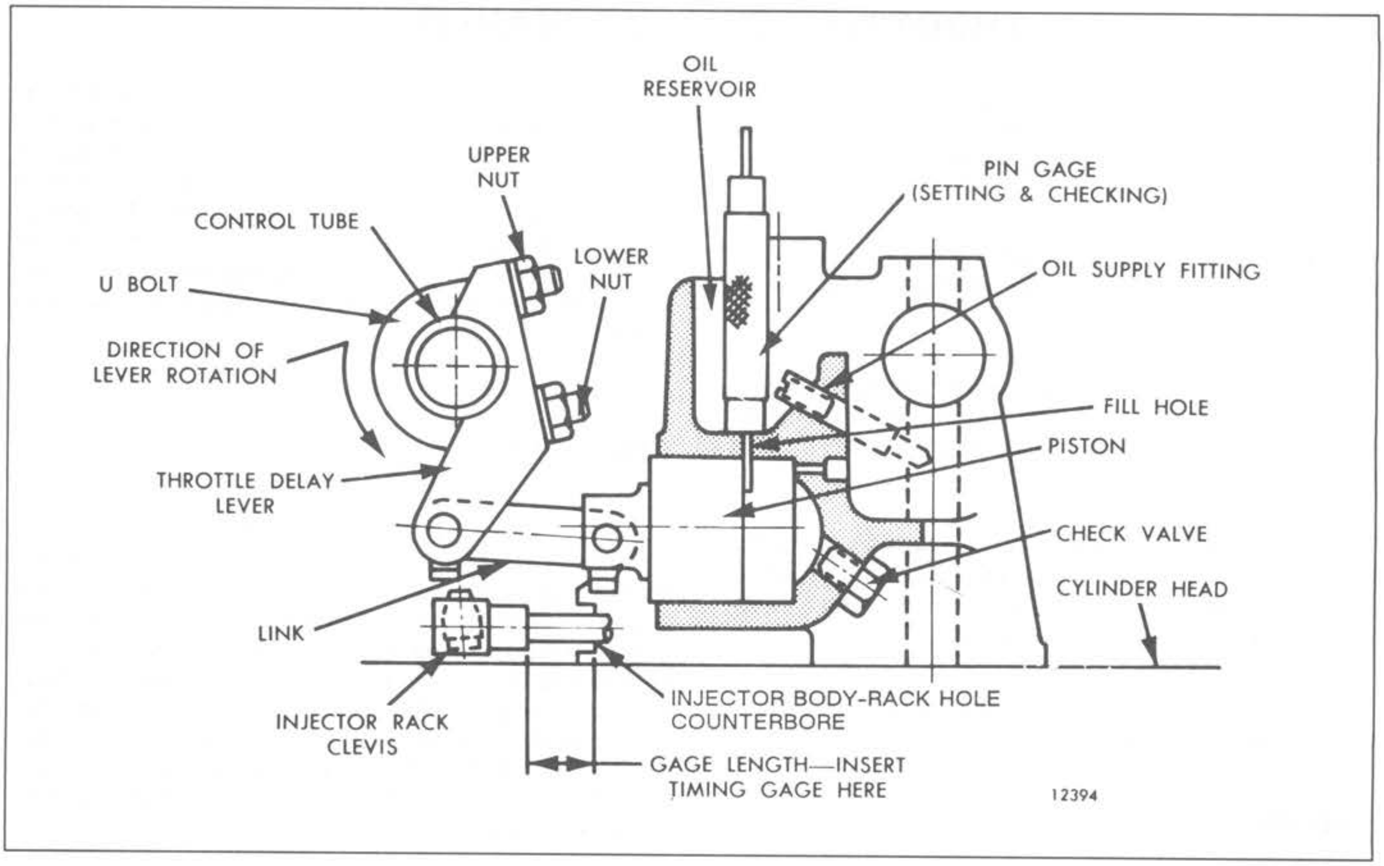


Fig. 4 – Adjusting Throttle Delay Cylinder (Current)

Service Note

The current throttle delay cylinder rocker arm bracket has a 5/64" diameter fill hole. The former throttle delay cylinder with a 1/4" diameter fill hole can be modified as follows:

1. Ream the fill hole to .2646"–.2666" diameter with a 17/64" reamer.
2. Remove any burrs formed in the throttle delay piston bore with fine emery cloth to be sure the piston moves freely.
3. Press a service bushing in the reamed hole and recheck the piston for free movement.
4. Remove and discard the original check valve. Install a new check valve.
5. Assemble and install the throttle delay cylinder. Then adjust it as outlined under *Adjustment (former Throttle Delay).*

Adjustment (Current Throttle Delay)

Whenever the injector rack control levers are adjusted, disconnect the throttle delay mechanism by loosening the U–bolt which clamps the lever to the injector control tube. After the injector rack control levers have been positioned, the throttle delay mechanism must be readjusted. With the engine stopped, proceed as follows:

1. Disconnect the throttle delay mechanism by loosening the U–bolt which clamps the lever to the injector control tube (Fig. 4).
2. To provide adequate lubrication of mechanical components, fill the throttle delay reservoir with clean engine oil. The oil reservoir does not have to remain full during the entire adjustment procedure.
3. Insert the appropriate throttle delay timing gage (see charts in Section 14) on the rack between the injector body rack hole counterbore and the shoulder on the injector rack clevis (Fig. 1). This is the No. 2 injector on 6V and 8V engines, the No. 5 injector on 12V engines and the No. 6 injector on 16V engines.
4. Hold the governor throttle lever in the *maximum speed* position. This should cause the injector rack to move toward the *full–fuel* position.
5. Insert pin gage J 25558 with the "go" (green .069") end in the cylinder fill hole. If the throttle delay housing has multiple holes, use the hole indicated in Fig. 5.

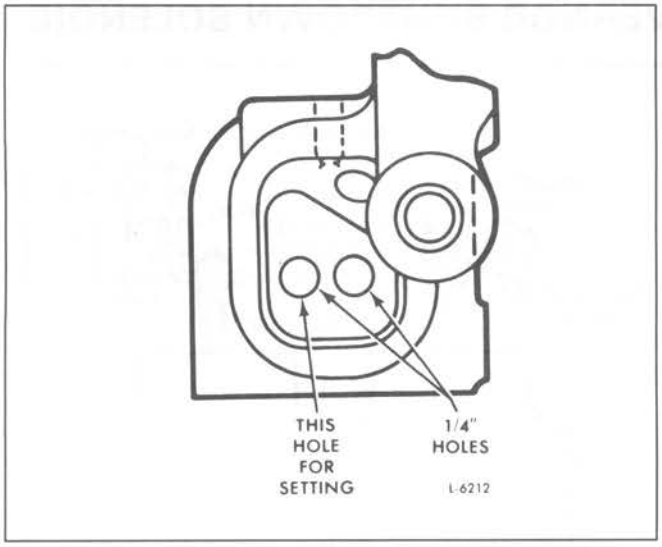


Fig. 5 – Throttle Delay with Multiple Fill Holes

6. Rotate the throttle delay lever in the direction shown in Fig. 4 until further movement is limited by the piston contacting the pin gage.

7. Tighten the U–bolt while exerting a slight pressure on the lever in the direction of rotation.

8. Check the setting, as follows:

    a. Remove the pin gage.

    b. Reinsert the "go" (green .069") end of the gage in the fill hole. If the gage will not go past the piston without resistance, increase the torque on the lower U–bolt nut. Remove the gage.

    c. Reverse the pin gage and attempt to insert the "no go" (red .072") end in the fill hole. If the "no go" end of the gage enters the fill hole past the piston without resistance, increase the torque on the upper U–bolt nut. It should not be possible to insert the gage past the piston without moving the injector racks toward the *no–fuel* position.

9. Release the governor throttle lever and remove the timing gage and pin gage. If either U–bolt nut is tightened without the pin gage being inserted, recheck the setting.

10. Move the injector control tube assembly between the *no–fuel* and the *full–fuel* position to make sure there is no bind.

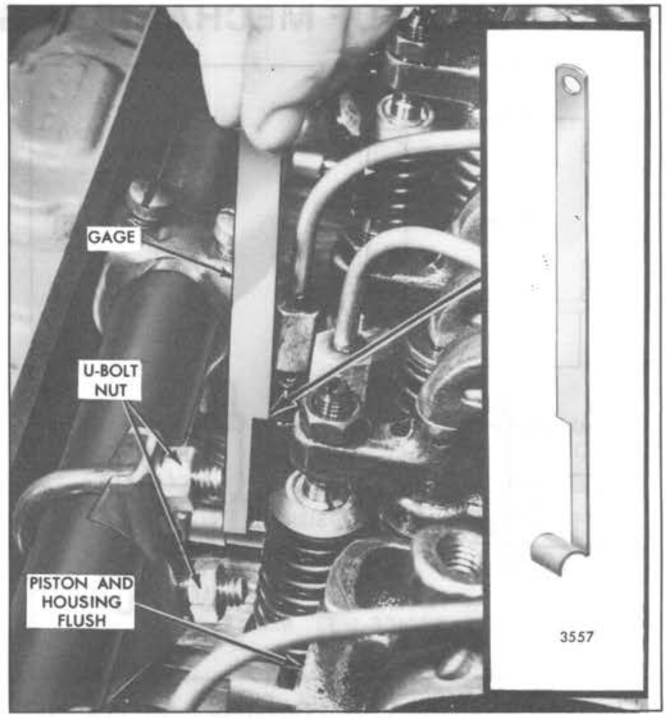


Fig. 6 – Adjusting Throttle Delay Cylinder (Former)

Adjustment (Former Throttle Delay)

Whenever the injector rack control levers are adjusted, disconnect the throttle delay mechanism by loosening the U–bolt which clamps the lever to the injector control tube. After the injector rack control levers have been positioned, the throttle delay mechanism must be readjusted. With the engine stopped, proceed as follows:

1. Refer to Fig. 6 and insert gage J 23190 (.454" setting) between the injector body and the shoulder on the injector rack. Then exert a light pressure on the injector control tube in the direction of full fuel.

2. Align the throttle delay piston so it is flush with the edge of the throttle delay cylinder.

3. Tighten the U–bolt on the injector control tube and remove the gage.

4. Move the injector rack from the no–fuel to the full–fuel position to make sure it does not bind.

ADJUSTMENT OF MECHANICAL GOVERNOR SHUTDOWN SOLENOID

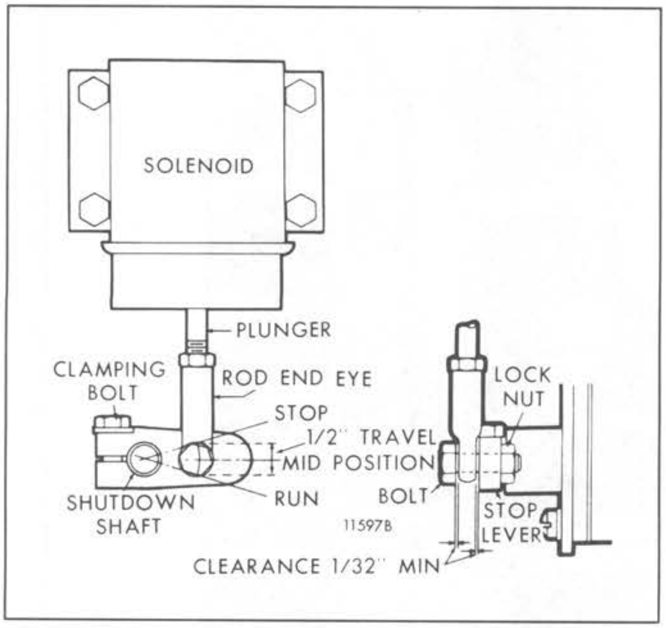


Fig. 7 – Typical Variable Speed Governor Lever Position

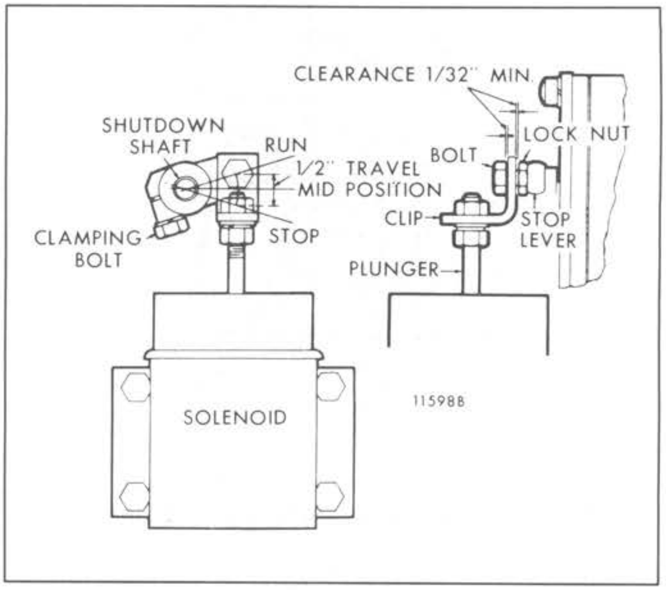


Fig. 8 – Typical Limiting Speed Governor Lever Position

When a governor shutdown solenoid is used on an engine equipped with a mechanical governor, the governor stop lever must be properly adjusted to match the shutdown solenoid plunger travel.

The solenoid plunger can be properly aligned to the governor stop lever as follows:

1. Remove the bolt connecting the rod end eye (variable speed governor) or the right angle clip (limiting speed governor) to the stop lever (Figs. 7 and 8). Align and clamp the lever to the shutdown shaft in such a way that, at its mid–travel position, it is perpendicular to the solenoid plunger. This assures that the linkage will travel as straight as possible. The solenoid plunger has available 1/2" travel which is more than adequate to move the injector control racks from the full–fuel to the complete no–fuel position and shut down will occur prior to attaining complete travel.

2. With the stop lever in the *run* position, adjust the rod end eye or right angle clip for minimum engagement on the solenoid plunger when the connecting bolt is installed. The oversize hole in the eye or clip will thereby permit the solenoid to start closing the air gap, with a resultant build–up of pull–in force prior to initiating stop lever movement.

3. The bolt through the rod end eye or the right angle clip should be locked to the stop lever and adjusted to a height that will permit the eye or clip to float vertically. The clearance above and below the eye or clip and the bolt head should be approximately 1/32" minimum.

   NOTICE: The locknut can be either on top of or below the stop lever.

4. Move the lever to the *stop* position and observe the plunger for any possible bind. If necessary, loosen the mounting bolts and realign the solenoid to provide free plunger motion.

FUEL MODULATOR

The fuel modulator is mounted on the left–bank cylinder head between the No. 3 and No. 4 cylinders on 8V engines and and consists of a cast housing containing a cylinder, piston, cam and spring (Fig. 9). The modulator mechanism is installed on the left bank between the No. 2 and No. 3 cylinders on 6V engines. A lever and roller assembly which controls the injector rack is connected to the injector control tube. An air supply line runs from the turbocharger discharge on the air inlet housing to the modulator housing, providing pressure to activate the piston.

The fuel modulator maintains the proper fuel–to–air ratio in the lower speed ranges where the mechanical governor would normally act to provide maximum injector output. It operates in such a manner that, although the engine throttle may be moved into the full–fuel position, the injector racks cannot advance to the full–fuel position until the turbine speed is high enough to provide sufficient air for combustion.

The modulator tells the fuel system the maximum amount of fuel the engine can efficiently use based on turbocharger boost pressure. Increased pressure forces the piston and cam out of the cylinder, allowing the rack to move toward full fuel. The spring behind the piston is calibrated to the pressure characteristics of the engine.

Effective with engine serial number 8VF–077480, a fuel modulator is available on Federal and California certified 8V–92TA (turbocharged–aftercooled) vehicle engines rated at 355 horsepower at 1800 rpm.

NOTICE: Effective with unit number 6VF154264, the turbochargers and blower bypass valves on marine engine models 8062–3404 and 8062–7404 were changed to improve fuel combustion efficiency and reduce smoke levels at high rpm. Fuel modulators on these engines must be set at .454" for optimum performance.

Inspection

At major repair or overhaul, inspect the roller and piston outer diameter and the cylinder bore inner diameter for wear. Also, inspect the operating surfaces – the lever roller, the roller pins at the cam pivot and the cam attachment to the piston. Replace parts, as required.

For optimum operating efficiency, the engine fuel modulator *must* be checked periodically and reset if required.

Checking and resetting the fuel modulator:

- Ensures that the engine emission-related adjustments comply with EPA requirements.
- Ensures a regulated fuel/air ratio to prevent overfueling and smoke.
- Ensures smooth, free operation of the fuel modulator and linkage.
- Ensures proper adjustment of the modulator to DDC factory specifications, thereby eliminating any previously made incorrect adjustment.

Check Fuel Modulator Setting

To check the fuel modulator setting, proceed as follows:

1. With the engine stopped, insert the correct rack gage between the injector body rack recess and the shoulder on the injector rack (Fig. 10). Use the injector next to and forward of the fuel modulator assembly. Insert the gage so that the handle is at a 45 degree angle. Fuel modulator specifications and setting tools are as follows:

TOOL	SETTING
J 9509–C	.404"
J 33156	.465"
J 34080	.480"
J 33157	.490"
J 24889	.345"
J 23190	.454"
J 24882	.385"
J 35735	.430"

NOTICE: Rack gages are marked with the tool number and specific dimensions. Dimensional tolerances are ± .002".

2. Hold the governor speed control lever in the *maximum speed* position and the run/stop lever in the *run* position.

3. Insert a .005" feeler gage between the modulator roller and cam (Figs. 9 & 11). The rack gage *must* fall over. The rack gage should stand at a 45 degree angle by itself when the .005" feeler gage is removed.

Adjust Fuel Modulator

Before the fuel injector rack control levers are adjusted, the fuel modulator lever and roller assembly must be positioned free of cam contact. This is done by loosening the clamp screw.

After the injector rack control levers have been properly positioned, adjust the modulator, as follows:

1. With the engine stopped, insert the correct rack gage between the injector body rack recess and the shoulder on the injector rack (Fig. 10). Use the injector next to and forward of the fuel modulator assembly. Insert the gage so that the handle is at a 45 degree angle.

2. Hold the governor speed control lever in the maximum speed position and the run/stop lever in the *run* position. *The rack gage must stand up while being held in place by the rack.*

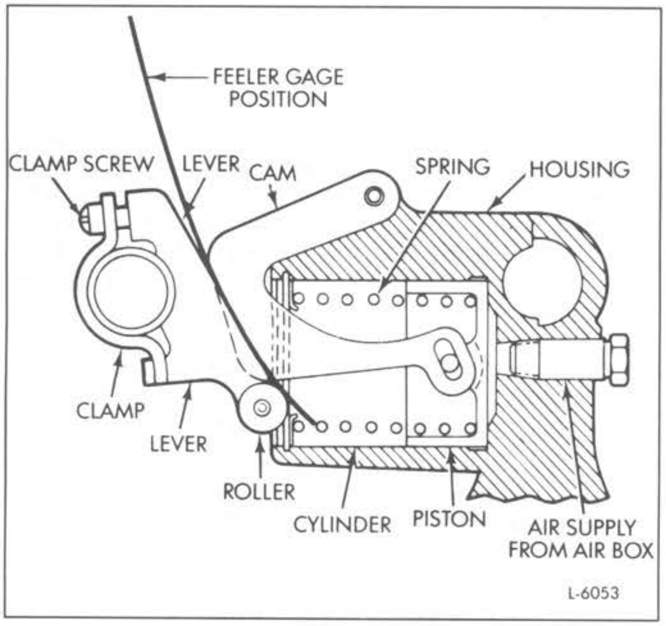


Fig. 9 – Fuel Modulator Assembly

3. With clamp loose, push the air box fuel modulator lever assembly until the roller contacts the cam with sufficient force to take up the roller and cam pin clearances. Insert a 3/8" x 3" x .017" feeler gage between the cam and the roller (see Figs. 9 & 11). Make sure the cam is centered, and tighten the clamp screw until the gage falls. Replace the .017" thick feeler gage with a .004" thick gage and tighten the screw further until the gage falls again.

4. While holding the governor lever in the maximum speed position, check the setting by verifying that the rack gage stands at a 45 degree angle by itself. Then, insert a .005" feeler gage between the modulator roller and cam. If the rack gage falls, the setting is correct.

5. Remove the gage.

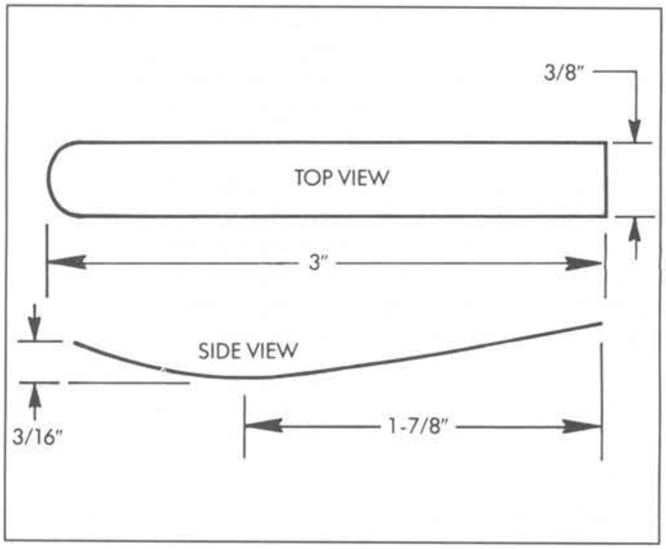


Fig. 11 – Rework of .017" and .004" Feeler Gage Stock

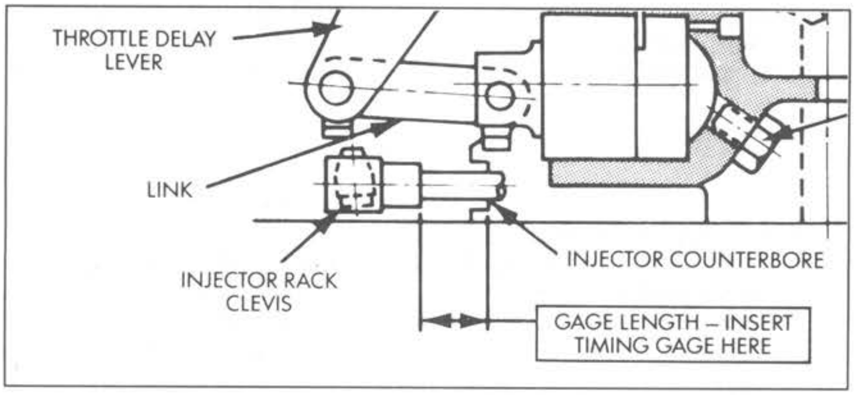


Fig. 10 – Rack Gage Position

SECTION 15

PREVENTIVE MAINTENANCE – TROUBLESHOOTING – STORAGE

CONTENTS

LUBRICATION AND PREVENTIVE MAINTENANCE

The *Lubrication and Preventive Maintenance Schedule* is intended as a guide for establishing a preventive maintenance schedule. The suggestions and recommendations for preventive maintenance should be followed as closely as possible to obtain long life and best performance from a Detroit Diesel engine. The intervals indicated on the Charts are time or miles (in thousands) of actual operation.

MAINTENANCE SCHEDULE EXPLANATION

The time or mileage increments shown apply only to the maintenance function described. These functions should be coordinated with other regularly scheduled maintenance such as chassis lubrication.

The daily instructions pertain to routine or daily starting of an engine and not to a new engine or one that has not been operated for a considerable period of time. For new or stored engines, carry out the instructions given under *Preparation for Starting Engine First Time* under *Operating Instructions* in Section 13.1.

EMISSION CONTROL MAINTENANCE SERVICE CHART

(VEHICLE ENGINES)

DAILY	
1. — Lubricating Oil	Ⓘ
2. — Fuel Tank	Ⓘ
3. — Fuel Lines and Flexible Hoses	Ⓘ
4. — Cooling System	Ⓘ
5. — Turbocharger	Ⓘ
3000 MILE INTERVALS	
6. — Battery	Ⓘ
7. — Tachometer Drive	Ⓘ
4000-6000 MILE INTERVALS	
8. — Air Cleaner (oil bath)	Ⓘ
9. — Drive Belts	Ⓘ
10. — Air Compressor	Ⓘ
11. — Throttle Control	Ⓘ
15,000 MILE INTERVALS	
(2.) — Fuel Tank	Ⓘ
(8.) — Air Cleaner (oil bath)	Ⓘ
25,000 MILE INTERVALS	
12. — Lubricating Oil Filter	Ⓡ

6 MONTHS OR 10,000 MILE INTERVALS	MONTHS / MILES (1000)	6 / 10	12 / 20	18 / 30	24 / 40	30 / 50	36 / 60	42 / 70	48 / 80	54 / 90	60 / 100
13. — Fuel Filter		Ⓡ	Ⓡ	Ⓡ	Ⓡ	Ⓡ	Ⓡ	Ⓡ	Ⓡ	Ⓡ	Ⓡ
14. — Coolant Filter & Water Pump*		Ⓘ	Ⓘ	Ⓘ	Ⓘ	Ⓘ	Ⓘ	Ⓘ	Ⓘ	Ⓘ	Ⓘ
15. — Starting Motor		Ⓘ	Ⓘ	Ⓘ	Ⓘ	Ⓘ	Ⓘ	Ⓘ	Ⓘ	Ⓘ	Ⓘ
(2.) — Fuel Tank			Ⓘ		Ⓘ		Ⓘ		Ⓘ		Ⓘ
(4.) — Cooling System (hoses)			Ⓘ		Ⓘ		Ⓘ		Ⓘ		Ⓘ
(10.) — Air Compressor			Ⓘ		Ⓘ		Ⓘ		Ⓘ		Ⓘ
16. — Air System			Ⓘ		Ⓘ		Ⓘ		Ⓘ		Ⓘ
17. — Exhaust System			Ⓘ		Ⓘ		Ⓘ		Ⓘ		Ⓘ
18. — Air Box Drain Tube				Ⓘ			Ⓘ			Ⓘ	
19. — Emergency Shutdown			Ⓘ		Ⓘ		Ⓘ		Ⓘ		Ⓘ
20. — Engine (steam clean)			Ⓘ		Ⓘ		Ⓘ		Ⓘ		Ⓘ
21. — Radiator			Ⓘ		Ⓘ		Ⓘ		Ⓘ		Ⓘ
22. — Shutter Operation			Ⓘ		Ⓘ		Ⓘ		Ⓘ		Ⓘ
23. — Oil Pressure			Ⓘ		Ⓘ		Ⓘ		Ⓘ		Ⓘ
24. — Governor						Ⓘ					Ⓘ
25. — Fuel Injector & Valve Clearance						Ⓘ					Ⓘ
26. — Throttle Delay						Ⓘ					Ⓘ
27. — Battery-Charging Alternator*											
28. — Engine & Transmission Mounts							Ⓘ				
29. — Crankcase Pressure							Ⓘ				
30. — Air Box Check Valves											Ⓘ
(1.) — Lubricating Oil*											
31. — Fan Hub*											
49. — Blower Bypass Valve											Ⓘ

ANNUALLY	
(3.) — Fuel Lines and Flexible Hoses	Ⓘ
(4.) — Cooling System	Ⓘ
(8.) — Air Cleaner (oil bath)	Ⓘ
32. — Thermostats & Seals	Ⓘ
33. — Blower Screen	Ⓘ
34. — Crankcase Breather	Ⓘ
35. — Fan (thermo-modulated)	Ⓘ
AS REQUIRED	
36. — Engine Tune-Up	

Ⓘ = INSPECT, CORRECT OR REPLACE (IF NECESSARY)

Ⓡ = REPLACE

* = SEE ITEM

INDUSTRIAL OFF HIGHWAY AND MARINE	TIME INTERVALS										
HRS.	DLY.	8	50	100	150	200	300	500	700	1,000	2,000
MILES		240	1,500	3,000	4,500	6,000	9,000	15,000	20,000	30,000	60,000
1. — Lubricating Oil	X				X						
2. — Fuel Tank	X							X	X		
3. — Fuel Lines and Flexible Hoses	X							X		X	
4. — Cooling System	X							X	X	X	
5. — Turbocharger	X										
6. — Battery				X							
7. — Tachometer Drive				X							
8. — Air Cleaners		X						X			
9. — Drive Belts		X				X					
10. — Air Compressor						X			X		
11. — Throttle and Clutch Controls						X					
12. — Lubricating Oil Filter								X		X	
13. — Fuel Strainer and Filter							X				
14. — Coolant Filter & Water Pump*								X			
15. — Starting Motor*											
16. — Air System									X		
17. — Exhaust System									X		
18. — Air Box Drain Tube										X	
19. — Emergency Shutdown									X		
21. — Radiator									X		
22. — Shutter Operation									X		
23. — Oil Pressure									X		
24. — Overspeed Governor								X			
26. — Throttle Delay*											
27. — Battery-Charging Alternator						X					
28. — Engine and Transmission Mounts											X
29. — Crankcase Pressure											X
30. — Air Box Check Valves*											
31. — Fan Hub*											
32. — Thermostats and Seals*									X		
33. — Blower Screen										X	
34. — Crankcase Breather										X	
36. — Engine Tune-Up*											
37. — Heat Exchanger Electrodes								X		X	
38. — Raw Water Pump	X										
39. — Power Generator				X			X				
40. — Power Take-Off		X	X					X			
41. — Marine Gear	X					X				X	
42. — Torqmatic Converter	X		X							X	
43. — Reduction Gear		X	X					X		X	
44. — Blower Bypass Valve*											

*See Item

Item 1 – Lubricating Oil

Check the lubricating oil level with the engine stopped. If the engine has just been stopped, wait approximately twenty (20) minutes to allow the oil to drain back to the oil pan. Add the proper grade oil, as required, to maintain the correct level on the dipstick (refer to Section 13.3).

NOTICE: Oil may be blown out through the crankcase breather if the crankcase is overfilled.

Make a visual check for oil leaks around the filters and the external oil lines.

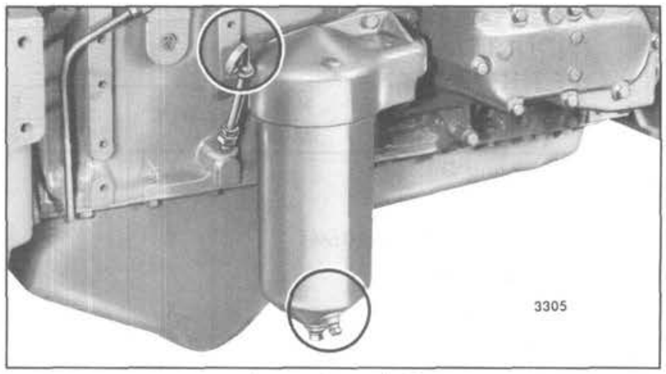
Change the lubricating oil at the intervals shown in the Chart. See Section 13.3 for drain intervals when using high sulfur fuel (above 0.50 mass percent).

ENGINE OIL CHANGE INTERVALS	
Service Application	Max. Engine Oil Change Interval
	Diesel Fuel Sulfur Content % by Wt. Max.
	0 to 0.50
Hwy. Truck (Long Distance Hauls)	20,000 Miles
City Transit Coaches	6,000 Miles
Pickup Delivery Truck Service (Stop–and–go short distance)	12,500 Miles
Industrial & Marine	150 Hours

When using high TBN/ash oils, a rule of thumb for oil change intervals is to drain the oil when the TBN drops to one–half of the new oil TBN. *Since lubricant composition varies from brand to brand the time and rate of TBN reduction will vary*. These differences manifested by the various high TBN/ash oils will influence the drain interval.

The drain interval may be established on the recommendations of an independent oil analysis laboratory or the oil supplier (based upon the used oil sample analysis) until the most practical oil change period has been determined.

If the lubricating oil is drained immediately after an engine has been run for some time, most of the sediment will be in suspension and will drain readily. Select the proper grade of oil in accordance with the instructions given in the *Lubrication Specifications* in Section 13.3



Items 1 and 12

Item 2 – Fuel Tanks

Keep the fuel tank filled to reduce condensation to a minimum. Select the proper grade of fuel in accordance with the *Fuel Specifications* in Section 13.3.

Open the drain at the bottom of the fuel tank every 500 hours or 15,000 miles to drain off any water and/or sediment.

Every 12 months or 20,000 miles (700 hours) tighten all fuel tank mountings and brackets. At the same time, check the seal in the fuel tank cap, the breather hole in the cap and the condition of the crossover fuel line. Repair or replace the parts, as necessary.

Diesel Fuel Contamination

The most common form of diesel fuel contamination is water. Water is harmful to the fuel system in itself, but it also promotes the growth of microbiological organisms (microbes). These microbes clog fuel filters with a "slime" and restrict fuel flow.

Water can be introduced into the fuel supply through poor maintenance (loose or open fuel tank caps), contaminated fuel supply or condensation.

Condensation is particularly prevalent on units which stand idle for extended periods of time, such as marine units. Ambient temperature changes cause condensation in partially filled fuel tanks.

Water accumulation can be controlled by mixing isopropyl alcohol (dry gas) into the fuel oil at a ratio of one pint (.5 liter) per 125 gallons (473 liters) fuel (or 0.10 by volume).

Marine units in storage are particularly susceptible to microbe growth. The microbes live in the fuel–water interface. They need both liquids to survive. These microbes find excellent growth conditions in the dark, quiet, non–turbulent nature of the fuel tank.

Microbe growth can be eliminated through the use of commerically available biocides. There are two basic types on the market.

1. The water soluble type treats *only the tank* where it is introduced. Microbe growth can start again if fuel is transferred from a treated to an untreated tank.

2. The diesel fuel soluble type, such as "Biobor" manufactured by U.S. Borax or equilvalent, treats *the fuel* itself, and therefore, the entire fuel system.

Marine units, or any other application, going into storage should be treated as follows: Add the biocide according to the manufacturer's instructions. This operation is most effective when performed as the tank is being filled. Add dry gas in the correct proportions.

If the fuel tanks were previously filled, add the chemicals and stir with a clean rod.

Item 3 – Fuel Lines And Flexible Hoses

Make a visual check for fuel leaks at the crossover lines and at the fuel tank suction and return lines. Since fuel tanks are susceptible to road hazards, leaks in this area may best be detected by checking for accumulation of fuel under the tanks.

The performance of engine and auxiliary equipment is greatly dependent on the ability of flexible hoses to transfer lubricating oil, air, coolant and fuel oil. Diligent maintenance of hoses is an important step in ensuring efficient, economical and safe operation of the engine and related equipment.

Check hoses daily as part of the pre–start up inspection. Examine hoses for leaks and check all fittings, clamps and ties carefully. Make sure that hoses are not resting on or touching shafts, couplings, heated surfaces including exhaust manifolds, any sharp edges or other obviously hazardous areas. Since all machinery vibrates and moves to a certain extent, clamps and ties can fatigue with age. To ensure continued proper support, inspect fasteners frequently and tighten or replace them, as necessary.

Leaks

Investigate leaks immediately to determine if fittings have loosened or cracked or if hoses have ruptured or worn through. Take corrective action immediately. Leaks are not only potentially detrimental to machine operation, but they also result in added expense caused by the need to replace lost fluids.

CAUTION: Personal injury and/or property damage may result from fire due to the leakage of flamable fluids such as fuel or lube oil.

Service Life

A hose has a finite service life. The service life of a hose is determined by the temperature and pressure of the air or fluid within it, its time in service, its mounting, the ambient temperatures, amount of flexing and vibration it is subject to. With this in mind, all hoses should be thoroughly inspected at least every 500 operating hours (1,000 hours for the fire–resistant fuel and lube hoses and heat–insulating turbo/exhaust system blanket) and/or annually. Look for cover damage or indications of damaged, twisted, worn, crimped, brittle, cracked or leaking lines. Hoses having the outer cover worn through or damaged metal reinforcement should be considered unfit for further service.

All hoses in or out of machinery should be replaced during major overhaul and/or after a maximum of five years service.

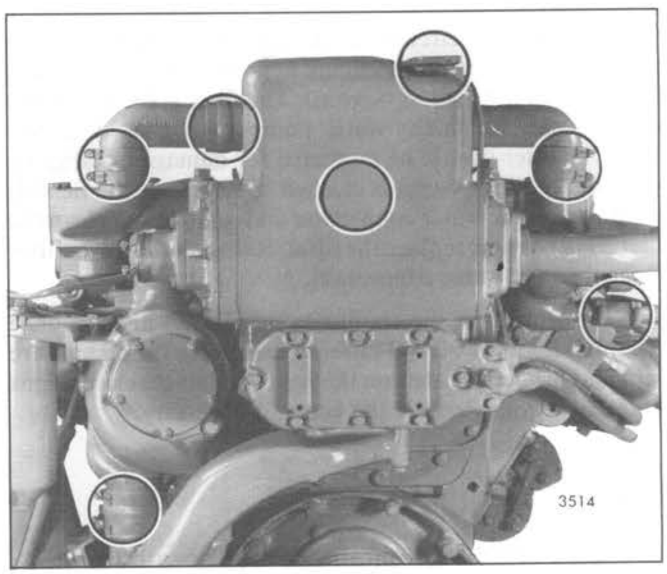
NOTICE: The new hose assemblies do not require automatic replacement after five years service or at major overhaul.

Item 4 – Cooling System

CAUTION: Do not remove the pressure control cap from the radiator or heat exchanger or attempt to drain the coolant until the engine has cooled. Once the engine has cooled, use extreme care when removing the cap. the sudden release of pressure from a heated cooling system can result in a loss of coolant and possible personal injury (scalding) from the hot liquid.

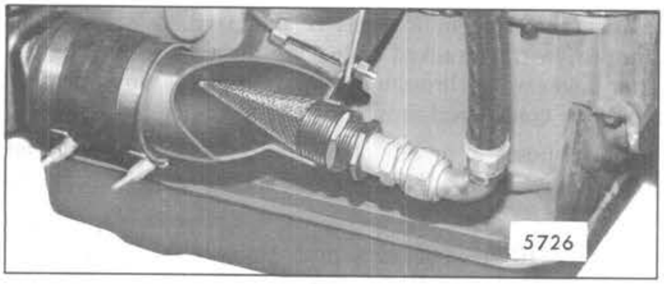
Check the coolant level daily and maintain it near the top of the heat exchanger tank or make sure it covers the radiator tubes. Add coolant, as necessary. *Do not overfill.*

Make a visual check for cooling system leaks. Check for an accumulation of coolant beneath the vehicle during periods when the engine is running and when the engine is stopped.



Item 4

In order to assure the integrity of the cooling system, it is recommended that a periodic cooling system pressure check be performed. Pressurize the cooling system (15–20 psi or 103–138 kPa) using radiator cap and cooling system tester J 24460–01. Do not exceed 20 psi (138 kPa). Any



Item 4

measurable drop in pressure may indicate an external/internal leak. Whenever the oil pan is removed, the cooling system should be pressure checked as a means of identifying any incipient coolant leaks.

Clean the cooling system annually (vehicle engines) or every 1,000 hours or 30,000 miles (non-vehicle engines) using a good radiator cleaning compound in accordance with the instructions on the container. After the cleaning operation, rinse the cooling system thoroughly with fresh water. Then, fill the system with soft water, adding a good grade of rust inhibitor or an ethylene glycol base antifreeze (refer to *Coolant Specifications* in Section 13.3). With the use of a proper antifreeze or rust inhibitor, this interval may be lengthened until, normally, this cleaning is done only in the spring or fall. The length of this interval will, however, depend upon an inspection for rust or other deposits on the internal walls of the cooling system. When a thorough cleaning of the cooling system is required, it should be reverse flushed.

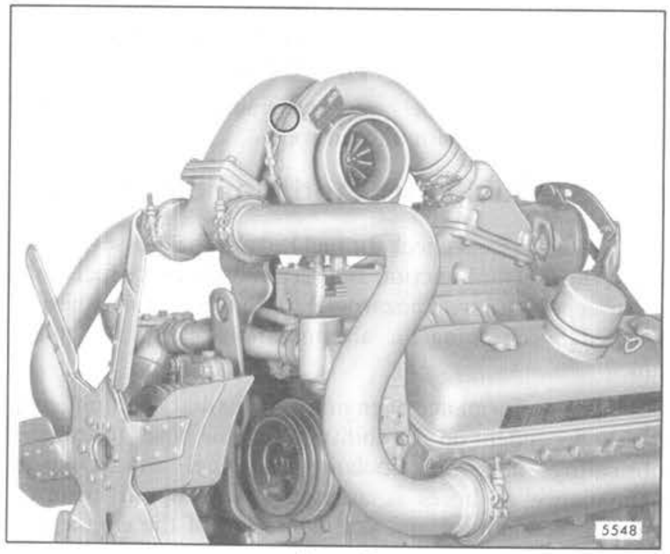
The coolant circulated through the intercoolers on a turbocharged intercooled engine is protected by a 20 mesh cone–shaped water filter (screen). The filter is located at the water connection in the water pump–to–engine oil cooler tube. The filter should be inspected for damage or clogging when the cooling system is cleaned. Disconnect the flexible water hose at the water connection and remove and clean the filter. If necessary, replace the filter. Reinstall the water filter (screen) in the water connection.

Inspect all of the cooling system hoses at least once every 700 hours or 20,000 miles to make sure the clamps are tight and properly seated on the hoses and to check for signs of deterioration. Replace the hoses, if necessary.

Item 5 – Turbocharger

CAUTION: To eliminate the possibility of personal injury when air inlet piping is removed, do not operate an engine with a blower–mounted or front center–mounted turbocharger unless the compressor inlet guard assembly or turbo inlet shield (J 26554–A) is installed.

Inspect the mountings, intake and exhaust ducting and connections for leaks. Check the oil inlet and outlet lines for leaks and restriction to oil flow. Check for unusual noise or vibration and, if excessive, remove the turbocharger and correct the cause.



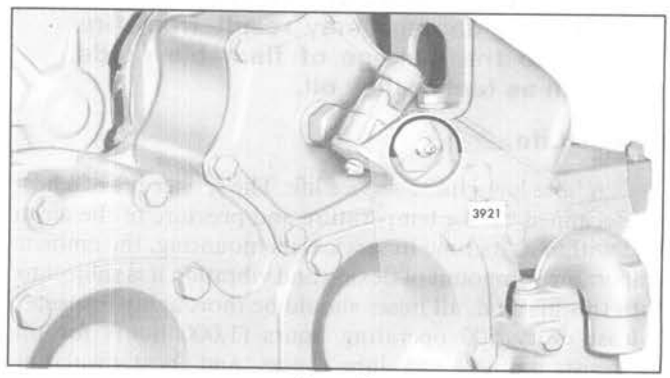
Item 5

Item 6 – Battery

Check the "eye" of maintenance–free batteries for charge. If lead–acid or low maintenance batteries are used, check the specific gravity of the electrolyte in each cell every 100 hours or 3,000 miles. In warm weather, however, it should be checked more frequently due to a more rapid loss of water from the electrolyte. The electrolyte level should be maintained in accordance with the battery manufacturer's recommendations.

Item 7 – Tachometer Drive

Lubricate the tachometer drive every 100 hours or 3,000 miles with an all purpose grease at the grease fitting. At temperatures above 30°F (–1°C), use a No. 2 grade grease. Use a No. 1 grade grease below this temperature.



Item 7

Item 8 – Air Cleaner

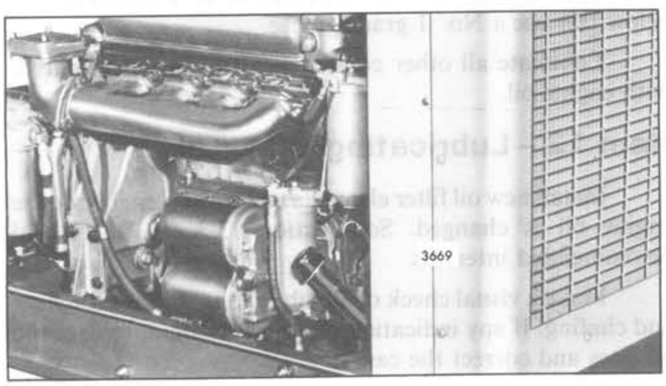
Under no engine operating conditions should the air inlet restriction exceed 25 inches of water (6.2 kPa) for non–turbocharged engines or 20 inches of water (5.0 kPa) for turbocharged engines. A clogged air cleaner element will cause excessive intake restriction and a reduced air supply to the engine.

Oil Bath

Remove the dirty oil and sludge from the oil bath type air cleaner cups and center tubes every 8 hours (every 6,000 miles for highway vehicle engines), or less if operating conditions warrant. Wash the cups and elements in clean fuel oil and refill the cups to the level mark with the same grade and viscosity *heavy–duty* oil as used in the engine. The frequency of servicing may be varied to suit local dust conditions. If heavy rain or snow has been encountered, check the air cleaner for an accumulation of water.

Remove and steam clean the air cleaner element and baffle annually.

It is recommended that the body and fixed element in the heavy–duty oil bath type air cleaner be serviced every 500 hours or 15,000 miles or as conditions warrant.



Item 8

Dry Type

Dry type air cleaner elements (Donaldson, Farr, etc.) used in on–highway applications should be discarded and replaced with new elements after one year of service, after 100,000 miles (Donaldson's recommended mileage interval) or when the maximum allowable air intake restriction has been reached (see Section 13.2), whichever comes first. No attenpt should be made to clean or reuse on–highway elements after these intervals.

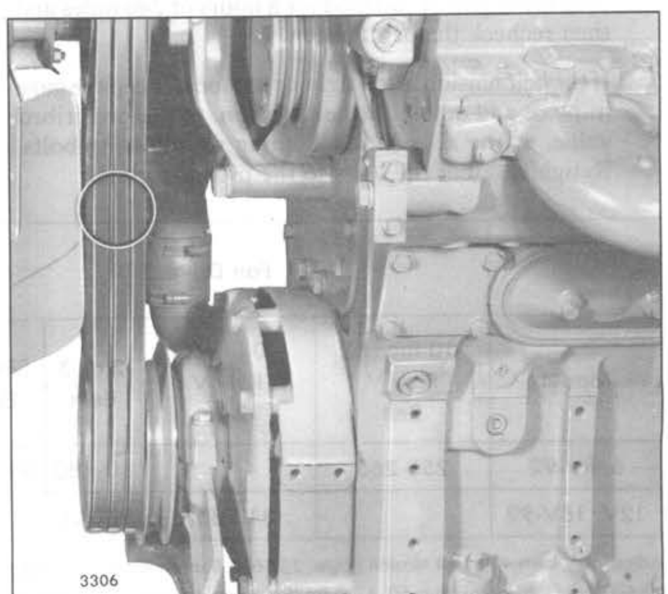
Dry type elements used in off–highway applications should be discarded and replaced with new elements after one year of service or when the maximum allowable air intake restriction has been reached (see Section 13.2), whichever comes first. In cases where the air cleaner manufacturer recommends cleaning or washing off–highway elements, the maximum service life is still one year or maximum restriction. Cleaning, washing and inspection must be done per the manufacturer's recommendations. Inspection and replacement of the cover gaskets must also be done per the manufacturer's recommendations.

Item 9 – Drive Belts

New standard V–belts will stretch after the first few hours of operation. Run the engine for 15 *seconds* to seat the belts, then readjust the tension. Check the belts and tighten the fan drive, pump drive, battery–charging generator or alternator and other accessory drive belts after 1/2 hour or 15 miles and again after 8 hours or 240 miles of operation. Thereafter, check the tension of the drive belts every 200 hours or 6,000 miles and adjust, if necessary. Belts should be neither too tight nor too loose. Belts which are too tight impose excess loads on the crankshaft, fan and/or alternator bearings, shortening both belt and bearing life. Excessively overtightened belts can result in crankshaft breakage. A loose belt will slip.

Replace all belts in a set when one is worn. Single belts of similar size should not be used as a substitute for a matched belt set; premature belt wear can result because of belt length variation. All belts in a matched belt set are within .032" of their specified center distances.

Adjust the belt tension so that a firm push with the thumb, at a point midway between the two pulleys, will depress the belt 1/2" to 3/4". If belt tension gage J 23600–B or equivalent is available, adjust the belt tension, as outlined in the Chart. When installing or adjusting an accessory drive belt, be sure the bolt at the accessory adjusting pivot point is properly tightened, as well as the bolt in the adjusting slot.



Item 9

Adjust Poly–V Fan Belt (16V–92)

The fan belt should be neither too tight nor too loose. Carelessness in making a belt adjustment can be dangerous. Too tight a belt imposes an undue load on the fan bearings and shortens the life of the belt. Too loose a belt allows slippage and lowers the fan speed, causes excessive belt wear and leads to overheating of the cooling system.

Before a Poly–V belt is installed, it is very important that the crankshaft pulley (10 grooves) and the fan drive pulley (11 grooves) are in alignment. The extra groove in this fan drive pulley can be on the inside or the outside of the pulley, depending upon alignment requirements.

Misalignment between the crankshaft pulley and the fan drive pulley cannot be more than .009" per inch of center line distance, A straight line can be determined by placing a straight edge on the rims of the pulleys. A spacer is available to facilitate pulley alignment, if necessary. The spacer mounts between the crankshaft pulley and the vibration damper hub.

Poly–V belts require a special procedure for proper belt tension.

1. After the belts have been initially adjusted, run the engine under a light load for 1/2 hour.
2. Stop the engine and check the belt tension with the belt "hot"; use belt tension gage J 23586 or equivalent, which has a range of 60 to 400 pounds.
3. If the tension value is not between 280 and 360 pounds, readjust the belt tension. Because the allowable load the crankshaft bearing can carry is critical, do not exceed the maximum tension value of 360 pounds.
4. Run the engine at full load for 8 hours or 240 miles and then recheck the belt tension.
5. If the belt tension is too tight or too loose, keep the gage in place and adjust the belt tension, to the prescribed value, at the accessory mounting or adjusting bolts. Retighten all of the bolts to the proper torque.
6. The belt tension should be rechecked every 200 hours or 6,000 miles of engine operation and readjusted, if necessary.

Item 10 – Air Compressor

Remove and wash all of the polyurethane sponge strainer parts every 500 miles (150 operating hours). The strainer element should be cleaned or replaced. If the element is cleaned, it should be washed in a commercial solvent or a detergent and water solution. The element should be saturated in clean engine oil, then squeezed dry before replacing it in the strainer. Be sure to replace the air strainer gasket if the entire air strainer is removed from the compressor intake.

For replacement of the air strainer element, contact the nearest Bendix Westinghouse or Midland–Ross dealer; replace with the polyurethane element, if available.

Every 12 months or 20,000 miles tighten the air compressor mounting bolts. If the air compressor is belt driven, check the belts for proper tension.

Item 11 – Throttle And Clutch Controls

Every 200 hours or 6,000 miles lubricate the throttle control mechanism. Use an all purpose grease (No. 2 grade) at temperatures ± 30°F (–1°C) and above. At temperatures below this use a No. 1 grade grease.

Lubricate all other control mechanisms, as required, with engine oil.

Item 12 – Lubricating Oil Filter

Install new oil filter elements and gaskets each time the engine oil is changed. See Section 13.3 for filters and recommended intervals.

Make a visual check of all lubricating oil lines for wear and chafing. If any indication of wear is evident, replace the oil lines and correct the cause.

When the engine is equipped with a turbocharger, pre–lubricate it as outlined under *Install Turbocharger* in Section 3.5.

	Fan Drive				Alternator or Generator Drive			AC Compressor Drive
Model	10 Rib (K) Poly V Belt	10 Rib (L) Poly V Belt	2 or 3 Belts	Single Belt	Two 3'8" or 1/2" Belts	One 1/2" Belt	8 Rib (K) Poly V Belts	4 Rib (K) Poly V Belts
6, 8V-92	255-265		60- 80	80-100	40-50	50-70	110-130	84-94
12V, 16V-92		310-360	90-120		40-50	50-70		

Adjust all V-belts with belt tension gage J 23600-B or equivalent. Adjust all Poly V-belts with belt tension gage J 23586 or equivalent *Range 60-400 lbs. Belt tension is 60 ± 10 lbs. for a single premium high capacity belt (.785" wide) used to drive a 12 cfm air compressor.

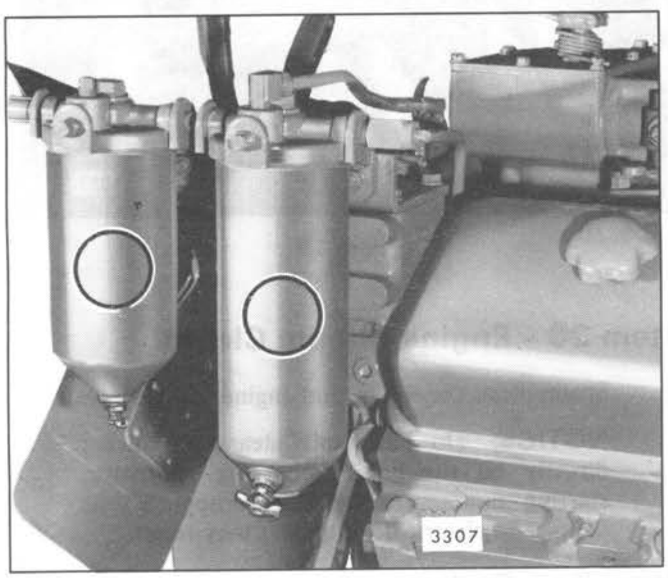
If the engine is equipped with a governor oil filter, change the element every 1,000 hours or 30,000 miles.

Check for oil leaks after starting the engine.

Item 13 – Fuel Strainer And Filter

Install new elements every 6 months or 10,000 miles (vehicle engines) and 300 hours or 9,000 miles (non–vehicle engines) or when plugging is indicated. See Section 13.3 for filter recommendations.

A method of determining when elements are plugged to the extent that they should be changed is based on the fuel pressure at the cylinder head fuel inlet manifold and the inlet restriction at the fuel pump. In a clean system, the maximum pump inlet restriction must not exceed 6 inches of mercury (20.3 kPa). With 6V and 8V non–turbocharged engines, at normal operating speed and with .080" restriction fittings, the fuel pressure is 45–70 psi (310–483 kPa). With 12V and 16V non–turbocharged engine at normal operating speeds and with .070" restriction fittings, the fuel pressure is 30–65 psi (207–448 kPa). With turbocharged engines, at normal operating speeds and with either .080" or .070" restriction fittings, the fuel pressure is 50–70 psi (345–483 kPa). Change the fuel filter elements whenever the inlet restriction at the fuel pump reaches 12 inches of mercury (41 kPa) at normal operating speeds and whenever the fuel pressure at the inlet manifold falls to the minimum fuel pressure shown above.



Item 13

Item 14 – Coolant Filter Water Pump

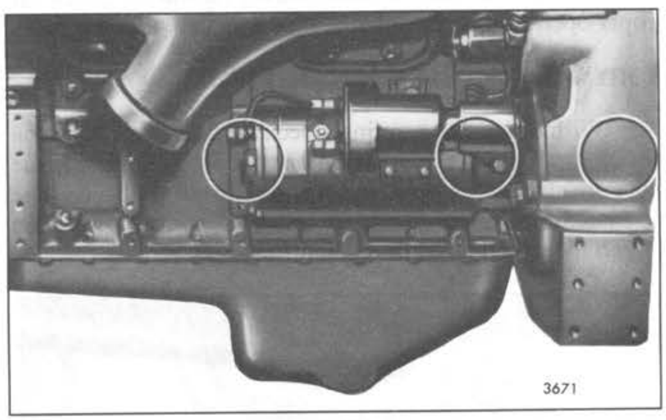
If the cooling system is protected by a coolant filter and conditioner, the filter element should be changed every 6 months or 10,000 miles (vehicle engines) and 500 hours or 15,000 miles (non–vehicle engines). Select the proper coolant filter element in accordance with the instructions given under *Coolant Specifications* in Section 13.3. Use a new filter cover gasket when installing the filter element. After replacing the filter and cover gasket, start the engine and check for leaks.

Inspect the water pump drain hole every 6 months for plugging. If plugged, clean out the drain hole with a tool made from a front crankshaft seal or equivalent.

Replace the water pump seal after it has been in service for 200,000 miles or 6,000 hours.

Item 15 – Starting Motor

VEHICLE ENGINES – Starting motors which are provided with lubrication fittings (grease cups, hinge cap oilers oil tubes sealed with pipe plugs) should be lubricated every 6 months or 10,000 miles. Add 8 to 10 drops of oil, of the same grade as used in the engine, to hinge cap oilers; if sealed tubes are provided, remove the pipe plugs, add oil and reseal the tubes. Grease cups should be turned down one turn. Refill the grease cups, if necessary. However, some starting motors do not require lubrication except during overhaul.



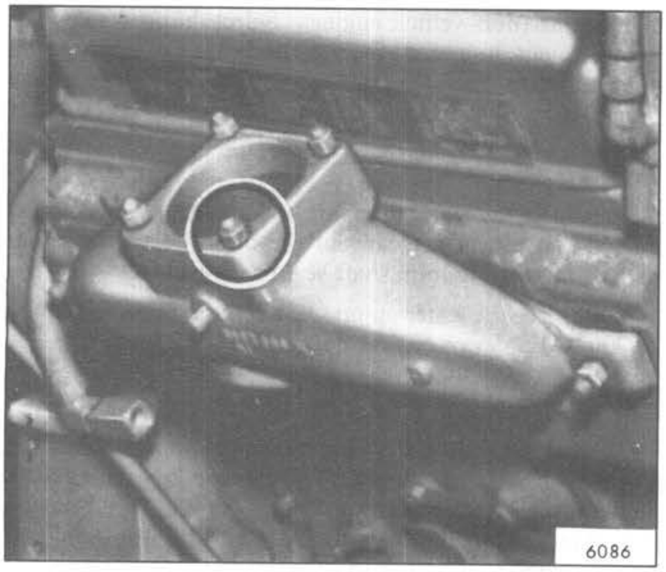
Item 15

NON–VEHICLE ENGINES – The electrical starting motor is lubricated at the time of original assembly. Oil can be added to the oil wicks, which project through each bushing and contact the armature shaft, by removing the pipe plugs on the outside of the motor. The wicks should be lubricated whenever the starting motor is taken off the engine or disassembled.

The Sprag overrunning clutch drive mechanism should be lubricated with a few drops of light engine oil whenever the starting motor is overhauled.

Item 16 – Air System

Check all of the connections in the air system to be sure they are tight. Check all hoses for punctures or other damage and replace, if necessary.



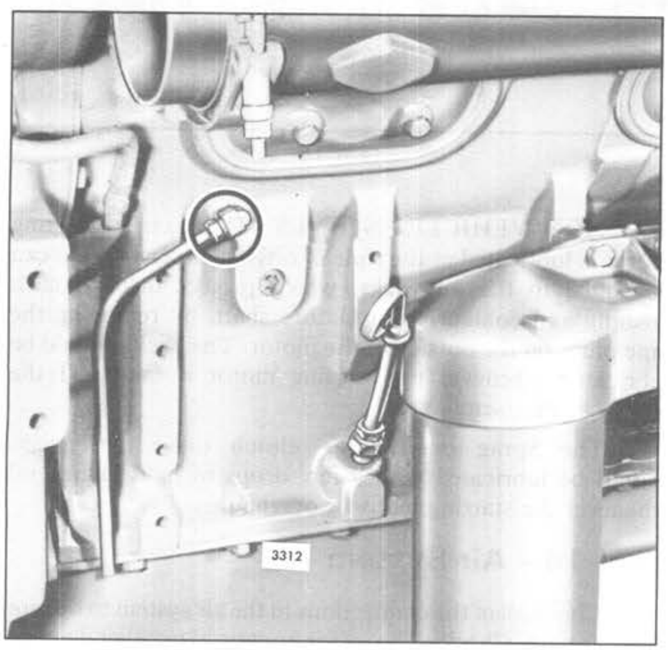
Item 17

Item 17 – Exhaust System

Check the exhaust manifold retaining nuts, exhaust flange clamp and other connections for tightness. Check for proper operation of the exhaust pipe rain cap, if one is used.

Item 18 – Air Box Drain Tube

With the engine running, check for flow of air from the air box drain tubes every 1,000 hours or 30,000 miles. If the tubes are clogged, remove, clean and reinstall the tubes. The air box drain tubes should be cleaned periodically even though a clogged condition is not apparent.

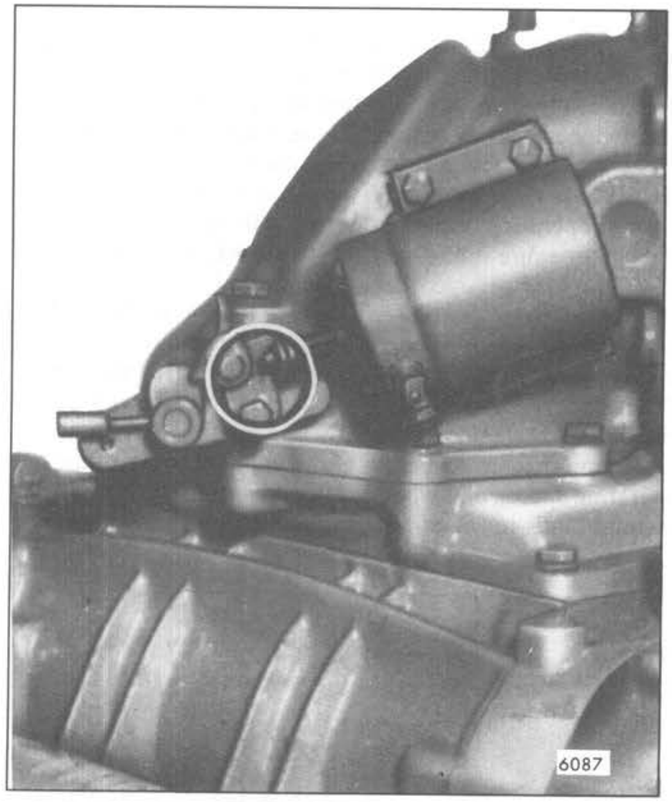


Item 18

If the engine is equipped with an air box drain tank, drain the sediment periodically.

Item 19 – Emergency Shutdown

With the engine running at idle speed, check the operation of the emergency shutdown every 700 hours or 20,000 miles. Reset the air shutdown valve in the *open* position after the check has been made.



Item 19

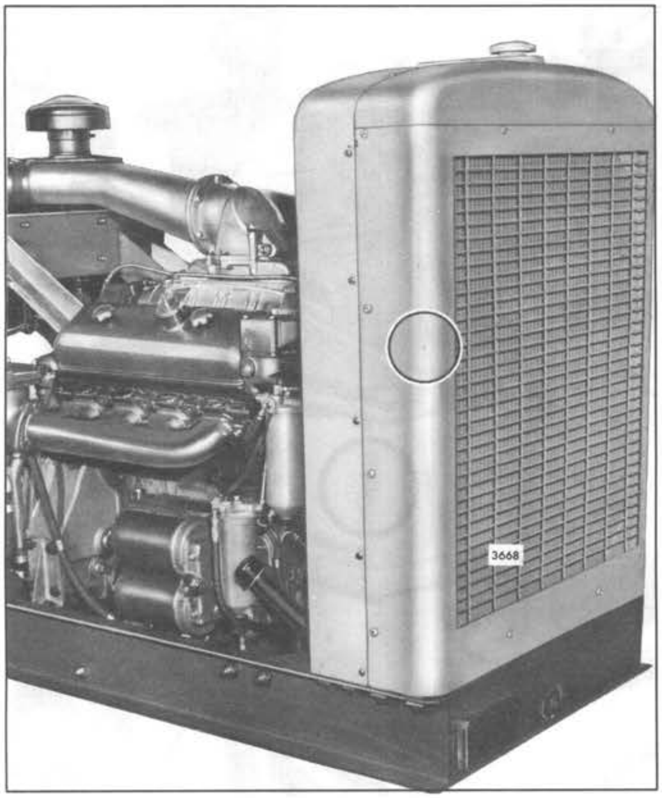
Item 20 – Engine (Steam Clean)

Steam clean the engine and engine compartment.

NOTICE: Do not apply steam or solvent directly on the battery–charging alternator, starting motor or electrical components as damage to electrical equipment may result.

Item 21 – Radiator

Inspect the exterior of the radiator core every 12 months or 20,000 miles (700 hours) and, if necessary, clean it with a quality grease solvent such as mineral spirits and dry it with compressed air. *Do not use fuel oil, kerosene or gasloine.* It may be necessary to clean the radiator more rrequently if the engine is being operated in extremely dusty or dirty areas.



Item 21

Item 22 – Shutter Operation

Check the operation of the shutters and clean the linkage and controls.

Item 23 – Oil Pressure

Under normal operation, oil pressure is noted each time the engine is started. In the event the engine is equipped with warning lights rather than pressure indicators, the pressure should be checked and recorded every 700 hours or 20,000 miles.

Item 24 – Governor

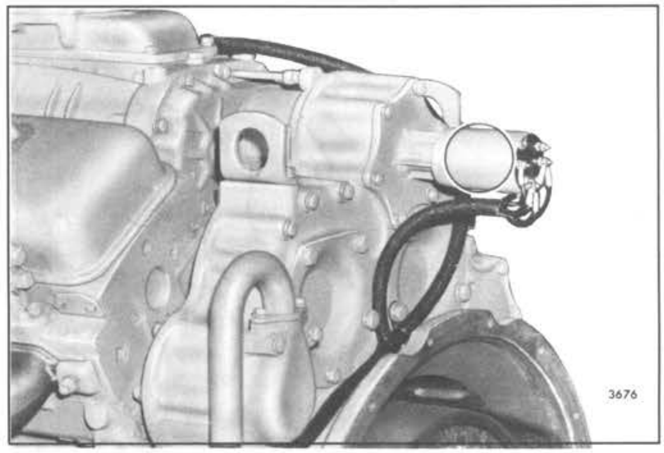
Check and record the engine idle speed and no–load speed. Adjust as necessary.

An idle speed lower than recommended will cause the engine to be accelerated from a speed lower than the speed at which the engine was certified.

A no–load speed higher than recommended will result in a full–load speed higher than rated and higher than the speed at which the engine was certified.

Overspeed Governor

Lubricate the overspeed governor, if it is equipped with a hinge–type cap oiler or oil cup, with 5 or 6 drops of engine oil every 500 hours or 15,000 miles. Avoid excessive lubrication and do not lubricate the governor while the engine is running.



Item 24

Item 25 – Fuel Injectors And Valve Clearance

Check the injector timing and exhaust valve clearance as outlined in Section 14.2 and 14.1 every 50,000 miles. The proper height adjustment between the injector follower and injector body is of primary importance to emission control.

Item 26 – Throttle Delay Fuel Modulator

Inspect and adjust, if necessary, every 30 months or 50,000 miles.

The **Throttle Delay** system limits the amount of fuel injected during acceleration by limiting the rate of injector rack movement with a hydraulic cylinder. The initial location of this cylinder must be set with the proper gage to achieve the appropriate time delay (Section 14.14).

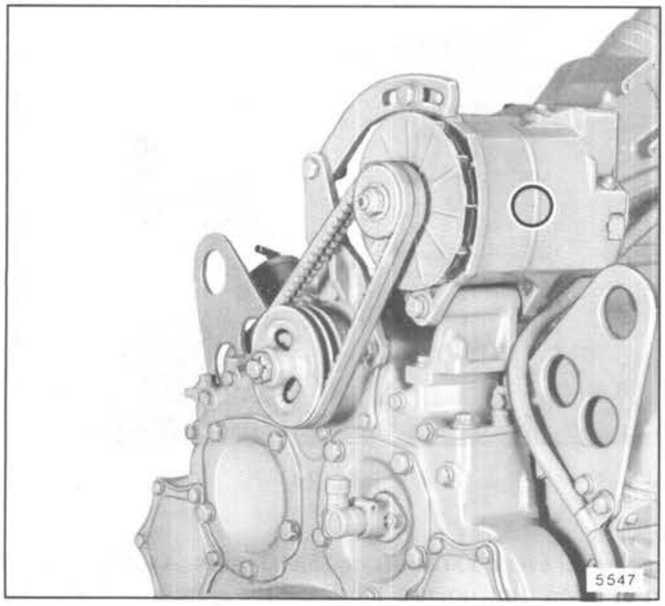
Inspect the check valve by filling the throttle delay cylinder with diesel fuel and watching for valve leakage while moving the throttle from the idle to the *full–fuel* position.

On the **Fuel Modulator**, inspect the roller and piston outer diameter and the cylinder bore inner diameter for wear and free operation. Also, inspect the operating surface of the lower roller, the roller pins at the cam pivot and the cam attachment to the piston. Replace parts, as required.

The fuel modulator must be set with the proper gage to achieve the correct fuel–to–air ratio (Section 14.14).

Item 27 – Battery–Charging Alternator

Battery–charging alternators are lubricated at time of manufacture and do not require further lubrication. Check terminals for corrosion and loose connections. Check for damaged or frayed insulation. Repair or replace wiring as required.



Item 27

Item 28 – Engine And Transmission Mounts

Check the engine and transmission mounting bolts and the condition of the mounting pads every 2,000 hours or 60,000 miles. Tighten and repair as necessary.

Item 29 – Crankcase Pressure

Check and record the crankcase pressure every 2,000 hours or 60,000 miles (refer to Section 15.2).

Item 30 – Air Box Check Valves

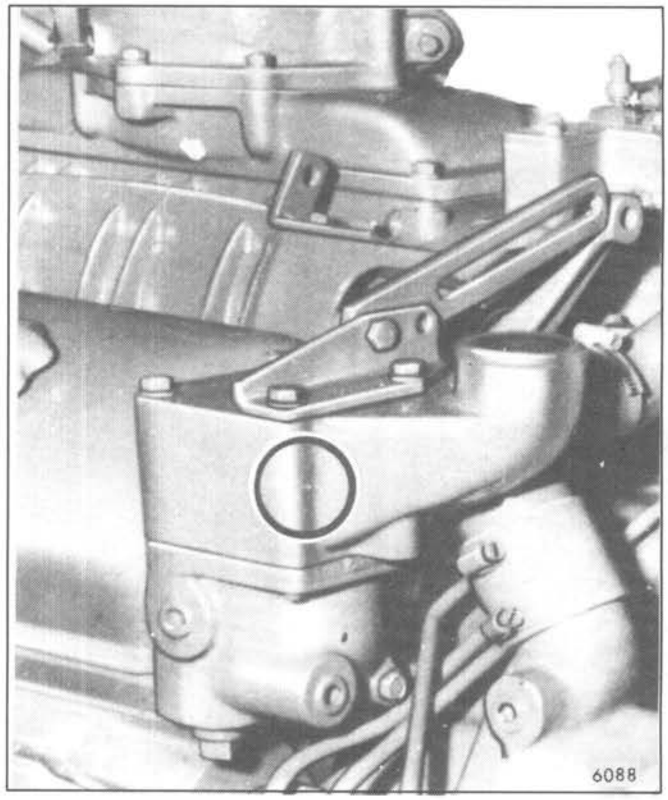
Every 100,000 miles or approximately 3,000 hours remove the air box check valves, clean them in solvent and blow out the lines with compressed air. Inspect for leaks after servicing.

Item 31 – Fan Hub

If the fan bearing hub assembly is provided with a grease fitting, use a hand grease gun and lubricate the bearings with one shot of Texaco Premium RB grease, or an equivalent Lithium base multi–purpose grease, every 20,000 miles (approximately 700 hours).

Every 2,500 hours or 75,000 miles (vehicle engines) or 4,000 hours (non–vehicle engines) clean, inspect and repack the fan bearing hub assembly with the above recommended grease (refer to Section 5.4).

At a major engine overhaul, remove and discard the bearings in the fan hub assembly. Pack the hub assembly, using new bearings, with Texaco Premium RB grease or an equivalent Lithium base multi–purpose grease.



Item 32

Item 32 – Thermostats And Seals

Check the thermostats (see Section 5.2.1) and seals at 5,000 hours (non–highway engines), 200,000 miles (highway engines) or once a year (preferably at the time the cooling system is prepared for winter operation). The thermostats and seals should *always* be replaced at overhaul.

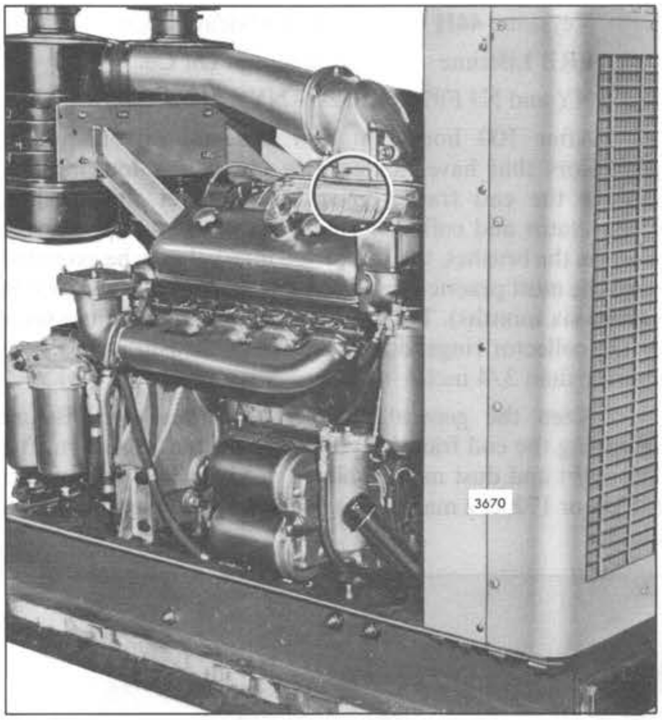
Item 33 – Blower Screen

Inspect the blower screen and gasket assembly annually (vehicle engines) or every 1,000 hours or 30,000 miles (non–vehicle engines) and, if necessary, clean the screen in fuel oil and dry it with compressed air. Install the screen and gasket assembly with the screen side of the assembly toward the blower. Inspect for evidence of blower seal leakage.

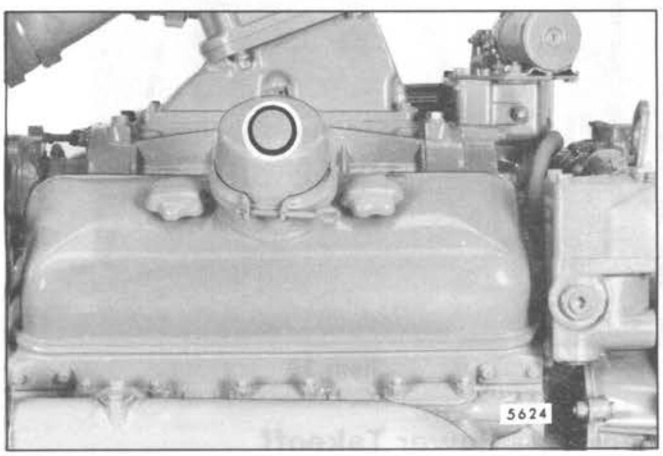
Item 34 – Crankcase Breather

Remove the externally mounted crankcase breather assembly annually (vehicle engines) or every 1,000 hours or 30,000 miles (non–vehicle engines) and wash the steel mesh pad in clean fuel oil. This cleaning period may be reduced or lengthened according to severity of service.

Clean the breather cap, mounted on the valve rocker cover, in clean fuel oil every time the engine oil is changed.



Item 33



Item 34

Item 35 – Fan (Thermo–Modulated)

DRIVE FLUID LEVEL – Check the fan drive fluid level to avoid improper operation and damage to the drive components.

Current modulated fan drive housings have an inspection plug for checking the fluid level. Formerly partial disassembly of the drive was necessary to make the fluid level check. Former units can be updated by installing a current drive housing which includes the fluid inspection plug and a grease fitting for lubricating the bearing.

1. Check the fan drive fluid level after the unit has been idle for at least 1/2 hour.
2. Turn the fan drive so that the inspection plug is 3/4" below the horizontal center line, then allow the silicone fluid to drain down an additional five (5) minutes.
3. Remove the inspection plug. If fluid begins to flow from the inspection hole, the drive has sufficient fluid. Replace the inspection plug.
4. If the fluid does not flow from the hole, proceed as follows:
   a. Rotate the fan drive downward and observe when the fluid begins to flow from the hole. If it is necessary to lower the drain hole more than 2" below the horizontal center line, the fan drive should be removed from the engine, disassembled and inspected for possible damage to the components.
   b. Turn the fan drive back so the inspection hole is 3/4" below the horizontal center line and add fluid until the overflow point is reached. Replace the inspection plug.

Use only the manufacturer's Special 20 Cenistroke fluid.

DRIVE BEARING LUBRICATION – The fan drive bearing should be lubricated as outlined in the chart with a Medium Consistency Silicone Grease (Dow Corning No. 44, or equivalent).

The bearing on current fan assemblies is lubricated through a grease fitting in the drive housing hub. Lubrication of the bearing in former assemblies requires the removal of the fan assembly and partial disassembly. The former assemblies can be updated to include a grease fitting by installing the current housing.

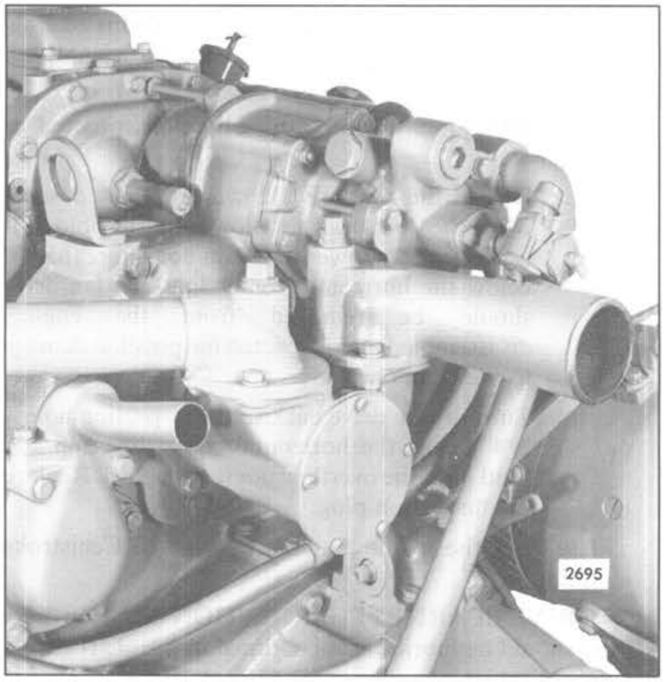
Item 36 – Engine Tune–Up

There is no scheduled interval for performing an engine tune–up. As long as the engine performance is satisfactory, no tune–up should be needed. Minor adjustments in the valve and injector operating mechanisms, governor, etc. should only be required periodically to compensate for normal wear on parts.

Item 37 – Heat Exchanger Electrodes And Core

Every 500 hours or annually, drain the water from the heat exchanger raw water inlet and outlet tubes. Then, remove the zinc electrodes from the inlet side of the raw water pump and the heat exchanger. Clean the electrodes with a wire brush or, if worn excessively, replace with new electrodes. To determine the condition of a used electrode, strike it sharply against a hard surface; a weakened electrode will break.

Drain the cooling system, disconnect the raw water pipes at the outlet side of the heat exchanger and remove the retaining cover every 1,000 hours or 30,000 miles and inspect the heat exchanger core. If a considerable amount of scale or deposits are present, contact a *Detroit Diesel Service Outlet*.



Item 37 and 38

Item 38 – Raw Water Pump

Check the prime on the raw water pump daily. The engine should not be operated with a dry pump. Prime the pump, if necessary, by removing the pipe plug provided in the pump inlet elbow and adding water. Reinstall the plug.

Item 39 – Power Generator

The power generator requires lubrication at only one point — the ball bearing in the end frame.

If the bearing is oil lubricated, check the oil level in the sight gage every 300 hours; change the oil every six months. Use the same grade and viscosity *heavy–duty* oil as specified for the engine. Maintain the oil level to the line on the sight gage. *Do not overfill.* After adding oil, recheck the oil level after running the generator for several minutes.

If the bearing is grease lubricated, a new generator has sufficient grease for three years of normal service. Thereafter, it should be lubricated at one year intervals. To lubricate the bearing, remove the filler and relief plugs on the side and the bottom of the bearing reservoir. Add grease until new grease appears at the relief plug opening. Run the generator a few minutes to vent the excess grease; then reinstall the plugs.

The following greases, or their equivalents, are recommended:

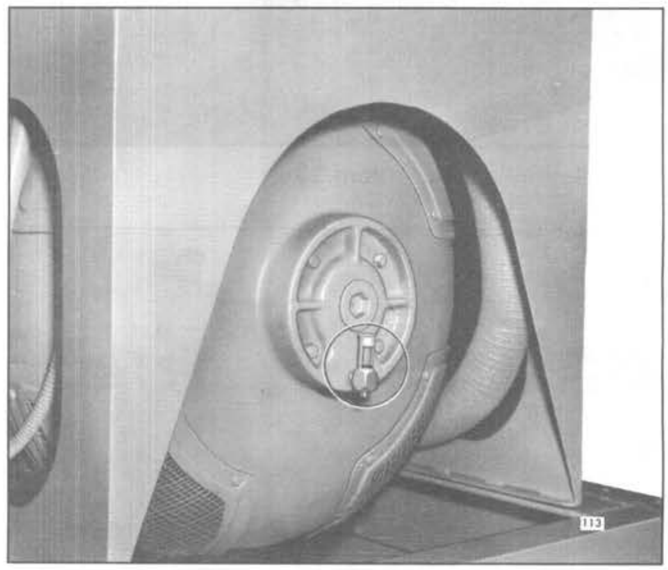
Keystone 44H – Keystone Lubrication Co.

BRB Lifetime – Socony Vacuum Oil Co.

NY and NJ F926 or F927 – NY and NJ Lubricant Co.

After 100 hours on new brushes, or brushes in generators that have not been in use over a long period, remove the end frame covers and inspect the brushes, commutator and collector rings. If there is no appreciable wear on the brushes, the inspection interval may be extended until the most practicable period has been established (not to exceed six months). To prevent damage to the commutator or the collector rings, do not permit the brushes to become shorter than 3/4 inch.

Keep the generator clean inside and out. Before removing the end frame covers, wipe off the loose dirt. The loose dirt and dust may be blown out with low pressure air (25 psi or 172 kPa maximum). Remove all greasy dirt with a cloth.



Item 39

Item 40 – Power Takeoff

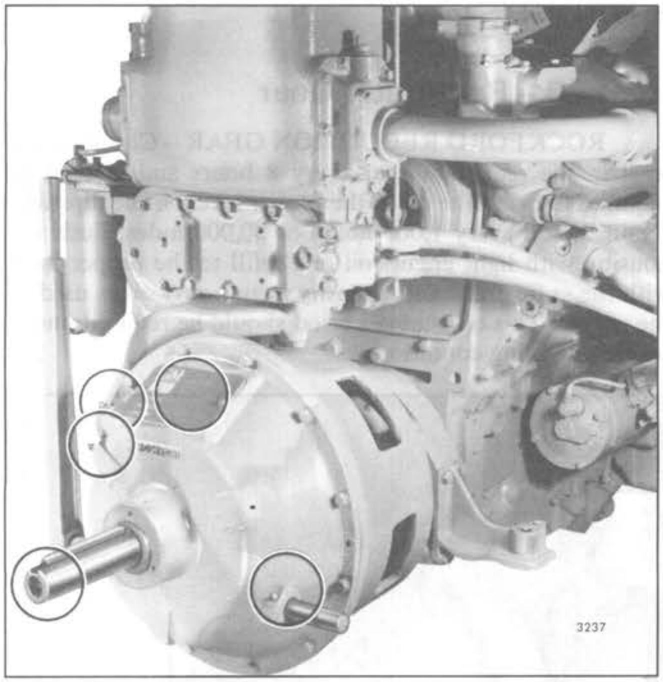
Lubricate all of the power takeoff bearings with an all purpose grease such as Shell Alvania No. 2, or equivalent. Lubricate sparingly to avoid getting grease on the clutch facings.

Lubricate the clutch release bearing and the disconnect mechanical rear drive shaft shielded bearing every 8 hours or 240 miles. The clutch release bearing in the 18" diameter clutch is pre–lubricated and is not provided with a grease fitting, since no further lubrication is required.

Lubricate the power takeoff main bearing, also the outboard bearing if the unit is so equipped, every 50 hours or 1,500 miles. Frequency of lubrication will depend on the working conditions of the bearing, shaft speeds and bearing loads. If may be necessary to lubricate this bearing more often than every 50 hours or 1,500 miles. Lubricate the front power takeoff clutch pilot ball bearing through the fitting in the outer end of the drive shaft every 50 hours or 1,500 miles. One or two strokes with a grease gun should be sufficient.

Remove the inspection hole cover and lubricate the clutch release levers and link pins sparingly every 500 hours or 15,000 miles. Lubricate the clutch release shaft through the grease fittings on the front of the housing every 500 hours or 15,000 miles.

Check the clutch facing for wear every 500 hours or 15,000 miles. Adjust the clutch, if necessary.

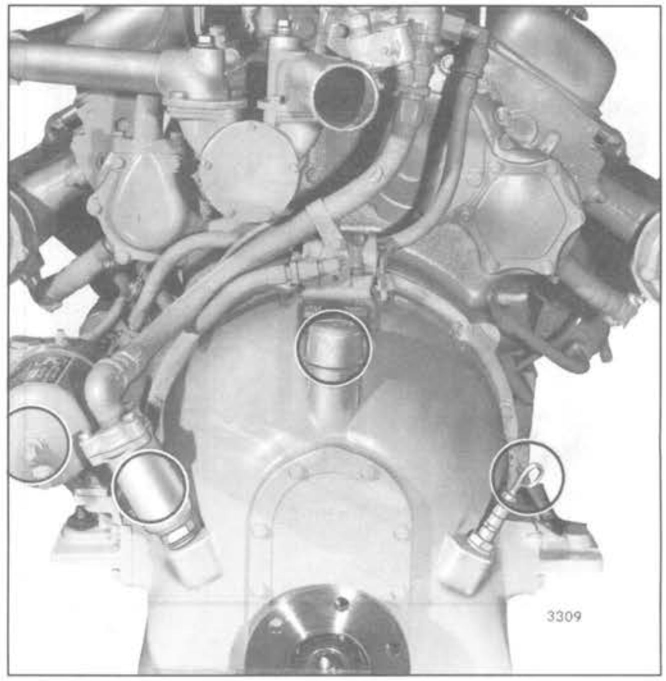


Item 40

Item 41 – Marine Gear

TORQMATIC MARINE GEAR (6V and 8V) – Check the oil level daily in the marine gear, with the controls in neutral and the engine running at idle speed. Add oil as required to bring it to the proper level on the dipstick. Use the same grade and viscosity *heavy–duty* oil as used in the engine. Series 3 oil should not be used in the marine gear. Drain the oil every 200 hours or 6,000 miles and flush the gear with light engine oil.

When refilling after an oil drain, bring the oil up to the proper level on the dipstick – approximately 6 quarts (5.7 liters) in the M type and 8 quarts (7.6 liters) in the MH type gear. Start and run the engine at light load for three (3) to five (5) minutes. Then, put the controls in neutral and run the engine at idle speed and check the oil level again. Bring the oil level up to the proper level on the dipstick.



Item 41

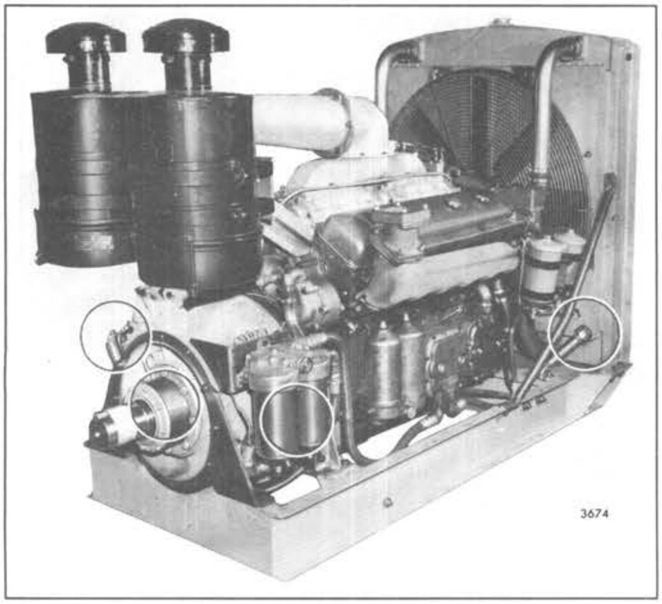
Every time the marine gear oil is changed, remove the oil strainer element, rinse it thoroughly in fuel oil, dry it with compressed air and reinstall it. Also, replace the full–flow oil filter element every time the marine gear oil is changed.

TWIN DISC MARINE GEAR (16V) – Check the oil level daily. Check the oil level with the engine running at low idle speed and the gear in neutral. Keep the oil up to the proper level on the dipstick. Use oil of the same *heavy–duty* grade and viscosity that is used in the engine.

Change the oil and the oil filter element every 1,000 hours or 30,000 miles. After draining the oil, thoroughly clean the removable oil screen and breather. Reinstall the breather and refill the marine gear with oil up to the full mark on the dipstick. Start the engine and, with the gear in neutral, run the engine at idle speed for three (3) to five (5) minutes. Then, stop the engine and check the oil level. If necessary, add oil to bring it up to the full mark on the dipstick.

Item 42 – Torqmatic Converter

Check the oil level in the Torqmatic converter and supply tank daily. The oil level must be checked while the converter is operating, the engine idling and the oil is up to operating temperature (approximately 200°F or 93°C). If the converter is equipped with an input disconnect clutch, the clutch must be engaged.



Item 42

Check the oil level after running the unit a few minutes. The oil level should be maintained at the proper level on the dipstick. If required, add hydraulic transmission fluid type "C–2" (see Chart). *Do not overfill* the converter as too much oil will cause foaming and high oil temperature.

Prevailing Ambient Temperature	Recommended Oil Specification
Above −10°F (−23°C)	Hydraulic Transmission Fluid, Type C-2.
Below −10°F (−23°C)	Hydraulic Transmission Fluid, Type C-2. Auxiliary preheat required to raise temperature in the sump to a temperature above −10°F. (−23°C)

OIL RECOMMENDATIONS

The oil should be changed every 1,000 hours or 30,000 miles for Series 400 through 900 converters. Also, the oil should be changed whenever it shows traces of dirt or effects of high operating temperature as evidenced by discoloration or strong odor. If the oil shows metal contamination, contact an authorized *Detroit Diesel Service Outlet* as this usually requires disassembly. Under severe operating conditions, the oil should be changed more often.

The converter oil breather, located on the oil level indicator (dipstick), should be cleaned each time the converter oil is changed. This can be accomplished by allowing the breather to soak in a solvent, then drying it with compressed air.

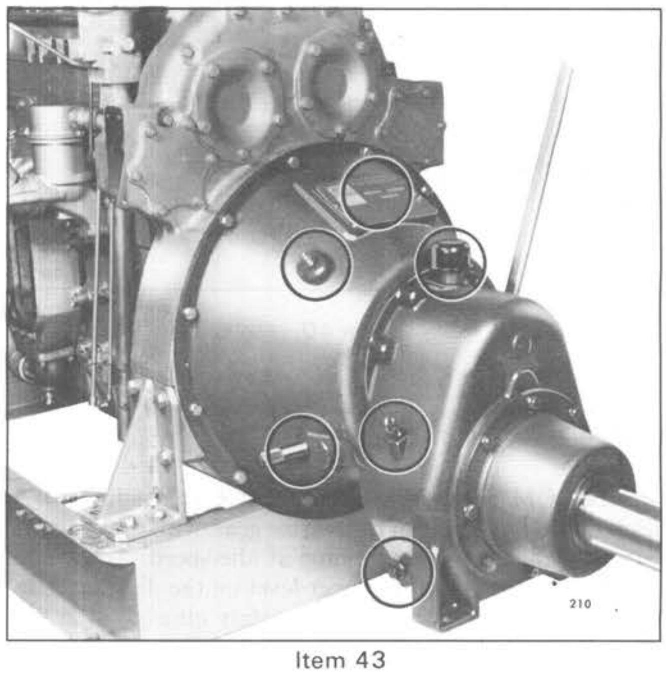
The full–flow oil filter element should be removed, the shell cleaned and a new element and gasket installed each time the converter oil is changed.

Lubricate the input clutch release bearing and ball bearing and the front disconnect clutch drive shaft bearing every 50 hours or 1,500 miles with an all purpose grease. Grease fittings are provided on the clutch housing. This time interval may vary depending upon the operating conditions. Over lubrication will cause grease to be thrown on the clutch facing, causing the clutch to slip.

The strainer (in the Torqmatic transmission) and the hydraulic system filters should be replaced or cleaned with every oil change.

Item 43 – Reduction Gear

ROCKFORD REDUCTION GEAR – Check the oil level in the reduction gear every 8 hours and add oil as required to bring the oil to the proper level on the dipstick. Drain the oil every 1,000 hours or 30,000 miles, flush the housing with light engine oil and refill to the proper level with the same grade and viscosity *heavy–duty* oil as used in the engine. This oil change period should be reduced under severe operating conditions.



Item 43

Lubricate the clutch release bearing through the grease fitting on the side of the housing every 8 hours or 240 miles of operation. The clutch release bearing in the 18" diameter clutch is pre–lubricated and is not provided with a grease fitting, since no further lubrication is required. Lubricate the front reduction clutch pilot ball bearing through the fitting in the outer end of the drive shaft every 50 hours or 1,500 miles. One or two strokes with a grease gun should be sufficient.

Remove the inspection hole cover and oil the clutch release levers and link pins sparingly every 500 hours or 15,000 miles. Lubricate the clutch release shaft through the grease fittings on the front of the housing every 500 hours or 15,000 miles.

Item 44 – Blower Bypass Valve

Every 100,000 miles or approximately 3,000 hours, remove the bypass blower valve and clean it in solvent, if necessary. Inspect for free operation of the valve and any scoring of the piston, piston guide or sleeve assembly. Repair or replace, as required.

TROUBLESHOOTING

Certain abnormal conditions which sometimes interfere with satisfactory engine operation, together with methods of determining the cause of such conditions, are covered on the following pages.

Satisfactory engine operation depends primarily on:

1. An adequate supply of air compressed to a sufficiently high compression pressure.
2. The injection of the proper amount of fuel at the right time.

Lack of power, uneven running, excessive vibration, stalling at idle speed and hard starting may be caused by either low compression, faulty injection in one or more cylinders, or lack of sufficient air.

Since proper compression, fuel injection and the proper amount of air are important to good engine performance, detailed procedures for their investigation are given as follows:

Locating A Misfiring Cylinder

1. Start the engine and run it at part load until it reaches normal operating temperature.
2. Stop the engine and remove the valve rocker covers.
3. Check the valve clearance (Section 14.1).
4. Start the engine. Then, hold an injector follower down with a screwdriver to prevent operation of the injector. If the cylinder has been misfiring, there will be no noticeable difference in the sound and operation of the engine. If the cylinder has been firing properly, there will be a noticeable difference in the sound and operation when the injector follower is held down. This is similar to short–circuiting a spark plug in a gasoline engine.
5. If the cylinder is firing properly, repeat the procedure on the other cylinders until the faulty one has been located.
6. If the cylinder is misfiring, check the following:
   a. Check the injector timing (refer to Section 14.2).
   b. Check the compression pressure.
   c. Install a new injector.
   d. If the cylinder still misfires, remove the cam follower (refer to Section 1.2.1) and check for a worn cam roller, camshaft lobe, bent push rod or worn rocker arm bushings.

Checking Compression Pressure

Compression pressure is affected by altitude as shown in Table 1.

Mininum Compression Pressure at 600 rpm				Altitude above Sea Level		+ Air Density
Turbocharged Engines		Non-Turbocharged Engines				
psi	kPa	psi	kPa	feet	meters	
450	3101	500	3445	500	152	.0715
415	2859	465	3204	2,500	762	.0663
385	2653	430	2963	5,000	1,524	.0613
355	2446	395	2722	7,500	2,286	.0567
330	2274	365	2515	10,000	3,048	.0525

+ Air density at 500 feet altitude based on 85° F (29.4° C) and 29.38 in. Hg (99.49 kPa) wet barometer.

TABLE 1

Check the compression pressure as follows:

1. Start the engine and run it at approximately one–half rated load until normal operating temperature is reached.
2. Stop the engine and remove the fuel pipes from the injector and fuel connectors of the No. 1 cylinder.
3. Remove the injector and install an adaptor and pressure gage (Fig. 1) from Diagnosis Kit J 9531–01.

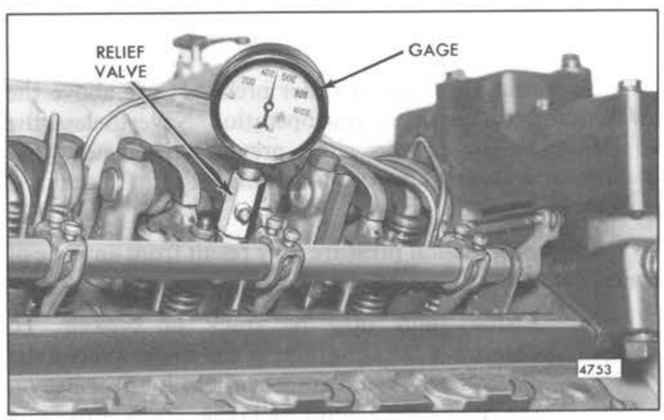


Fig. 1 – Checking Compression Pressure

4. Use a spare fuel pipe to fabricate a jumper connection between the fuel inlet and return manifold connectors. This will permit fuel from the inlet manifold to flow directly to the return manifold.
5. Start the engine and run it at a 600 rpm. Observe and record the compression pressure indicated on the gage. *Do not crank the engine with the starting motor to obtain the compression pressure.*

6. Perform Steps 2 through 5 on each cylinder. The compression pressure in any one cylinder at a given altitude above sea level should not be less than the minimum shown in Table 1. In addition, the variation in compression pressures between cylinders must not exceed 25 psi (172 kPa) at 600 rpm.

   EXAMPLES: – If the compression pressure readings were as shown in Table 2, it would be evident that No. 2L cylinder should be examined and the cause of the low compression pressure be determined and corrected.

The pressures in Table 2 are for a turbocharged engine operating at an altitude near sea level.

Cylinder	Gage Reading	
	Psi	kPa
1L	470	3239
1R	465	3204
2L	430	2963
2R	460	3170
3L	465	3204
3R	460	3170

TABLE 2

Note that all of the cylinder pressures are above the low limit for satisfactory engine operation. Nevertheless, the No. 2L cylinder compression pressure indicates that something unusual has occurred and that a localized pressure leak has developed.

Low compression pressure may result from any one of several causes:

A. Piston rings may be stuck or broken. To determine the condition of the rings, remove the air box cover and inspect them by pressing on the rings with a blunt tool (Fig. 2). A broken or stuck ring will not have a "spring–like" action.

B. Compression pressure may be leaking past the cylinder head gasket, the valve seats, the injector tube or a hole in the piston.

Engine Out Of Fuel

The problem in restarting the engine after it has run out of fuel stems from the fact that after the fuel is exhausted from the fuel tank, fuel is then pumped from the primary fuel strainer and sometimes partially removed from the secondary fuel filter before the fuel supply becomes insufficient to sustain engine firing. Consequently, these components must be refilled with fuel and the fuel pipes rid of air in order for the system to provide adequate fuel for the injectors.

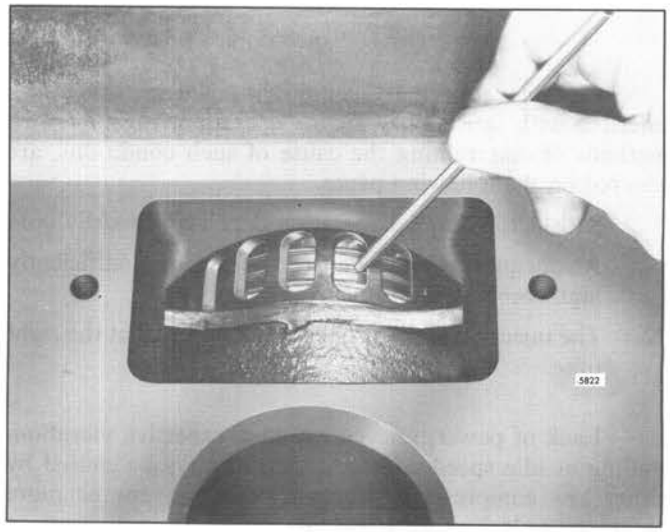


Fig. 2 – Inspecting Piston Rings

When an engine has run out of fuel, there is a definite procedure to follow for restarting it:

1. Fill the fuel tank with the recommended grade of fuel oil. If only partial filling of the tank is possible, add a minimum of ten (10) gallons (38 liters) of fuel.
2. Remove the fuel strainer shell and element from the strainer cover and fill the shell with fuel oil. Install the shell and element.
3. Remove and fill the fuel filter shell and element with fuel oil as in Step 2.
4. Start the engine. Check the filter and strainer for leaks.

   NOTICE: In some instances, it may be necessary to remove a valve rocker cover and loosen a fuel pipe nut to bleed trapped air from the fuel system. Be sure the fuel pipe is retightened securely before replacing the rocker cover. Use a new gasket when reinstalling a valve rocker cover.

Primer J 5956 may be used to prime the entire fuel system. Remove the filler plug in the fuel filter cover and install the primer. Prime the system. Remove the primer and install the filler plug.

Fuel Flow Test

The proper flow of fuel is required for satisfactory engine operation. Check the condition of the fuel pump, fuel strainer and fuel filter, as outlined in *Troubleshooting* (Section 2.0).

Crankcase Pressure

The crankcase pressure indicates the amount of air passing between the oil control rings and the cylinder liners into the crankcase, most of which is clean air from the air box. A slight pressure in the crankcase is desirable to prevent the entrance of dust. A loss of engine lubricating oil through the breather tube, crankcase ventilator or dipstick hole in the cylinder block is indicative of excessive crankcase pressure.

The causes of high crankcase pressure may be traced to excessive blow–by due to worn piston rings, a hole or crack in a piston crown, loose piston pin retainers, worn blower oil seals, defective blower, cylinder gaskets or excessive exhaust back pressure. Also, the breather tube or crankcase ventilator should be checked for obstructions.

The crankcase pressure may be checked with a manometer. The manometer should be connected to the oil level dipstick opening in the cylinder block.

Check the readings obtained at various engine speeds with the *Engine Operating Conditions* (Section 13.2). The dipstick adaptor must not be below the level of the oil when checking the crankcase pressure.

Exhaust Back Pressure

A slight pressure in the exhaust system is normal. However, excessive exhaust back pressure seriously affects engine operation. It may cause an increase in the air box pressure with a resultant loss of efficiency of the blower. This means less air for scavenging which results in poor combustion and higher temperatures.

Causes of high exhaust back pressure are usually a result of an inadequate or improper type of muffler, an exhaust pipe which is too long or too small in diameter, an excessive number of sharp bends in the exhaust system, or obstructions such as excessive carbon formation or foreign matter in the exhaust system.

The exhaust back pressure, measured in inches of mercury, may be checked with a manometer in the engine diagnosis test kit J 9531–01. Connect the manometer to an exhaust manifold (except on turbocharged engines) by removing the 1/8" pipe plug which is provided for that purpose. If there is no opening provided, drill an 11/32" hole in the exhaust manifold companion flange and tap the hole to accommodate a 1/8" pipe plug.

On turbocharged engines, check the exhaust back pressure in the exhaust piping 6" to 12" from the rear face of the turbine. The tapped hole must be in a comparatively straight pipe area for an accurate measurement.

Check the readings obtained at various speeds with the *Engine Operating Conditions* (Section 13.2).

Air Box Pressure

Proper air box pressure is required to maintain sufficient air for combustion and scavenging of the burned gases. Low air box pressure is caused by a high air inlet restriction, damaged blower rotors, an air leak from the air box (such as leaking end plate gaskets) or a clogged blower air inlet screen or a stuck *open* blower bypass valve.

High air box pressure can be caused by partially plugged cylinder liner ports or a stock *closed* blower bypass valve.

Lack of power or black or grey exhaust smoke are indications of low air box pressure.

To check the air box pressure, connect a manometer to an air box drain tube.

Check the readings obtained at various speeds with the *Engine Operating Conditions* in Section 13.2.

Air Inlet Restriction

Excessive restriction of the air inlet will affect the flow of air to the cylinders and result in poor combustion and lack of power. Consequently, the restriction must be kept as low as possible considering the size and capacity of the air cleaner. An obstruction in the air inlet system or dirty or damaged air cleaners will result in a high blower inlet restriction.

Check the air inlet restriction with a water manometer connected to a fitting in the air intake ducting located 2" above the air inlet housing (non–turbocharged engines) or compressor inlet (turbocharged engines). When inserting a fitting at this point is impractical (non–turbocharged engines), the manometer may be connected to the engine air inlet housing. The restriction at this point should be checked at a specific engine speed. Then, the air cleaner and ducting should be removed from the air inlet housing and the engine again operated at the same speed while noting the manometer reading.

The difference between the two readings, with and without the air cleaner and ducting, is the actual restriction caused by the air cleaner and ducting.

Check the normal air inlet vacuum at various no load speeds and compare the results with the *Engine Operating Conditions* (Section 13.2).

PROPER USE OF MANOMETER

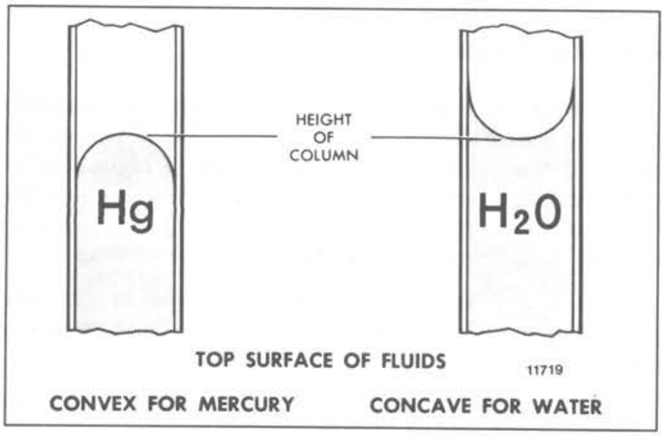


Fig. 3 – Comparison of Column Height for Mercury and Water Manometers

The U–tube manometer is a primary measuring device indicating pressure or vacuum by the difference in the height of two columns of fluid.

Connect the manometer to the source of pressure, vacuum or differential pressure. When the pressure is imposed, add the number of inches one column of fluid travels up to the amount the other column travels down to obtain the pressure (or vacuum) reading.

The height of a column of mercury is read differently than that of a column of water. Mercury does not wet the inside surface; therefore, the top of the column has a convex meniscus (shape). Water wets the surface and therefore has a concave meniscus. A mercury column is read by sighting horizontally between the top of the convex mercury surface (Fig. 3) and the scale. A water manometer is read by sighting horizontally between the bottom of the concave water surface and the scale.

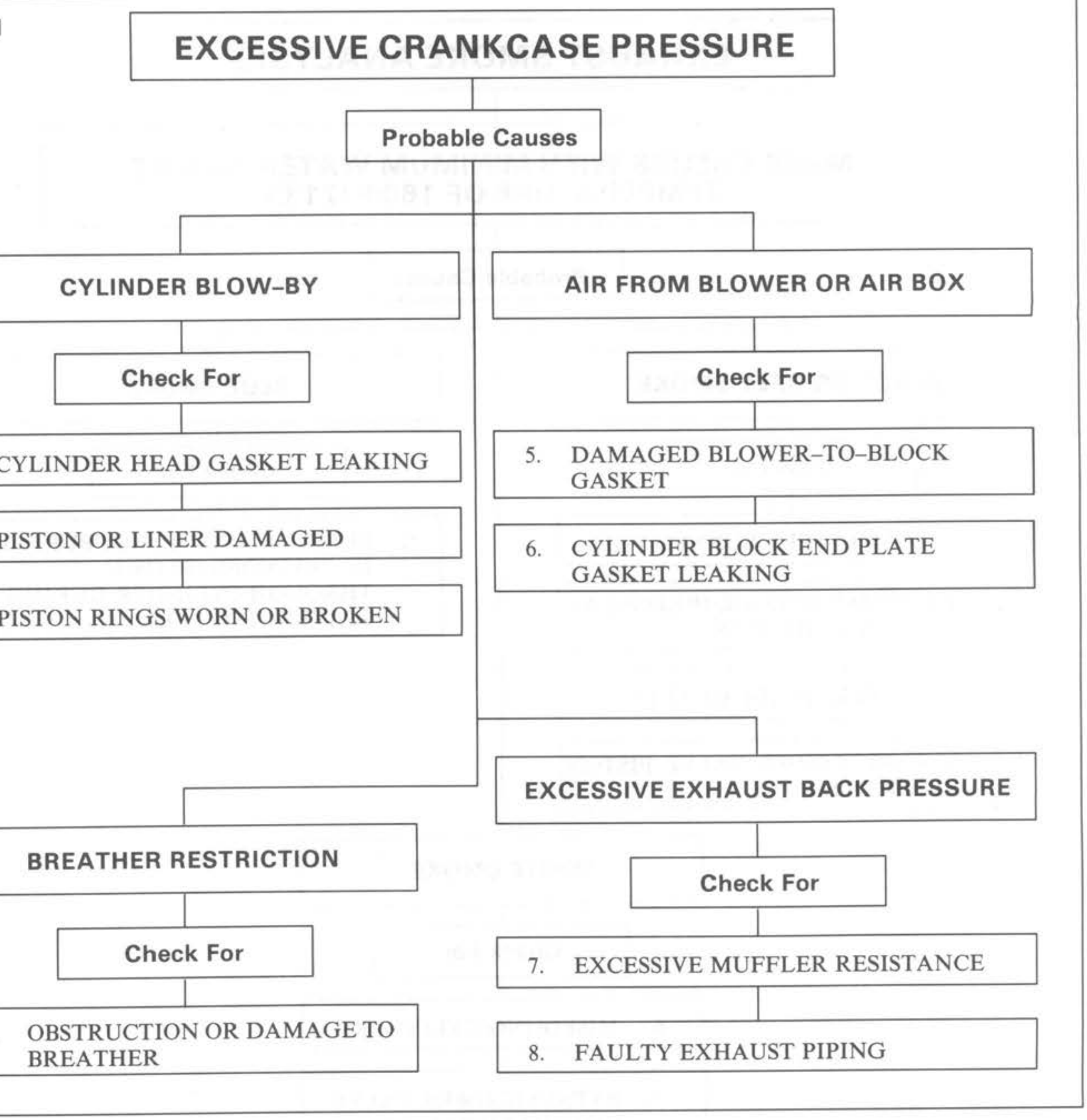
Should one column of fluid travel further than the other column, due to minor variations in the inside diameter of the tube or to the pressure imposed, the accuracy of the reading obtained is not impaired.

Refer to Table 3 to convert the manometer reading into other units of measurement.

PRESSURE CONVERSION CHART		
1" water	=	.0735" mercury
1" water	=	.0361 psi
1" mercury	=	13.6000" water
1" mercury	=	.4910 psi
1 psi	=	27.7000" water
1 psi	=	2.0360" mercury
1 psi	=	6.895 kPa
1 kPa	=	.145 psi

TABLE 3

Chart 1



SUGGESTED REMEDY

1. Check the compression pressure and, if only one cylinder has low compression, remove the cylinder head and replace the head gaskets.
2. Inspect the piston and liner and replace damaged parts.
3. Install new piston rings.
4. Clean and repair or replace the breather assembly.
5. Replace the blower–to–block gasket.
6. Replace the end plate gasket.
7. Check the exhaust back pressure and repair or replace the muffler if an obstruction is found.
8. Check the exhaust back pressure and install larger piping if it is determined that the piping is too small, too long or has too many bends.

Chart 2

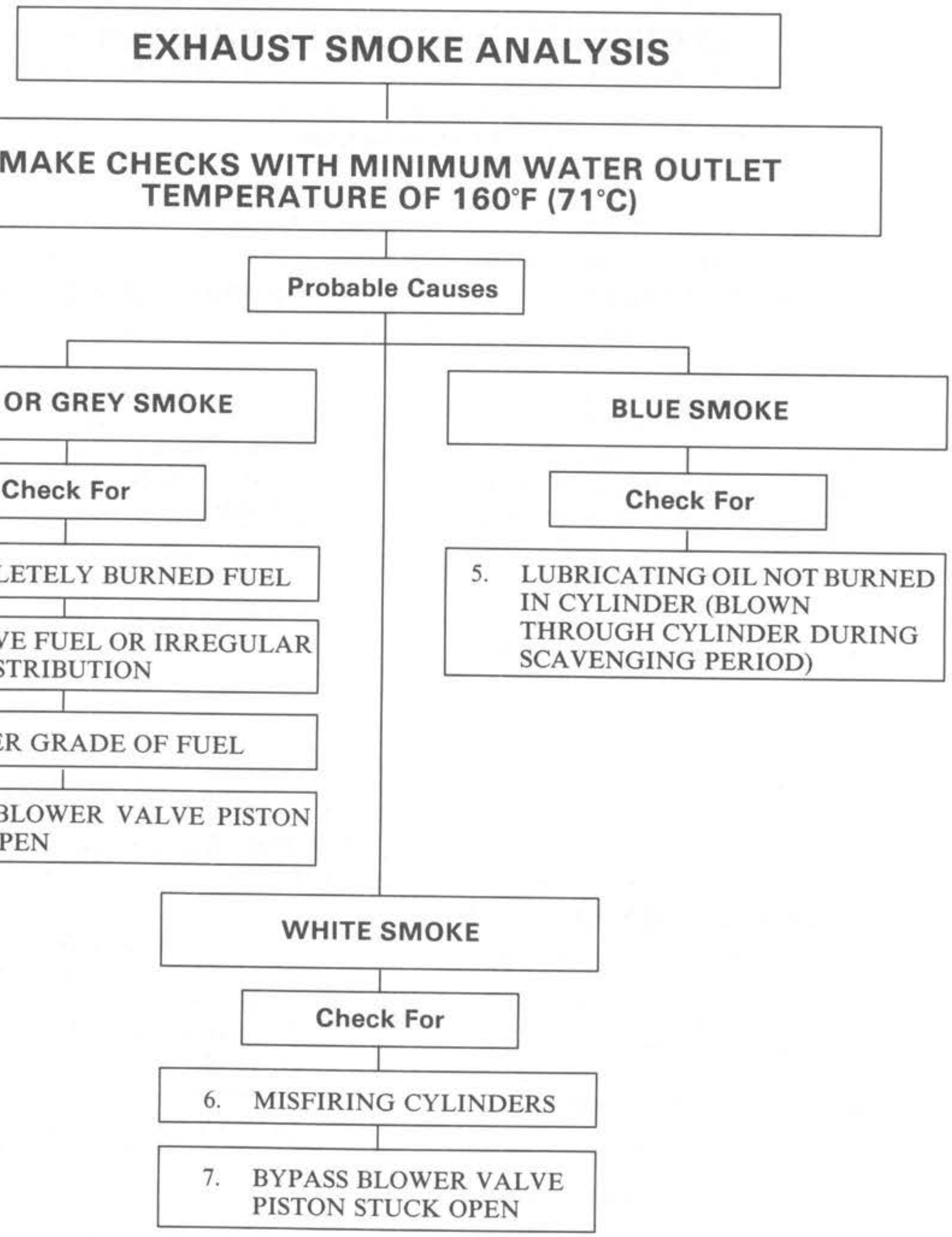

EXHAUST SMOKE ANALYSIS
MAKE CHECKS WITH MINIMUM WATER OUTLET TEMPERATURE OF 160°F (71°C)
Probable Causes
BLACK OR GREY SMOKE
Check For
1. INCOMPLETELY BURNED FUEL
2. EXCESSIVE FUEL OR IRREGULAR FUEL DISTRIBUTION
3. IMPROPER GRADE OF FUEL
4. BYPASS BLOWER VALVE PISTON STUCK OPEN
BLUE SMOKE
Check For
5. LUBRICATING OIL NOT BURNED IN CYLINDER (BLOWN THROUGH CYLINDER DURING SCAVENGING PERIOD)
WHITE SMOKE
Check For
6. MISFIRING CYLINDERS
7. BYPASS BLOWER VALVE PISTON STUCK OPEN

Chart 2

EXHAUST SMOKE ANALYSIS

SUGGESTED REMEDY

1. High exhaust back pressure or a restricted air inlet causes insufficient air for combustion and will result in incompletely burned fuel.

High exhaust back pressure is caused by faulty exhaust piping or muffler obstruction and is measured at the exhaust manifold outlet with a manometer. Replace faulty parts.

Restricted air inlet to the engine cylinders is caused by clogged cylinder liner ports, air cleaner or blower air inlet screen. Clean these items. Check the emergency stop to make sure that it is completely open and readjust it if necessary.

2. If the engine is equipped with a throttle delay, check for the proper setting, leaky check valve and restricted filling of the piston cavity with oil from the reservoir.

If the engine is equipped with a fuel modulator, check the cam to determine if it is stuck in the *full fuel* position. Verify tightness of the roller lever clamp on the control tube. Determine correctness (refer to Section 14.14) of the installed fuel modulator piston spring and check if the spring has taken a permanent "set" or if the spring rate is too low.

The above affects only excessive acceleration smoke, but does not affect smoke at constant speed.

Check for improperly timed injectors and improperly positioned injector rack control levers. Time the fuel injectors and perform the appropriate governor tune–up.

Replace faulty injectors if this condition still persists after timing the injectors and performing the engine tune–up.

Avoid lugging the engine as this will cause incomplete combustion.

3. Check for use of an improper grade of fuel. Refer to *Fuel Specifications* in Section 13.3.

4. Check the blower bypass valve piston (if so equipped) to determine if it is stuck in an *open* position. Check for scoring of the valve piston or piston guide. Replace the valve assembly if the above conditions are noted.

5. Check for internal lubricating oil leaks and refer to the *High Lubricating Oil Consumption* Chart.

6. Check for faulty injectors and replace as necessary.

White smoke or misfire at idle may occur when any one or more injector's idle output is considerably higher or lower than the remainig injectors operated by the same control tube. Significant differences in injector idle output will affect firing impulses since some cylinders are receiving too much fuel while others are receiving little or no fuel at idle. The cylinder that is not firing at idle may be detected by shorting out the injector with a screwdriver. Depress the injector follower to prevent injector operation. If there is a change noted in the engine (i.e., noise or RPM), the injector can be considered operational. If no change is noted in the engine, one cause could be that the injector is not providing sufficient fuel at idle for combustion. The rack screw should then be adjusted to increase fuel output. Turn the injector rack screw slightly (no more than 1/8 of a turn) to change the idle output. This adjustment should only be made after any heavy hitting injectors have been identified and adjusted to reduce idle output. Heavy hitting injectors generally contribute to a louder cylinder firing impulse/sound. After adjusting the suspected problem injectors, accelerate the engine several times and allow it to return to idle.

Check for low compression and consult the *Hard Starting* Chart.

The use of low cetane fuel will cause this condition. Refer to *Fuel Specifications* in Section 13.3.

7. (Same as Step 4).

Chart 3

HARD STARTING

Probable Causes

ENGINE WILL NOT ROTATE

Check For

1. LOW BATTERY VOLTAGE, LOOSE STARTER CONNECTIONS OR FAULTY STARTER
2. DEFECTIVE STARTING MOTOR SWITCH
3. INTERNAL SEIZURE

LOW CRANKING SPEED

Check For

4. IMPROPER LUBRICATING OIL VISCOSITY
5. LOW BATTERY OUTPUT
6. LOOSE STARTER CONNECTIONS OR FAULTY STARTER

NO FUEL

Check For

7. AIR LEAKS, FLOW OBSTRUCTION, FAULTY FUEL PUMP, FAULTY INSTALLATION
8. INJECTOR RACKS NOT IN FULL-FUEL POSITION WHEN STARTING AID SCREW IS NOT USED

LOW COMPRESSION

Check For

9. EXHAUST VALVES STICKING OR BURNED
10. COMPRESSION RINGS WORN OR BROKEN
11. CYLINDER HEAD GASKET LEAKING
12. IMPROPER VALVE CLEARANCE ADJUSTMENT
13. BLOWER NOT FUNCTIONING
14. BLOWER BYPASS VALVE STUCK OPEN

INOPERATIVE STARTING AID AT LOW AMBIENT TEMP

Check For

15. IMPROPER OPERATION OF FLUID STARTING AID

Chart 3

HARD STARTING

SUGGESTED REMEDY

1. Refer to Items 2, 3 and 5 and perform the operations listed.
2. Replace the starting motor switch.
3. Hand crank the engine at least one complete revolution. If the engine cannot be rotated a complete revolution, internal damage is indicated and the engine must be disassembled to ascertain the extent of damage and the cause.
4. Refer to *Lubrication Specifications* in Section 13.3 for the recommended grade of oil.
5. Recharge the battery if a light load test indicates low or no voltage. Replace the battery if it is damaged or will not hold a charge.

   Replace terminals that are damaged or corroded.

   At low ambient temperatures, use of a starting aid will keep the battery fully charged by reducing the cranking time.
6. Tighten the starter connections. Inspect the starter commutator and brushes for wear. Replace the brushes if badly worn and overhaul the starting motor if the commutator is damaged.
7. To check for air leaks, flow obstruction, faulty fuel pump or faulty installation, consult the *No Fuel or Insufficient Fuel* Chart.
8. Check for bind in the governor–to–injector linkage. Readjust the governor and injector controls, if necessary.
9. Remove the cylinder head and recondition the exhaust valves.
10. Remove the air boxcovers and inspect the compression rings through the ports in the cylinder liners. Overhaul the cylinder assemblies if the rings are badly worn or broken.
11. To check for compression gasket leakage, remove the coolant filler cap and operate the engine. A steady flow of gases from the coolant filler indicates either a cylinder head gasket is damaged or the cylinder head is cracked. Remove the cylinder head and replace the gaskets or cylinder head.
12. Adjust the exhaust valve clearance.
13. Remove the flywheel housing cover at the blower drive support. Then remove the snap ring and withdraw the blower drive shaft from the blower. Inspect the blower drive shaft and drive coupling. Replace the damaged parts. Bar the engine over. If the blower does not rotate, remove the air inlet adaptor and visually inspect the blower rotors and end plates. If visual distress is noted, remove the blower (refer to Section 3.4.1).
14. Check the blower bypass valve piston (if so equipped) to determine if it is stuck in an *open* position. Check for scoring of the valve piston or piston guide. Replace the valve assembly if the above conditions are noted.
15. Operate the starting aid according to the instructions under *Cold Weather Starting Aids*.

Chart 4

ABNORMAL ENGINE OPERATION

Probable Causes

UNEVEN RUNNING OR FREQUENT STALLING

Check For

1. LOW COOLANT TEMPERATURE
2. INSUFFICIENT FUEL
3. FAULTY INJECTORS
4. LOW COMPRESSION PRESSURES
2. GOVERNOR INSTABILITY (HUNTING)

LACK OF POWER

Check For

6. IMPROPER ENGINE ADJUSTMENTS (TUNE–UP) AND GEAR TRAIN TIMING
7. INSUFFICIENT FUEL
8. INSUFFICIENT AIR
9. ENGINE APPLICATION
10. HIGH RETURN FUEL TEMPERATURE
11. HIGH AMBIENT AIR TEMPERATURE
12. HIGH ALTITUDE OPERATION
13. BLOWER BYPASS VALVE STUCK OPEN

DETONATION

Check For

14. OIL PICKED UP BY AIR STREAM
15. LOW COOLANT TEMPERATURE
16. FAULTY INJECTORS

Chart 4

ABNORMAL ENGINE OPERATION

SUGGESTED REMEDY

1. Check the engine coolant temperature gage and, if the temperature does not reach 160°–197°F (71°–92°C) while the engine is operating, consult the *Abnormal Engine Coolant Temperature* Chart.
2. Check engine fuel spill back and if the return is less than specified, consult the *No Fuel or Insufficient Fuel* Chart.
3. Check the injector timing and the position of the injector racks. If the engine was not tuned correctly, perform an engine tune–up. Erratic engine operation may also be caused by leaking injector spray tips. Replace the faulty injectors.
4. Check the compression pressures within the cylinders and consult the *Hard Starting* Chart if compression pressures are low.
5. Erratic engine operation may be caused by governor–to–injector operating linkage bind or by faulty engine tune–up. Perform the appropriate engine tune–up procedure as outlined for the particular governor used.
6. If the engine is equipped with a throttle delay, check for the proper setting, binding or burrs on the piston or bracket, and a plugged discharge orifice.

If equipped with a fuel modulator, determine if there is any interference with the roller assembly or roller contact with the cam at *wide open throttle (WOT)* position. Check for burrs and binding on the piston and bracket bore. Determine correctness (refer to Section 14.14) of the installed fuel modulator spring and check if the spring has taken a permanent "set", or if the spring rate is too high.

Perform an engine tune–up if performance is not satisfactory.

Check the engine gear train timing. An improperly timed gear train will result in a loss of power due to the valves and injectors being actuated at the wrong time in the engine's operating cycle.

7. Perform a *Fuel Flow Test* and, if less than the specified fuel is returning to the fuel tank, consult the *No Fuel or Insufficient Fuel* Chart.
8. Check for damaged or dirty air cleaners and clean, repair or replace damaged parts.

Remove the air box covers and inspect the cylinder liner ports. Clean the ports if they are over 50% plugged.

Check for blower air intake obstruction or high exhaust back pressure. Clean, repair or replace faulty parts.

Check the compression pressures (consult the *Hard Starting* Chart).

9. Incorrect operation of the engine may result in excessive loads on the engine. Operate the engine according to the approved procedures.
10. Check the engine fuel spill–back temperature. The return fuel temperature must be less than 150°F (66°C) or a loss in horsepower will occur. This condition may be corrected by installing larger fuel lines or relocating the fuel tank to a cooler position.
11. Check the ambient air temperature. An increase in fuel inlet temperature above 90°F (32°C) will result in a brake horsepower loss of approximately 2% per 20°F (11°C) increment of fuel temperature increase. Relocate the engine air intake to provide a cooler source of air.
12. Engines lose horsepower with increase in altitude. The percentage of power loss is governed by the altitude at which the engine is operating.
13. Check the blower bypass valve piston (if so equipped) to determine if it is stuck in an *open* position. Check for scoring of the valve piston or piston guide. Replace the valve assembly if the above conditions are noted.
14. Fill oil bath air cleaners to the proper level with the same grade and viscosity lubricating oil that is used in the engine.

Check for a defective blower–to–block gasket. Replace the gasket, if necessary.

15. Refer to Item 1 of this chart.
16. Check injector timing and the position of each injector rack. Perform an engine tune–up, if necessary. If the engine is correctly tuned, the erratic operation may be caused by an injector check valve leaking, spray tip holes enlarged or a broken spray tip. Replace faulty injectors.

Clean the air box and drain tubes to prevent accumulations that may be picked up by the air stream and enter the engine's cylinders.

Inspect the check valve as follows:

a. Disconnect the drain tube between the check valve and the air box drain tube nut at the air box cover.
b. Run the engine and note the air flow through the valve at idle engine speed.
c. If the check valve is operating properly, there will be no air flow at engine speeds above idle.

Inspect the blower oil seals by removing the air inlet housing and watching through the blower inlet for oil radiating away from the blower rotor shaft oil seals while the engine is running. If oil is passing through the seals, overhaul the blower.

Chart 5

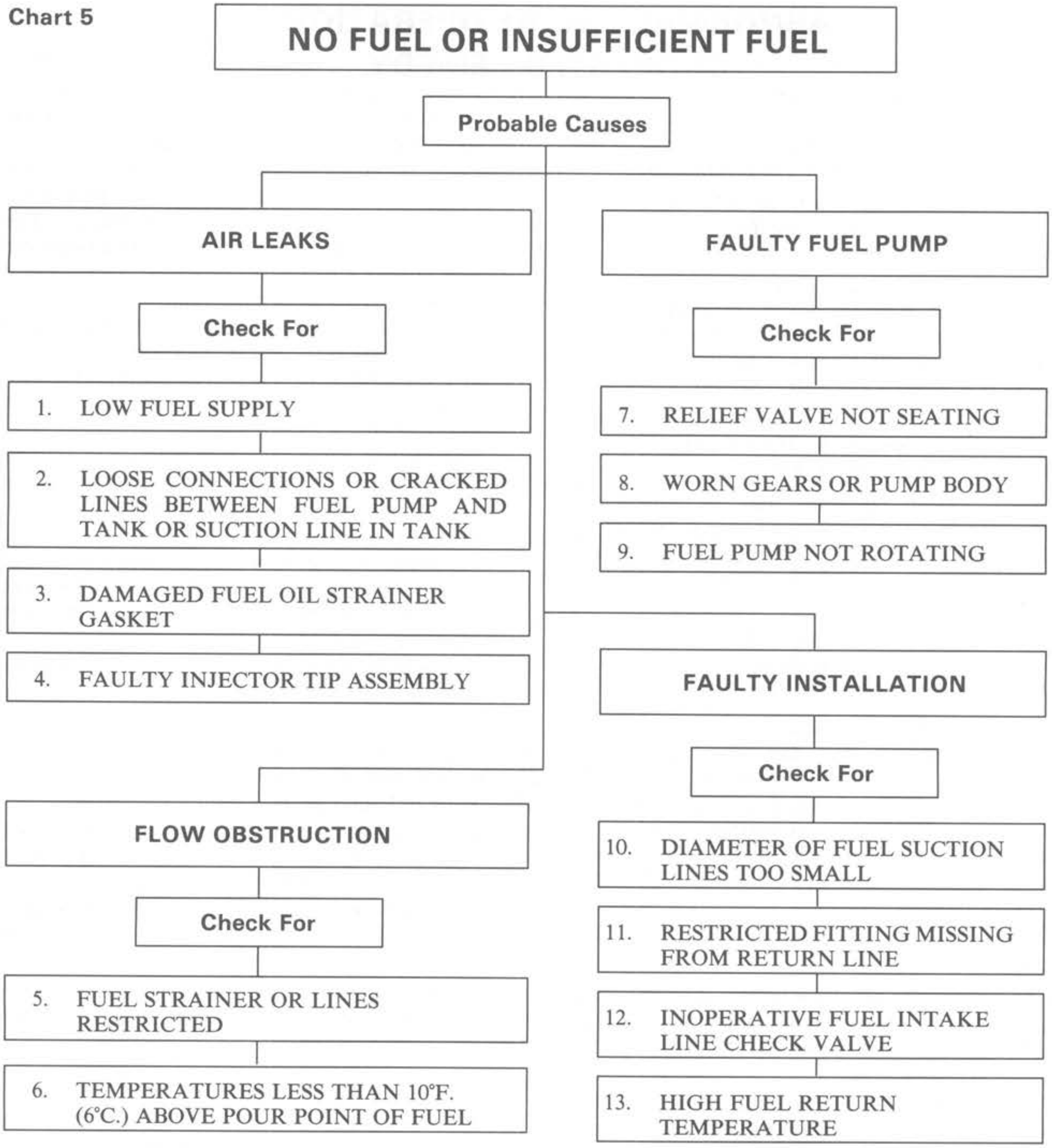

NO FUEL OR INSUFFICIENT FUEL
Probable Causes
AIR LEAKS
Check For
1. LOW FUEL SUPPLY
2. LOOSE CONNECTIONS OR CRACKED LINES BETWEEN FUEL PUMP AND TANK OR SUCTION LINE IN TANK
3. DAMAGED FUEL OIL STRAINER GASKET
4. FAULTY INJECTOR TIP ASSEMBLY
FAULTY FUEL PUMP
Check For
7. RELIEF VALVE NOT SEATING
8. WORN GEARS OR PUMP BODY
9. FUEL PUMP NOT ROTATING
FLOW OBSTRUCTION
Check For
5. FUEL STRAINER OR LINES RESTRICTED
6. TEMPERATURES LESS THAN 10°F. (6°C.) ABOVE POUR POINT OF FUEL
FAULTY INSTALLATION
Check For
10. DIAMETER OF FUEL SUCTION LINES TOO SMALL
11. RESTRICTED FITTING MISSING FROM RETURN LINE
12. INOPERATIVE FUEL INTAKE LINE CHECK VALVE
13. HIGH FUEL RETURN TEMPERATURE

Chart 5

NO FUEL OR INSUFFICIENT FUEL

SUGGESTED REMEDY

1. The fuel tank should be filled above the level of the fuel suction tube.
2. Perform a *Fuel Flow Test* and, if air is present, tighten loose connections and replace cracked lines.
3. Perform a *Fuel Flow Test* and, if air is present, replace the fuel strainer gasket when changing the strainer element.
4. Perform a *Fuel Flow Test* and, if air is present with all fuel lines and connections assembled correctly, check for and replace faulty injectors.
5. Perform a *Fuel Flow Test* and replace the fuel strainer and filter elements and the fuel lines, if necessary.
6. Consult the *Fuel Specifications* in Section 13.3 for the recommended grade of fuel.
7. Perform a *Fuel Flow Test* and, if inadequate, clean and inspect the valve seat assembly.
8. Replace the gear and shaft assembly or the pump body.
9. Check the condition of the fuel pump drive and blower drive and replace defective parts.
10. Replace with larger tank–to–engine fuel lines.
11. Install a restricted fitting in the return line.
12. Make sure that the check valve is installed in the line correctly; the arrow should be on top of the valve assembly or pointing upward. Reposition the valve, if necessary. If the valve is inoperative, replace it with a new valve assembly.
13. Check the engine fuel spill–back temperature. The return fuel temperature must be less than 150°F (66°C) or a loss in horsepower will occur. This condition may be corrected by installing larger fuel lines or relocating the fuel tank to a cooler position.

Chart 6

HIGH LUBRICATING OIL CONSUMPTION

Probable Causes

EXTERNAL LEAKS

Check For

1. OIL LINES OR CONNECTIONS LEAKING
2. GASKET OR OIL SEAL LEAKS
3. AUTOMATIC OIL FILLER
4. OIL PULLOVER – AIR COMPRESSOR
5. OVERFILLED CRANKCASE
6. PLUGGED BREATHERS
7. HIGH CRANKCASE PRESSURE
8. BLUE EXHAUST SMOKE
9. EXCESSIVE OIL IN AIR BOX

INTERNAL LEAKS

Check For

10. BLOWER OIL SEALS LEAKING
11. TURBO OIL SEALS LEAKING
12. OIL COOLER CORE LEAKING
13. WORN EXHAUST VALVE GUIDES

OIL CONTROL AT CYLINDER

Check For

14. LOW COMPRESSION
15. PISTON PIN RETAINER LOOSE
16. OIL CONTROL RINGS WORN, BROKEN, IMPROPERLY INSTALLED OR SCORED
17. EXCESSIVE OIL IN AIR BOX
18. DIRT IN AIR INTAKE SYSTEM
19. SCORED LINERS OR PISTONS
20. EXCESSIVE INSTALLATION ANGLE
21. EXCESSIVE OIL IN CRANKCASE

Chart 6

HIGH LUBRICATING OIL CONSUMPTION

SUGGESTED REMEDY

NOTE: Lube oil consumption must be verified after each repair is made.

1. & 2. Repair oil leaks by replacing necessary gaskets, seals or tightening connections. Steam cleaning the engine and operating at no–load rpm, (engine at operating temperature) will often reveal excessive oil leaks.

3. Consult the original equipment manufacturer for proper repair of the automatic oil filler system.

4. Check the air compressor for oil pullover and/or remove and replace the compressor.

5. Check dipstick and tube for proper oil pan levels to correct overfilled crankcase.

6. Check crankcase pressure. Clean breathers and recheck crankcase pressure.

7. Overhaul blower, turbocharger or rekit engine (refer to Items 10, 11, 15 and 16). Also, refer to the *Excessive Crankcase Pressure* Chart.

8. Remove and inspect exhaust manifolds and stacks for wetness or oil discharge. Excessive clearance between the valve stem and the valve guide can produce oil in the cylinders and stack. Repair the valve guides and/or install valve stem seals.

9. Refer to the *Abnormal Engine Operation* Chart.

10. Remove the piping from the air inlet housing and remove from the to blower. Operate the engine at approximately one–half throttle and at idle and inspect blower end plates for evidence of oil leakage past the seals. Use a flashlight to illuminate the end plates. If excessive oil leakage is evident on the end plates, overhaul blower.

CAUTION: The blower rotors are exposed and rotating during the test. Contact with the rotors must be avoided as personal injury could result.

11. Check for indications of oil on compressor or turbine sides of the turbocharger. Refer to Section 3.5 of the Service Manual for the proper procedure to determine turbocharger oil seal leakage.

12. Pressure test cooling system. If leak is found, remove and replace the oil cooler. Inspect the engine coolant for lubricating oil contamination; if contaminated, replace the oil cooler core. Then, use a good grade of cooling system cleaner to remove the oil from the cooling system.

13. Replace worn exhaust valve guides.

14. Take compression test – refer to Item 16.

15. Run engine at idle speed with the air boxcover removed (one at a time) to determine if oil is uncontrolled as evidenced by slobbering out the liner ports. Inspect all cylinders as more than one may be slobbering. Repair affected cylinders. Slobbering can also be caused by worn oil control rings.

CAUTION: Hot lubricating oil could be blown out the air box during this test. Contact with the hot oil could cause severe burns.

16. Check for faulty engine air induction system allowing contaminated air to enter the engine. A compression test with excessively low readings will indicate worn out cylinders. Remove and replace cylinder kits.

17. Refer to Items 10, 11, 15 and 16.

18. Refer to Item 16.

19. Check the crankshaft thrust washers for wear. Replace wore and defective parts.

20. Decrease the installation angle.

21. Fill the crankcase to the proper level only.

Chart 7

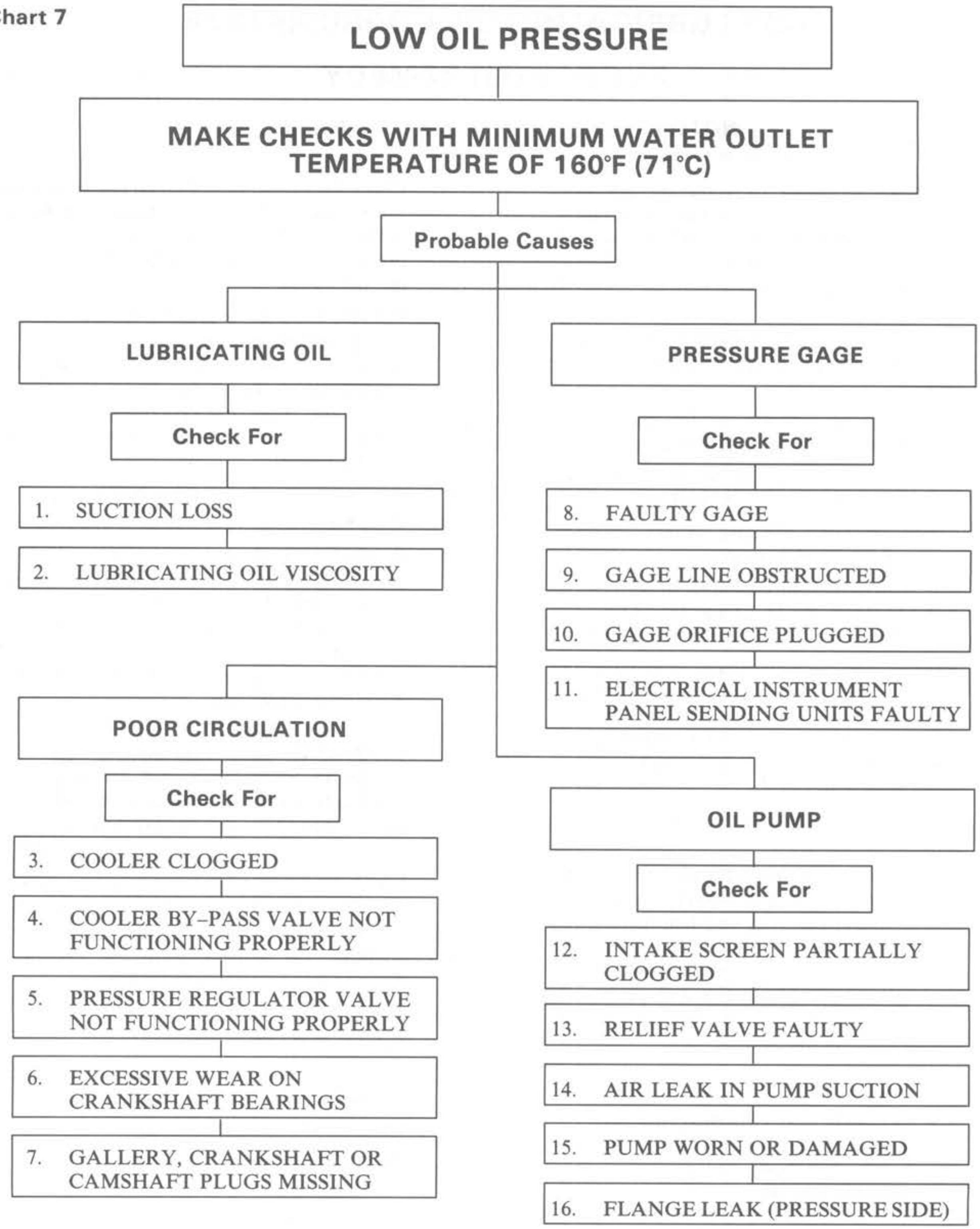

LOW OIL PRESSURE
MAKE CHECKS WITH MINIMUM WATER OUTLET TEMPERATURE OF 160°F (71°C)
Probable Causes
LUBRICATING OIL
Check For
1. SUCTION LOSS
2. LUBRICATING OIL VISCOSITY
PRESSURE GAGE
Check For
8. FAULTY GAGE
9. GAGE LINE OBSTRUCTED
10. GAGE ORIFICE PLUGGED
11. ELECTRICAL INSTRUMENT PANEL SENDING UNITS FAULTY
POOR CIRCULATION
Check For
3. COOLER CLOGGED
4. COOLER BY–PASS VALVE NOT FUNCTIONING PROPERLY
5. PRESSURE REGULATOR VALVE NOT FUNCTIONING PROPERLY
6. EXCESSIVE WEAR ON CRANKSHAFT BEARINGS
7. GALLERY, CRANKSHAFT OR CAMSHAFT PLUGS MISSING
OIL PUMP
Check For
12. INTAKE SCREEN PARTIALLY CLOGGED
13. RELIEF VALVE FAULTY
14. AIR LEAK IN PUMP SUCTION
15. PUMP WORN OR DAMAGED
16. FLANGE LEAK (PRESSURE SIDE)

Chart 7

LOW OIL PRESSURE

SUGGESTED REMEDY

1. Check the oil and bring it to the proper level on the dipstick or correct the installation angle.
2. Consult the *Lubrication Specifications* in Section 13.3 for the recommended grade and viscosity of oil.

Check for fuel leaks at the injector nut seal ring and fuel pipe connections. Leaks at these points will cause lubricating oil dilution (refer to Section 2.0).

3. A plugged oil cooler is indicated by excessively high lubricating oil temperature. Remove and clean the oil cooler core.
4. Remove the bypass valve and clean the valve and valve seat and inspect the valve spring. Replace defective parts.
5. Remove the pressure regulator valve and clean the valve and valve seat and inspect the valve spring. Replace defective parts.
6. Change the bearings. Consult the *Lubrication Specifications* in Section 13.3 for the proper grade and viscosity of oil. Change the oil filters.
7. Replace missing plugs.
8. Check the oil pressure with a reliable gage and replace the gage if found faulty.
9. Remove and clean the gage line; replace it, if necessary.
10. Remove and clean the gage orifice.
11. Repair or replace defective electrical equipment.
12. Remove and clean the oil pan and oil intake screen. Consult the *Lubrication Specifications* in Section 13.3 for the proper grade and viscosity of oil. Change the oil filters.
13. Remove and inspect the valve, valve bore and spring. Replace faulty parts.
14. Disassemble the piping and install new gaskets.
15. Remove the pump. Clean and replace defective parts.
16. Remove the oil pan and tighten the oil pump end cover bolts.
17. Remove the flange and replace the gasket.

Chart 8

ABNORMAL ENGINE COOLANT OPERATING TEMPERATURE

Probable Causes

ABOVE NORMAL

Check For

1. INSUFFICIENT HEAT TRANSFER
2. POOR CIRCULATION

BELOW NORMAL

Check For

3. IMPROPER CIRCULATION
4. EXCESSIVE LEAKAGE AT THERMOSTAT SEAL

SUGGESTED REMEDY

1. Clean the cooling system with a good cooling system cleaner and thoroughly flush to remove scale deposits.

Clean the exterior of the radiator core to open plugged passages and permit normal air flow.

Adjust fan belts to the proper tension to prevent slippage.

Check for an improper size radiator or inadequate shrouding.

Repair or replace inoperative temperature–controlled fan or inoperative shutters.

2. Check the coolant level and fill to the filler neck if the coolant level is low.

Inspect for collapsed or disintegrated hoses. Replace faulty hoses.

Thermostat may be inoperative. Remove, inspect and test the thermostat; replace if found faulty.

Check the water pump for a loose or damaged impeller.

Check the flow of coolant through the radiator. A clogged radiator will cause an inadequate supply of coolant on the suction side of the pump. Clean the radiator core.

Remove the coolant filler cap and operate the engine, checking for combustion gases in the cooling system. The cylinder head must be removed and inspected for cracks and the head gaskets replaced if combustion gases are entering the cooling system.

Check for an air leak on the suction side of the water pump. Replace defective parts.

3. The thermostat may not be closing. Remove, inspect and test the thermostat. Install a new thermostat, if necessary.

Check for an improperly installed heater.

4. Excessive leakage of coolant past the thermostat seal(s) is a cause of continued low coolant operating temperature. When this occurs, replace the thermostat seal(s).

VEHICLE LOW POWER/PERFORMANCE AT LOW MILEAGE

1. **Determine the basis for the concern.** Does the concern indicate slow acceleration from a stop or slow engine recovery when changing gears? The answers to these questions often provide the proper information for the investigation.

   a. Is the truck being driven according to recommended procedures? For example, down shifting an engine with a throttle delay at high speed (rather than at low speed) will cause the engine to recover power slowly, creating an impression of low power. Driver training would help.

   b. Are the driver's expectations of vehicle performance realistic, considering truck gear ratios, loads and engine rated speed and power? The distributor or regional office should be consulted to assist in evaluation of vehicle performance (shift points and gradability, for example).

2. **Check customer engine and vehicle order specifications and vehicle road speeds, if necessary.**

   a. Determine if the engine no–load speed (rpm) and horsepower meet customer order specifications. The O.E.M. truck dealer or Detroit Diesel Regional Office can assist in this area.

   b. It is normal for the actual engine no–load speed to be slightly less (5 to 20 rpm) than the no–load speed set at Detroit Diesel due to engine accessories (air compressor, power steering pump, etc.) installed by the O.E.M. There is a ± 25 rpm manufacturing tolerance for no–load speed setting. It would be normal, therefore, for an engine order specification of 2050 rpm no–load speed to check out at 2025 to 2075 rpm in the vehicle.

   c. The rated full–load engine speed will not change because of a slight change of no–load speed (rpm) resulting from the addition of O.E.M. accessory loads.

   d. Engine speed combined with rear axle ratios and tire size provide the resultant vehicle geared road speed which may be a basis for customer concern.

   e. Vehicle highway speed is a result of the gear ratios, engine speed and gross vehicle weight. For purposes of discussion, geared speed is the speed the truck would reach with the transmission in direct drive and the engine at rated speed. Geared speed (GS) in Miles Per Hour (mph) can be computed as follows:

$$GS = \frac{\text{Full Load engine RPM} \times 60}{\text{Axle ratio} \times \text{tire revolutions/mile}}$$

EXAMPLE:

$$GS = \frac{1900 \text{ rpm} \times 60}{4.11 \times 504} = 55 \text{ mph}$$

The vehicle could be expected to have a maximum road speed somewhat more than 55 mph (2050 x 55/1900 = 59.3) mph on level pavement with 2050 rpm no–load engine speed. This maximum vehicle speed of 59.3 mph may not be reached because of parasitic and frictional power losses. These power losses are a result of the vehicle power train and engine–driven accessories. At speeds over 50 mph *wind resistance* can be responsible for the greatest engine power or road speed loss.

These vehicle speed calculations can be used to compare designed performance with actual performance. In the example it would be expected that the vehicle should operate between approximately 55 and 59 mph with typical loads and on level pavement. If during tests the loaded vehicle operates at calculated road speeds on level pavement (without a head wind), re–evaluate the source and reason for the power concern. Average the speeds attained on a two or three mile level run both into the wind and with the wind, to determine maximum possible road speed with vehicle unloaded.

   f. Accuracy of the vehicle speedometer and tachometer is important. Low–reading instruments have caused some low power concerns. These instruments should be checked for accuracy at both high and low speed.

3. **Check for improper assembly of engine related parts and accessories installed by the vehicle manufacturer (O.E.M.).** Parts and accessories that can contribute to low power/performance are:

   a. Throttle linkage and governor shut down (adjustment).

   b. Fuel supply and return line (size and installation).

   c. Fuel filters (leaking or contaminated).

   d. Fuel tanks (construction, return and supply line installation; fuel temperature should not exceed maximum allowable) – (see Section 2.5.1).

   e. Air intake and exhaust components (size and installation).

   f. Jacobs brake (installation and adjustment). See Items 11 thru 14.

   g. Fuel heater (restriction).

   h. Water separator (restriction).

4. **Check governor throttle and shutdown linkage adjustment as follows:**
   a. Improper adjustment of vehicle throttle linkage and governor shut down are the most frequent causes of low power/performance concerns. When the vehicle throttle (accelerator pedal) is fully depressed, the governor throttle lever should move from *idle* to the *full–throttle* position. Low power will result if the vehicle throttle linkage cannot reach the *full–throttle* position.
   b. The governor run–stop lever (mechanism) normally installed by the O.E.M. must be adjusted to allow an air gap or clearance (.020 min.) between the stop lever and the air or electric solenoid. Improper adjustment (lack of air gap) of the run–stop lever mechanism will not allow the injector control rack(s) to reach the *full–fuel* position, thus resulting in low power/performance.
5. **Check fuel system for pressure and flow as follows:**
   a. First, start and run the engine. Check for proper fuel pressure at specified engine speeds (refer to Section 13.2). Checking fuel pressure will reveal conditions related to fuel flow restriction, fuel pump relief valve operation and performance conditions caused by high or low fuel pressure.
   b. If fuel pressures are according to specifications, disconnect the fuel return line from the fitting at the fuel tank and check return flow rate. Hold open end in a clean container. Start and run the engine at 1000 rpm. Place the end of the fuel return line beneath the fuel level in the receptacle. After a few minutes no air or gas bubbles should be present. If any bubbles are detected, determine the cause for air entering the fuel system and repair, as required. Air in the fuel system is normally caused by a leak at fuel connections and/or filters between the suction side of the fuel pump to the supply tank and not between the pressure side of the pump and engine. Minimum fuel return rates are provided in Section 2.0.
   c. If no air bubbles are present and return rate is below minimum specifications, check for fuel flow restrictions which can be caused by fuel heaters, water separators, undersize, improperly routed or damaged fuel lines, contaminated fuel filters or high fuel pressure resulting from a plugged restricted fitting.
   d. *Always make sure there is sufficient fuel supply (at lead 1/3 of normal capacity) in the fuel tanks.*
6. **Check crankcase for lube oil overfill.** Overfilled engine crankcase can cause low power and higher–than–normal lubricating oil temperature. Normally, oil levels should be at or slightly below the oil pan–to–block split line with vehicle on level ground.
7. **Check engine horsepower, if necessary.** First, insure engine is at the proper operating temperature. The horsepower measurement before and after corrective action can be used to evaluate the results of the troubleshooting and repair effort. Record this power at appropriate time while troubleshooting. The actual horsepower reading should not be used to judge if engine performance is satisfactory but used only to see if a noticeable power change has taken place. Fuel quality, engine–driven accessories, drive line or tires can contribute to low power readings. It should be noted that No. 1 diesel fuel can produce up to 7% less horsepower than No. 2 fuel. Blends of No. 1 and No. 2 (common in winter) will produce less horsepower, depending on the percent of the blend.
8. **Check for evidence of brake dragging, bad driveline bearings or misaligned axles.**
9. **Check for excessive air intake restriction.** Undersize or dirty air cleaner elements, damaged or obstructed air inlet piping can also cause low power.
10. **Check turbocharger exhaust connections and exhaust system components.** A damaged, undersized or otherwise restricted muffler or exhaust system can result in high exhaust back pressure and subsequent loss of engine power.
11. **Check for proper location of rocker cover(s).** If the cover(s) has been pushed towards the injector control tube assembly (inboard on Vee engines), the injector control lever movement may be restricted by the cover. This condition will not allow injectors to reach full fuel, thereby causing a low power/performance condition. Situations that can cause this condition are:
    a. Use of engine lifting apparatus that contacts the rocker cover(s).
    b. Incorrect reinstallation of rocker cover(s) after removal for various reasons (Jacobs brake installation, for example).
12. **Check throttle delay or fuel modulator operation.** If the engine is equipped with a throttle delay, check for the proper setting and a plugged discharge orifice. If the engine is equipped with a fuel modulator, check for a pinched air supply line. Determine if there is any interference with the roller assembly or improper roller–to–cam contact when governor throttle lever is in the *full–throttle* position. Check for smooth operation of the piston in the bore. Check for excessive air leakage between the piston and cylinder which may be caused by excessive piston clearance due to wear.

13. Check governor–to–injector linkage. Removal of the governor and rocker cover(s) will be necessary to detect any binding or restriction of linkage movement.

14. Check engine tune–up and make necessary corrections. If all previous steps do not reveal cause for a confirmed low power/performance condition, engine tune–up settings may be considered a probable cause. It is normal for tune–up settings to vary when using correct setting procedures. Some items influencing tune–up measurements are differences in gages, individuals and mechanical variations.

At Detroit Diesel Corporation, engine tune–up settings are conducted using electronic and dial indicator gaging equipment. Finally, to determine that tune–up is within accepted tolerances, the engine is tested to assure that horsepower output is to published specifications.

Jacobs brake installation or adjustment errors can cause low power/performance conditions.

When making tune–up adjustments, refer to Section 14 for specifications.

Periodic inspection of tune–up gages is necessary to determine if damaged or worn. Injector timing gages are marked with the timing dimensions and have an allowable tolerance of ± .001". Rack gages are marked with the specific dimension and have an allowable tolerance of ± .002".

STORAGE

PREPARING ENGINE FOR STORAGE

When an engine is to be stored or removed from operation for a period of time, special precautions should be taken to protect the interior and exterior of the engine, transmission and other parts from rust accumulation and corrosion. The parts requiring attention and the recommended preparations are given below.

It will be necessary to remove all rust or corrosion completely from any exposed part before applying a rust preventive compound. Therefore, it is recommended that the engine be processed for storage as soon as possible after removal from operation.

The engine should be stored in a building which is dry and can be heated during the winter months. Moisture absorbing chemicals are available commercially for use when excessive dampness prevails in the storage area.

TEMPORARY STORAGE (30 DAYS OR LESS)

To protect an engine for a temporary period of time, proceed as follows:

1. Drain the engine crankcase.
2. Fill the crankcase to the proper level with the recommended viscosity and grade of oil.
3. Fill the fuel tank with the recommended grade of fuel oil. Operate the engine for two minutes at 1200 rpm and no load.

   NOTICE: Do not drain the fuel system or the crankcase after this run.
4. Check the air cleaner and service it, if necessary, as outlined in Section 3.1.
5. If freezing weather is expected during the storage period, add an ethylene glycol base antifreeze solution in accordance with the manufacturer's recommendations. Drain the raw water system and leave the drain cocks open.
6. Clean the entire exterior of the engine (except the electrical system) with fuel oil and dry it with compressed air.
7. Seal all of the engine openings. The material used for this purpose must be waterproof, vaporproof and possess sufficient physical strength to resist puncture and damage from the expansion of entrapped air.

An engine prepared in this manner can be returned to service in a short time by removing the seals at the engine openings, checking the engine coolant, fuel oil, lubricating oil, transmission and priming the raw water pump, if used.

EXTENDED STORAGE (MORE THAN 30 DAYS)

To prepare an engine for extended storage, (more than 30 days), follow this procedure:

1. Drain the cooling system and flush with clean, soft water. Refill with clean, soft water and add a rust inhibitor to the cooling system (refer to *Corrosion Inhibitor* under *Coolant Specifications* in Section 13.3).
2. Remove, check and recondition the injectors, if necessary, to make sure they will be ready to operate when the engine is restored to service.
3. Reinstall the injectors, time them and adjust the exhaust valve clearance.
4. Circulate the coolant by operating the engine until normal operating temperature is reached (see Section 13.2).
5. Stop the engine.
6. Drain the engine crankcase, then reinstall and tighten the drain plug. Install new lubricating oil filter elements and gaskets.
7. Fill the crankcase to the proper level with a 30 weight preservative lubricating oil MIL-L-21260C, Grade 2.
8. Drain the fuel tank. Refill with enough clean No. 1 diesel fuel or pure kerosene to permit the engine to operate for about ten minutes. If it isn't convenient to drain the fuel tank (i.e., marine) use a separate portable supply of the recommended fuel.

   NOTICE: If engines in vehicles or marine units are stored where condensation of water in the fuel tank may be a problem, add pure, waterless isopropyl alcohol (isopropanol) to the fuel at a ratio of one pint (0.5 liter) to 125 gallons (473 liters) of fuel or .010% by volume. Where biological contamination of fuel may be a problem, add a biocide such as Biobor JF, or equivalent, to the fuel. When using a biocide, follow the manufacturer's concentration recommendations and observe all cautions and warnings.

9. Drain and disassemble the fuel filter and strainer. Discard the used elements and gaskets. Wash the shells in clean No. 1 diesel fuel or pure kerosene and insert new elements. Fill the cavity between the element and shell with No. 1 diesel fuel or pure kerosene and reinstall on the engine. If spin–on fuel filters and strainers are used, discard the used cartridges, fill the new ones with No. 1 diesel fuel or pure kerosene and reinstall on the engine.

10. Operate the engine for five minutes to circulate the clean fuel oil throughout the engine.

11. Refer to *Section 3.1* and service the air cleaner.

12. MARINE GEAR

a. Drain the oil completely and refill with clean oil of the recommended grade and viscosity. Remove and clean or replace the strainer and filter elements.

b. Start and run the engine at 600 rpm for 10 minutes to coat all of the internal parts of the marine gear with clean oil. Engage the clutches alternately to circulate clean oil through all of the moving parts.

NOTICE: The performance of this step is not necessary on torque converter units.

13. TORQMATIC CONVERTER

a. Start and operate the engine until the temperature of the converter oil reaches 150°F (66°C).

b. Stop the engine, remove the converter drain plug and drain the converter.

c. Remove the filter element.

d. Start the engine and stall the converter for **twenty seconds** at 1000 rpm to scavenge the oil from the converter. *Due to lack of lubrication, do not exceed the 20 second limit.*

e. Install the drain plug and a new filter element.

f. Fill the converter to the proper operating level with a commercial preservative oil which meets specification MIL–L–21260C, Grade 2. Oil of this type is available from the major oil companies.

g. Start the engine and operate the converter for at least 10 minutes at a minimum of 1000 rpm. Engage the clutch, then stall the converter to raise the oil temperature to 225°F (107°C).

NOTICE: Do not allow the oil temperature to exceed 225°F (107°C). If the unit does not have a temperature gage, *do not stall the converter for more than thirty seconds.*

h. Stop the engine and allow the converter to cool to a temperature suitable to the touch.

i. Seal the breather and all of the exposed openings with moisture proof tape.

j. Coat all exposed, unpainted surfaces with preservative grease. Position all of the controls for minimum exposure and coat them with grease. The external shafts, flanges and seals should also be coated with grease.

14. POWER TAKEOFF

a. Use an all purpose grease such as Shell Alvania No. 2, or equivalent, and lubricate the clutch throwout bearing, clutch pilot bearing, drive shaft main bearing, clutch release shaft and the outboard bearings (if so equipped).

b. Remove the inspection hole cover on the clutch housing and lubricate the clutch release lever and link pins with a hand oiler. *Avoid getting oil on the clutch facing.*

c. If the unit is equipped with a reduction gear, drain the gear box and flush with light engine oil. If the unit is equipped with a filter, clean the shell and replace the filter element. Refill the gear box to the proper level with the grade of oil indicated on the name plate.

15. TURBOCHARGER

Since turbocharger bearings are pressure lubricated through the external oil line leading from the engine cylinder block while the engine is operating, no further attention is required. However, the turbocharger air inlet and turbine outlet connections should be sealed off with moisture resistant tape.

16. HYDROSTARTER SYSTEM

Refer to Section 12.6.1 for the lubrication and preventive maintenance procedure.

17. Apply a *non–friction* rust preventive compound to all exposed parts. If convenient, apply the rust preventive compound to the engine flywheel. If not, disengage the clutch mechanism to prevent the clutch disc from sticking to the flywheel.

NOTICE: Do not apply oil, grease or any wax base compound to the flywheel. The cast iron will absorb these substances which can "sweat" out during operation and cause the clutch to slip.

18. Drain the engine cooling system.

19. Drain the preservative oil from the engine crankcase. Reinstall and tighten the drain plug.

20. Remove and clean the battery and battery cables with a baking soda solution and rinse them with fresh water. Do not allow the soda solution to enter the battery. Add distilled water to the electrolyte, if necessary, and fully charge the battery. Store the battery in a cool (never below 32°F or 0°C) dry place. Keep the battery fully charged and check the level and the specific gravity of the electrolyte regularly.

21. Insert heavy paper strips between the pulleys and belts to prevent sticking.

22. Seal all engine openings, including the exhaust outlet, with moisture resistant tape. Use cardboard, plywood or metal covers where practical.

23. Clean and dry the exterior painted surfaces of the engine and spray with a suitable liquid automobile body wax, a synthetic resin varnish or a rust preventive compound.

24. Protect the engine with a good weather–resistant tarpaulin and store it under cover, preferably in a dry building which can be heated during the winter months.

Detroit Diesel Corporation does not recommend the outdoor storage of engines (or transmission). Nevertheless, DDC recognizes that in some cases outdoor storage may be unavoidable. If units must be kept out–off–doors, follow the preparation and storage instructions already given. Protect units with quality, weather–resistant tarpaulins (or other suitable covers) arranged to provide air circulation.

NOTICE: *Do not use plastic sheeting for outdoor storage.* Plastic is fine for indoor storage. When used outdoors, however, enough moisture can condense on the inside of the plastic to rust ferrous metal surfaces and pit aluminum surfaces. If a unit is stored outside for any extended period of time, severe corrosion damage can result.

The stored engine should be inspected periodically. If there are any indications of rust or corrosion, corrective steps must be taken to prevent damage to the engine parts. Perform a complete inspection at the end of one year and apply additional treatment as required.

PROCEDURE FOR RESTORING AN ENGINE TO SERVICE WHICH HAS BEEN IN EXTENDED STORAGE

1. Remove the covers and tape from all of the openings of the engine, fuel tank and electrical equipment. *Do not overlook the exhaust outlet.*

2. Wash the exterior of the engine with fuel oil to remove the rust preventive.

3. Remove the rust preventive from the flywheel.

4. Remove the paper strips from between the pulleys and the belts.

5. Remove the drain plug and drain the preservative oil from the crankcase. Reinstall the drain plug. Then, refer to *Lubrication System* in Section 13.1 and fill the crankcase to the proper level, using a pressure prelubricator, with the recommended grade of lubricating oil.

6. Fill the fuel tank with the fuel specified under *Fuel Specifications* (Section 13.3).

7. Close all of the drain cocks and fill the engine cooling system with clean soft water and a rust inhibitor. If the engine is to be exposed to freezing temperatures, fill the cooling system with a solution of water and an ethylene glycol base antifreeze (refer to Coolant Recommendations in Section 13.3).

8. Install and connect the battery.

9. Service the air cleaner as outlined in Section 3.1.

10. POWER GENERATOR

Prepare the generator for starting as outlined under *Operating Instructions* in Section 13.

11. MARINE GEAR

Check the marine gear; refill it to the proper level, as necessary, with the correct grade of lubricating oil.

12. TORQMATIC CONVERTER

a. Remove the tape from the breather and all of the openings.

b. Remove all of the preservative grease with a suitable solvent.

c. Start the engine and operate the unit until the temperature reaches 150°F (66°C). Drain the preservative oil and remove the filter. Start the engine and stall the converter for twenty seconds at 1000 rpm to scavenge the oil from the converter.

NOTICE: A Torqmatic converter containing preservative oil should only be operated enough to bring the oil temperature up to 150°F (66°C).

d. Install the drain plug and a new filter element.

e. Refill the converter with the oil that is recommended

under*Lubrication and Preventive Maintenance* (Section 15.1).

13. POWER TAKE–OFF

Remove the inspection hole cover and inspect the clutch release lever and link pins and the bearing ends of the clutch release shaft. Apply engine oil sparingly, if necessary, to these areas.

14. HYDROSTARTER

a. Open the relief valve on the side of the hand pump and release the pressure in the system.

b. Refer to the filling and purging procedures outlined in *Hydraulic Starting System* (Section 12.6.1). Then drain, refill and purge the hydrostarter system.

15. TURBOCHARGER

Remove the covers from the turbocharger air inlet and turbine outlet connections. Refer to the lubricating procedure outlined in *Preparation for Starting Engine First Time* in Section 13.1.

16. After all of the preparations have been completed, start the engine.

NOTICE: Before subjecting the engine to a load or high speed, it is advisable to check the engine tune–up.

